An independent report presented to
the Australian Government Minister for Sustainability,
Environment, Water, Population and Communities

by the
State of the Environment 2011 Committee

Australian Government
Department of Sustainability, Environment,
Water, Population and Communities
Dear Minister,

It is with great pleasure that I, on behalf of the independent State of the Environment 2011 Committee, present the fourth national assessment of the state of Australia’s environment.

*Australia state of the environment 2011* builds on 15 years of experience in national reporting on the state of the environment and, for the first time in Australian national state of the environment reporting, includes graded ‘report-card style’ assessments, discussions of risk and resilience, and future outlooks.

In addition to meeting the requirements of the *Environment Protection and Biodiversity Conservation Act 1999*, this report aims to give Australians the best, clearest possible answers to three questions:

- What is the current condition of the Australian environment?
- What are the risks the Australian environment faces and are we doing enough to protect it?
- Where is the Australian environment headed?

The report finds that much of Australia’s diverse environment and heritage is in largely good or improving condition, and identifies aspects of the environment where the current condition is poor or deteriorating. Our changing climate, and our growing population and economy are now confronting us with new challenges. Our approach to managing these challenges will directly influence the future condition of the Australian environment.

It is our hope that this report will increase community awareness and understanding of Australia’s environmental issues and assist decision-makers to determine priorities and make national and regional policy and management decisions that improve Australian environmental outcomes.

I commend the report to you and, through you, to the people of Australia.

Dr Tom Hatton
Chair
State of the Environment 2011 Committee
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summary</strong></td>
<td>1</td>
</tr>
<tr>
<td><strong>Approach</strong></td>
<td>19</td>
</tr>
<tr>
<td>State of the environment 2011</td>
<td>21</td>
</tr>
<tr>
<td>Reading this report</td>
<td>26</td>
</tr>
<tr>
<td>Reading each chapter</td>
<td>28</td>
</tr>
<tr>
<td>Reporting context</td>
<td>37</td>
</tr>
<tr>
<td><strong>Drivers</strong></td>
<td>41</td>
</tr>
<tr>
<td>Key findings</td>
<td>42</td>
</tr>
<tr>
<td>Introduction</td>
<td>45</td>
</tr>
<tr>
<td>Climate change</td>
<td>47</td>
</tr>
<tr>
<td>Population growth and distribution</td>
<td>52</td>
</tr>
<tr>
<td>Economic growth</td>
<td>57</td>
</tr>
<tr>
<td>Summary</td>
<td>61</td>
</tr>
<tr>
<td><strong>Atmosphere</strong></td>
<td>65</td>
</tr>
<tr>
<td><strong>Inland water</strong></td>
<td>187</td>
</tr>
<tr>
<td><strong>Land</strong></td>
<td>261</td>
</tr>
<tr>
<td><strong>Marine environment</strong></td>
<td>371</td>
</tr>
<tr>
<td><strong>Antarctic environment</strong></td>
<td>465</td>
</tr>
</tbody>
</table>

vi
Forest of red gums, New South Wales
Photo by Matt Lauder
Approach
... we must develop a rational approach to the definition of ecological health, methods to measure that health, and mechanisms to incorporate protection of ecological health into society’s decision-making processes.

State of the Environment 2011

Under Section 516B of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), the Minister for the Environment must cause a report on the Australian environment to be prepared every five years and to be tabled in each house of parliament within 15 days of receiving the report.

The EPBC Act defines ‘environment’ as:

a ecosystems and their constituent parts, including people and communities
b natural and physical resources
c the qualities and characteristics of locations, places and areas
d heritage values of places
e the social, economic and cultural aspects of the above.

Australia state of the environment 2011 (SoE 2011) is the fourth national assessment of the state of Australia’s environment, and the third independent assessment under the EPBC Act.

1.1 Purpose

The purpose of this report is to capture and present key information on the state of the Australian environment. This is a comprehensive review of the state and trends of the environment, the pressures on it and the drivers of those pressures, management initiatives in place to address environmental concerns and the impacts of those initiatives, its resilience and the unmitigated risks that threaten it. These analyses are brought together into an overall assessment of the outlook for our environment.

In addition to meeting the requirements of the EPBC Act, this report aims to:

- provide relevant, credible and useful information on environmental issues to decision-makers and the public
- increase awareness of environmental issues among decision-makers and the public
- support evidence-based environmental management decisions that lead to more sustainable use and effective conservation of our environmental resources
- identify ways in which the environmental evidence base could be strengthened.

Overall, the SoE 2011 Committee hopes that the report will help ministers, relevant government departments and other decision-makers to determine priorities, and make national regional policy and management decisions that improve Australian environmental outcomes.

The committee also understands the importance of the community’s role in supporting and driving environmental change. The report therefore also provides clear and accessible information for the public—including business leaders, employees, students and householders—about the state of our environment. ‘At a glance’ sections and assessment summaries condense the wealth of material within the report to support understanding and use of the information.
1.2 New in 2011

The SoE 2011 Committee, with encouragement from the Minister for the Environment, set out to improve the relevance and usefulness of SoE reporting for evidence-based decision-making.

For the first time in Australian national SoE reporting, SoE 2011 goes beyond a descriptive summary of evidence to include graded ‘report-card style’ assessments of condition and trends (see Box 1.2 in Section 3.1), discussions of risk and resilience, and future projections or ‘outlooks’. This structure was inspired by the Great Barrier Reef outlook report 2009,1 which set a new benchmark for improved relevance to managers and policy makers in evidence-based environmental assessments.2

Where quantitative information was limited, the committee consulted with a range of relevant experts to provide insight into the state of our environment. In many cases, this involved consultative workshops that enabled expert opinion to be included in SoE in 2011.

1.3 The independent State of the Environment 2011 Committee

This report was produced by the SoE 2011 Committee (Box 1.1), with support from the Australian Antarctic Division and the Information Management Division of the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC). The eight members of the committee were appointed in 2009 by the then Minister for the Environment. Each member was selected based on their scientific credibility, leadership capabilities, research and writing experience, networking and communication skills, and awareness of national environmental policy and decision-making contexts.

The committee worked together to determine a list of reporting themes and an appropriate structure and approach for the report and assessments, and to develop and present the overall messages of the report. Each member of the committee led the coordination and drafting of at least one chapter of this report, drawing on various sources of reliable data, input from other contributors and comments by independent reviewers and DSEWPaC (ex officio member Dr Barbara Wienecke compiled the Antarctic chapter with support from the Australian Antarctic Division). Throughout the development of the report, the committee advocated for accurate, robust and meaningful environmental reporting and identification of policy issues, but not for any particular policy position. (The full terms of reference for the chair and committee are available on the SoE website.a)

The committee was supported in its work by the National Environmental Reporting section of DSEWPaC, a steering committee of departmental senior executives, members of the cross-jurisdictional SoE Reporting Forum, the Indigenous Advisory Committee and many others who are recognised in the Acknowledgements section of this report.

1.4 Quality assurance

The SoE 2011 Committee is an independent committee of experts who used the best available evidence and extensive consultation to produce a robust, peer-reviewed report that is rigorous and highly credible.

1.4.1 Assessments

The report presents assessments of the current state or condition of the environment, the pressures on it, and its management, resilience, risks and outlook. The best available information has been used as much as possible to inform the report, select assessment components and determine grades for status and trends with as much certainty as possible. Information has been used from a wide range of data sources (referenced in the report), and from extensive consultations with experts in a variety of scientific disciplines across Australia. In many cases, workshops were held with experts to gather evidence and information, discuss issues and gauge opinion.

The authors have indicated the strength of the evidence and consensus for their conclusions within each set of assessments (see Box 1.2 in Section 3.1).

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a  www.environment.gov.au/soe
Box 1.1 State of the Environment 2011 Committee

Chair

**Thomas (Tom) Hatton** PhD PSM is the Director of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Wealth from Oceans Flagship. He was previously Director of CSIRO’s Water for a Healthy Country Flagship. He has 25 years of research experience in ecohydrology and catchment hydrology, and has led significant environmental research projects across Australia. He was awarded the inaugural national WE Wood Award for Scientific Excellence in Salinity R&D in 1999. For his work leading the Murray-Darling Sustainable Yields Assessment, he was awarded the CSIRO Chairman’s Medal for Research Excellence. His contribution to water and environmental research was recognised with the Public Service Medal in the 2008 Australia Day Honours.

Members

**Steven Cork** PhD is an ecologist and futurist who spent 25 years at CSIRO researching the ecology of Australian and north American mammals, and the interactions between biodiversity and human welfare. He led CSIRO’s Ecosystem Services Program (1998–2002) and played a key role in writing the scenarios for the world’s ecological futures for the United Nations Millennium Ecosystem Assessment. His career has focused strongly on interactions between science and policy, and he spent five years working as a policy officer in the Australian Government’s environment department. He is now Principal Consultant at Ecolnsights, where he works as a futurist, strategist and ecological adviser. He also leads a major project on the resilience of Australia in the private sustainability research and development organisation Australia 21, and is an Adjunct Professor in the Crawford School of Economics and Government at the Australian National University.

**Peter Harper** is a Deputy Australian Statistician at the Australian Bureau of Statistics (ABS). Peter has worked at the ABS for almost 30 years. Since 2004, he has been responsible for the ABS’s environment statistics program, during which time there have been a number of significant developments. At the ABS, Peter is responsible for a diverse range of subjects, including labour, demography, industry, agriculture, rural and regional, and environment statistics. He is also actively engaged in international work relating to environment statistics, including chairing the United Nations Committee of Experts on Environmental Economic Accounting.

**Robert Joy** is Adjunct Professor at the School of Global Studies, Social Science and Planning at RMIT University. He is the appointed independent site supervisor for the Gunns pulp mill development in Tasmania, former Chairman of Greenfleet Australia and Deputy Chairman of the Environment Protection Authority Victoria. He has 25 years of experience in policy development and program delivery in environment protection and resource management.

**Peter Kanowski** is Professor of Forestry in the Fenner School of Environment and Society at the Australian National University (ANU). He has been researching, teaching and working in forest and environmental policy for 20 years, initially at Oxford University and subsequently at ANU. Peter was a panel member in the 2003–04 Council of Australian Governments National Bushfire Inquiry and a contributor to the 2006 Australian State of the Environment report.

**Richard Mackay** AM is a partner of Godden Mackay Logan Pty Ltd, Heritage Consultants, and Adjunct Professor in the Archaeology Program at La Trobe University. He has more than 20 years of experience in cultural resource management and is a Member of the Order of Australia for services to heritage and archaeology. He is currently Chair of the Australian World Heritage Advisory Committee and the Greater Blue Mountains World Heritage Area Advisory Committee. He was previously a Director of the New South Wales National Trust, a member of the Heritage Council of New South Wales and a member of the Australia International Council on Monuments and Sites Burra Charter Working Party.

**Neil McKenzie** PhD is Chief of CSIRO Land and Water. Neil has 25 years of research experience in soil science. His research has focused on quantitative methods for mapping soil and land resources. Neil is actively involved in shaping public policy on scientific aspects of land and water resource management in Australia. He is also playing a lead role internationally in establishing a global soil information system to ensure more informed responses to food security, carbon dynamics and environmental management.
Members continued

Trevor Ward PhD is an independent Perth-based marine ecologist specialising in performance assessment systems for marine ecosystems and biodiversity. He provides strategic policy and technical advice to government agencies, fisheries managers, conservation groups and local communities worldwide on the conservation and sustainable management of marine ecosystems and fisheries. He has published widely in marine ecology and environmental management, and in 1996 was jointly awarded the CSIRO Chairman’s Medal for excellence in marine science. He currently holds appointments as Visiting Professor at the University of Queensland, Adjunct Associate Professor at the University of the Sunshine Coast and Adjunct Senior Research Fellow at the University of Western Australia.

Ex officio member

Barbara Wienecke PhD is a research scientist at the Australian Antarctic Division. She has studied the foraging ecology of penguins and other seabirds for more than 20 years. Since 1993, she has spent many seasons in Antarctica, the subantarctic and South America, and has published the results of her work in international journals and books. She is a member of the American Association for the Advancement of Science, the American Society for Ornithology, the Cooper Ornithological Society and Birds Australia.

1.4.2 Peer review and fact checking

Independent peer review was used to validate and strengthen the content of the report and supplementary technical reports (available on the SoE website\(^b\)). Independent reviewers were asked to provide an anonymous and objective assessment identifying unfounded assertions, omissions of relevant data or analyses, and issues with methodology, clarity or objectiveness. More than 40 commissioned external peers reviewed chapter drafts and supplementary materials. Each chapter was reviewed by at least three independent peers, selected on the basis of their relevant expertise. Details of the peer-review process, comments from peer reviewers and responses from the SoE 2011 Committee on how feedback was incorporated into improving the chapters are available on the SoE website.\(^b\)

Data have been sourced from the most credible sources available. Before peer review, major data providers were asked to review components of chapters related to their contributions to ensure the accuracy of information presented.

1.5 Accessing State of the Environment 2011 information and products

This report is part of a suite of products, including plain-English summaries and technical reports, that are available free of charge as hard copies from DSEWPaC’s Community Information Unit (1800 803 772) or online from the SoE website.\(^b\)

\(^b\) www.environment.gov.au/soe
Reading this report

Structure of the report

The report comprises 12 chapters:

1. **Approach** provides an outline of the reporting context, including the legislative requirements and aims for the report, and a description of the methodologies used to make assessments and present results.

2. **Drivers** explains the three main factors that underpin the major pressures acting on environmental systems: climate change, population growth and economic growth, and looks at the trends in these.

These introductory chapters are followed by nine ‘theme’ chapters. These represent biogeographic or conceptual aspects of the Australian environment: atmosphere, inland water, land, marine environment, Antarctic environment, biodiversity, heritage, built environment and coasts. Each theme chapter provides detailed assessments of the current state, pressures, management responses, resilience, risks and outlooks for that theme.

3. **Atmosphere** differs from previous reports in that it considers climate change at length—and its implications for the Australian environment—as well as ambient air quality.

4. **Inland water** looks at the evolving state of water resources in the world’s driest inhabitable continent, in the context of a major drought and a period of ambitious water policy reform.

5. **Land** considers the state of our soil and vegetation resources, the pressures they face, and issues and priorities for management.

6. **Marine environment** details the condition of the marine environment; the existing impacts of fisheries, oil and gas extraction and coastal development, and the potential impacts of climate change; and issues around marine management.

7. **Antarctic environment** looks at the global importance and evolving state of the Antarctic environment, the ongoing changes to marine and terrestrial ecosystems resulting from human activity, and the significance of climate change in the region.

8. **Biodiversity** summarises the condition of Australia’s living resources and highlights the challenges of management in the context of human dependence on biodiversity for ecosystem services.

9. **Heritage** deals with the extent and condition of Australia’s rich Indigenous, natural and cultural heritage, the threats each faces from natural and human processes, and the challenges of management.

10. **Built environment** discusses the state of Australia’s cities and towns, and considers the impacts of population and economic growth, and climate change on our urban environments, and issues of strategic management across jurisdictions in a time of change.

11. **Coasts** considers the special features of the interface between ocean and land, the challenges to coasts posed by climate change and management responses to pressures on our coastlines.

12. **Future reporting** describes how environmental information and reporting is evolving to support understanding and decisions.
### Answering your questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
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<tbody>
<tr>
<td>What are the key findings of SoE 2011?</td>
<td><strong>Key findings</strong> are presented at the beginning of the Summary section at the start of the report.</td>
</tr>
<tr>
<td>What are the key drivers of environmental change in Australia?</td>
<td>See Chapter 2</td>
</tr>
<tr>
<td>What are the key findings from each theme?</td>
<td>Each chapter starts with the <strong>Key findings</strong> from the theme.</td>
</tr>
<tr>
<td>What are the key points from each section?</td>
<td>Short plain-English summaries are provided in the <strong>At a glance</strong> box at the beginning of each section in every chapter.</td>
</tr>
<tr>
<td>What are the short answers to the state of our environment, the pressures on it and our environmental management?</td>
<td>In the chapter sections on state and trend, pressures and management of the environment, <strong>Assessment summaries</strong> present a summary and visual grading of the key components of our environment (see Box 1.2 in Section 3.1)</td>
</tr>
</tbody>
</table>
| What is the condition of our:                                          | **Atmosphere?** See Chapter 3  
**Inland water?** See Chapter 4  
**Land?** See Chapter 5  
**Antarctic environment?** See Chapter 7  
**Heritage?** See Chapter 9  
**Coasts?** See Chapter 11  
**Marine environment?** See Chapter 6  
**Biodiversity?** See Chapter 8  
**Built environment?** See Chapter 10  |
| What are the important features of the themes that are examined in SoE 2011? | See Section 1 of the theme chapters.                                                                                                                                                                   |
| What are the state and trends of our environment?                      | See Section 2 of the theme chapters.                                                                                                                                                                  |
| What are the pressures on our environment?                             | See Section 3 of the theme chapters.                                                                                                                                                                  |
| How effective is our environmental management?                         | See Section 4 of the theme chapters.                                                                                                                                                                  |
| How resilient is our environment?                                      | See Section 5 of the theme chapters.                                                                                                                                                                  |
| What are the major unmitigated risks to our environment?               | See Section 6 of the theme chapters.                                                                                                                                                                  |
| What is the outlook for our environment?                               | See Section 7 of the theme chapters.                                                                                                                                                                  |
| What is the future of environmental information and reporting?         | See Chapter 12                                                                                                                                                                                         |
| How has SoE 2011 been developed?                                       | See this chapter, Sections 1–3                                                                                                                                                                          |
| Who wrote SoE 2011?                                                    | See this chapter, Box 1.1                                                                                                                                                                              |
| Is additional information available?                                   | Other SoE products, including plain-English summaries, and technical and workshop reports, are available free of charge in hard copy from DSEWPac’s Community Information Unit (1800 803 772) or online from the SoE website. |

Reading each chapter

Each theme includes assessments at a national scale using a similar approach and structure (Figure 1.1). The Coasts chapter is structured in a different format to reflect the cross-cutting nature of coastal issues and information.

The SoE 2011 approach builds on an internationally accepted framework for SoE reporting—the DPSIR (drivers–pressures–state–impact–response) framework. This framework recognises a chain of causal links from driving forces, such as economic development, through to environmental impacts of human-induced pressures and the management responses aimed at mitigating those pressures. In this report, discussion of resilience, emerging risks and environmental outlooks complements the basics of the DPSIR framework.

Figure 1.1 Approach to reporting on Australia’s environment
3.1 State and trend

What is the current state and trend in condition of the environment?

After an introduction to the theme, each chapter assesses the state and trend of various ‘components’ of the environment. As with previous national SoE reports, the best available evidence is assessed to provide the most accurate picture possible of the state of the Australian environment. This evidence is discussed and presented in the body of each thematic section on the state, and summarised in theme-specific assessment summaries of state and trend.

In the assessment summaries for state and trend, the environmental components are identified and described, then assigned one of four grades of present condition (very good, good, poor, very poor) and one of three grades of change over time (improving, stable, deteriorating). The scale of four condition grades is used across all the chapters except for the Atmosphere chapter, where five grades are used to describe ambient air quality, in line with nationally agreed reporting practice. The specific definitions of each grade are described at the end of the assessment summaries. An indication of confidence in each grade and the evidence supporting it is also provided (see Box 1.2).

Box 1.2 Assessment summaries

The assessment summaries in State of the Environment 2011 provide snapshots of key information, and focus on identifying areas for continued or more concentrated attention on strengthening environmental systems to cope with pressures in the future. Assessment summaries are provided for state and trend, pressures and management responses in each of the themes (Figure A shows a sample assessment summary for state). The summary text in the assessment tables should be read in conjunction with the explanatory text in each section of the theme chapters.

The authors have indicated the strength of the evidence for assessments with a ‘level of confidence’. If adequate high-quality data were available or consensus was high, confidence is indicated as high. If there were only limited data or consensus to determine grades, confidence is indicated as low. Where data are insufficient to attempt scores, this is also indicated, and the component remains on the list to remind readers that it is still an important aspect of the Australian environment, and that more information is needed to improve our understanding and capacity to respond to environmental challenges.

Figure A Structure of assessment summaries throughout the report
3.2 Pressures

What are the pressures affecting the environment and how are they impacting upon the state of the environment?

Each theme chapter examines the pressures that arise from the three main drivers of environmental change discussed in Chapter 2: Drivers—climate change, a growing population and associated demands for economic growth. The legacy impacts of pressures that were more intensive in the past, such as water diversion and land clearing at large scales, are also examined.

Pressures are described and assessed according to their level of impact. Results of the assessments are summarised in the same type of format as the assessments for state in the previous section. Pressures are reported on a scale of four grades of impact (very low impact, low impact, high impact, very high impact) and a scale of three grades of trend over time (improving, stable, deteriorating). Again, the definitions of each grade are theme specific and described in each assessment summary.

3.3 Management effectiveness

How are management activities and responses affecting the state of the environment and the pressures upon it?

Management responses are linked to trends in state and pressures in two ways. Patterns of improvement or declines trigger reactive management responses, and those actions then contribute to changes in pressures and state over time. Management is also a significant contributor to the overall resilience of a system and directly affects the likelihood and consequences of environmental risks. Understanding effectiveness of past and current management responses is an essential part of understanding and improving the state of our environment.

In each theme chapter, management responses are first identified and described, then assessed according to six elements of management: understanding, planning, inputs, processes, outputs and outcomes (Box 1.3).

These six elements allow all stages and components of management to be examined, as well as the impacts of those efforts on reducing pressures and improving environmental outcomes. This assessment method is based on a well-accepted evaluation framework initially established by the World Commission on Protected Areas,3-4 and has since been trialled worldwide as an approach to assessing a wide range of initiatives related to conservation and sustainable resource use. Examining management responses in this way shows where there are strengths and weaknesses in management efforts.

Results from assessments in each theme chapter are presented in a summary table that examines how management is addressing the pressures identified in the previous section of the chapter. Management effectiveness against pressures is graded on a scale of four levels of effectiveness (very effective, effective, partially effective, ineffective) and a scale of three grades of trend over time (improving, stable, deteriorating).

Management responses that are assessed in this report are those that relate to environmental issues at a national scale. The assessments attempt to account for the cumulative contributions, or gaps, across a wide range of jurisdictional and institutional boundaries. Very few management actions (or assessment methodologies) are designed for national delivery, such as implementing national-scale legislation or grants programs. The vast majority of management actions towards conserving and sustaining Australia’s environmental values are delivered locally. Since states and territories lead much of the management aimed at regulating business practices, and local government bodies lead much of the management of urban and rural development, assessments in this report include consideration of the cumulative contributions, or gaps, of smaller scale management activities. Specific case studies are included throughout the chapters to illustrate important points, but are not presented as surrogates or indicators of how management programs are faring more broadly.
### Box 1.3 Grading management effectiveness

The following six elements of management effectiveness, and associated assessment criteria and scoring system (developed by the SoE 2011 Committee) were used in assessing current and recent national-scale responses to pressures on each theme environment.

<table>
<thead>
<tr>
<th>Elements of management effectiveness and assessment criteria</th>
<th>Grades</th>
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<tbody>
<tr>
<td><strong>Management context</strong> (understanding of environmental issues; adequacy of regulatory control mechanisms and policy coverage)</td>
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<tr>
<td><strong>Understanding of context</strong>&lt;br&gt;Decision-makers and environmental managers have a good understanding of:</td>
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<tr>
<td>• environmental and socioeconomic significance of environmental values, including ecosystem functions and cultural importance</td>
<td><strong>Very effective</strong>: Understanding of environmental and cultural systems and factors affecting them is good for most management issues&lt;br&gt;<strong>Effective</strong>: Understanding of environmental and cultural systems and factors affecting them is generally good, but there is some variability across management issues&lt;br&gt;<strong>Partially effective</strong>: Understanding of environmental and cultural systems and factors affecting them is only fair for most management issues&lt;br&gt;<strong>Ineffective</strong>: Understanding of environmental and cultural systems and factors affecting them is poor for most management issues</td>
</tr>
<tr>
<td>• current and emerging threats to values</td>
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<tr>
<td>Environmental considerations and information have a significant impact on national policy decisions across the broad range of government responsibilities</td>
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<tr>
<td><strong>Planning</strong>&lt;br&gt;Policies and plans are in place that provide clarity on:</td>
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<td>• objectives for management actions that address major pressures and risks to environmental values</td>
<td><strong>Very effective</strong>: Effective legislation, policies and plans are in place for addressing all or most significant issues. Policies and plans clearly establish management objectives and operations targeted at major risks. Responsibility for managing issues is clearly and appropriately allocated&lt;br&gt;<strong>Effective</strong>: Effective legislation, policies and plans are in place, and management responsibilities are allocated appropriately, for addressing many significant issues. Policies and plans clearly establish management objectives and priorities for addressing major risks, but may not specify implementation procedures&lt;br&gt;<strong>Partially effective</strong>: Legislation, policies and planning systems are deficient, and/or there is lack of clarity on who has management responsibility, for a number of significant issues&lt;br&gt;<strong>Ineffective</strong>: Legislation, policies and planning systems have not been developed to address significant issues</td>
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<tr>
<td>• roles and responsibilities for managing environmental issues</td>
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<tr>
<td>• operational procedures, and a framework for integration and consistency of planning and management across sectors and jurisdictions</td>
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<tr>
<td><strong>Management capacity</strong> (adequacy of resources, appropriateness of governance arrangements and efficiency of management processes)</td>
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<tr>
<td><strong>Inputs</strong>&lt;br&gt;Resources are available to implement plans and policies, including:</td>
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<tr>
<td>• financial resources</td>
<td><strong>Very effective</strong>: Financial and staffing resources are largely adequate to address management issues. Biophysical and socioeconomic information is available to inform management decisions&lt;br&gt;<strong>Effective</strong>: Financial and staffing resources are mostly adequate to address management issues, but may not be secure. Biophysical and socioeconomic information is available to inform decisions, although there may be deficiencies in some areas&lt;br&gt;<strong>Partially effective</strong>: Financial and staffing resources are unable to address management issues in some important areas. Biophysical and socioeconomic information is available to inform management decisions, although there are significant deficiencies in some areas&lt;br&gt;<strong>Ineffective</strong>: Financial and staffing resources are unable to address management issues in many areas. Biophysical and socioeconomic information to support decisions is deficient in many areas</td>
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<tr>
<td>• human resources</td>
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<td>• information</td>
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### Box 1.3 continued

<table>
<thead>
<tr>
<th>Elements of management effectiveness and assessment criteria</th>
<th>Grades</th>
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<tr>
<td><strong>Management capacity continued</strong></td>
<td></td>
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<tr>
<td><strong>Processes</strong></td>
<td></td>
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<tr>
<td>A governance system is in place that provides for:</td>
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<tr>
<td>• appropriate stakeholder engagement in decisions and implementation of management activities</td>
<td></td>
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<tr>
<td>• adaptive management for longer term initiatives</td>
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<tr>
<td>• transparency and accountability</td>
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<tr>
<td><strong>Very effective</strong>: Well-designed management systems are being implemented for effective delivery of planned management actions, including clear governance arrangements in place, appropriate stakeholder engagement, active adaptive management and adequate reporting against goals</td>
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<tr>
<td><strong>Effective</strong>: Well-designed management systems are in place, but are not yet being fully implemented</td>
<td></td>
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<tr>
<td><strong>Partially effective</strong>: Management systems provide some guidance, but are not consistently delivering around implementation of management actions, stakeholder engagement, adaptive management or reporting</td>
<td></td>
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<tr>
<td><strong>Ineffective</strong>: Adequate management systems are not in place. Lack of consistency and integration of management activities across jurisdictions is a problem for many issues</td>
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</tr>
<tr>
<td><strong>Achievements</strong> (delivery of expected products, services and impacts)</td>
<td></td>
</tr>
<tr>
<td><strong>Outputs</strong> Management objectives are being met with regard to:</td>
<td></td>
</tr>
<tr>
<td>• timely delivery of products and services</td>
<td></td>
</tr>
<tr>
<td>• reduction of current pressures and emerging risks to environmental values</td>
<td></td>
</tr>
<tr>
<td><strong>Very effective</strong>: Management responses are mostly progressing in accordance with planned programs and are achieving their desired objectives. Targeted threats are being demonstrably reduced</td>
<td></td>
</tr>
<tr>
<td><strong>Effective</strong>: Management responses are mostly progressing in accordance with planned programs and are achieving their desired objectives. Targeted threats are understood and there are measures in place to manage them</td>
<td></td>
</tr>
<tr>
<td><strong>Partially effective</strong>: Management responses are progressing and showing signs of achieving some objectives. Targeted threats are understood and measures are being developed to manage them</td>
<td></td>
</tr>
<tr>
<td><strong>Ineffective</strong>: Management responses are either not progressing in accordance with planned programs (significant delays or incomplete actions) or the actions undertaken are not achieving their objectives. Threats are not actively being addressed</td>
<td></td>
</tr>
<tr>
<td><strong>Outcomes</strong> Management objectives are being met with regard to improvements in resilience of environmental values</td>
<td></td>
</tr>
<tr>
<td><strong>Very effective</strong>: Resilience of environmental values is being maintained or improving. Values are considered secure against known threats</td>
<td></td>
</tr>
<tr>
<td><strong>Effective</strong>: Resilience of environmental values is improving, but threats remain as significant factors affecting environmental systems</td>
<td></td>
</tr>
<tr>
<td><strong>Partially effective</strong>: The expected impacts of management measures on improving resilience of environmental values are yet to be seen. Managed threats remain as significant factors influencing environmental systems</td>
<td></td>
</tr>
<tr>
<td><strong>Ineffective</strong>: Resilience of environmental values is still low or continuing to decline. Unmitigated threats remain as significant factors influencing environmental systems</td>
<td></td>
</tr>
</tbody>
</table>
3.4 Resilience

What is the capacity of the environment to retain or recover essentially the same structure and functions when it experiences shocks or disturbances?

After assessments of state, pressure and management, the condition of environmental and cultural systems is revisited in terms of their resilience. This report adopts the definition of resilience as ‘the capacity of a system to experience shocks while retaining essentially the same function, structure and feedbacks, and therefore identity’.

This definition is based on a large body of research (e.g. Walker et al.,5 Resilience Alliance6) and recognises that the resilience of the environment and of human societies cannot be considered separately from one another as they interact in so many ways. These coupled ‘social–ecological systems’ cannot adapt to change by staying exactly the same—in fact, resisting change is likely to make a system inflexible and vulnerable to shocks. Therefore, a resilient system is considered to be one that allows change within limits. In the analyses here, resilience is deemed not as either positive or negative but simply as an attribute of a system that arises from a broad suite of characteristics.

The resilience of coupled social–ecological systems is based on three characteristics:

- the amount of change the system can undergo and still retain the same controls on function and structure
- the degree to which the system is capable of self-organisation
- the ability to build and increase the capacity for learning and adaptation.

In turn, these characteristics are based on the system’s:

- diversity (including diversity of ideas, resources, responses, skills and experience, as well as diversity of species)
- modularity (connections and redundancies between parts of the systems, such that a collapse of one part does not cause collapse of the whole system)
- tightness of feedbacks (how quickly and strongly the consequences of change in one part of the system are felt and responded to in other parts).

We cannot assess resilience quantitatively, based on our current understanding, information and modelling capabilities. In this report, resilience is therefore discussed in a qualitative way rather than in a report-card format. It is possible to identify aspects of coupled social–ecological systems that are likely to add to or detract from resilience, and this can help to guide long-term decision-making.

In each theme chapter, the resilience of environmental values in the theme is generally examined by discussing four components:

- an interpretation of what resilience means for the theme
- any evidence of past resilience, such as cases in which a system has previously recovered from a disturbance
- identification of the main factors affecting resilience, such as vulnerability and exposure
- the anticipated ability of systems and their associated functions to cope with future disturbances, whether chronic, acute or sporadic.

The discussions are framed around the relations between particular disturbances and their likely impacts on the functionality of a particular system in immediate and longer terms. Both specific resilience (to known pressures) and general resilience (to unknown or future pressures) are discussed, and case studies are used to illustrate key points, using examples of responses to shocks in the past.

3.5 Risk

What are the key impacts of current and emerging pressures? When we take into account management interventions and resilience, how likely and potentially severe are these impacts?

In assessing risk, the focus shifts from historical trends and current status to projections about what the future may hold. The assessment uses information from the preceding assessments to examine the likely environmental impacts of pressures that are unmitigated by management responses and resilience. It also examines new impacts that may be emerging due to changing pressures and drivers. The impacts may be either chronic in nature, such as ‘health disorders due to poor air quality’, or sporadic one-off events, such as ‘sudden reduction in vegetation cover due to mega-fires’.
The risk associated with an impact is a combination of two factors:

- the likelihood of an event, action or activity occurring that will create an impact
- the extent and severity of the consequences of that impact on environmental values if it does arise.

For a particular potential issue, risk is assessed qualitatively; grades of risk are assigned by selecting the most appropriate descriptor from a scale of five categories for each of the two factors (Box 1.4).

The sections on risks provide a snapshot of current and emerging risks that relate to the values featured in each chapter.

Box 1.4 Assessing risk

The following approach, definitions and grading scales for risk assessments were adapted from the principles and guidelines outlined by Standards Australia, and interpreted for each reporting theme according to the nature of the values, impacts and management responses that are dealt with in the theme chapter.

The overall risk of an impact on environmental values is determined by examining both the likelihood that the impact will take place and the severity of anticipated consequences if it does occur. The following definitions are used as a national-scale framework for risk assessments across the theme chapters.

Risk = likelihood × consequence

Likelihood is the probability (expected frequency) of an impact due to a pressure. Frequency refers to the time period in which the impacts are expected to be manifest. The likelihood of an impact is assessed on a scale of five levels of frequency, adapted from those used by the Intergovernmental Panel on Climate Change. The chapters cover a very wide range of environments, so the time periods between impacts are equally diverse and are adapted to be theme specific.

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost certain</td>
<td>Expected to occur almost continuously throughout the year; or expected to occur at any time in the near future</td>
</tr>
<tr>
<td>Likely</td>
<td>Not expected to be continuous, but will probably occur at least once each year; or could occur at any time in the near future</td>
</tr>
<tr>
<td>Possible</td>
<td>Expected to occur two to three times within a 10-year period</td>
</tr>
<tr>
<td>Unlikely</td>
<td>Not expected to occur regularly within a 10-year period, but can be expected to occur one to three times within a 100-year period</td>
</tr>
<tr>
<td>Rare</td>
<td>Not expected to occur within the next 100 years</td>
</tr>
</tbody>
</table>

Consequence is the extent and severity of impacts. Consequence is assessed on a scale of five levels of severity and extent. The nature of consequences at local and regional levels is considered, but the analyses in the theme chapters represent the results of a national-scale assessment.

<table>
<thead>
<tr>
<th>Consequence</th>
<th>Severity and extent of expected impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catastrophic</td>
<td>Impact will seriously affect environmental values, disrupting major environmental structures or functions. Potentially irreversible</td>
</tr>
<tr>
<td>Major</td>
<td>Impact will seriously affect environmental values, disrupting many environmental structures or functions. Long periods of recovery</td>
</tr>
<tr>
<td>Moderate</td>
<td>Impact will affect environmental values, disrupting some aspects of environmental structures or functions, but recovery periods are relatively short</td>
</tr>
<tr>
<td>Minor</td>
<td>Impact will be limited and affect only minor environmental values. Recovery periods are relatively short</td>
</tr>
<tr>
<td>Insignificant</td>
<td>Impact will be very limited and have no discernable effect on environmental values, including sensitive populations, communities and assets</td>
</tr>
</tbody>
</table>
Results of the risk assessment are presented in a likelihood–consequence matrix that provides a visual snapshot of the significance of the risks. Impacts that were assessed as rare and/or of insignificant consequence are not included in the matrix or given further attention in the SoE report, but the categories are included in the matrix for reasons of completeness.

The assessments do not extend into discussions about risk management but instead highlight the key challenges, many of which are then examined further in the final section of each theme chapter—Outlook.

3.6 Outlook

Taking into account current and likely future pressures, system resilience, management effectiveness and identified risks, what is the likely future state of our environment?

The last section of each theme chapter focuses on the long-term outlook for the environment, including a discussion of the key factors that are likely to have the greatest influence on future status and trends. The outlooks are based on our understanding of how environmental and cultural systems have reacted to pressures in the past and projections of how they might continue to change if those pressures persist. Implications of continuing to manage the environment under current approaches are discussed in the context of current and new challenges presented by the major drivers of environmental change. The outlook section highlights the main challenges facing our environment and our decision-makers in the near and distant future.

Assessments and reports necessarily vary between chapters according to differences in:

- precedents for national reporting (e.g. there are existing protocols for assessing ambient air quality, which are used in the Atmosphere chapter)
- components to be assessed (e.g. drainage divisions are a practical choice for the Inland water chapter but do not work for the Atmosphere chapter)
- appropriate timescales for trends and assessment (e.g. much longer time periods are required to track changes in climate, such as temperature trends, than to assess trends in land-use practices)
- pressures most affecting the theme and significance of common pressures (e.g. an assessment of the effects of fishing is found in the Marine environment and Antarctic environment chapters, while pressures associated with land-use practices feature strongly in the Inland water, Land, Biodiversity and Coasts chapters; assessments of the effects of pollution are common to many chapters but results vary according to theme)
- maturity and scale of management responses (e.g. the Inland water chapter looks at the early stages of reforming national water management systems, and the Land chapter includes analyses of a long progression of local and national-scale conservation and restoration initiatives)
- meaning of resilience (e.g. interpretations reflect differences in the nature of the systems being assessed and the range of spatial and temporal scales relevant for discussing system functions).

The components and basis for assessment are described in each chapter, as are the timescales against which values are assessed.

3.7 Variation across themes

With the exception of the Coasts chapter, all theme chapters have followed the overall approach to assessing and reporting described above. Assessments are theme specific, and reflect values, pressures and measures that are meaningful for the particular systems being reported on in the chapter.
SoE 2011 is one of a range of environmental and sustainability reports that are produced at national, state and territory levels to fulfil both Australian and international reporting requirements.

4.1 National context

SoE 2011 draws from both national and jurisdictional-level reports. At a national scale, two main reports relate to SoE reporting: the five-yearly intergenerational report from the Australian Government Treasury\(^\text{11}\) and the Measure of Australia’s progress series from the Australian Bureau of Statistics.\(^\text{12}\) Although these reports focus on social and economic sustainability, more recent editions of both reports include coverage of environmental issues, and analyses of the linkages among social, economic and environmental aspects of sustainability.

Other national reporting protocols, such as those relating to air quality standards in the National Environment Protection Measures established under the National Environment Protection Council Act 1994, are also incorporated in the analyses presented in this report.

At a jurisdictional level, each state and territory produces a regular state of the environment report, and the chapters in this report draw strongly on relevant findings from these.

The jurisdictional reports have some limitations that make it difficult for them to be used to inform the national report, as there are many practical and longstanding differences in approaches to SoE reporting across jurisdictions. However, considerable effort has been made to align the scope, structure and methodologies of jurisdictional reports to strengthen their quality and complementarities, and to avoid duplication. In 2000, the Australian and New Zealand Environment and Conservation Council released Core environmental indicators to be used for reporting on the state of the environment,\(^\text{13}\) which was aimed at encouraging consistency to allow SoE information to be comparable across jurisdictions. A cross-jurisdictional SoE Reporting Forum has also been established with members from all Australian SoE reporting agencies, to provide a mechanism to improve quality and linkages across SoE reports.

4.2 International context

Australia is an active participant in numerous international partnerships, meetings and events concerning the environment, water, heritage and sustainable development. These that cover the full range of environmental issues include the Governing Council of the United Nations Environment Programme, the Commission on Sustainable Development, the Organisation for Economic Co-operation and Development (OECD), the Global Environment Facility, the World Heritage Committee, the South Pacific Regional Environment Programme and numerous multilateral conventions.

Australia makes regular reports to these and other international forums. These reports include assessments of how Australia meets its own environmental objectives and fulfils international commitments. Two particularly relevant and recent national-scale assessments are the OECD’s environmental performance reviews and the national reports to the United Nations Convention on Biological Diversity, outlined below. Australia also participates in the development and implementation of many other international agreements relating to environmental and biodiversity conservation and sustainable use.

4.2.1 Organisation for Economic Co-operation and Development environmental performance reviews

The OECD has conducted two independent reviews (1998 and 2008) of Australia’s national environment and environmental management as a part of its series of environmental performance reviews of member countries. The first review set baseline information for assessing future environmental progress, and the
second review examined performance across three areas: environmental management, sustainable development and international commitments.

The 2008 review provided an encouraging assessment of Australia’s performance. It made 45 recommendations for future progress, many of which feature in this report as recent initiatives or achievements. They include advances in water reform, expansion of the national reserve system, integrated management across jurisdictions at regional scales, continued improvements to national environmental datasets and information sharing, efforts to improve energy efficiency and decouple environmental pressures from economic growth, broadened participation in land-use planning, and the introduction of a carbon tax.

### 4.2.2 Reports to the United Nations Convention on Biological Diversity

Australia has been engaged with the United Nations Convention on Biological Diversity (CBD) since the inception of ad hoc working groups in the lead-up to the ratification of the convention at Rio in 1992. The Australian Government is now preparing for the Rio +20 Convention, at which progress over the past two decades will be discussed and revised targets will be negotiated.

The most recent national progress report to the CBD was submitted in 2009. It identified the major current and long-term threats to Australia’s biodiversity as climate change, pest species and disease, loss and fragmentation of habitat, marine and coastal pollution, disruption to natural water flow and fire regimes, population growth, and unsustainable development. The report also stated a number of priorities for managing environmental threats, all of which feature in SoE 2011: building ecological resilience, conserving connectivity, mainstreaming biodiversity issues in decision-making and improving the information base to support decisions.

### 4.2.3 Other international reporting contexts

Australia is a party to a number of other multilateral environmental agreements, international activities, organisations and partnerships for which SoE reporting is an obligation or has direct relevance.
References


Drivers of Australia's environment
The principal drivers of Australia’s environment—and its future condition—are climate variability and change, population growth and economic growth.

Our challenge is to mitigate the degree and potential impacts of climate change, and to decouple national growth from increased pressures on our environment.

Climate variability and climate change have a direct impact on the condition of Australia’s environment.

As the driest inhabitable continent, Australia is particularly vulnerable to the potential effects of climate change. We face a significant challenge in understanding the environmental implications of climate change, and how we might mitigate those impacts or adapt to them.

Australia’s exposure to climate change is dependent on global greenhouse gas emissions.

In 2000, the Intergovernmental Panel on Climate Change developed emissions scenarios to guide global climate projections. Since 2005, global emissions of greenhouse gases have continued to track above the middle of the scenario range. Based on our current understanding of atmospheric processes, the implication is that current policies will not achieve the significant reductions needed to mitigate profound climate change.

It is likely that we are already seeing the effects of climate change in Australia.

Australian average surface temperatures rose by nearly 1 °C between 1910 and 2009. Warming was modest in the early part of this period, declined slightly between 1935 and 1950, and then rapidly increased. The decade 2000–09 was the nation’s warmest on record. Some regions have had temperatures increase by 2 °C since 1960. The frequency of hot nights has increased and the frequency of cold nights has declined. Rainfall trends are more difficult to distinguish, given the large natural variability across regions and over time. During the past few decades, cool season (April to November) rainfall has largely decreased in the south-west and south-east when compared with natural variability, and winter season rainfall in the south-west of Western Australia has declined by about 15% since the mid-1970s.

Climate models project that, by 2030, average annual temperatures across Australia are likely to warm by 1 °C (above 1990 temperatures), with warming of 0.7–0.9 °C in coastal areas and 1–1.2 °C inland. Drying is likely in southern areas of Australia, especially in winter, and in southern and eastern areas in spring. Changes in summer tropical rainfall in northern Australia remain highly uncertain.

The Australian economy is projected to grow by 2.7% per year until 2050.

Higher labour productivity gains could increase this to 3% per year.
Under the base scenario, Australia’s population of 22.2 million people in 2010 is projected to grow to 35.9 million by 2050.

This figure may be 30.2 million under a scenario that assumes less net migration and historically low fertility rates. The projected development of infrastructure (e.g. housing, transport, water supply, energy, communications) strongly correlates with anticipated population growth, reflecting the long-standing pattern of association between these variables. In the absence of effective policies to reduce the impacts of population growth, it will remain an effective indicator of future pressures.

We have opportunities to decouple population and economic growth from pressure on our environment.

There is ample historical evidence of a strong correlation between population and economic growth, and increased resource use and waste production. However, we are not necessarily bound by this history. The opportunities to decouple this relationship through innovation and improved efficiency are many and varied.

We have become, by the power of a glorious evolutionary accident called intelligence, the stewards of life’s continuity on earth. We did not ask for this role, but we cannot abjure it. We may not be suited to it, but here we are.

In the long run a healthy economy can only exist in symbiosis with a healthy ecology.

Robert Costanza and Lisa Wainger, Washington Post, 2 September 1990

Audience at the 2010 Tamworth Country Music Festival, New South Wales
Photo by June Underwood
Introduction

The condition, trend and outlook for the Australian environment are subject to some major drivers of change. Understanding and quantifying these drivers is fundamental to understanding the past, present and future state of our environment.

The 2008 Victorian state of the environment report framed the consideration of these drivers particularly well, and this national State of the Environment report builds on their approach in developing our outlook on Australia’s environment. This approach recognises three major drivers on the environment.

Climate change is a direct driver of change. Population growth (with associated growth in the built environment) and economic growth (with associated increases in consumption of resources and generation of waste) are indirect drivers. As a direct driver, climate change has direct and ongoing effects on the environment, as higher temperatures and changing rainfall regimes in some areas can be expected to have profound and pervasive control over a host of natural processes that underpin the condition and trend of ecosystems. The effects of indirect drivers are mediated by other processes, including the policies, culture and technology that we bring to bear on our use of our environment. For example, population growth is likely to continue to drive the need for expanded suburban development. The size of this impact will depend on how sensitive the planning has been towards local environmental assets and values, and on the effectiveness of policies to improve the energy efficiency of housing and transport.

Economic growth will probably include increased demand for energy and other resources, as well as increased waste generation, with all the accompanying environmental implications for resource development, emissions and waste disposal. Alternatively, economic growth may be largely decoupled from increased consumption of resources and increased waste. Improvements in the efficiency of resource use have led to a weakening of the link between economic growth and energy use over recent decades (Figure 2.1).

![Figure 2.1 Australian energy consumption 1970–2010 and projected consumption 2011–30](image)
However, in the short to medium term, continued growth can be expected to lead to further increases in demand for energy, with consequent flow-on effects for resource development and emissions. In the longer term, if emissions of greenhouse gases (GHGs) are to be stabilised and then reduced, economic growth will need to be largely decoupled from increased GHG emission, consumption and waste.

There is no question that human activity, through each of these major drivers, has the ongoing potential to degrade our environment. However, establishing clear and precise relationships between these drivers and environmental impacts is not easy, particularly when we are projecting outlooks. The task is made even more complex when we consider the strong and diverse interactions among climate change, economic growth and population growth. Climate change and economic growth—and, to a smaller extent, population growth—are subject to global processes largely outside the control of Australia. If the collective effect of the GHG emission reduction policies and actions of other nations largely determines the magnitude and rate of climate change, and if Australia’s population and economic growth is strongly subject to future unknown domestic policy as well as global conditions, how can we assess the potential impact of these drivers on our environment?

This report considers scenarios of future climate, population and economy (this chapter), and the implications for the environment from those projections (in each of the nine themed chapters). This report uses the best available scenarios for these drivers—as reflected in their scientific pedigree as well as their general recognition by the Australian Government—as the most robust projections applicable to national planning.

Understanding the trends and environmental implications of these drivers is fundamental to establishing what a sustainable Australia might look like.
Climate change

Climate has always been a prime determinant of the Australian environment and its condition, with droughts and floods perhaps more characteristic than for other inhabited continents. The recent drought in south-east Australia is unprecedented in both its length and intensity (lasting from 1997 to 2010 in some areas). Research has shown that changes in the large-scale weather patterns affecting south-east Australia are associated in part with climate change. Therefore, it is likely that climate change, together with natural variability—and potentially land-use change—contributed to this drought. Similarly, research has found that the rainfall decline in south-west Western Australia since the mid-1970s is likely to be at least partly due to anthropogenic (caused by human activity) increases in GHGs. The drought in south-west Western Australia continues unabated. Understanding the causes and consequences of such events is crucial to any assessment of the current state of our environment and its recent trends.

There is strong and growing evidence that our climate, with its very high natural variability from year to year, is changing at a rate unprecedented in the geological record. Therefore, any outlook for the environment must incorporate our climate. The implications of climate change are potentially profound, and extend beyond the more obvious and direct impacts on inland waters, terrestrial and marine ecosystems and biodiversity, to our cultural heritage and built environment.

Forward projection of climate is scientifically challenging and inherently uncertain. There is a strong scientific consensus that anthropogenic emissions of GHGs have an impact on climate. New climate science and climate modelling is regularly published. The most robust statements on climate change since the 2006 State of the Environment report reside in the Intergovernmental Panel on Climate Change’s (IPCC) fourth assessment report. The significance of this body of work lies not only in the breadth and scope of the science contributing to the assessment, but also in the structured comparison of climate projections based on 23 of the world’s global climate models across an agreed set of emissions scenarios. The results of this comparison give us a picture of the strong commonalities among the global climate model predictions, as well as the uncertainties in their predictions of climate and GHG emissions. The IPCC’s scientific undertaking to produce and review the material for the fourth assessment report is impressive and unique. In the time since its release, aspects of the reporting process have been challenged, but not the underlying scientific content.

Has the science of climate change, as reported in the fourth assessment report—and now nearly four years old—significantly departed from those findings in that time? In response to the widespread interest in this general question, climate change science and data were reviewed and updated in time for the 2009 Copenhagen Climate Summit. The report reinforced the basic scientific linkages between human activity and climate reported by the IPCC, and found that global carbon dioxide emissions from burning fossil fuel continue to track near the highest scenarios considered by the IPCC. The Climate Commission’s 2011 report, The critical decade: climate science, risks and responses, makes the reality, certainty and implications of our changing climate clear and immediate.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology (BoM) summarised the IPCC findings with respect to Australia. Climate projections are available for the nation, and every state and territory, for the years 2030, 2050 and 2070. These projections include seasonal and annual rainfall and temperature estimates relative to the period 1980–99. Uncertainty in these projections for a given emissions scenario reflects the degree of disagreement among the global climate models, uncertainty in the scenarios and underlying uncertainty in our ability to capture natural processes in our climate models.

Emissions-driven climate change is obviously dependent on the anticipated use of fossil fuels into the future. The IPCC special report on emissions scenarios groups emissions scenarios into four families (A1, A2, B1 and B2). Each of these represent alternative development pathways and resulting GHG emissions under current policies, but with varying rates of population increase, economic growth and increases in resource-use efficiencies. The low, medium and...
Climate change | Drivers

High scenarios referred to in the CSIRO and BoM projections correspond to the B1 (economic growth based on clean, resource-efficient technologies), A1B (economic growth based on a balance between resource-efficient and fossil fuel-intensive industries) and A1F1 (fossil fuel-intensive growth), respectively. The projected emissions from the IPCC special report are shown in Figure 2.2. Since 2005, global GHG emissions have continued to track above the middle of the IPCC’s scenario range—between A1B and A1F1, with the temporary consequences of the 2008–09 global financial crisis evident.

The estimated increase in annual average temperature by 2030 (relative to 1990) is around 1.0 °C, with warming of 0.7–0.9 °C in coastal areas and 1–1.2 °C inland. By 2050, projected annual warming ranges from 0.8 °C to 1.8 °C; by 2070, the projected warming ranges from 1.8 °C (low GHG emissions scenario) to 5 °C (high emissions scenario). Figure 2.3a illustrates the low and high probability estimates for warming in 2030. There are indications from climate modelling that temperature extremes may also be changing, with a strong projected increase in warm nights, fewer frosts and longer heatwaves.

Figure 2.2 Annual industrial carbon dioxide (CO₂) emissions for 1990–2008 and 2009

Black circles represent the years 1990–2008, and the open circle represents 2009. Emissions fall within the range of all 40 emissions scenarios (grey shaded area) and six illustrative marker scenarios (coloured lines) of the IPCC special report. The inset in the upper left corner shows these scenarios to the year 2100.

Resurfacing and revegetation of former open-cut iron mine, Koolan Island, Western Australia

Photo by Jean-Paul Ferrero
The IPCC climate model results indicate that rainfall is likely to be reduced in southern areas of Australia, especially in winter, and in southern and eastern areas in spring. The contraction in the rainfall belt towards the higher latitudes (Figure 2.3b) would likely cause these variations. Future changes in summer tropical rainfall in northern Australia remain highly uncertain. Nevertheless, it is likely that the most intense rainfall events in most locations will become more extreme and more frequent, driven by a warmer, wetter atmosphere.

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**Figure 2.3** Projected changes across Australia in (a) annual average temperatures between 1980–99 and 2030, and (b) annual average precipitation in 2030 (compared with the period 1980–99)

The projections give an estimate of the average climate around 2030 considering consistency among climate models. Individual years will show variation from this average. The 50th percentile (the midpoint of the spread of model results) provides a best-estimate result. The 10th and 90th percentiles (lowest 10% and highest 10% of the spread of model results) provide a range of uncertainty. Emissions scenarios are from the IPCC Special report: emissions scenarios. Low emissions is the B1 scenario, medium is A1B and high is A1FI.
Figure 2.3  continued

Source: CSIRO Climate Change in Australia website (www.climatechangeinaustralia.gov.au): Australia’s future climate for (a) national temperature change 2030, annual and (b) national rainfall change 2030, annual.
Population growth and distribution

Human population growth is a potential cause of environmental change worldwide, including Australia, even without considering the impact of changes on living standards or resource use per capita. Historically, a higher population has generally translated into an amplified demand for resources, a larger physical footprint for our settlements and more waste going back into the environment. At the global scale, the Millennium Ecosystem report\(^{16}\) states that, over the past 50 years, humanity has changed ecosystems more rapidly and extensively than any comparable time in human history, largely to meet increased demands for resources.

However, it is not appropriate to attribute all past Australian environmental degradation to the direct or indirect effects of population growth. Many of our historical environmental impacts are related to poor land and water practices, poor development policies or phenomena such as introduced pests.\(^{17}\) None of these are directly related to population growth, nor would they be immediately remedied if Australia had fewer people. Nevertheless, many of the pressures on the Australian environment do scale to some degree with:

- how many of us there are or will be
- where most of us live or are likely to live in the future (i.e. near the coast and in the suburbs of large metropolitan centres)
- the material demands that our lifestyles place on the environment
- the technologies and practices used in interacting with the environment.

Australia’s population is growing. The factors that determine this growth are mortality, fertility and net migration. The largest factor influencing population growth over the past decade has been net overseas migration rather than natural increase, although less so than over previous decades. Scenarios of future growth developed by the Australian Bureau of Statistics and by the Australian Government Treasury use plausible ranges of each of these factors in combination to generate population projections, although to some degree these are constrained by historical trends. The best recent synthesis of these analyses for both population and associated economic projections is the 2010 intergenerational report (IGR) by the Treasury.\(^{2}\) The population projections in the IGR build on those published by the Australian Bureau of Statistics in 2008.\(^{18}\)

Australian mortality rates have fallen significantly over the past century; these falls have added to population growth and the proportion of older people in the Australian population. Australia’s crude mortality rate has fallen from 9.1 deaths per 1000 people per year in 1968 to 6.7 deaths per 1000 people per year in 2008. Mortality rates have fallen for both sexes, particularly for those aged 50 or more, since 1970. The life expectancy for Australians remains among the highest in the world. The 2006–08 life tables indicated that life expectancy at birth for men had risen to 79.2 years and for women to 83.7 years (an increase of 24.0 and 24.9 years, respectively, since 1901–10).

The total fertility rate is the average number of children a woman gives birth to in her lifetime; 2.1 is considered to be the fertility rate needed to keep the long-term population stable in the absence of changes in mortality rates and if there is no net migration. The 2008 estimate of the world total fertility rate is 2.5, ranging from 1.2 to 7.1. Most developed countries have fertility rates below the replacement rate.

Australian fertility peaked at 3.5 births per woman in 1961 (the end of the post–World War 2 baby boom). Subsequently, the total fertility rate of Australian women declined rapidly during the 1960s and 1970s, stabilised during the 1980s, then declined further until 2001. Since that time, fertility has been generally increasing to reach almost two births per woman in 2008, the highest since 1977 (Figure 2.4). The IGR base scenario projects fertility to fall slightly to 1.9 by 2013, and stay at that level for the remainder of the projection period. Although the fertility projection is below the natural replacement rate, natural increase remains positive throughout the projection period because relatively more women are currently in the younger rather than older age groups.
Australia’s current fertility rate is higher than many Organisation for Economic Co-operation and Development (OECD) countries, including Italy, Germany, Japan and Canada, and is well above the OECD average of 1.68 (2007 data). It remains below those of New Zealand (2.18 in 2008) and the United States (OECD estimate of 2.12 in 2007).

Of the three basic factors determining population (fertility, mortality and migration), the net migration rate is most subject to policy intervention, and thus the most uncertain in projections. Again, the most current scenario is provided by the IGR, which assumes in the base scenario that net migration will fall relatively sharply from an average of around 244 000 people per year from June 2006 to June 2009, to 180 000 people per year from 2012 and beyond, with an unchanged age–gender profile. To illustrate the long-term historical trends and future projections in migration, it is useful to express migration relative to the resident population (Figure 2.5). The average rate of net overseas migration assumed over the IGR projection period is around the average observed over the past 40 years; to project population growth this far into the future naturally has its uncertainties, but is nevertheless useful for anticipating potential implications for our environment.

**Figure 2.4** Australian fertility rates since 1950

*Source: Australian Government Treasury* including projections developed by the Australian Bureau of Statistics and the Treasury

**Figure 2.5** Rate of absorption of net overseas migration

Historical trends 1925–2010, and projected rates to 2050.

*Source: Australian Government Treasury*
Table 2.1  Australian population history and base scenario projections

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>0–14</td>
<td>3.6 (28.8)</td>
<td>4.2 (19.1)</td>
<td>4.9 (19.0)</td>
<td>5.4 (18.3)</td>
<td>5.7 (17.4)</td>
<td>6.2 (17.2)</td>
</tr>
<tr>
<td>15–64</td>
<td>7.9 (62.8)</td>
<td>15.0 (67.4)</td>
<td>16.6 (64.7)</td>
<td>18.2 (62.4)</td>
<td>20.0 (61.3)</td>
<td>21.6 (60.2)</td>
</tr>
<tr>
<td>65–84</td>
<td>1.0 (7.8)</td>
<td>2.6 (11.7)</td>
<td>3.7 (14.3)</td>
<td>4.8 (16.6)</td>
<td>5.6 (17.2)</td>
<td>6.3 (17.6)</td>
</tr>
<tr>
<td>85 and over</td>
<td>0.1 (0.5)</td>
<td>0.4 (1.8)</td>
<td>0.5 (2.1)</td>
<td>0.8 (2.7)</td>
<td>1.3 (4.0)</td>
<td>1.8 (5.1)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>12.5</strong></td>
<td><strong>22.2</strong></td>
<td><strong>25.7</strong></td>
<td><strong>29.2</strong></td>
<td><strong>32.6</strong></td>
<td><strong>35.9</strong></td>
</tr>
</tbody>
</table>

* a Rounded to nearest 100 000

Note: Population as at 30 June

Sources: Australian Government Treasury, Australian Bureau of Statistics, Treasury projections

Taking these three factors together, Australia’s population in all age groups is projected to increase (Table 2.1). Over the next 40 years, the rate of growth is projected to slow slightly to 1.2% annually, compared with the 1.4% experienced over the previous 40 years. At the same time, the population will continue to age.

The low population growth scenario is based on net overseas migration of 100 000 per year, which is lower than the 30-year historical average to 2008 of 109 000, and total fertility of 1.7 births per woman, which reflects the historical minimum reached in 2001. This gives an annual growth rate of 0.8%, lower than the 1.2% annual population growth that is projected under the base scenario (Table 2.2).

Table 2.2  Australian population projections—low and base case

<table>
<thead>
<tr>
<th>Age range</th>
<th>2010 (Population in millions)</th>
<th>2050 (Population in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–14</td>
<td>4.2 (19.1)</td>
<td>4.6 (15.1)</td>
</tr>
<tr>
<td>15–64</td>
<td>15.0 (67.4)</td>
<td>17.8 (58.9)</td>
</tr>
<tr>
<td>65–84</td>
<td>2.6 (11.7)</td>
<td>6.1 (20.0)</td>
</tr>
<tr>
<td>85 and over</td>
<td>0.4 (1.8)</td>
<td>1.8 (6.0)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>22.2</strong></td>
<td><strong>30.2</strong></td>
</tr>
</tbody>
</table>

* a Rounded to nearest 100 000

Note: Population as at 30 June

Sources: Australian Government Treasury, Treasury projections

It is not just the size of the Australian population that determines the impact on the environment. The geographical distribution and composition of the population may also be important factors. For example, the population may be growing more rapidly in areas of particular environmental sensitivity, such as the coasts, than in other areas. Changes in the age structure of the population or household sizes may have implications for the consumption of particular natural resources as a result of ‘lifecycle’ effects, where different age groups have different demand profiles (e.g., an ageing population is likely to increase demands for health services).

The Australian population is highly urbanised, tends to live close to the coast and is concentrated in metropolitan urban areas (Figure 2.6). In 2006, 88% of Australians lived in metropolitan urban areas compared with 58% in 1911. Some rural areas, and some small urban areas, have experienced and continue to experience population declines. Australia’s biggest cities are mostly located near the coast, meaning that the vast majority of the Australian population (85%) lives within 50 kilometres of the coast.

According to the most recent Australian Bureau of Statistics population projections, under the ‘middle case’ assumptions, the proportion of people living in the capital cities will increase from 64% in 2006 to 67% in 2056. Population projections are not available for other geographical dissections, but it is logical to assume that much of the remaining population growth will also continue to occur within coastal regions.

Where in Australia this population growth is likely to occur and its implications for the built environment of our cities and regions, heritage and natural environment is considered throughout this report.
Figure 2.6 Population distribution of Australia, excluding Cocos (Keeling) and Christmas islands, 30 June 2010
Over the past century, the structure of the Australian economy (as reflected in employment by industry) changed markedly. The significance of agriculture reduced, manufacturing declined from peak levels reached in the 1950s and 1960s, and there has been a steady rise of the already dominant service sector since 1950 (Figure 2.7).

![Figure 2.7 Employment by industry](source: Reproduced from the Reserve Bank of Australia)

Data are interpolated between 1900 and 1910.

Australia’s real gross domestic product (GDP) grew by an average of 3.3% per year between 1970 and 2010, and GDP per capita grew by 1.9% between 1970 and 2010. Our national standard of living, at least in economic terms, continues to grow faster than our population; we are an increasingly affluent society. The structure of Australia’s economy has also changed over this period, with an increased share of the economy driven by the services and resources industries (Figure 2.8). Since different industries exert different pressures on the environment, future structural changes in the economy can be expected to have an impact—either positively or negatively—on the environment.

Economic growth is supported by population, productivity and participation in the economy. The 2010 IGR projections of economic growth are based in part on the population projections discussed in Section 3 (see Table 2.1). Economic growth will, to some extent, offset the economic implications of an ageing population. It is also assumed that labour productivity will continue to increase at the 30-year historical average of 1.6% per year for the next 40 years.

Under these assumptions, the base scenario for Australia’s economic outlook is an average annual growth in real GDP of 2.7% to 2050, with per capita increases of 1.5%. This scenario indicates a somewhat slower economic growth than currently, largely due to the consequences of an ageing population on participation rates. A more optimistic scenario in the 2005 IGR of Australia’s future economy is based on maintaining productivity gains of 2% per year; under these assumptions, real annual GDP growth would average 3% to 2050.

Just as an increasing population does not necessarily translate proportionately to increased environment impact, neither does a growing economy. However, there is strong historical evidence that this has been the case and thus will likely continue into the future. As the economy of Australia expands, it is likely that our consumption of resources and production of waste will also increase. In its 2008 report on Australia’s environmental performance, the OECD recommended that Australia:

... make concerted efforts to decouple environmental pressures from economic growth, especially those pressures from the energy, transport and household sectors, including urban growth.

Historical trends can give insights into future trends in resource consumption and waste production, but do not consider significant changes in policy and the rate of technological innovation. Of course, in the real world, neither policies nor technology tend to be static, as demonstrated clearly in Box 2.1, which examines changes in the management of solid waste. From 1996 to 2009, government policy (strongly influenced by a growing community desire to recycle), together with improved technology, successfully diverted tens of millions of tonnes of solid waste from landfill into productive uses. This saved large quantities of valuable materials, and significant amounts of embodied energy and water.
Although the slowdown in the rate of increase in recovery shown in Figure A (Box 2.1) is disappointing, it is important to note the significance of the gap between the ‘total waste’ line and the ‘recovery’ line. This represents a significant environmental and economic net benefit in terms of saved resources (including energy and water). Table 2.3 shows the GHG emissions avoided, and the amount of energy and water saved by recycling a tonne of various materials.

The connections among energy use, water use, GHG emissions and waste production are complex, changeable and sometimes overstated. For example, total energy use by water utilities in Sydney, Melbourne, Perth, Brisbane, Gold Coast and Adelaide in 2006–07 was 7.1 petajoules, meeting the water supply and treatment needs of 12.5 million people.

This figure is approximately 0.2% of total urban energy use and less than 15% of the energy used for residential water heating; water supply and treatment are not strongly coupled to urban energy usage. Using a more energy-intensive future metropolitan scenario at 2030 (15.8 million people), with each person using 225 litres of residential water per day and a mix of supply sources (e.g. 40% desalination, 40% reuse and 20% new freshwater sources), would double the energy usage by water utilities compared with 2006–07 levels, but still only represent 0.3% of total urban energy use.30

As shown in Box 2.2, behavioural change can be a major factor influencing the nature of the linkage between population growth and the consumption of particular resources.
Box 2.1 Solid waste

Although the reliability of data on generation and management of solid waste in Australia is highly variable (making year-to-year and state-to-state comparisons difficult), there is general agreement between public and private sector observers that the long-term national trend of increasing solid waste generation is continuing.\(^{23}\) Data from the Environment Protection and Heritage Council for 2008–09 indicate a national total of around 46.8 million tonnes.\(^{29}\) Fortunately, over the past decade and a half, a significant proportion of the total waste stream has been diverted from landfill (around 52% in 2008–09). This has been achieved through the efforts by households, industry and governments to reuse, recycle and recover valuable materials from the waste stream.

Figure A shows how, after a period of rapid growth in the rate of diversion between 1996–97 and 1999–2000, while the rate of recovery has continued to increase, that increase has been matched by the increase in waste generated (which between 2002–03 and 2008–09 grew by 40%, compared with the population, which grew by 9.8%).\(^{24-26}\)

**Figure A** Waste generation, disposal and recovery in Australia, 1996–97 to 2008–09

Note: Waste and recycling data are generated in variable ways by a range of agencies, which means that there are wide disparities in the detail, geographic coverage, scale, timeframes and scope of the data. Within those limitations, effort has been made to ensure the accuracy of the information presented. Comprehensive data were not always available, and readers should exercise a degree of caution when using this information. Data methods and definitions have also changed between 2006–07 and 2008–09.


<table>
<thead>
<tr>
<th>Materials</th>
<th>Global warming tonnes (CO₂ equivalent)</th>
<th>Energy gigajoules (low heating value)</th>
<th>Water (kilolitres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>15.85</td>
<td>171.10</td>
<td>181.77</td>
</tr>
<tr>
<td>Concrete</td>
<td>0.02</td>
<td>0.28</td>
<td>1.28</td>
</tr>
<tr>
<td>Cardboard/paper recycling</td>
<td>0.06</td>
<td>9.32</td>
<td>25.41</td>
</tr>
<tr>
<td>Food and garden organics</td>
<td>0.25</td>
<td>0.18</td>
<td>0.44</td>
</tr>
<tr>
<td>Glass</td>
<td>0.56</td>
<td>6.07</td>
<td>2.30</td>
</tr>
<tr>
<td>Mixed plastics</td>
<td>1.53</td>
<td>58.24</td>
<td>−11.37</td>
</tr>
</tbody>
</table>

\(\text{CO}_2 = \text{carbon dioxide}\)

\(^a\) Positive values are benefits, negative values are impacts

Source: Environmental Protection and Heritage Council\(^{29}\)
Box 2.2 Household water consumption

In the face of widespread drought, and in response to increasing water supply charges and effective public education campaigns, household water consumption declined significantly in most states and territories from 2000–01 to 2008–09. There is little doubt that domestic water supply authorities will be watching closely to see whether the reductions in per capita consumption shown in Figure A are maintained following the widespread heavy rains in 2010 and early 2011, which restored many previously depleted water storages.

![Bar chart showing household water consumption from 2000–01 to 2008–09](chart)

**Figure A** Per capita household water consumption, 2000–01 to 2008–09

It is worth noting that the 2010 IGR makes reference to the important negative implications of unmitigated climate change to our future economy. It includes information from *The Garnaut Climate Change Review*, which conservatively estimated that unmitigated climate change would leave the Australian GDP in 2100 approximately 8% lower than it would be in the absence of climate change, with even greater impacts on consumption and real wages. This finding was more recently substantiated. Unmitigated climate change involves additional significant risks and nonmarket costs not captured by such estimates. The IGR concluded that:

... to best manage these risks to Australia’s future productivity growth, Australia needs to contribute to an effective global response to climate change.
Summary

The major drivers of changes to the Australian environment—climate change, population growth and economic growth—are historically related to environmental impact. Without significant policy and technological change (in some cases requiring global adoption), we can expect these relationships to continue into the future.

This chapter has examined the future direction and magnitude of these three crucial drivers. There is significant uncertainty in any and all of these predictions, partly due to uncertainties in the underlying science and projections, and partly due to the options available to Australians to minimise the negative environmental impacts of a growing nation and a high standard of living. In the latter, there is significant room for hope.
References


6 Deo RC, Syktus JJ, McAlpine CA, Wong KK. The simulated impact of land cover change on climate extremes in eastern Australia. 18th World IMACS/MODSIM Congress, Cairns, Australia, 13–17 July 2009.


Sentinel Peak, Grampians, Victoria
Photo by Michael Boniwell
Our environment is a national issue requiring national leadership and action at all levels.

There have been significant advances in many aspects of environmental management over the past decade, but management approaches and responsibilities are often fragmented across Australian, state and territory, and local governments. This can hamper our ability to address the legacies of past pressures like land clearing, ongoing pressures like invasive species, and emerging challenges like climate change. National leadership and commitment, together with the cooperation and coordination of all governments and stakeholders, including the Australian community, are important foundations for the future of Australia’s environment and heritage.

Effective environmental management requires adequate information.

Knowledge and information systems are the basis for sound adaptive management. That is, we need to understand the state and trends of our environment, the impacts of the pressures on our environment and the impacts of our management strategies, so that we can progressively adapt and improve those strategies. Long-term collection of national data on trends of many aspects of the environment is currently limited, which severely constrains the ability of Australian governments to develop and enact evidence-based environmental policy. A new national initiative—the National Plan for Environmental Information—offers the opportunity to address this serious deficiency.

Earth is warming, and it is likely that we are already seeing the effects of climate change in Australia. As the driest inhabitable continent, Australia is particularly vulnerable to climate change.

Although Australia’s climate is naturally highly variable, evidence—which continues to accumulate—shows that temperatures are increasing and rainfall distribution patterns are changing. Models project that, by 2030, average annual temperatures across Australia are likely to increase by 1 °C (above 1990 temperatures). Drying is likely in southern areas of Australia. Climate change will profoundly change the Australian environment, presenting widespread and significant risks to our ecosystems, native vegetation, water security, agricultural production systems and coastal communities.

Early action by Australia to reduce emissions and to deploy targeted adaptation strategies will be less costly than delayed action.

Major reductions in greenhouse gas emissions are urgently needed, both nationally and internationally, to minimise the level of climate change. Per person, Australia’s emissions are the largest of any country in the Organisation for Economic Co-operation and Development (OECD). The Fifth national communication on climate change sets out the Australian Government’s strategic approach to climate change. Such an overarching strategy, implemented at all levels of government via a range of policies, plans and programs, is essential if we are to succeed in limiting climate change and addressing key areas of vulnerability through adaptation.
The goal of life is living in agreement with nature.

Zeno, in Lives of eminent philosophers, Diogenes Laertius, 3rd century AD

Ambient air quality and air pollution management in Australia’s urban centres are generally good, but the impact of urban air quality on health is still a matter of serious concern.

National health-based standards are rarely exceeded for prolonged periods, and very high levels of pollution are usually associated with short-lived extreme events such as bushfires and dust storms. There is clear evidence that periods of poor urban air quality impact adversely on human health (particularly on the health of susceptible individuals). Some 3000 deaths were attributable to this cause in 2003—nearly twice the national road toll.

Pressures of past human activities and recent droughts are affecting our inland water systems.

In northern and remote Australia, human impacts have not significantly affected ecosystem function; in most southern regions, inland water ecological processes have changed substantially since settlement, and ecosystem function is significantly affected. The populations of many native species have declined. During the past decade (more in some areas), the southern half of the continent experienced a drought of unprecedented duration and extent, which dramatically changed inland water environments, and there is evidence that this partly reflects a changing climate.

Meeting our water needs will be a critical challenge.

Demands for water will increase as Australia’s population grows, and withdrawing water changes our inland water ecosystems. However, increased demand could be met without taking much more fresh water out of the environment (but potentially with other environmental costs, including increased energy use associated with desalination or wastewater recycling). Reduced water use will also play a part—Australia’s water consumption fell 25% from 2004–05 to 2008–09. Climate change poses the largest future threat to our inland water systems. Current water-sharing rules tend to favour water entitlement holders over environmental flows in dry times.

Australia’s land environment is threatened by widespread pressures.

Invasive species, inappropriate fire patterns and grazing are having a significant impact on much of our land environment. Grazing is Australia’s most widespread land use and its environmental impact appears to be mixed, with impacts diminished in some regions but increased in others since widespread monitoring began in 1992. The areas managed for conservation and by Indigenous Australians have expanded (each now more than 20% of Australia’s land area). Land clearing is slowing, but still averaged around 1 million hectares per year during 2000–10. The legacy impacts of land clearing are substantial, with loss and fragmentation of native vegetation. The extent of land clearing is now balanced by that of regrowth, although the character of regrowth is different from that of the original vegetation.
Threats to our soil, including acidification, erosion and the loss of soil carbon, will increasingly affect Australia’s agriculture unless carefully managed.

Acidification and erosion currently affect large areas, although wind erosion has decreased in response to better agricultural practices. In 2001, it was estimated that soil acidity affected 50 million hectares of surface layers and 23 million hectares of subsoil layers, estimated to cost $1.585 billion per year in lost agricultural production. Soil carbon is central to maintaining soil health, and can also be a significant source or sink for greenhouse gases, depending on land management.

The overall condition of the Australian marine environment is good, but integrated management will be key to the future conservation of our ocean resources.

Nearshore marine areas adjacent to intensive settlement have suffered the most from human activities; open ocean conditions are generally good. However, the pressures on all these areas are increasing, and the early warning signs of degradation are becoming commonplace in a number of ecosystems and habitats. An integrated national system of multilevel governance for conservation and management would enable the natural wealth of our oceans to be maintained in the face of challenges, and would reward us with healthier oceans and increasing economic returns.

The ocean climate is changing and we will need to adapt.

There are likely to be major impacts in the coming decades from increasing sea level, increased incidence and severity of extreme weather events, altered ocean currents, changing patterns of biodiversity, and changing productivity. In particular, ocean acidification will have a major impact on marine ecosystems, since it can affect the base of marine food webs by diminishing the ability of planktonic organisms, which are food for many other organisms, to form shells.

The Antarctic environment is showing clear signs of climate change, which is likely to have profound effects on Antarctic species and ecosystems.

The East Antarctic Ice Sheet is losing ice at its coastal fringes—about 60 billion tonnes each year since 2006. The loss is occurring at an increasing rate and may contribute significantly to sea level rise. The upper layers of the Southern Ocean have warmed by 0.2 °C since the 1950s. This rate of warming is faster than elsewhere in the world. Warmer waters enable alien species to extend their range southward. Invading species are likely to outcompete, and perhaps replace, native species. Antarctic vertebrates, including seabird, penguin, seal, whale and numerous fish species, are highly specialised to survive in the Antarctic. It is not known whether they can adapt to new conditions arising from climate change, and it is likely that some species will not survive the coming decades.

Our unique biodiversity is in decline, and new approaches will be needed to prevent accelerating decline in many species.

Many of Australia’s species, and even whole groups of species, are unique to this continent, and Australia is identified as one of the world’s ‘megadiverse’ countries. However, there have been major declines in many components of biodiversity since European settlement, and data on pressures suggest that many species continue to decline, despite promising investment to address these pressures. Australian governments and nongovernment organisations are trialling new approaches to managing ecological systems. This includes supporting connected corridors of vegetation, which have the potential to make major advances in conserving our biodiversity.
Our extraordinary and diverse natural and cultural heritage is currently in good condition, but is threatened by natural and human processes, and a lack of public sector resourcing.

Australians place a high value on our rich natural, Indigenous and historic heritage. However, our heritage lists and protected areas do not include all of the places with heritage value, nor are they truly representative. Although the processes used to protect and manage Australian heritage are internationally recognised, some are cumbersome and under-resourced. Comprehensive assessments, more flexible approaches and better resourcing are needed to support conservation.

Australia’s built environment faces many pressures and consumes significant natural resources, although consumption may be slowing.

The majority of Australians (87% in 2006) live in urban areas. An increasing need for urban space and buildings, increasing traffic congestion and increasing consumption are affecting the livability and environmental efficiency of the built environment. Traffic congestion, in particular, is of growing concern. However, growth in traffic may be levelling and use of public transport is increasing. Emerging evidence suggests that energy and water use may be slowing due to improved technology and better recognition of the need to reduce human environmental impact.

Coastal regions bring together many of the issues affecting other parts of the environment, and coordinated management will be needed to mitigate pressures.

Our coasts, as well as being some of our most iconic natural areas, are some of Australia’s most heavily settled areas. Pressures include urban expansion and the cumulative effects of small developments. Some trends, such as expansion of conservation and Indigenous areas and improvements in land-management practices, are acting to reduce some pressures. Climate change will have a major impact on our coasts, particularly through sea level rise. The implementation of recommendations from Managing our coastal zone in a changing climate: the time to act is now would support a more strategic approach to managing coastal resources. The Australian Government has now noted or agreed in principle to most of these recommendations and appears set to take action on many.

Australians cannot afford to see themselves as separate from the environment.

The Australian environment is precious. Our ecosystems, biodiversity and heritage are vulnerable to the choices we make. At the same time, we depend on them for our survival and wellbeing. Our ecosystems, and the biodiversity they support, provide services that are fundamental to human life, such as regulation of the atmosphere, maintenance of soil fertility, food production, filtration of water, and pest control. The major future drivers of change—climate change, population growth, economic development and associated consumption of natural resources, as well as the pressures that these drivers place on the environment—will need to be managed carefully if our society is to achieve a sustainable relationship with the Australian environment.
The balance of nature is not a status quo; it is fluid, ever shifting, in a constant state of adjustment.

Rachel Carson, *Silent spring*, 1962
Summary

The 2011 State of the Environment (SoE) report aims to give Australians the best possible and clearest answers to three basic questions:

- What is the current condition of the Australian environment?
- What are the risks the Australian environment faces and are we doing enough to protect it?
- Where is the Australian environment headed?

Much of Australia’s environment and heritage is in good shape, or improving. Other parts are in poor condition or deteriorating. Some of the pressures on our environment arise from past decisions (or even just bad luck) that have left an ongoing legacy of impact. Our changing climate, and growing population and economy are now confronting us with new challenges.

The consequences of our past environmental and heritage management are reflected in a number of environment indicators that continue to cause concern. Introductions of feral animals and weeds, widespread land clearing, the drainage of wetlands, intensive harvesting of fish stocks and a host of other past actions will continue to exert pressures on our environment regardless of environmental policies and management that now prohibit or minimise such actions, and regardless of our management of the drivers of climate change, and growing population and economy. For example, if we did not add one more person or business to the nation, the ongoing impacts of feral goats, rabbits, cane toads, land clearing and vegetation dieback would continue to be significant.

In general, environmental and heritage management in Australia reflects a sound understanding of this historical context, and translates into environmental and heritage planning with clear intent. Future environmental impacts are not necessarily based on historical relationships between growth and resource use, biodiversity loss or environmental degradation. There is evidence that we have the means to disconnect, at least to some degree, the relationship between growth and environmental impact that has been seen in the past. While our population and economy have continued to expand, we are no longer subjecting the continent to wholesale land clearing or unmitigated industrial pollution, and sea-floor trawling is now limited. We no longer develop water resources without any reference to the needs of the environment. We attempt to recognise and protect Indigenous heritage. And although we have had only limited success in controlling introduced weeds and pests, we now take biosecurity very seriously so that we might not have as many new pests to deal with.

However, the resources required to reverse or reduce historical impacts are in many cases beyond the means of even a wealthy nation like Australia. Conservation investments and interventions tend to focus on our environmental and heritage assets that are of greatest value and under greatest threat. With this focus, significant restoration of the environment towards its pre-settlement condition will continue to be elusive.

If we consider the major environmental challenges we now face, the most confronting is the prospect of
a changing climate. This is, in part, because climate is such a direct and pervasive driver of environmental response, in part because global warming is something beyond our near-term or local control, and in part because of the uncertainties of scientific prediction and global policy. Climate change is now widely understood as a prime risk to both our environment and our society, and is clearly a major item on our national agenda. The Climate Commission’s (2011) report, *Climate science, risks and responses*, makes the reality, certainty and implications of our changing climate clear and immediate. These implications extend to regional security and threats to our export markets.

The growth in global greenhouse gas emissions since 2005 is tracking above the middle of the Intergovernmental Panel on Climate Change’s (2000) scenario range. There is also a very large amount of inertia in the atmospheric–oceanic system, which will drive climate change for centuries to come, even if global mitigation efforts dramatically reduce emissions. Together, these factors mean that we are facing climate consequences for the foreseeable future. Key sectors of the Australian environment are vulnerable to relatively small increases in temperature or drying, or to projected increases in sea level. We note the evidence that early action by Australia to reduce emissions and to deploy targeted adaptation strategies will be less costly than delayed action. To the extensive analyses and national dialogue on this issue, we will only add that we can expect to be surprised by both the vulnerability and the resilience of different parts of our environment and heritage.

Australia will continue to do what we can to redress the legacy of our mixed history of environmental and heritage management, while ensuring we mitigate or wisely adapt to the ongoing drivers of climate change, population growth and economic growth. To support this, we will need to choose our environmental (and sustainability) indicators with equal wisdom. These indicators need to measure the effects and effectiveness of our current and future approaches to environmental sustainability to allow us to improve our strategies.

Assessing the state of Australia’s environment is inherently difficult. Australia is a big country, with a wide variety of ecosystems and heritage. There are many unconnected means by which we gather and store information on our environment, and accessing this information at a national scale is tremendously complicated and not always possible. These are the challenges faced by every SoE report, and why many of the assessments made in this report are indicated as uncertain and in some cases not possible. We look forward to continuing progress towards improved environmental information systems across jurisdictions, industries and communities. Although there will always be a call for more measurement and new understanding of our environment and heritage, there is also great value latent in the information we have already collected if we can access it more efficiently and effectively.

But although more and better information is essential, it is not all we need to meet our challenges. What is clear from this report is that the complexity of environmental management in a changing world demands a more integrated approach to planning, and management focused on achieving and maintaining the environmental values.

The difficulties we face with a national SoE report in terms of inadequate data are in part a symptom of a lack of national coordination. Australia is a federation with nine major jurisdictions and hundreds of local authorities, plus thousands of individual government departments and nongovernment organisations. The responsibility for environmental governance is shared among the three Australian levels of government, and with the community and the private sector. Furthermore, jurisdictional divides establish precise spatial boundaries of control, each with their own focus and purposes. Developing and implementing integrated approaches to address common objectives can therefore be challenging.
However, the Australian environment crosses these boundaries, and its management needs rarely reflect our organisational and administrative structures. Nor do national territorial boundaries limit Australia’s environmental obligations under international treaties and agreements, including the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), China Australia Migratory Bird Agreement, Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar), International Convention for the Regulation of Whaling and the United Nations Convention on the Law of the Sea.

Because of this complexity, the Australian Government has an important national role to play in environmental management. This role is leadership—partly through the government’s own actions and partly through national coordination. This leadership extends to priority setting, funding and handling of policy on national issues; coordination of programs, information gathering and sharing; and coordination of guidelines and standards. National programs such as the Murray–Darling Basin Plan, Caring for our Country and the National Reserve System are also important in providing overarching systems for particular aspects of our environment. The prognosis for the environment at a national level is highly dependent on how seriously the Australian Government takes its leadership role.

Four trends in environmental management stand out over the past decade. The first is that the Australian Government has exerted stronger leadership on a number of important environmental issues, such as biodiversity conservation and water governance. The second is that the Australian, and state and territory governments have given much greater emphasis to regional-scale environmental management, complementing the roles of different levels of government and of community-based organisations such as Landcare. The third is the use by governments of an array of market-based mechanisms to complement regulation as a means of realising environmental goals. Finally, Indigenous Australians have become more formally involved in the management of their land and sea country.

These trends in environmental management will influence the future condition of the Australian environment. The current state and trends and the outlook over the coming decades vary for different dimensions of our natural and cultural environments.
Summary

Atmosphere

Over the relatively short span of 250 years, and for the first time in human history, we have changed and are continuing to change the composition of the atmosphere on a global scale. Levels of carbon dioxide, the most important greenhouse gas, have increased by around 39% above pre-industrial levels, principally due to burning fossil fuels. This has led to a clearly defined trend of increasing average global temperatures, and there is growing evidence of consequent changes in the complex interlinked atmospheric, oceanic and terrestrial processes that shape climate at global, continental and regional scales.

For Australia, as the driest inhabitable continent (with a climate characterised by high levels of variability), climate change poses a clear and present threat. Although projections of Australia’s future climate at national and regional scales are still uncertain, the most recent comprehensive review of modelling outcomes shows that a continuing, spatially variable rise in temperatures across the continent is highly likely. Projections of rainfall are more variable, but half of the 23 models considered by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology show an increase in annual and summer rainfall in northern Australia, while nearly all show a decrease in winter rainfall in the south-west and along the south coast.

In addition to the risks of increasing temperatures, and changes in rainfall amount and seasonality, a key risk associated with climate change is the likelihood of more frequent and more severe extreme weather events, such as floods, droughts and heatwaves. Such primary atmospheric risks in turn generate a broad series of secondary and tertiary risks, including increased mortality and morbidity due to heatwaves and spread of disease vectors, reduced stream flows and groundwater recharge, reduced soil moisture and loss of topsoil, and changes in habitat with attendant risk to biodiversity. An increase in bushfires is also likely.

Depletion of the stratospheric ozone layer, particularly in the form of the seasonal ‘ozone hole’ over Antarctica, remains of concern, as the ozone layer limits the amount of harmful ultraviolet light reaching the lower layers of the atmosphere. Since peaking in the mid-1990s, levels of stratospheric chlorine and bromine from chlorofluorocarbons and other ozone depleting substances (ODSs) have decreased and are continuing to decrease. However, the latest World Meteorological Organization Scientific assessment of ozone depletion (2010) cautions that ‘… ozone depletion will continue for many more decades because several key ODSs last a long time in the atmosphere after emissions end’. This has important implications for the climate, since all ODSs (except methyl bromide) are powerful greenhouse gases and recovery of the ozone layer is expected to interact with climate change through a complex series of linkages.

Ambient (outdoor) air quality in Australia’s major urban centres is generally good. National health-based standards are rarely exceeded for prolonged periods, and poor air quality is usually associated with short-lived extreme events such as bushfires and dust storms that generate very high levels of particle pollution. Despite substantial growth in population, expansion of industry and greatly increased use of motor vehicles, levels of carbon monoxide, lead, nitrogen dioxide and sulfur dioxide have declined in urban areas over the past 10 years. By contrast, levels of particles and the secondary pollutant ozone have not decreased. Monitoring results continue to show that peak ozone levels occasionally exceed the standards in some centres, and standards for particle pollution are often exceeded for short periods in most metropolitan cities. Despite a generally favourable situation, research in Australia and overseas has shown that urban air pollution continues to be a significant cause of death and illness in the community. By one estimate, there were some 3000 deaths in Australia due to urban air pollution in 2003—nearly twice the national road toll.
Prospects of achieving significant reductions in peak levels of particles and ozone will be influenced by a range of factors, including continued tightening of vehicle emission standards, availability and reliability of public transport, increased take-up of cleaner forms of production, continued expansion of major cities, rising temperatures, and more frequent extreme events associated with climate change.

Given the high proportion of time most Australians spend indoors, it is surprising that Australian data on indoor air quality are relatively scarce and that there are no specific national guidelines for indoor air quality. Although government intervention to improve indoor air quality has increased during the past decade, such action has focused on smoking bans in public venues and in workplaces, leaving the domestic environment largely unregulated.

During the past decade (longer in some areas), the southern half of the continent experienced a drought of unprecedented duration and extent. This dramatically changed the character of inland water environments. Except for the south-west corner of the continent, the drought ended in late 2010 with widespread flooding. The recovery of river and wetlands ecosystems following these floods will provide crucial insights into how inherently resilient these systems are—if this recovery is appropriately monitored.

With some additional management intervention and investment, the inland water environment is likely to remain in generally good condition in northern Australia, and poor but potentially improving condition across much of the south, with only limited regions with continuing serious deterioration. The principal risk to inland environmental health that remains poorly mitigated is the likelihood of a drying climate for our southern catchments; current water allocation rules tend to favour water entitlement holders over environmental flows in dry times.

Inland water

Using water from our environment is fundamental to our sustainability as a society. We have had an ambitious decade of water policy reform, with all states and territories committing to the principles of the National Water Initiative. This initiative is designed around a market, regulatory and planning-based system to manage surface water and groundwater resources for rural and urban use in a way that optimises economic, social and environmental outcomes. This commitment includes provision of adequate water for sustaining the environment.

Most of the current impacts on Australia’s inland water environments result from our historical legacy of land-use change, pest and weed introductions, and water resource development. Although there is only limited capacity to reverse many historical impacts, there is reason to believe that projected population and economic growth can be significantly decoupled from future pressures on our inland water ecosystems: Australia is using less water, and while Australia’s rising population will increase demand for urban water, this is likely to be met without taking proportionately more fresh water out of the environment.

Land

The situation and outlook for the land environment are mixed. Although we have made progress in many aspects of managing Australia’s land environment, the trends for many indicators of land environmental values remain adverse, and are likely to be exacerbated by climate change.
Although vegetation and soils are in relatively good condition across large areas of Australia, this is not the case in much of the intensive land-use zone where agricultural production is concentrated, nor in some parts of the rangelands. The rate of land clearing, one of the most significant pressures on the land environment, averaged around 1 million hectares per year in 2000–10. By the end of the decade, the continental extent of land clearing was balanced by the extent of regrowth—although the character and values of the two forms of vegetation are often different. The impacts of other landscape-scale pressures—principally invasive species, and inappropriate fire and grazing regimes—are increasing in many areas. In agricultural systems, loss of soil carbon, and soil acidification and erosion, are problematic and may have major impacts on production.

Livestock grazing is the most extensive of Australia’s land uses, practised across 55% of the continent. The conservation and Indigenous estates have continued to expand; each now represents more than 20% of Australia’s land area. The effectiveness of management has improved for most land uses, particularly for those that are most intensive, but needs to improve further in many land-use systems to protect and sustain their environmental values. The expansion of human settlements, and of new forms of mining, are having locally significant impacts in those regions where they are concentrated.

Some governance and institutional arrangements for the land environment have changed substantially during the reporting period, but remain suboptimal in a number of important respects. Levels of investment in management of the land environment, in research and development, and in knowledge and information systems that enable good land management are significant but still inadequate.

Climate change is expected to have profound effects on the land environment, particularly on native vegetation and production systems. Some native vegetation communities are likely to disappear, others will change substantially in extent and composition, and novel ecosystems will arise. Impacts on production systems are likely to be mixed, but generally adverse.

**Marine environment**

Australia’s oceans and coastal marine ecosystems are overall in good condition and have experienced only gradual decline, although there are many local coastal areas where ecosystems are in poor or very poor condition as a result of local pressures. Indeed, some of the world’s worst examples of impacts from pollution can be found in Australian waters. Australia is world leading in many areas of marine management, but low levels of pressures have allowed environmental resilience to remain high in many regions. Now, there are strong signals that many of our marine systems and resources have reached their finite limit and pressures are building to levels where impacts can be easily seen in many of the regions.

Nearshore development is proceeding quickly, replacing vegetated landscapes with hard surfaces that interrupt wetland functions and estuarine flows. Land-based sources of pollution and expanding pressure on coastal lands continue to be a significant concern, despite strong improvements in land-use planning and the management of many point sources of pollution. Fishing has reduced most populations of sought-after species to low levels, mainly in previous decades. The maintenance of these low population levels by present-day management policies probably has significant flow-on consequences for the resilience and persistence of marine biodiversity in all inshore waters.

The major looming threat for our oceans and coastal waterways is the changing global climate, which is creating significant changes in ecosystems, biodiversity, shorelines and coastal lands. It threatens our wealth generation from the oceans, and the existence of our coral reefs at their present-day scale and grandeur. A proliferation of oil and gas exploration and extraction, together with the new energy and water systems, and other shoreline industries, brings not only important initiatives in wealth generation, but also a major new set of risks to our waters that will require intensive strategic and regional management.
Regionally, the north-west is beginning to come under intense development pressure from the resource extraction sectors (oil and gas, mining, fishing, shipping). The marine values and assets of the north region remain relatively pristine, although, even there, mining and river damming are growing pressures. The south-east region remains under the greatest stress, with a legacy of impacts from a wide variety of sources, and is suffering the greatest impacts from changing climate—the East Australian Current is changing its pattern of extension into Tasmanian waters with the intensification of gyres and increases in temperature.

The interaction of accelerating changes in the climate with existing land uses, fishing systems, shoreline industries and new risks is presenting ocean management with unprecedented challenges. There is a plethora of responses to this situation, many of which are achieving good outcomes; some are reducing pressures, and holding ecosystems and biodiversity in good condition. However, the evidence is that our management systems are still too fractured, weakly coordinated and poorly integrated to halt the accelerating degradation of the unique values of our oceans and coastal ecosystems. The early signals of such decline are now evident across a number of areas of our coastal waters. Perhaps the most critical challenge of all now confronts us—our ability to design and deliver good, effective and efficient governance to address the known threats and accelerating risks to our unique marine environment.

Antarctica is changing. The rate of change varies around the continent, but some areas—for example, the Antarctic Peninsula—are changing very quickly. The most important factors contributing to this change are climate change, the occurrence of extreme events and human impacts. East Antarctica, where Australia operates, has so far changed comparatively slowly but it, too, is getting warmer. There is still little understanding about how various factors may interact. For example, recent research has discovered a link between the ozone hole and the rate of warming in East Antarctica. While the ozone hole exists, clouds forming as part of the processes that create the thinning of ozone appear to shield the continent from warming. Predictions are that a recovery of the ozone layer will significantly increase the rate of warming. A key activity of the Australian Antarctic bases is research to assess the impact of climate change on the Antarctic environment and its ecosystems. It will also be important to understand the wider implications of Antarctic changes, as the atmospheric and oceanographic processes of Antarctica are important drivers for the weather in the Southern Hemisphere.

The rate at which the physical environment of the region is changing appears to be faster than the rate at which organisms, especially those of a higher order, can adapt to the changes. Although many uncertainties still exist, some populations are changing in size. Not all populations are decreasing, but, in the long term, they may be outcompeted by species that can adapt to the changing ecosystems or be replaced by species whose range is now extending from warmer climes into the Antarctic region. It is likely that some Antarctic species will not survive the coming decades.
Biodiversity

Biodiversity in Australia has declined since European settlement. This decline is seen in all components of biodiversity—genes, species, communities and ecosystems—and the evidence from pressures suggests that many components of biodiversity continue to decline. This trend is variable, because components of biodiversity appear to be persisting well in some areas, especially where human impacts are minimal, but declining significantly in others. Declines have historically been greater in southern Australia than in the north; however, recent reports of significant declines in small mammals and birds in northern Australia suggest that at least some components of biodiversity in the north are less secure than previously thought.

Long-term collection of data on trends in biodiversity and their implications is very limited, and most jurisdictions are unable to draw detailed conclusions about the state or trends of major animal and plant groups. Despite promising investment by all jurisdictions in addressing the main pressures on biodiversity, state of the environment reports around the nation continue to conclude that the decline in biodiversity is not being arrested or reversed. Most pressures on biodiversity that arise directly or indirectly from human activities appear to still be strong, and those that have declined, such as land clearing, continue to have legacy effects that will last for years or decades.

However, despite this bleak history, there is hope for the future. Australian governments and nongovernment organisations have been debating and trialling new approaches to biodiversity management, including ways to engage the right stakeholders at the right times and in the right places. This nation is poised to build on these trials and, if wise decisions are made, there is potential to make major advances. However, the legacies of past pressures like land clearing, ongoing pressures like invasive species and emerging challenges like climate change will take decades to address, so even in the most optimistic scenarios we will not see overnight change.

As Australia’s population grows, serious thought needs to be given to the dependence of people on biodiversity and natural resources, and how we protect those resources. Human activities have the potential to lead to further declines in components of biodiversity, which will seriously affect the delivery of environmental benefits to Australians and reduce our quality of life. Improving the collection of information that will allow us to understand the effects of interactions and interrelationships between humans and biodiversity over the long term is vital. Most of the potential risks and surprises affecting biodiversity also present opportunities if Australians think strategically, anticipate, prepare and act.

Heritage

Our heritage includes those places with natural, Indigenous or historic values that we have inherited and want to pass on to future generations. Heritage provides an important context for our perception of ourselves as Australians, and is part of the ‘social glue’ that binds communities together and expresses identity. Australians see natural and cultural heritage as important, but also as vulnerable, but these sentiments are not reflected in the resources devoted to heritage assessment and conservation.

The systems we use to manage our heritage are cumbersome: land reserves, inventories and statutes. These structures do not adequately identify, protect, manage, resource or celebrate our nation’s natural, historic and cultural landscape. Our heritage is, as a consequence, at risk from the impacts of climate change, the threats arising from development and the pressures arising from population growth.
Although the value of our natural heritage is widely recognised, neither private nor public natural heritage places are adequately protected. The National Reserve System continues to improve, but reservation of a truly representative set of landholdings is hampered by factors such as perceived economic values.

Climate change poses major risks to natural heritage and, if its impacts are to be managed effectively, scientists and managers will need to work proactively and together. Our natural heritage is also threatened by inappropriate land use, development pressures, loss of habitat and invasive species. Adverse effects can be minimised through thorough understanding of natural heritage resources, recognition of the benefits of public–private partnerships and a ‘whole-of-landscape’ approach to conservation and management.

There is increasing recognition of the importance of Australia’s Indigenous heritage by all Australians. However, Indigenous heritage in Australia is inadequately documented and protected. Incremental destruction continues. The inclusion of Indigenous heritage places within protected reserved lands is therefore particularly important. ‘Closing the Gap’ is a welcome initiative, as is the increasing involvement of Indigenous people in sustainable land and sea management. However, loss of language, knowledge and traditional practices continues to erode Indigenous cultural traditions and connections to country.

There are many well-managed Australian historic heritage places that remain in good condition. However, statutory lists and registers are inconsistent and incomplete. Historic heritage conservation is not well supported by planning and assessment systems and is directly threatened by development pressure, often because heritage is identified only after a project is proposed and is therefore perceived as ‘the problem’. Population shifts and inadequate incentives for private owners also threaten historic heritage. A wider range of management approaches would enhance the place of historic heritage in the community and facilitate effective conservation.

Overall, the outlook for Australia’s heritage will depend on government leadership and two key factors: firstly, willingness to undertake thorough assessments that lead to comprehensive natural and cultural heritage inventories, and truly representative areas of protected land; and, secondly, our ability to respond to emerging threats through improved resourcing and more flexible heritage management approaches and processes.

**Built environment**

Australia’s diverse built environment faces many pressures—driven by population and economic growth, and climate change—and is only in a fair shape. An increasing urban footprint, increasing traffic congestion and increasing consumption are impacting on the livability and environmental efficiency of our cities and towns. Traffic congestion, in particular, is of growing concern in our cities. Residents are also concerned about the look and design of their cities; in the biggest cities, there are concerns about whether they are clean, well maintained and unpolluted.

The Australian built environment consumes significant natural resources, including water, energy and land. There is also significant waste generation, although there is emerging evidence that growth in the use of natural resources and waste generation may be slowing. Climate change is creating increased risks to the built environment through the greater likelihood of weather-related events such as mega-storms.

Management of the built environment is characterised by complex arrangements involving federal, state and territory, and local governments, as well as the private sector, and these arrangements lack coordination. Recent Council of Australian Governments initiatives to reform capital city planning, as well as the recently released National Urban Policy, seek to address this issue. Overall, the outlook for the built environment is mixed, with the negative impacts of the expected increased physical size of cities and increased traffic congestion offset by prospects for improved management and more efficient use of natural resources.
Coasts

Variations in climate, and changes in population size and composition around Australia’s coasts have been major drivers of pressure on Australian coasts over the past decades, including both natural and built environments. Concerns about how to deal with the pressures caused by these drivers, as well as how to prepare for possible future climate change, have been the focus for adaptation responses in the past decade. Some trends have acted to reduce some pressures. These include expansion of conservation and Indigenous areas, decline in the extent of native forest managed for wood production and a corresponding increase in the extent managed for conservation, and improvements in land-management practices that have reduced the flows of sediments and chemicals to the coast that were characteristic of major rainfall events in the past.

There are also examples of promising responses to coastal challenges by governments, working individually and together, but outcomes in relation to a number of major issues are still far from ideal. There is significant uncertainty regarding how species and ecological systems will be impacted by climate change, and local governments are expressing concern about the lack of guidelines, standards and national strategic approaches to addressing coastal development, growing populations and environmental impacts. The recent Hawke report recommended changes to the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) that would allow it to be applied more strategically, and at ecosystem and landscape scales. Many of these recommendations have been accepted by the Australian Government. It remains to be seen whether action is sufficient and soon enough to allow assessment and successful management of the cumulative effects of small developments along the coastal strip.

The 2009 report from the House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts, Managing our coastal zone in a changing climate: the time to act is now, noted that there is limited national collaboration and cooperation to achieve consistencies, efficiencies and agreements on issues such as variations in planning laws, capacities of local councils, monitoring coastal habitat change and legal liabilities. It made 47 recommendations to address these issues. Most of these recommendations have been noted or accepted in principle by the Australian Government. As with the responses to the review of the EPBC Act, the quality and timeliness of actions will be critical if existing challenges to coastal sustainability are to be addressed and looming ones prepared for.

Recent research comparing Australian coastal governance with examples elsewhere in the world has concluded that, in many parts of Australia, the ability to adapt to emerging pressures, especially climate change, is low and declining. Recommended remedies include: (a) allocate authority and resources between levels of governance according to their effectiveness at each level; (b) strengthen development rules and incentives to relocate as an unwanted threshold is approached; (c) allow for uncertainties by enabling rules and incentives to be changed when circumstances change; (d) reassign public and private benefits, costs, risks, uncertainties and responsibilities from governments to beneficiaries of development; and (e) institutionalise catastrophes as opportunities for change, not signals to rebuild. There is potential for these issues to be addressed in the responses to the key reports mentioned above, but this will require strong leadership from both government and other sectors.

The major emerging risks that remain incompletely addressed for Australia’s coasts are those related to climate change—especially sea level rise—and demographic change. The future of coastal Australia will depend largely on how rapidly these changes occur, how extreme they are, and how all Australians prepare for and respond to these risks. Desirable futures are most likely if major reform of coastal governance is achieved in the next decade or sooner, which is possible but not guaranteed.
Cumulus congestus and cumulonimbus capillatus with incus (anvil), Parkdale, Victoria

Photo by Ken Hayes
Atmosphere
Key findings

Earth is warming.

Since the release of the *Fourth assessment report: climate change 2007* from the Intergovernmental Panel on Climate Change, observations and research outcomes have further confirmed and strengthened the position that Earth is warming and that human emissions of greenhouse gases are the primary cause. Even in 2007, mainstream science held this view with a high level of certainty, and now this certainty has increased. Internationally, there is a clear consensus among atmospheric scientists that mean global temperatures have generally risen compared with pre-industrial levels in 1750.

Large step-changes in climate may occur.

Smooth changes are the exception rather than the norm in the global climate system, which is nonlinear in nature. This means that a number of feedback mechanisms exist that can amplify or accelerate climate change and have the potential to cause large step-changes (sudden or major changes) in regional and global climate. Should such changes occur, adaptive strategies framed around incremental change are unlikely to be adequate to prevent major harmful impacts on key sectors. Instead, what the Commonwealth Scientific and Industrial Research Organisation describes as ‘transformational’ change will be needed and ‘a major scientific and societal challenge [will be needed] to understand and decide how, where, and when this transformational change is required’.

We are already seeing changes in Australia’s variable climate.

Although Australia’s climate is naturally highly variable, evidence continues to accumulate that temperatures are increasing and rainfall distribution patterns are changing.

Major reductions in greenhouse gas emissions are urgently needed nationally and internationally.

Per person, Australia’s greenhouse gas emissions are the largest of any country in the Organisation for Economic Co-operation and Development (OECD)—26.8 tonnes in 2008, which is nearly twice the OECD average. If the world’s current emissions path is projected to 2070, warming in Australia is expected to be in the range of 2.2–5.0 °C, with widespread and significant risk to Australia’s natural ecosystems, water security and coastal communities. Even if national and international mitigation efforts increase dramatically over the next decade or two, leading to a rapid stabilisation of greenhouse gas emissions, temperatures will remain at elevated levels for centuries to come.
We will need both a national approach and approaches at the state and territory level to mitigate and adapt to climate change.

Australia’s *Fifth national communication on climate change* sets out the Australian Government’s strategic approach to the challenge of climate change. Such an overarching strategy—implemented via a range of policies, plans and programs—is essential if Australia is to succeed in mitigating climate change and addressing key areas of vulnerability through adaptation. At the same time, as the communication notes, all three levels of government share responsibility for addressing climate change and are involved in planning and implementing a diverse range of climate-related programs.

Despite the success of the Montreal Protocol in controlling ozone depleting substances (ODSs), depletion of stratospheric ozone will continue for some decades.

Concentrations of chlorofluorocarbons and other ODSs in the atmosphere have been decreasing since the mid-1990s, but many of these substances are long lived and will continue to affect stratospheric ozone for some decades. Nevertheless, the prospects for recovery of the stratospheric ozone layer by around mid-century continue to be good.

Australia has met its targets in controlling ODSs.

Australia continues to be a leading supporter of international action to control the production and use of ODSs, meeting or exceeding its phase-out obligations under the Montreal Protocol.

Ambient air quality in Australia’s major urban centres is generally good.

National health-based standards are rarely exceeded for prolonged periods, and very high levels of pollution are usually associated with short-lived extreme events such as bushfires and dust storms that generate very high levels of particulate pollution. Levels of carbon monoxide, nitrogen dioxide, sulfur dioxide and lead in urban air have decreased over the past two decades, but ozone and particle levels have not declined. Prospects for achieving reductions in levels of these two pollutants will be influenced by a number of factors, most notably vehicle technology, the extent of ongoing low-density suburban development and the availability of reliable public transport, and the impact of climate change on urban airsheds (regions sharing a common flow of air).
Despite this broadly favourable situation, the impact of urban air quality on health is still a matter of serious concern. There is clear evidence that periods of poor urban air quality impact adversely on human health (particularly on the health of susceptible individuals). One source estimates that urban air pollution accounts for 1% of deaths and illness in Australia, with some 3000 deaths attributable to this cause in 2003—nearly twice the national road toll. Research into the health effects of particles and ozone, as well as pollutants such as sulfur dioxide, indicates there is no threshold level below which they have no health effect. This means that sensitive individuals, such as asthmatics and people with respiratory or cardiovascular disease, may be affected even when air quality standards are met.

Management of pollution affecting our air quality is generally good, but ongoing effort will be required to secure past gains and achieve further improvements.

The generally good quality of our urban air is largely due to the progressive tightening of national vehicle emission and fuel standards over the past 20 years, and the control of industrial, commercial and domestic sources of air pollution. The outlook for the next decade is that this favourable situation is likely to continue, despite the pressures associated with population and economic growth. However, this outcome is not assured, and there are sound public health, economic and social equity arguments to support ongoing efforts to reduce pollutant emissions and associated impacts on health and amenity.

Most Australians spend more than 90% of their time indoors.

The quality of indoor air is affected by many factors, notably building materials (particularly volatile materials like glues and paints), ventilation, furnishings and appliances (particularly unflued gas appliances), environmental tobacco smoke and cleaning agents. Despite the potentially significant health effects of indoor air, data on indoor air quality in Australia are limited. Australia has no specific guidelines for indoor air quality and therefore no firm basis upon which to form assessments of overall status and trend. Over the past decade, Australian governments have employed regulatory and nonregulatory approaches to improve indoor air quality, chiefly through interventions targeting environmental tobacco smoke (in commercial premises where food is prepared or consumed, shopping malls and public buildings) and unflued gas heaters (particularly in schools).
# Contents

## 1 Introduction

### 2 Climate

#### 2.1 State and trends of Australia’s climate
- 2.1.1 Temperature
- 2.1.2 Rainfall
- 2.1.3 Climate research

#### 2.2 Pressures affecting Australia’s climate
- 2.2.1 Emissions sources
- 2.2.2 Emissions trends
- 2.2.3 Direct (primary) effects of pressures on climate
- 2.2.4 Indirect (secondary and tertiary) effects of pressures on climate

#### 2.3 Effectiveness of management
- 2.3.1 Understanding and research
- 2.3.2 Planning and strategy
- 2.3.3 The role and coordination of different levels of government
- 2.3.4 Management outputs and outcomes

## 3 Ambient air quality and other atmospheric issues

### 3.1 State and trends of Australia’s atmosphere
- 3.1.1 Stratospheric ozone
- 3.1.2 Ambient air quality

#### Assessment summary 3.1—pressures affecting Australia’s climate

#### Assessment summary 3.2—effectiveness of climate change management

### 3.3 Current and emerging risks to Australia’s climate

#### Assessment summary 3.3—current and emerging risks to Australia’s climate

#### Assessment summary 3.4—metropolitan cities’ score card for ozone (four-hour) NEPM standard, based on analysis of air quality index values 1999–2008

#### Assessment summary 3.5—metropolitan cities’ score card for particles (PM$_{10}$) NEPM 24-hour standard, based on analysis of air quality index values 1999–2008

#### Assessment summary 3.6—regional cities’ score card for ozone (four-hour) NEPM standard, based on analysis of air quality index values 1999–2008

#### Assessment summary 3.7—regional cities’ score card for particles (PM$_{10}$) NEPM 24-hour standard, based on analysis of air quality index values 1999–2008
The issue of climate change is one that we ignore at our own peril. ... our continued use of fossil fuels is pushing us to a point of no return. And unless we free ourselves from a dependence on these fossil fuels and chart a new course on energy ... we are condemning future generations to global catastrophe.

Barack Obama, *Energy independence and the safety of our planet*, 3 April 2006
Introduction

In the seventh year of the reign of the Emperor Nero, the philosopher Seneca commented on the quality of the air in Rome:

As soon as I had gotten out of the heavy air of Rome and from the stink of the smoky chimneys thereof, which, being stirred, poured forth whatever pestilential vapours and soot they have enclosed in them, I felt an alteration of my disposition. *Lucius Annaeus Seneca*

Seneca was probably not the first, and certainly not the last, to comment adversely on the quality of urban air. Until quite recently, the histories of major cities such as London have been punctuated by complaints from kings and commoners alike about pollution of the air and its effects on amenity and health. Throughout the 19th and much of the 20th centuries, uncontrolled industrial emissions, lack of effective collection and treatment of sewage, and widespread burning of fossil fuels combined to make most large cities unattractive and unhealthy places to live. The great London smog of December 1952, which is now reckoned to have claimed as many as 8000 lives, was but one of a number of instances of killer smogs.

Historically, Australian cities too have suffered from poor air quality—Melbourne was known as ‘Smellbourne’ in the 1880s, due largely to the lack of an effective system for treating and disposing of sewage well away from the city. By the mid-1960s, air pollution in some of Australia’s largest cities had reached levels prompting broad public and political concern:

Evidence received by the Committee indicates that an air pollution problem already exists in some parts of Australia and while not yet a problem of the magnitude existing in well known centres of pollution such as London, New York, Los Angeles and Tokyo, [it is] a problem which nevertheless warrants urgent planning and action. *Parliament of Australia*, p. 4

Fortunately, the quality of the air in Australian cities has improved significantly during the past 20–30 years in response to a mix of regulatory and nonregulatory approaches to controlling both point and diffuse sources of pollution, applied at national, state and local levels. Such improvements have occurred despite growing populations, expansion of industry and greatly increased use of motor vehicles. Monitoring of the air in our cities against national health-based standards shows that episodes of poor and very poor air quality are limited, often being associated with extreme events such as bushfires and dust storms. Despite this, each year, urban air pollution is estimated to account for more deaths than the nation’s road toll.

Clearly there is still a need to press for further improvements in our urban air quality, particularly as new scientific knowledge emerges about the impacts of pollutants such as fine particles. Nevertheless, the focus of scientific, political and community concern has shifted to another essential issue for the atmosphere—the effects on the world’s climate of changes in the atmosphere caused by human activities. Here, over the relatively short span of 250 years and for the first time in human history,
we have changed and are continuing to change the composition of the atmosphere on a global scale. This has led to a clearly defined trend of increasing average global temperatures (Figure 3.1), and there is increasing evidence of consequent changes in the complex set of interlinked atmospheric, oceanic and terrestrial processes that shape climate at the global, continental and regional scales.8-11

Australians, on a per capita basis, contribute disproportionately to the emissions of carbon dioxide (CO₂) and other greenhouse gases (GHGs) that are driving these changes. As inhabitants of the driest of the world’s inhabitable continents—much of which is unsuitable or only marginally suitable for agriculture—Australians have more at risk than most in a warming world.12-13

This chapter is divided into two sections: climate, and ambient air quality and other atmospheric issues. The climate section discusses the influence of GHGs, particularly those generated by human activities, on Earth’s climate and some of the likely impacts of global climate change on human health and the environment. The second part of the chapter discusses other aspects of the atmosphere, including stratospheric ozone, ambient air quality and indoor air quality.

**Figure 3.1** Changes in global average surface air temperature (smoothed over 11 years) relative to 1990

The dark blue line represents data from Hadley Centre (United Kingdom Meteorological Office); the red line is GISS (NASA Goddard Institute for Space Studies, United States) data. The broken lines are projections from the Intergovernmental Panel on Climate Change Third Assessment Report, with the shading indicating the uncertainties around the projections.
Climate

References to Australia’s variable climate abound in both academic literature and the arts, with Dorothea Mackellar’s description of her love for a ‘sunburnt country, a land … of drought and flooding rains …’ springing readily to mind. Marked variability in temperature and rainfall, together with frequent but irregular occurrences of extreme weather events, has long been recognised as a key characteristic of climate in most parts of our continent. On more than one occasion, confusion of short-term runs of favourable climate with long-term norms led farmers to push into areas where their agricultural systems proved to be unsustainable. As we move into the second decade of the 21st century, we are increasingly recognising signs that our already variable climate is changing.14

2.1 State and trends of Australia’s climate

Perhaps the salient feature of the Australian environment over the past decade, at least for the majority of Australians, was an extended drought. This drought was characterised not only by low rainfall but also by higher than average temperatures. For many places, the severity and duration of drought were unprecedented, with profound environmental, social and economic implications. In southern Australia, the drought (sometimes known as the millennium drought) lasted from 2000 to 2010, although in some areas it began as early as 1997. For parts of the country, the drought broke in 2010 (in some cases, with extreme flooding); in other places, like the south-west of Western Australia, the extended drought deepened further.
2.1.1 Temperature

From 1970 to 2010, Australia’s mean daily temperature rose in almost all parts of the country (Figure 3.2).

The increase in terrestrial temperatures over this period was consistent with a general warming of ocean surface temperatures around Australia (Figure 3.3). To the south-east of the continent, the southward extension of the East Australian Current has continued, with consequences for marine ecosystems and biodiversity in the ocean off the coast of eastern Tasmania.

Figure 3.2 Trend in mean temperature, 1970–2010 (°C per 10 years)
Figure 3.3  Trend in sea surface temperature for the Australian region, 1970–2010 (°C per 10 years)
2.1.2 Rainfall

From 1970 to 2010, total annual rainfall declined over much of eastern Australia and south-west Western Australia (Figure 3.4). This decline in rainfall affected all capital cities except Darwin. In contrast, rainfall increased over north-west and central Western Australia.

The 13-year period from April 1997 to March 2010 (156 months) shows rainfall deficiencies for much of south-western and south-eastern Australia, and south-eastern Queensland (Figure 3.5). Most notable are the large areas of lowest rainfall on record for this period: large parts of Western Australia’s south-western coast, western Tasmania and large areas in Victoria received the lowest rainfall on record for the 13-year period.

For the more recent eight-year period from April 2002 to March 2010 (96 months), much of south-eastern Australia still experienced severe, long-term rainfall deficiencies. Approximately 95% of Victoria received...
rainfall in the lowest 10% of historical totals when considered over such a period. The south-eastern corner of Queensland also had serious to severe rainfall deficiencies over this period. Serious to severe deficiencies also remained in central to eastern coastal districts of South Australia, large areas of Tasmania (especially in the north), and a large area covering the south-west coast and adjacent inland regions of Western Australia. Rainfall deficiencies across the south-western and south-eastern corners of the continent have been most severe in autumn and winter.

For the 12 months from April 2009 to March 2010 (Figure 3.6), serious to severe rainfall deficiencies remained evident over much of the central Western Australian coast, reaching inland to cover much of the Pilbara and Gascoyne districts, where they intensified to some extent. Serious to severe rainfall deficiencies also remain over the south-east coastal

Figure 3.5 Rainfall deficiencies over 156 months, 1 April 1997 – 31 March 2010

‘Serious deficiency’ refers to rainfalls in the lowest 10% of historical totals, but not in the lowest 5%; ‘severe deficiency’ refers to rainfalls in the lowest 5% of historical totals; and ‘lowest on record’ refers to the lowest rainfalls since at least 1900, when the data analysed begin.
and Great Southern districts of Western Australia, with a small area near Esperance reporting the lowest rainfall on record for the period.

However, from March 2010, large parts of the continent experienced above-average rainfall, associated with an extremely strong La Niña event (Figure 3.7). (A La Niña event refers to a periodic cooling of ocean surface waters off the western coast of South America. This leads to low rainfall in countries along that coast and in the south-west of the United States, and above-average rainfall in countries of the western Pacific, including the Philippines and northern and eastern Australia—

---

**Figure 3.6** Rainfall deficiencies over 12 months, 1 April 2009 – 31 March 2010

'Serious deficiency' refers to rainfalls in the lowest 10% of historical totals, but not in the lowest 5%; 'severe deficiency' refers to rainfalls in the lowest 5% of historical totals; and 'lowest on record' refers to the lowest rainfalls since at least 1900, when the data analysed begin.
outcomes that are the opposite of those associated with an El Niño event.) Most notably, eastern Australia received widespread record-breaking rains, with associated loss of life and massive damage to agriculture, homes and infrastructure. For the Murray–Darling Basin averaged as a whole, 2010 was the seventh wettest start to the year since records began in 1900. This rainfall has effectively ended a prolonged (decade or longer) sequence of very low rainfall years across parts of eastern Australia, most notably in the central and lower Murray–Darling Basin and south-east Queensland. Although Victoria experienced its wettest summer since 1974 in 2010–11, long-term rainfall deficiencies remained during autumn and winter.
South-west Western Australia missed out on La Niña-driven rainfall for most of 2010, experiencing its lowest winter rainfall on record. However, this situation changed markedly over the summer of 2010–11. Averaged across the state, summer rainfall was the second highest on record. In the north, this mainly reflected the influence of the monsoon that was active throughout the summer. Across the state more generally, it reflected the impact of the particularly strong La Niña. In much of the lower south-west, the Bureau of Meteorology characterised summer rainfall as ‘very much above average’, due mainly to rainfall in January. Despite this, during the 12 months from March 2010, rainfall in the lower south-west ranged from below average to the lowest on record.

2.1.3 Climate research

Variability and extremes of weather are key characteristics of Australia’s climate. Australian scientists are increasingly coming to understand the complex interplay of atmospheric and oceanic processes that shape our climate in both the short and the long term, and the processes that are responsible for cycles of drought and wet years in different parts of the country. These include natural events, such as fluctuations between El Niño and La Niña conditions in the Pacific, variations in the Indian Ocean Dipole, the southern annular mode and longer term features such as the Interdecadal Pacific Oscillation.

Against this background of natural variability, identifying a climate change ‘signal’ is often challenging. The Commonwealth Scientific and Industrial Research Organisation (CSIRO), in the phase 1 report on the South Eastern Australian Climate Initiative, contrasts the recently ended 13-year drought in the southern Murray–Darling Basin and Victoria with other droughts since 1900. The report notes that:

- the most recent drought was generally limited to southern Australia (in comparison with previous droughts, including the severe Federation and World War 2 droughts)
- the recent period has experienced lower annual variability in rainfall, characterised by a complete absence of wet years

- a characteristic of recent rainfall across the southern Murray–Darling Basin, and the south-east of the continent in general, has been severe deficiencies (occurring as a step-change) in autumn and early winter rainfall
- the loss of early-season rainfall across both south-eastern and south-western parts of the continent has led to dramatically reduced streamflow and water storage in the past two decades.

The report concludes that, although natural variability is likely to have contributed to episodic drought (i.e. sequences of very dry years), the major and prolonged decline in rainfall is at least partly due to the effects of global warming on large-scale atmospheric circulation (specifically, the intensification of high-pressure cells across southern Australia—a phenomenon referred to as the ‘subtropical ridge’). The report further suggests that the changes in rainfall and streamflow data during the drought may be indicative of a climatic shift in south-eastern Australia similar to that experienced in south-west Western Australia, where one study has suggested that half of the 10–15% decrease in winter rainfall experienced since around 1975 is attributable to climate change.

Despite the uncertainties, there is an increasingly robust scientific consensus on the effects of climate change at a continental scale on temperature and on likely future impacts under the various climate change scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). With respect to temperature, the IPCC’s fourth assessment concluded that Australian temperatures have increased and that most of the rise can be attributed to human-induced increases in emissions of GHGs. In the case of rainfall, a longstanding result from climate modelling over the past two decades demonstrates that global warming leads to increased rainfall in the tropics and decreased rainfall in mid-latitude regions, including more prolonged drought. Rainfall intensity (periods of heavy rain) is expected to increase, including in regions where an overall decline in rainfall is projected. However, determining the extent (if any) of the contribution of climate change to particular climatic events such as drought remains problematic and is an ongoing area of research.
2.2 Pressures affecting Australia’s climate

Since the start of the industrial era (about 1750), the overall effect of human activities on climate has been a warming influence. The human impact on climate during this era greatly exceeds that due to known changes in natural processes, such as solar changes and volcanic eruptions.

Intergovernmental Panel on Climate Change

The energy balance of Earth’s atmosphere is influenced by the presence of trace levels of GHGs, the most important of which are carbon dioxide, methane, short-lived tropospheric ozone, nitrous oxide and the synthetic GHGs (e.g., chlorofluorocarbons [CFCs] and hydrofluorocarbons [HFCs]). Water vapour (a major GHG) and natural and industrial aerosols are also important in the atmospheric energy balance, as is natural variability in solar radiation. However, although the net effect of aerosols is known to be negative, there is considerable uncertainty about its magnitude. Similarly, there is uncertainty about the size of the effect of variations in solar radiation on Earth’s energy balance since the start of the industrial era, although it is known to have been positive.

The effect of factors such as solar radiation, GHGs and aerosols on the energy balance is termed ‘radiative forcing’ (Box 3.1).

Box 3.1 Radiative forcing

Radiative forcing is defined by the Intergovernmental Panel on Climate Change as ‘...a measure of the influence a factor [such as greenhouse gases] has in altering the balance of incoming and outgoing energy in the Earth–atmosphere system and is an index of the importance of the factor as a potential climate change mechanism.’

Warming of climate is a response to positive forcings, whereas cooling is a response to negative forcings. ‘Radiative forcing is usually quantified as the rate of energy change per unit area of the globe as measured at the top of the atmosphere and is expressed in units of “watts per square metre.”’

Source: Intergovernmental Panel on Climate Change

At a glance

The energy balance of Earth’s atmosphere is influenced by the presence of trace levels of greenhouse gases (GHGs), such as carbon dioxide, methane, nitrous oxide and water vapour (a major GHG), and natural and industrial aerosols. Since the start of the industrial era (around 1750), human activity (principally the burning of fossil fuels) has caused significant increases in the concentrations of these GHGs. Measurements at global background monitoring stations, such as the Cape Grim Baseline Air Pollution Station in Tasmania, show GHG concentrations continuing to increase in line with long-term trends and future projections. Per person, Australia’s GHG emissions are the largest of any country in the Organisation for Economic Co-operation and Development (OECD) (26.8 tonnes in 2008—nearly twice the OECD average), reflecting Australia’s heavy reliance on fossil fuels for our primary energy.

Under policy settings applicable before the release of the Australian Government’s Securing a Clean Energy Future plan in July 2011, Australia’s emissions were projected to grow by 113 megatonnes of carbon dioxide equivalents (MtCO₂-e), or 19.6%, between 2010 and 2020. This would have brought the nation’s annual emissions to 690 MtCO₂-e in 2020, an increase of 23% from 2000 levels. The Securing a Clean Energy Future plan aims to achieve Australia’s unconditional emissions reduction target—a reduction of 5% on 2000 levels by 2020. This will require abatement of at least 159 MtCO₂-e (23%) by 2020. To achieve Australia’s 15% conditional target, a 31% reduction would be needed.
Over the past two and a half centuries, human activity (principally the burning of fossil fuels) has caused significant increases in the concentrations of GHGs (Figure 3.8). In the case of the principal GHG (carbon dioxide), the CSIRO global GHG-observing network recorded a preliminary global atmospheric concentration of 388 ppm (parts per million) for 2010 (Raupach & Fraser, updated by CSIRO)—an increase of 39% from 280 ppm, the IPCC’s estimate of pre-industrial levels. CSIRO observations show that the preliminary global average methane concentration in 2010 was 1796 ppb (parts per billion)—an increase of 157% above estimated pre-industrial levels of 700 ppb. CSIRO observations also show that global nitrous oxide levels in 2010 were 324 ppb, a rise of 20% from pre-industrial levels of 270 ppb.

![Figure 3.8 Major greenhouse gas levels over the past 1000 years](image)

ppb = parts per billion; ppm = parts per million
Source: MacFarling Meure et al. updated by P Krummell, the Centre for Australian Weather and Climate Research and the Commonwealth Scientific and Industrial Research Organisation, unpublished data
In addition to the three main GHGs, there is a number of fluorinated gases—such as CFCs, HFCs, perfluorocarbons (PFCs) and sulfur hexafluoride—sourced from a range of industrial processes and from business and home use.\textsuperscript{27} Although these gases are present in the atmosphere in only trace amounts, they are long lived and have global warming potentials thousands of times that of an equivalent concentration of carbon dioxide when assessed on a 100-year timescale.\textsuperscript{30} They can therefore contribute significantly to global warming in the medium to long term and are included in the set of gases (HFCs, PFCs, sulfur hexafluoride) covered by Annex A of the Kyoto Protocol (an international agreement aimed at stabilising GHG concentrations in the atmosphere). The production and consumption of CFCs and other ozone depleting substances (ODSs) are covered by the Montreal Protocol on Substances that Deplete the Ozone Layer (see Sections 3.2.1 and 3.3.1).

Fluorinated gases made up around 12\% of total global radiative forcing due to GHGs in 2010, similar to the situation in 1995 (13\%). Under scenario A1B of the IPCC Special report on emissions scenarios, their contribution to global radiative forcing will decrease to 6\% by 2100 (Raupach & Fraser,\textsuperscript{27} updated by CSIRO), reflecting the gradual decline in CFCs in the atmosphere and increasing levels of HFCs.

The increased concentrations of human-generated GHGs have resulted in an increased absorption in the lower atmosphere of the heat radiated from Earth’s surface, causing a rise in the global mean surface temperature of 0.74 ± 0.18 °C over the century from 1906 to 2005.\textsuperscript{31} However, this rise did not occur uniformly across the century, as average global temperatures did not increase between the 1940s and the 1970s.\textsuperscript{32} More recently, the 1998–2008 decade was characterised by little warming overall and a decrease of 0.2 °C between 2005 and 2008 (followed by an increase in 2009 and 2010, the most recent years for which data are available).\textsuperscript{33}

Based on their analysis of this recent hiatus in warming, Kaufman et al.\textsuperscript{33} concluded that the warming

\textbf{Box 3.2 Carbon dioxide equivalent emissions}

Each of the six greenhouse gases listed under Annex A of the Kyoto Protocol has a different greenhouse warming potential. The term ‘carbon dioxide equivalent’ (CO$_2$-e) refers to a single measure that combines the global warming effect of all the Annex A gases into a single meaningful number. Specifically, CO$_2$-e is the emissions of carbon dioxide that would cause the same heating of the atmosphere as a particular mass of Annex A greenhouse gases. The Annex A greenhouse gases are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.\textsuperscript{35-36}
effects of GHG emissions during 1998–2008 have been partially offset by a combination of natural and anthropogenic (human-generated) factors. The natural factors (which were largely responsible for the offset) were a decline in solar insolation (a measure of the solar radiation energy received by Earth in a given time) as part of a normal 11-year cycle, and a cyclical shift from El Niño to La Niña conditions. These were supplemented by the anthropogenic factor—a rapid rise in short-lived emissions of sulfur due to large increases in coal use across Asia, particularly China. The sulfate aerosols formed by these emissions absorb solar radiation and reflect sunlight back into space (resulting in a negative radiative forcing). Sulfate aerosols, together with other pollutants, are thought to be largely responsible for the lack of increase in average global temperature over the 1940s to 1970s.34

Although Kaufman et al.33 concluded that the recent hiatus in warming resulted principally from natural factors, they stressed that this does not contradict the IPCC’s statement that ‘most of the global average warming over the past 50 years is very likely due to anthropogenic GHG increases …’8

Measurements at global background monitoring stations, such as the Cape Grim Baseline Air Pollution Station in Tasmania, show carbon dioxide and nitrous oxide concentrations continuing to increase, in line with long-term trends and future projections, whereas methane levels, after a decade-long pause, have resumed rising since 2007. The reasons for this variability in the growth rate of methane concentrations are complex, but the period of stability in the late 1990s and early years of this century was probably due to a reduction in the rate of growth of emissions from the oil and gas industry and an approach to equilibrium, where anthropogenic methane releases are matched by the atmosphere’s ability to remove methane. Growth in emissions since 2007, which has occurred in the Arctic and in the tropics, may be caused by increased releases from wetlands due to unusually high temperatures (Arctic) and precipitation (tropics).37

In absolute terms, Australia’s emissions of GHGs (558 megatonnes of carbon dioxide equivalents [MtCO₂-e]) appear small alongside major emitters such as China and the United States (7233 MtCO₂-e and 6914 MtCO₂-e, respectively), but they are not insignificant, being on a par with countries such as France, Italy and the Republic of Korea (550–570 MtCO₂-e per year; all data are for 2005).38

Per person, Australia’s emissions are the largest of any Organisation for Economic Co-operation and Development (OECD) country—26.8 tonnes in 2008, nearly twice the OECD average (Figure 3.9).12-13

![Figure 3.9 Greenhouse gas emissions per person](image-url)

CO₂-e = carbon dioxide equivalents; OECD = Organisation for Economic Co-operation and Development
2.2.1 Emissions sources

The energy sector (comprising stationary energy, transport and fugitive emissions from fuels) continues to be the dominant source of Australia’s GHG emissions, accounting for 74% of net emissions, including those associated with land use, land-use change and forestry (LULUCF) (Figure 3.10). Within this sector, stationary energy accounts for 52%, comprising electricity (37%) and fuel combustion (15%).

Australia’s very high level of emissions per person reflects the nation’s heavy reliance on fossil fuels as a primary energy source and, in particular, the dominant role of coal (an emissions-intensive fuel) in the production of electricity (Figure 3.11).

Although the transport and agricultural sectors both contribute around a sixth of Australia’s net GHG emissions, transport’s contribution is almost entirely through emissions of carbon dioxide, whereas agriculture’s contribution is through methane and nitrous oxide— gases with global warming potentials many times that of carbon dioxide (Figure 3.12). (The 100-year warming potential of methane is 21 times that of carbon dioxide; the figure for nitrous oxide is 310.)

![Figure 3.10 Greenhouse emissions by sector, Kyoto accounting, 2009](image)

![Figure 3.11 Fuel mix contributing to total primary energy supply, 2008](image)
Under Article 3.3 of the Kyoto Protocol, parties can use net changes in GHG emissions associated with direct human-induced LULUCF activities that occurred since 1990 to meet their emission reduction commitments. Australia, in meeting its obligations to account for its GHG emissions under the protocol, includes net emissions associated with LULUCF. However, these tend to vary significantly from year to year, reflecting variability in climate; peaks (such as in 2007) are associated with extreme events such as bushfires and drought, which lead to major loss of carbon from vegetative and soil sinks.

2.2.2 Emissions trends

As a signatory to the Kyoto Protocol (ratified in 2007), Australia is committed to limiting increases in net GHG emissions to 108% of its 1990 levels by 2008–2012 (the ‘Kyoto commitment period’). As reported in 2010 in its Fifth national communication on climate change (under the United Nations Framework Convention on Climate Change), Australia remains on track to meet this commitment, largely due to a major reduction in emissions associated with LULUCF (80% from 1990 to 2008) and, more particularly, to less land clearing over the same period (Figure 3.13).
In contrast, from 1990 to 2009, emissions (excluding LULUCF) grew by 30.5% (Figure 3.14). The largest increase was in the stationary energy sector, which includes emissions from fuel consumption for electricity generation; fuels consumed in the manufacturing, construction and commercial sectors; and other sources such as domestic heating. This sector grew by 51%, driven by a mix of factors, notably rising population and household incomes, and growth in demand for energy associated with substantial increases in the export of resources. In the same period, transport grew by 35% in response to increases in the number of vehicles. Fugitive emissions (which typically result from leaks during the production, processing, transport, storage and distribution of raw fossil fuels) increased by 23%, chiefly because of increased emissions from coal mines. Emissions due to industrial processes rose by 21%, principally associated with increased production of HFCs as substitutes for ozone depleting CFCs, and substantial (220%) growth in emissions from the chemical industry.

The waste and agricultural sectors are the only ones to have recorded a decline in emissions from 1990 to 2009 (22% and 2%, respectively). In the waste sector, this reflected the increasing capture of methane from landfill in response to a combination of regulatory pressure.

**Figure 3.13** Australian greenhouse gas emissions, 1990–2012 (projected), including emissions associated with land use, land-use change and forestry

\[ CO_2 \text{-e} = \text{carbon dioxide equivalents; } Mt = \text{megatonne} \]

Source: Adapted from Australian Government Department of Climate Change and Energy Efficiency, with permission
and commercial gain (through use of the emissions as a source of energy). In agriculture, increases in emissions during the 1990s due to rising fertiliser use and savanna burning have been reversed since 2002, reflecting reduced fertiliser use and a significant drop in crop and animal production due to drought.39,42-43

Since 2000, Australia’s emissions of GHGs (excluding LULUCF) have grown by an average of 1.1% per year. This compares with average annual growth of 1.9% from 1990 to 2000. The difference is principally attributable to a slower rate of growth of emissions from stationary sources and transport, as well as a decrease in emissions from agriculture. Like most OECD countries, Australia experienced a reduction in annual GHG emissions during the global financial crisis. However, the reduction was only marginal, with emissions (excluding LULUCF) falling from 551 MtCO₂-e in 2008 to 546 MtCO₂-e in 2009—a fall of 0.9%.39 By comparison, the United States and the European Union experienced reductions in emissions growth of approximately 7% during the same timeframe.44

This marginal decline in Australia’s emissions is only a minor and temporary divergence from the continuing longer term growth trend (Figure 3.15).

CO₂-e = carbon dioxide equivalents; Mt = megatonne
Note: Figures for 2009–10 are preliminary estimates.
Source: Australian Government Department of Climate Change and Energy Efficiency, with permission

Figure 3.14 Net greenhouse gas emissions by sector, excluding land use, land-use change and forestry
Under policy settings applying before the release of the Australian Government’s Securing a Clean Energy Future plan, Australia’s emissions were projected to grow by some 113 MtCO₂-e (19.6%) from 2010 to 2020. This would have brought Australia’s annual emissions (including LULUCF) to 690 MtCO₂-e in 2020, an increase of 23% from 2000 levels. The projected growth was mainly due to anticipated emissions from the extraction and processing of energy resources to meet expected continued strong export demand. This contrasted with previous decades, when most emissions growth related to electricity generation. From 2010 to 2020, emissions from electricity generation were projected to grow much more slowly than in the past, increasing by only 6% (12 MtCO₂-e). This reflected the factoring into the projection of a significant increase in the use of renewable energy sources for generation of electricity, in response to the Renewable Energy Target. The target, which was established by the Australian Government in 2009, aims to ensure that 20% of Australia’s electricity supply comes from renewable sources by 2020.⁴⁶ The Securing a Clean Energy Future plan aims to achieve Australia’s unconditional emissions reduction target—a reduction of 5% on 2000 levels by 2020. This will require abatement of at least 159 MtCO₂-e (23%) in 2020.⁴⁷ (See Section 2.3.2 for details of the plan.)

CSIRO and the Bureau of Meteorology’s latest State of the climate report⁴⁸ concludes that, in the

Figure 3.15 National Greenhouse Gas Inventory, actual quarterly emissions estimate and trend emission estimate, June quarter 2000 – June quarter 2010

The national inventory does not include estimates of net emissions from Article 3.3 of the Kyoto Protocol (land use, land-use change and forestry activities), which are estimated on an annual basis only. Emission estimates have been compiled by the Australian Government Department of Climate Change and Energy Efficiency using the methods incorporated in the Australian Greenhouse Emissions Information System, preliminary activity data obtained under the National Greenhouse and Energy Reporting System and from a range of publicly available sources—principally the Australian Bureau of Agricultural and Resource Economics and Sciences, the Australian Bureau of Statistics, the Australian Energy Market Operator and the Australian Government Department of Resources, Energy and Tourism. As more data become available from these sources—in particular the National Greenhouse and Energy Reporting System—these preliminary activity data will be replaced and the estimates of emissions revised before submission to the United Nations. The department’s assessment is that the 90% confidence interval for the national inventory (before taking account of Article 3.3 activities) is ± 1% (i.e. there is a 90% probability that future revisions will be limited to ± 1% of the current estimate).
coming decades, Australia will be hotter and much of the continent will be drier. More specifically, the report summarises the main direct effects of climate change as follows:

- By 2030, projections show average temperatures rising by 0.6–1.5 °C, in addition to an existing rise of around 0.7 °C since 1960.
- By 2070, if growth in GHG emissions continues in line with past trends, projected warming will be in the range of 2.2–5.0 °C. Even at the lower end of this range, the projected increase is near or above the level regarded by many climate scientists as likely to trigger ‘dangerous climate change’. (See Schneider and Lane49 for a discussion of the complexities of the concept of dangerous climate change.)
- Compared with the last two decades of the 20th century, southern Australia is likely to experience reduced winter rain, and spring rainfall declines are expected in southern and eastern areas. In southwest Western Australia, reductions in autumn rainfall are likely to add to pressures associated with the existing decades-long decline in winter rain. Northern Australia is likely to experience an increase in annual and summer rainfall.50

In addition to directly affecting large-scale aspects of climate, such as average temperature and precipitation, human-induced climate change has the potential to alter the frequency and severity of extreme events, such as storms, floods, droughts and heatwaves.50-53 As noted above, separating the effect of climate change from that of natural processes can be difficult, and this uncertainty greatly complicates efforts to characterise likely changes in these extreme events. Nevertheless, improving our understanding of the vulnerabilities associated with such changes is an essential step in planning our adaptation to climate change.54

### 2.2.4 Indirect (secondary and tertiary) effects of pressures on climate

Direct effects on climate, such as those outlined in Section 2.2.3, trigger indirect effects further down a complex chain of cause and effect. These are products of the profound and pervasive influence of climate, both on a host of natural processes that underpin the condition and trend of ecosystems, and on a range of demographic, economic and social processes and systems. The complex nature of the effects of changes in climate is illustrated in Figure 3.16 in relation to human health.

![Figure 3.16 Pathways by which climate change affects human health, including local modulating influences and the feedback influence of adaptation measures](source: Redrawn from McMichael et al.,55 with permission)
Australia’s *Fifth national communication on climate change* (under the United Nations Framework Convention on Climate Change) draws on the work of the IPCC to outline a wide range of indirect effects of climate change:

- decreased water availability and water security, due to
  - reduced rainfall in southern Australia and south-west Western Australia
  - increased evaporation, which reduces run-off to streams and recharge of groundwater systems
- coastal zone impacts, such as inundation from sea level rise
- damage to energy, water, communications and built infrastructure
- a decline in agricultural productivity due to increased drought and fire
- damage to iconic natural ecosystems, such as the Great Barrier Reef and Kakadu National Park
- a decline in biodiversity.

Other sources identify additional indirect effects of climate change, such as:

- likely increases in the frequency of days of extreme bushfire risk, and of dust storms, linked to widespread reductions in levels of soil moisture
- changes to human health, including
  - some positive, particularly in the first part of the century, when some areas will benefit from a reduction in cold weather
  - some negative, resulting from factors such as more frequent and intense heatwaves, particularly later in the century (Table 3.1), and possible extension in the range of various disease vectors (notably mosquitoes).

### Table 3.1 Change in likely temperature-related deaths due to climate change

In the baseline case, any increase in number of deaths is due to the expanding and ageing of the population. The next three cases are best-estimate cases and use the 50th percentile rainfall and relative humidity and 50th percentile temperature for Australia. The final case (right-hand side) is an illustrative ‘bad-end story’ that uses the 10th percentile rainfall and relative humidity and 90th percentile temperature for Australia (a hot, dry extreme).

<table>
<thead>
<tr>
<th>Region</th>
<th>Baseline—no human-induced climate change</th>
<th>No-mitigation case</th>
<th>Global mitigation with CO$_2$-e stabilisation at 550 ppm by 2100</th>
<th>Global mitigation with CO$_2$-e stabilisation at 450 ppm by 2100</th>
<th>Hot, dry extreme case</th>
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<td>1 164</td>
<td>1 614</td>
</tr>
<tr>
<td>WA</td>
<td>419</td>
<td>515</td>
<td>418</td>
<td>685</td>
<td>419</td>
</tr>
<tr>
<td>Australia</td>
<td>7 717</td>
<td>8 562</td>
<td>7 115</td>
<td>11 234</td>
<td>7 061</td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; CO$_2$-e = carbon dioxide equivalent; NSW = New South Wales; NT = Northern Territory; ppm = parts per million; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

Source: Garnaut

---

Partial solar eclipse through a thick plume of bushfire smoke, 4 December 2002, Broken Bay, New South Wales

Photo by Manfred Gottschalk
During the second half of January 2009, Victoria experienced an unprecedented heatwave. Maximum day-time and night-time temperature records were broken by significant margins, and new records were set for the duration of extreme heat. From 27 to 31 January, much of Victoria experienced maximum temperatures 12–15 °C above normal. For three of these days (28–30 January), the maximum was above 43 °C, peaking at 45.1 °C on 30 January (Table A).

**Table A** Temperatures in Victoria, 26 January – 1 February 2009

<table>
<thead>
<tr>
<th></th>
<th>Maximum day-time temperature (°C)</th>
<th>Minimum night-time temperature (°C)</th>
<th>Mean temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday 26 January</td>
<td>25.5</td>
<td>14.4</td>
<td>19.9</td>
</tr>
<tr>
<td>Tuesday 27 January</td>
<td>36.4</td>
<td>16.6</td>
<td>26.5</td>
</tr>
<tr>
<td>Wednesday 28 January</td>
<td>43.4</td>
<td>18.8</td>
<td>31.1</td>
</tr>
<tr>
<td>Thursday 29 January</td>
<td>44.3</td>
<td>25.7</td>
<td>35.0</td>
</tr>
<tr>
<td>Friday 30 January</td>
<td>45.1</td>
<td>25.7</td>
<td>35.4</td>
</tr>
<tr>
<td>Saturday 31 January</td>
<td>30.5</td>
<td>22.5</td>
<td>26.5</td>
</tr>
<tr>
<td>Sunday 1 February</td>
<td>33.8</td>
<td>20.3</td>
<td>27.0</td>
</tr>
</tbody>
</table>

The impact of the heatwave on public health was clearly identifiable and substantial. The effects were similar to those of the catastrophic 2003 European heatwave, which had an estimated total excess mortality of 70 000. In Victoria, the Department of Health calculated a figure of 374 excess deaths over the average number in the same weeks of the preceding five years (an increase of 62% in all-cause mortality).

In addition to this marked spike in mortality, there was a pronounced impact on morbidity, which was reflected in increases in ambulance emergency case load (46% over the three hottest days), locum general practitioner visits (almost four-fold increase in heat-related attendances), and emergency room attendances (eight-fold increase in heat-related presentations). Not surprisingly, as shown in Figure A, the elderly were the group most affected, with people over 75 years of age being disproportionately represented in both mortality and morbidity.

As with any extreme climatic event, estimating the extent to which climate change played a role over and above natural variability is problematic. Nevertheless, an increase in the frequency of such extreme temperature–driven events is entirely consistent with the now decades-long upward trend of average temperatures and with the results from studies modelling a broad range of climate change scenarios.

![Figure A](image-url) Deaths in Victoria by age group between 26 January and 1 February, 2004–08 and 2009

These data from the Registrar and the State Coroner’s Office are provisional and, although these are expected to account for the vast majority of deaths, may be revised over time. It is possible that deaths relating to the heatwave occurred or were reported outside the period of analysis, thereby underestimating the impact. Certainly, the vast majority of short-term mortality is expected to have been captured.

Source: Department of Human Services Victoria, using data from the Bureau of Meteorology and the Victorian Registry of Births, Deaths and Marriages
3.1 Assessment summary

Pressures affecting Australia’s climate

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse gases</td>
<td>Under policy settings applying before the release of the Australian Government’s Securing a Clean Energy Future plan, Australia’s emissions were projected to grow by 113 MtCO₂-e (19.6%) between 2010 and 2020. This would have brought Australia’s annual emissions (including emissions from land use, land-use change and forestry) to 690 MtCO₂-e in 2020, an increase of 23% from 2000 levels. To achieve the nation’s minimum target of a 5% cut on 2000 levels by 2020 will require a reduction of 159 MtCO₂-e (23% compared with the projected 2020 level). The Securing a Clean Energy Future plan aims to achieve this reduction by 2020. To achieve Australia’s 15% conditional target, a 31% reduction would be needed. Climate change modelling indicates that average temperatures will rise, the number of dry days will increase, and intense rainfall events will increase in many areas. More frequent bushfires, dust storms and heatwaves, and attendant impacts on human health, can all be expected.</td>
<td>Very high impact</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
</tbody>
</table>

Recent trends

- Improving
- Stable
- Deteriorating
- Unclear

Confidence

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

Grades

- Very low impact: Few or no impacts have been observed, and accepted predictions indicate that future effects are likely to be minor
- Low impact: Current pressures have been observed to have had a limited impact on some aspects of climate, and there is concern that, based on accepted predictions, these may worsen
- High impact: Current pressures are probably already having serious impacts on important aspects of climate and are expected to worsen, with serious implications for a broad range of areas
- Very high impact: Current pressures are already having very serious impacts on important aspects of climate (such as temperature, rainfall and extreme events) with very serious flow-on effects in a broad range of areas

MtCO₂-e = megatonnes of carbon dioxide equivalents
2.3 Effectiveness of management

As a developed country that is a signatory to the United Nation’s Framework Convention on Climate Change, every four years Australia submits a national communication on climate change that sets out the national strategy to address climate change and reports on progress made over the reporting period. In Australia’s most recent national communication (the fifth), which was submitted in 2010, the government describes its climate change strategy as comprising ‘three pillars’: mitigating emissions, adapting to unavoidable climate change and helping to shape a global solution (Figure 3.17). As the communication notes, the strategy and key policies and measures it encompasses have been informed by:

- a significant improvement in the national climate science research effort
- a comprehensive, in-depth analysis to identify the best mix of approaches to deal with climate change (the Garnaut Climate Change Review)
- extensive consultation with business and the community.42

If Australia is to achieve the national 2020 target of a 5% reduction in greenhouse gas emissions below 2000 levels, the range and effectiveness of abatement measures being applied in both the public and private sectors will need to be greatly increased. This is the key aim of Securing a Clean Energy Future, the Australian Government’s climate change plan released in July 2011, which sets out details of a mechanism to establish a price on carbon and drive reductions in emissions via least-cost means. The plan also builds on existing measures, such as the legislated 20% Renewable Energy Target and the Carbon Farming Initiative, to promote development of renewable energy sources, energy efficiency and action to sequester carbon. At the time of writing (July 2011), the Australian Government proposes to introduce the necessary supporting legislation to parliament before the end of the year.

Current governance is complex, because three tiers of government need to be involved in working with the private sector and the community to plan for and implement effective mitigation and adaptation measures. Coordination of federal and state programs has improved via actions by the Council of Australian Governments (COAG). Understanding of the science of climate change as it relates to Australia is continuing to improve, as is confidence in modelling projections at both national and regional scales. There is extensive support for policy and priority setting at a national level through the initial Garnaut Climate Change Review (2008) and subsequent review update (2011) and through an improved national greenhouse gas emissions reporting system. The Australian Government has established a broad (‘three-pillars’) strategy, underpinned by the Renewable Energy Target, an energy efficiency strategy and a national adaptation framework that was adopted by COAG in 2007.

The Australian Government has committed around $15 billion to climate change initiatives. States and territories are also applying significant resources to mitigation and adaptation programs.
2.3.1 Understanding and research

Information about climate change and its likely impacts is the first requirement of good adaptation and mitigation policies. This requires strengthening of the climate-related research effort in Australia. Garnaut,\textsuperscript{13} p. xli

In the six years since the fourth national communication, international climate change science has advanced significantly, through many hundreds of studies of the complex, interacting processes driving change in the atmosphere, oceans and terrestrial systems. The base of empirical evidence has greatly expanded, as have the power and sophistication of climate change modelling at global, continental and regional scales. This has enabled better informed and more precise understanding of risks, and analysis of opportunities to mitigate and adapt to future change.\textsuperscript{9,61-62}

Australia is recognised as being particularly vulnerable to the effects of climate change.\textsuperscript{25,63} Acting on the need to improve our understanding of the risks to the environmental systems that support our economy and to identify opportunities to manage such risks via mitigation and adaptation, the Australian Government established the National Climate Change

\begin{figure}
\centering
\includegraphics[width=\textwidth]{Figure_3.17.png}
\caption{Australia’s three-pillar climate change strategy}
\end{figure}

CPRS = Carbon Pollution Reduction Scheme; UNFCCC = United Nations Framework Convention on Climate Change

Source: Australian Government Department of Climate Change and Energy Efficiency\textsuperscript{42}
Adaptation Research Facility in 2007 and the National Framework for Climate Change Science in 2009. It also committed to substantial investments in climate science: $31.2 million over four years from 2009 for the Australian Climate Change Science Program (with matching contributions from CSIRO and the Bureau of Meteorology); $387.7 million in research infrastructure over four years to increase Australia’s capacity to respond to climate change and improve protection of Australia’s marine territory; and a number of scientific partnerships between CSIRO, the Bureau of Meteorology, and state and territory governments.\(^{42,64}\) (Details of grants made under the Australian Climate Change Science Program can be accessed at the Department of Climate Change and Energy Efficiency website.\(^a\))

In December 2007, Australia ratified the Kyoto Protocol and established a new Department of Climate Change (now Climate Change and Energy Efficiency) to take the lead across government on climate change, providing a focus for policy development and advice, both domestically and internationally. Since then, Australia’s system for measuring and reporting on GHG emissions and energy use by major industry sectors and for estimating losses and gains from vegetation and soil sinks (the National Greenhouse Gas Inventory) has substantially improved. This reporting system underpins Australia’s commitment under the protocol to a GHG emissions target of 108% above 1990 levels for the first commitment period (2008–12). The statutory framework for this system was established in 2007 with the introduction of the National Greenhouse and Energy Reporting Act 2007. The Act streamlines reporting with the establishment of a single reporting point for emissions and energy data and, since 2008, mandates reporting by companies exceeding thresholds for emissions and energy production. The framework also enables Australia to meet its reporting requirements under the Kyoto Protocol through the establishment of a national registry of emissions units. Planning and quality control systems associated with the national inventory have also been strengthened.\(^{42}\)

2.3.2 Planning and strategy

Governments have a key role to play in mitigation of, and adaptation to, climate change, including:

- supporting scientific studies that are unlikely to be undertaken by the private sector (particularly relevant to the Australian Government)
- providing information to the private sector and the community to encourage and assist adaptation (relevant to all tiers of government, but of particular importance to state, territory and local governments)
- adopting policy settings that facilitate adaptation and a regulatory framework that supports, rather than distorts, effective market signals (a critical role for the Australian Government, but one that state and territory governments can significantly reinforce)
- employing policy mechanisms such as land-use planning, building codes and product standards to deal with situations where short-term market responses may act to restrict longer term adaptive action (primarily relevant to state and territory governments, but also to the Australian Government for setting minimum energy performance standards and the Building Code of Australia, and to local governments, which play an important role in on-ground implementation)
- fully factoring climate change into planning, resourcing and managing the provision of public goods and services such as public health and safety, emergency services, flood and coastal protection, water supply, drainage and sewerage services, protection of public lands, parks and reserves, fisheries and other natural resources (relevant to all three tiers of government, but especially to state, territory and local governments).

A key part of the Australian Government’s three-pillars strategy has been the introduction of a price on carbon to drive reductions in emissions via least-cost means. An initial attempt in 2008–10 to do this by means of an emissions trading scheme (the Carbon Pollution Reduction Scheme) failed to gain bipartisan support in parliament and did not proceed.
In July 2011, the Australian Government released its new plan for the introduction of a price on carbon (titled Securing a Clean Energy Future). Although the plan has four components (a carbon price, renewable energy, energy efficiency and land-based action to sequester carbon), the critical element is a mechanism to put a price on carbon and thereby stimulate least-cost abatement measures.47

Unlike the earlier failed attempt to move directly to a carbon emissions trading scheme, the plan involves moving to a trading scheme via a three-year transitional period. During this period, starting from 1 July 2012, facilities directly emitting 25,000 tonnes or more of CO₂-e per year (excluding transport fuel emissions) and large suppliers of natural gas will have to buy and surrender to the Australian Government a carbon permit for each tonne of GHG they emit. The government will issue as many permits as businesses need to cover their emissions. The starting price will be fixed at $23 per tonne, increasing by 2.5% per year in real terms. GHGs for which permits will have to be purchased are carbon dioxide, methane and nitrous oxide, and PFC emissions from the aluminium sector. Existing legislation relating to synthetic GHGs will be used to apply an equivalent tax on manufacturing and import of all the synthetic GHGs covered by the Kyoto Protocol—HFCs, PFCs and sulfur hexafluoride. In combination, this will cover around 60% of Australia’s emissions, including emissions from electricity generation, stationary energy, some business transport, nonlegacy waste, industrial processes and fugitive emissions. (Emissions from agriculture will not be covered.)

On 1 July 2015, the fixed price (or carbon tax) period will be replaced by an emissions trading scheme (ETS). Under the ETS, the government will set an annual carbon pollution cap that will determine the number of permits issued. Market forces will then act to influence the price of a permit at any time. However, for the first three years of the scheme, a ceiling and floor price will be in place to limit extreme price volatility. The ceiling will be set at $20 per tonne above the anticipated international price, rising by 5% per year in real terms. The floor price will start at $15 per tonne and increase by 4% per year in real terms. The role of the ceiling and floor price will be reviewed in the third year of operation of the ETS. From the outset of the ETS, businesses will be able to purchase international permits from credible carbon markets. Until 2020, businesses will be able use international permits to meet up to 50% of their required permits each year. (This restriction will be reviewed in 2016.)

Fifty per cent of the revenue from the carbon pricing mechanism will be used to assist households to deal with price impacts. The balance will be divided between supporting a range of industries directly or indirectly affected by the introduction of a carbon price (including energy-intensive, trade-exposed industries) and expanding existing funding for clean energy and energy efficiency programs.

The plan provides for a legislated independent expert body (the Climate Change Authority) to advise government on matters such as future pollution caps, indicative national emissions trajectories and long-term emissions budgets, and the progress made towards national reduction targets. Legislation will also establish a clean-energy regulator to administer the carbon pricing mechanism.

Although a carbon price will not apply to agriculture, the plan will continue the existing Carbon Farming Initiative to encourage and support farmers and land managers to reduce emissions and store carbon in soil and vegetation. Funding for such actions will be available through an ongoing Biodiversity Fund ($946 million over the first six years) and an ongoing Carbon Farming Futures program ($429 million over the first six years).

Under the plan, the existing Renewable Energy Target will be complemented by the establishment of a new statutory authority, the Australian Renewable Energy Agency, which will provide funding for projects through a range of competitive grants programs. The agency will consolidate existing funding of $3.2 billion over nine years to support innovation in renewable energy and will make additional funds available. In addition, a Clean Energy Finance Corporation will be established to invest in the commercialisation and deployment of renewable energy and in enabling technologies, energy efficiency and low-emissions technologies.

Emissions reduction targets for 2020, to which the Australian Government had already committed, have been maintained, and the long-term target (2050) has increased from 60% to 80% of 2000 levels (Box 3.4). To meet the government’s minimum emissions reduction target (a 5% reduction from 2000 levels by 2020) in the face of projected continuing growth in emissions will require abatement of at least 159 MtCO₂-e (23%) by 2020.

At the time of writing (July 2011), the Australian Government proposes to introduce the necessary supporting legislation to parliament before the end of the year.
Box 3.4 Australia’s climate change targets

Emissions
Kyoto target: to limit net increases in greenhouse gas emissions to an average of 108% of 1990 levels across 2008–12. Australia is on track to meet this target, largely due to a significant reduction in land clearing during the late 1990s, which was achieved via controls at state level.

2020 target range: to achieve emissions reductions of between 5% and 25% below 2000 levels by 2020:

- 5%—an unconditional commitment even in the absence of an international commitment
- 15%—a target Australia is prepared to adopt if there is a global agreement that falls short of securing atmospheric stabilisation at 450 parts per million (ppm) CO₂-e (carbon dioxide equivalents), but under which all major economies commit to significant emissions reductions and advanced economies accept reductions comparable with Australia’s
- 25%—agreed by Australia in Appendix 1 to the Copenhagen Accord, provided the world agrees to an ambitious global deal capable of stabilising levels of greenhouse gases in the atmosphere at 450 ppm CO₂-e or lower.

2050 target: In July 2011 (as part of its Securing a Clean Energy Future plan) the Australian Government increased the national 2050 emissions reduction target from a 60% reduction on 2000 levels to an 80% reduction. Developed countries need to achieve a 60% reduction to stabilise global greenhouse gas levels in the range 450–550 ppm by 2050. At 450 ppm, the estimated likelihood of limiting global mean temperature rise to 2 °C above pre-industrial levels is around 50%. At 550 ppm, a rise of 3 °C is likely. The Commonwealth Scientific and Industrial Research Organisation estimates that around 97% of the Great Barrier Reef will be bleached each year if temperatures rise to within this range.

Energy efficiency
Renewable Energy Target: to source 20% of Australia’s electricity supply from renewable resources by 2020.

Sources: Australian Government; Australian Government Department of Climate Change and Energy Efficiency; United Nations Framework Convention on Climate Change; Garnaut; Preston & Jones

Hermannsburg solar array providing electricity to local communities, near Alice Springs, Northern Territory
Photo by Steven David Miller
2.3.3 The role and coordination of different levels of government

An overarching Australian Government strategy—implemented via a range of policies, plans and programs—is essential if Australia is to succeed in mitigating climate change and addressing key areas of vulnerability through adaptation. However, in Australia’s federal system, it is also imperative that other Australian governments play their part in the national initiative and that their actions are coordinated effectively with those of the Australian Government.

Table 3.2 lists examples of key climate change policies and strategies established at state and territory level. In addition to seeking to mitigate climate change through means such as renewable energy targets, electricity feedback tariffs and energy efficiency programs, each jurisdiction’s policies and strategies focus on the need to identify vulnerabilities and opportunities associated with climate change and to implement appropriate adaptive actions.

<table>
<thead>
<tr>
<th>State/territory</th>
<th>Policy response or strategy</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian Capital Territory (ACT)</td>
<td>Weathering the Change—the ACT Climate Strategy 2007–2025</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electricity Feed-in (Renewable Energy Premium) Act 2008</td>
<td></td>
</tr>
<tr>
<td>New South Wales</td>
<td>Greenhouse Plan</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Draft Climate Change Action Plan</td>
<td>To replace Greenhouse Plan</td>
</tr>
<tr>
<td></td>
<td>Greenhouse Gas Reduction Scheme (formerly the Greenhouse Gas Abatement Scheme)</td>
<td>Trading aspects to cease when a national emissions trading scheme commences</td>
</tr>
<tr>
<td></td>
<td>Renewable energy target</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Promotion of energy-efficient buildings</td>
<td>Encourages adoption of National Australian Built Environment Rating System</td>
</tr>
<tr>
<td>Northern Territory (NT)</td>
<td>Climate Change Policy</td>
<td>A $34-million action plan that commits NT to becoming carbon neutral by 2018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Provides a plan for lowering land clearing rate and protecting coastal wetlands</td>
</tr>
<tr>
<td>Queensland</td>
<td>ClimateSmart 2050</td>
<td>State climate change strategy</td>
</tr>
<tr>
<td></td>
<td>ClimateSmart Adaptation 2007–2012</td>
<td>Action plan for managing effects of climate change</td>
</tr>
<tr>
<td></td>
<td>Smart Energy Policy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Renewable Energy Fund</td>
<td></td>
</tr>
<tr>
<td>South Australia</td>
<td>Tackling Climate Change—South Australia’s Greenhouse Strategy 2007–2020</td>
<td>Deals with a range of mitigation and adaptation actions</td>
</tr>
<tr>
<td></td>
<td>Electricity (Feed-in Schemes—Solar Systems) Amendment Act 2008</td>
<td>Bill to amend 2008 Act introduced in April 2011 to increase benefits while limiting total cost of scheme</td>
</tr>
<tr>
<td></td>
<td>Residential Energy Efficiency Scheme</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Draft Adaptation Framework</td>
<td>A guide to government agencies, local government, nongovernment organisations, business and the community</td>
</tr>
</tbody>
</table>
### Table 3.2 continued

<table>
<thead>
<tr>
<th>State/territory</th>
<th>Policy response or strategy</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasmania</td>
<td>Framework for Action on Climate Change</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Community Grants Programs</td>
<td>Micro-grants (up to $3000) and ClimateConnect grants (up to $30 000)</td>
</tr>
<tr>
<td>Victoria</td>
<td>Taking Action for Victoria’s Future—Victorian Climate Change White Paper, 2010</td>
<td>Comprehensive framework that addresses mitigation and adaptation</td>
</tr>
<tr>
<td></td>
<td>Climate Change Act 2010</td>
<td>Deals with a range of matters, including providing for an emissions reduction target of 20% by 2020; establishing property rights in forestry, carbon sequestration and soil carbon; empowering the Environment Protection Authority to regulate emissions</td>
</tr>
<tr>
<td></td>
<td>Climate Change Adaptation Plan and community-based climate change preparedness programs</td>
<td>Key adaptation actions under the white paper</td>
</tr>
<tr>
<td></td>
<td>Victorian Renewable Energy Target Scheme</td>
<td>Sets annual statutory targets and issues renewable energy certificates</td>
</tr>
<tr>
<td>Western Australia</td>
<td>Climate Change Adaptation and Mitigation Strategy</td>
<td>Under development</td>
</tr>
<tr>
<td></td>
<td>Low Emissions Energy Development Fund</td>
<td>$30 million available to support development of technologies</td>
</tr>
<tr>
<td></td>
<td>Residential feed-in tariff scheme</td>
<td>Provides eligible residential system owners with a subsidy rate of 40 cents per kilowatt hour for energy exported to the electricity grid</td>
</tr>
</tbody>
</table>

Sources: Parliament of Australia, state and territory agency websites

In February 2008, the Australian Government commissioned a strategic review of all climate change programs (the Wilkins review) to determine whether existing climate change programs are efficient, effective and complementary to the Carbon Pollution Reduction Scheme (CPRS)—so that climate change can be addressed at least cost to the economy. The review recommended, among other things, a reduction in the number of federal programs and a clarification of roles of the Australian and state and territory governments. More specifically, it suggested a rationalisation of activities, with the Australian Government to focus on mitigation measures and the states and territories to concentrate on adaptation via the Council of Australian Governments (COAG) National Adaptation Framework, which aims to build our capacity to manage climate change impacts and reduce vulnerability in key sectors and regions. However, in the three years since the release of the Wilkins review, it has become clear that a thorough rationalisation of activities along these lines is unlikely to be practicable, given the important role of state and territory governments in areas such as promotion of energy efficiency and renewable energy sources, land-use planning and public transport.

In responding to this element of the Wilkins review, the Australian Government emphasised the importance of COAG in engaging the states and territories. Examples of cooperation and coordination cited included finalising the expanded national Renewable Energy Target scheme, developing the COAG Energy Efficiency Strategy, adopting the National Adaptation Framework in 2007, reviewing existing climate change programs and developing new initiatives.
Local government, as the tier of government closest to the community, has a particularly important role in engaging businesses and community groups in identifying key vulnerabilities to climate change (and potential opportunities); setting priorities; and developing and implementing adaptation strategies that take full account of local conditions, resource availability and community capacity to deal with change. As Professor Garnaut notes:

> The appropriate adaptation response will always depend on a range of local circumstances. Therefore, unlike the mitigation effort, adaptation is best seen as a local, bottom-up response. *Garnaut*, p. 363

Local government actions to mitigate and adapt to climate change have been assisted in Australia and internationally by Cities for Climate Protection® (CCP®)—an international campaign initiated by the International Council for Local Environmental Initiatives (ICLEI), which ‘provides a framework for local governments to integrate climate protection policies with actions that address immediate municipal concerns’. Between 1998–99 and 2007–08, Australian councils participating in the CCP Australia campaign reported a total abatement of 18 million tonnes of CO₂-e. In 2009, as part of the rationalisation of programs following the Wilkins review, Australian Government funding of around $1.5 million per year for the CCP® program was halted on the basis that it was not complementary to the CPRS. The decision, which was strongly criticised by local government and the Australian Greens party, attracted limited media attention (e.g. see Cubby). Under its present title, CCP—Integrated Action®, the campaign continues to assist local governments and their communities with action to mitigate climate change (CCP-Mitigate®) and to adapt to climate change (CCP-Adapt®).

In the final analysis, although action by all tiers of government will be needed to adapt to climate change, ‘adaptation is a shared responsibility—governments, business and the community all have a stake and a role in responding to climate change impacts’.

2.3.4 Management outputs and outcomes

Efforts by government, the business sector and the broader community to reduce GHG emissions are essential to minimise the degree of climate change and associated consequences. Table 3.3 summarises the projected reductions in emissions from major abatement policies and measures put in place by the Australian and state and territory governments. The projected reduction averaged across each year during the Kyoto commitment period (2008–12) is 56 MtCO₂-e, and the projected reduction in 2020 is 109 MtCO₂-e.
Table 3.3 Projected annual reductions in greenhouse gas emissions from government policies and programs

<table>
<thead>
<tr>
<th>Schemea</th>
<th>Kyoto commitment period (2008–12) average (MtCO₂-e)</th>
<th>2020 (MtCO₂-e)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Renewable Energy Target</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Large-scale Renewable Energy Target</td>
<td>8.6</td>
<td>26.3</td>
</tr>
<tr>
<td>• Small-scale Renewable Energy Scheme</td>
<td>0.2</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>National Strategy on Energy Efficiency</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Equipment Energy Efficiency Program</td>
<td>6.3</td>
<td>20.3</td>
</tr>
<tr>
<td>• Energy efficiency requirements: building codes</td>
<td>4.2</td>
<td>11.8</td>
</tr>
<tr>
<td>• Mandatory disclosure requirements: buildings</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>• Framework Cool Efficiency Program</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>• Phase-out of incandescent lighting</td>
<td>1.0</td>
<td>1.9</td>
</tr>
<tr>
<td>• Phase-out of inefficient water heaters</td>
<td>0.1</td>
<td>4.1</td>
</tr>
<tr>
<td>• Energy Efficiency Opportunities Program</td>
<td>2.7</td>
<td>4.2</td>
</tr>
<tr>
<td><strong>Queensland Gas Scheme</strong></td>
<td>2.2</td>
<td>4.3</td>
</tr>
<tr>
<td><strong>Victorian Energy Efficiency Target and Energy Saver Incentive Scheme</strong></td>
<td>0.2</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Greenhouse Gas Abatement Program</strong></td>
<td>3.4</td>
<td>3.6</td>
</tr>
<tr>
<td><strong>Greenhouse Challenge Plus</strong></td>
<td>5.3</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>Biofuel Act 2007 (New South Wales)</strong></td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>New South Wales and Queensland land clearing legislation</strong></td>
<td>18.0</td>
<td>18.4</td>
</tr>
<tr>
<td><strong>Other measures</strong></td>
<td>3.8</td>
<td>5.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>56</td>
<td>109</td>
</tr>
</tbody>
</table>

MtCO₂-e = megatonnes of carbon dioxide equivalent

a These estimates do not attempt to indicate the economic efficiency of programs or to calculate the cost per tonne of abatement.
b Only a selection of policies and measures are presented here. Overlap between policies and measures has been deducted from these estimates. Therefore, each estimate reflects the net abatement attributed to that policy or measure.
c Figures may not total to the number shown due to rounding.

Source: Australian Government Department of Climate Change and Energy Efficiency46
However, due to the long lifetimes (decades or centuries) of most GHGs and the length of time for oceans to adjust to changes in the temperature of the atmosphere, even if emissions were to cease completely, the world’s climate will continue to change for centuries. Under realistic scenarios involving the cessation of carbon dioxide emissions, the elevated global surface temperature and thermal expansion of the oceans associated with carbon dioxide will persist for more than 1000 years. As there will be some unavoidable consequences of climate change, it is critical that strategies to adapt to inevitable climate change are developed and implemented, particularly in areas of greatest vulnerability to change. In Australia, our natural ecosystems, coastal communities and water security are particularly vulnerable, having a limited range of ability to cope with climate change (Figure 3.18).

Commenting on Australia’s vulnerability, the IPCC noted in 2007:

... even if adaptive capacity is realized, vulnerability becomes significant for 1–2 °C of global warming. Energy security, health (heat-related deaths), agriculture and tourism have larger coping ranges and adaptive capacity (than natural ecosystems, coastal communities and water security), but they may become vulnerable if global warming exceeded 3 °C. *Intergovernmental Panel on Climate Change*

Since then, further studies suggest that the risks may be more immediate than indicated by the IPCC.

![Figure 3.18](image-url)
3.2 Assessment summary

Effectiveness of climate change management

Summary

Greenhouse gases and climate change

**Understanding:** Good understanding of broad processes and improving confidence in modelling projections at both national and regional scales. Extensive support for policy and priority setting at national level through initial Garnaut Climate Change Review (2008) and subsequent review update (2011) and through an improved national greenhouse emissions reporting system.

**Planning:** Australian Government has established a broad (‘three-pillars’) strategy underpinned by a legislated 20% Renewable Energy Target and Energy Efficiency Strategy. In July 2011, the government released a plan to establish a price on carbon and encourage least-cost abatement measures. Legislation to give effect to this is expected to be introduced to parliament in the latter half of 2011. A National Adaptation Framework was adopted by COAG in 2007. Level of strategic planning to mitigate and adapt to climate change varies considerably from state to state (e.g. in relation to adaptation to potential impacts of sea level rise).

**Inputs:** Around $15 billion committed to climate change initiatives by the Australian Government. Significant funds are available to support climate science at both national and state levels. Significant resources are also being applied by states and territories to mitigation and adaptation programs.

**Processes:** Governance is complex, with three tiers of government needing to be involved. Coordination of federal and state and territory programs has been improved via COAG actions.

**Outputs and outcomes:** Current and projected levels of success of federal and state and territory abatement programs are limited. To achieve the national 2020 target of a 5% reduction in greenhouse gas emissions below 2000 levels, abatement measures will need to be greatly increased.

Recent trends

- Improving
- Stable
- Deteriorating
- Unclear

Confidence

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

Grades

- Very effective
- Effective
- Partially effective
- Ineffective

COAG = Council of Australian Governments
2.4 Resilience of Australia’s climate

Earth’s atmosphere and oceans form a complex, coupled system, characterised at a global scale by a high level of short-term resilience. In general, significant global climate change has typically occurred over thousands of years in the geological record, rather than over decades or centuries. This is because changes to climate forcing (such as changes to incoming solar energy or atmospheric chemistry) typically occur over very long timescales. Only in the past few decades have the cumulative effects of human activities reached a scale that threatens to challenge Earth’s short-term resilience and drive change in the global climate at rates unprecedented in recent geological history.8,76

2.4.1 Resilience of our climate

To date, the apparent resilience of the atmospheric–oceanic system has been a major factor limiting the rate and extent of change in climate (largely due to the capacity of the oceans to absorb carbon dioxide and heat). However, there is rising concern among climate scientists that, unless the growth in GHG emissions is soon slowed and reversed, continued increase in water temperature will reduce the oceans’ capacity to remove carbon dioxide from the atmosphere.77-78

At present, the oceans remove about a quarter of human-produced carbon dioxide emissions. As a result, the oceans have gradually become more acidic (with a reduction in the pH of surface waters of about 0.1 during the past 250 years). This trend is generally expected to continue, with a further reduction of 0.2–0.3 pH units occurring by 2100. Should this happen, it could have a major impact on the wide variety of marine organisms with carbonate skeletons, notably corals and plankton, thus potentially affecting the entire marine food chain (see Chapter 6: Marine environment).10

However, this remains an area of considerable uncertainty, as evidenced by the work of Law and her colleagues,79 whose modelling did not find a saturating Southern Ocean carbon sink due to recent climate change. Rather, they concluded that, although carbon uptake was reduced by wind forcing, forcing due to heat and freshwater flow resulted in an increased uptake. Debate on this issue is continuing in the scientific literature (e.g. see Zickfeld et al.80 and Le Quéré et al.81).

2.4.2 Resilience of our environment and society

Although the changing physical resilience of the atmospheric–oceanic system is a critically important focus of concern, so too is the resilience of different human and animal populations to the changes in climate that are already occurring and will continue
for the foreseeable future. The degree to which any population is resilient will depend on its sensitivity to specific elements of climate change and its capacity to adapt. Sensitivity will be influenced by factors such as location and the level of security of food and water supplies. In human populations and in the ecosystems of which they are part, adaptive capacity is strongly influenced by the rate at which change occurs. In the case of humans, this markedly affects our ability to anticipate change, develop adaptive strategies and marshal resources to adjust to change in a way that minimises harm and takes advantage of opportunities.

Resilience of human populations to climate change will vary between and within nations. As a general rule, within any society, the most marginal groups in terms of income, health and education are likely to be the most sensitive to climate change and the least well equipped to adapt without assistance from those better off. At the international scale, this generalisation holds true, as evidenced by many small island states that are highly sensitive to climate change–induced sea level rise and have inherently limited scope for adaptation. A critical role for policy makers at both national and international levels is therefore to recognise and reflect these variations in ‘social resilience’ when framing measures to adapt to climate change.

In the Australian context, a significant number of coastal communities are sensitive to sea level rise, particularly the Indigenous communities of Torres Strait, a number of which face inundation from rising sea levels. Across the nation, 160 000–250 000 homes are estimated to be potentially at risk of inundation from a 1.1-metre rise in sea level.\textsuperscript{82} By comparison with most small island states, the great majority of Australia’s coastal communities have considerable scope and resources to plan for and adapt to such change. However, without effectively coordinated planning and action at national, state and local levels, the potential resilience of these communities may not be realised.

For many of Australia’s Indigenous communities, climate change represents a major threat. In addition to sea level rise, increasing temperatures and likely (but less certain) changes in seasonal rainfall will impact these communities in many ways, including through changes to plant and animal populations.\textsuperscript{83} This is not to suggest that these communities lack resilience or a willingness and capacity to identify and seize opportunities that are likely to accompany change. As Professor Marcia Langton noted in an address to the National Indigenous Land and Sea Management Conference held in Broken Hill in November 2010, ‘... opportunities emerging from climate change includ[e] a growing industry in which Indigenous land and sea managers can be involved, such as carbon abatement and sequestration, solar and wind farms, biodiesel, and tidal energy. Green collar jobs should be black collar jobs. Indigenous rangers can provide very good environmental management services that can be marketed’\textsuperscript{84}
2.5 Risks to Australia’s climate

Observations and research outcomes since 2008 have confirmed and strengthened the position that the mainstream science then held with a high level of certainty, that the Earth is warming and that human emissions of greenhouse gases are the primary cause. Garnaut

As noted in Chapter 2: Drivers, global GHG emissions have (since 2005) continued to track above the middle of the IPCC’s scenario range—between A1B (economic growth based on a balance between resource-efficient and fossil fuel-intensive industries) and A1F1 (fossil fuel-intensive growth). Given the longevity of most GHGs in the atmosphere and the slow rate at which the temperature of the oceans changes, we know that the lower atmosphere and oceans will continue to warm for centuries after emissions are stabilised. Even if the most optimistic scenarios for carbon dioxide reductions were to be realised, increased temperatures associated with carbon dioxide emissions will be ‘largely irreversible for 1000 years after emissions stop’.

In addition to the risks of increasing temperatures and changes in rainfall amount and seasonality, a key risk associated with climate change is the likelihood of more frequent and/or severe extreme weather events, such as floods, droughts and heatwaves, and an increase in bushfires. However, although the number of intense cyclones may increase, the total number of cyclones is likely to decline. Such primary ‘atmospheric’ risks generate a broad series of secondary and tertiary risks, many of which are explored elsewhere in this report. These include increased mortality and morbidity due to heatwaves and spread of disease vectors, reduced streamflows and groundwater recharge, reduced soil moisture, and changes in habitat with attendant risk to biodiversity. The summary of risks below assumes a timeframe of 30–40 years.
### 3.3 Assessment summary

**Current and emerging risks to Australia’s climate**

<table>
<thead>
<tr>
<th>Catastrophic</th>
<th>Major</th>
<th>Moderate</th>
<th>Minor</th>
<th>Insignificant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Almost certain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>■ Continuing spatially variable rise in temperatures across the continent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Likely | | | | |
| ■ Reduced rainfall in southern areas, especially in winter, and in southern and eastern areas in spring | ■ Increased geographic range of disease vectors (e.g. mosquitoes) | | | |
| ■ Increased evaporation and reduced soil moisture | | | | |
| ■ Increased frequency and severity of wildfires | | | | |
| ■ Increased frequency of heatwaves | | | | |

| Possible | | | | |
| ■ One or more climate change tipping points are passed, triggering abrupt, nonlinear and irreversible changes in the climate system | ■ Increased severity of extreme weather events such as cyclones | | | |

| Unlikely | | | | |
| | | | | |

| Rare | | | | |
| | | | | |

Nota considerato

**Explanation of terms:**

- **Almost certain:** >90% probability of occurring during the specified timeframe
- **Likely:** >66% – ≤90% probability of occurring during the specified timeframe
- **Possible:** >33% – ≤66% probability of occurring during the specified timeframe
- **Unlikely:** >10% – ≤33% probability of occurring during the specified timeframe
2.6 Outlook for Australia’s climate

The weight of scientific opinion is that developed countries need to reduce their greenhouse gas emissions by 60% by 2050 against 2000 emission levels, if global greenhouse gas concentrations in the atmosphere are to be stabilised between 450 and 550 ppm by mid-century. Garnaut, p. xvi

The IPCC uses the term ‘equilibrium climate sensitivity’ to refer to ‘the global average surface warming following a doubling of carbon dioxide concentrations [from pre-industrial levels of 280 ppm]. This is likely [i.e. more than 66% probable] to be in the range of between 2 °C and 4.5 °C with a best estimate of about 3 °C’. This best estimate has been generated from geological evidence, climate modelling and 20th century observations. Based on the estimate, stabilisation at 450 ppm CO₂-e would provide a 50% probability that global mean temperature increase could be limited to 2 °C, while stabilisation at 550 ppm would likely result in a rise of at least 3 °C. Although the magnitude of future changes in global temperatures is important, it is the rate of change that will cause the biggest impacts. A rise of around 2 °C over just two centuries is expected to lead to widespread and significant risks to Australia’s natural ecosystems, water security and coastal communities.

Unfortunately, the prospects of an international agreement on a framework to stabilise global emissions at either 450 ppm or 550 ppm appear to be limited. Analysing developed nations’ pledges to reduce emissions made under the Copenhagen Accord of December 2009, the World Resources Institute concluded that, collectively, they could by 2020 achieve a reduction of 12–19% below 1990 levels. However, the institute noted that this was well below the 25–40% reductions that the IPCC indicated were needed to achieve stabilisation at 450 ppm and thereby reduce the risk of overshooting the goal of limiting global mean temperature rise to 2 °C (agreed under the accord and by the Major Economies Forum and the G8). Even at 450 ppm, the risk of overshooting is still considerable (in the range 26–78%).
Against a background of global emissions continuing to track between the IPCC’s A1F1 scenario (fossil fuel–intensive growth) and the A1B scenario (economic growth based on a balance between resource-efficient and fossil fuel–intensive industries), projections of Australia’s growth in GHG emissions to 2020, based on policy settings applying before the release of the Australian Government’s Securing a Clean Energy Future plan, showed an increase of 23% above 2000 levels (taking emissions to 690 MtCO₂-e). The Securing a Clean Energy Future plan aims to prompt a move away from ‘business as usual’, achieving the nation’s minimum 2020 target of a 5% cut on 2000 levels by reducing emissions by at least 159 MtCO₂-e (23%) in 2020. To achieve Australia’s 15% conditional target, a 31% (216 MtCO₂-e) reduction from the projected 2020 level would be needed.

Although mitigation is central to Australia’s broad climate change strategy, at the time of writing (July 2011), there is still no bipartisan support at the federal level for a key element of that strategy—establishing a price on carbon. This is despite the view of widely respected economists such as Lord Nicholas Stern and Professor Ross Garnaut on the central importance of pricing carbon to mitigating carbon emissions, and the conclusion of the recent Productivity Commission’s research report, Carbon emission policies in key economies.

The basic theory of externalities identifies the source of the economic problem in untaxed or unpriced emissions of GHGs. The externality requires a price for emissions: that is the first task of mitigation policy. Stern, p. 40

Economy-wide pricing of carbon is the centre piece of any policy designed to reduce emissions at the lowest possible costs. Garnaut, p. 2

... the consistent finding from this study is that much lower-cost abatement could be achieved through broad, explicit carbon pricing approaches [than from existing policies] irrespective of the policy settings in competitor economies. Productivity Commission, p. 155

Despite the lack of bipartisan agreement on the need to put a price on carbon, legislation needed to give effect to key elements of the government’s Securing a Clean Energy Future plan is expected to come into effect before the end of 2011, with the anticipated support of three independent members of the House of Representatives and of the Greens in the Senate. As described in Section 2.3.2, the central element of this plan is a mechanism to establish a price on carbon and drive reductions in emissions via least-cost means.

However, even if national and international mitigation efforts increase dramatically over the next decade or two, temperatures will remain at elevated levels for centuries to come. Mitigation of future GHG emissions is therefore aimed at limiting future climate change and avoiding catastrophic climate change tipping points, rather than returning the climate system to a pre-industrial state. Beyond mitigation, our most important strategy will be adaptation. Our capacity as a society to adapt to a changing climate will depend on many factors, in particular:

1. the rate of change

2. the degree of exposure to the effects of change, which will vary not only geographically and from sector to sector, but also between different groups in society

3. the strength and diversity of the economy

4. our capacity to innovate

5. our capacity for behavioural change

6. our ability to expand our knowledge base and apply that knowledge in planning and decision-making

7. a willingness to accept uncertainty and not to use it as a reason for postponing necessary action.

Australia, with its highly developed economy and physical, human and social capital, is better placed than many nations to anticipate the threats and opportunities associated with climate change and to take adaptive action in the short to medium term. Areas of opportunity include sequestering carbon in the soil and via large-scale landscape revegetation programs, supporting innovation in renewable energy and energy-saving technologies, and developing highly resilient systems of agricultural production. Although it is critical that these and other opportunities are identified and seized, in some key sectors—such as natural ecosystems, coastal communities and water security—our scope for adaptation through incremental change is limited and our exposure to risk is high. This combination makes us vulnerable to a temperature rise of even 1–2 °C.
Even sectors with greater scope for adaptation (such as energy security, health, agriculture and tourism) are likely to be vulnerable if, in the absence of highly effective global mitigation efforts, temperatures rise by 2–5 °C. A temperature rise of this magnitude is not just a remote possibility. If the world continues along its present emissions track, Australia’s average temperature is projected to rise 2.2–5.0 °C by 2070.

It should be noted that smooth changes are the exception rather than the norm in the climate system, which is nonlinear in nature. This means that a number of feedback mechanisms exist that can amplify or accelerate climate change, with the potential to cause large step-changes in regional and global climate. Such mechanisms include rapid melting of terrestrial ice caps and changes to the large-scale circulation of the oceans. Rapid changes in climate forcing mechanisms in the geological history of the planet have been associated with sudden climate shifts; hence, failure to mitigate GHG emissions increases the likelihood of precipitating such events. In general, dramatic climate shifts have not been factored into future climate scenarios that policy makers and economists have worked with, and our ability to adapt to such changes is largely unknown.

Should such changes occur, adaptive strategies framed around incremental change are unlikely to be adequate to prevent major harmful impacts on key sectors. Instead, what CSIRO describes as ‘transformational’ change will be needed, and ‘a major scientific and societal challenge [will be] to understand and decide how, where, and when this transformational change is required.’
Ambient air quality and other atmospheric issues

This section describes aspects of the atmosphere other than the effects of atmospheric composition on climate.

3.1 State and trends of Australia’s atmosphere

Assessing the state of Australia’s atmosphere in essence involves assessing the impact of a number of contaminants on three main areas: the stratospheric ozone layer, ambient (outdoor) air and indoor air.

3.1.1 Stratospheric ozone

The stratosphere is the layer of the atmosphere that begins at an altitude of around 10 kilometres above Earth’s surface and extends to approximately 50 kilometres. It is situated between the troposphere (near Earth’s surface) and the mesosphere. Stratospheric ozone limits the amount of harmful ultraviolet B (UVB) light (UVB wavelengths are 280–315 nanometres) passing through to lower layers of the atmosphere. The ozone layer, therefore, has a vital role in protecting life on Earth, as increased levels of UVB may result in damage to a range of biological systems, including human health. In humans, UVB—although necessary for the production of vitamin D—causes nonmelanoma skin cancer and is a significant factor in the development of malignant melanoma. In addition, it is associated with the development of cataracts. (However, it should be noted that, whereas ozone in the stratosphere is protective of human health, ozone near the ground, where it can be breathed in, is a pollutant and harmful to health. Section 3.1.2 further discusses ozone as a pollutant.)

Global observations of atmospheric levels of the major ozone depleting substances (ODSs)—principally chlorofluorocarbons and halons (used as refrigerants, industrial solvents, flame retardants and propellants in aerosol spray cans)—show them reaching a peak in the mid-1990s and declining since then. As a result, stratospheric levels of the breakdown products of ODSs (such as chlorine and bromine), which react with and destroy ozone, have also begun to decline. This drop is expected to continue with the ongoing phase-out of these ODSs under the Montreal Protocol. However, the stability of these substances will result in the continued depletion of stratospheric ozone for many decades.

Ambient air quality in Australia’s major urban centres is generally good. National health-based standards are rarely exceeded for prolonged periods, and very high levels of pollution are usually associated with short-lived extreme events, such as bushfires and dust storms, that generate very high levels of particulate pollution. Despite substantial population growth, industry expansion and greatly increased motor vehicle use, levels of carbon monoxide, nitrogen dioxide, sulfur dioxide and lead have declined in urban areas over the past two decades.

However, this overall favourable situation should not be taken to imply that air quality in our major cities does not impact on human health. Levels of particles and of the secondary pollutant ozone have not decreased. Both these pollutants are known to impact on cardiovascular and respiratory health. Research into the health effects of particles and ozone, along with pollutants such as sulfur dioxide, indicates that there is no threshold level below which they have no health effect. This means that sensitive individuals—such as asthmatics and people with respiratory or cardiovascular disease—may be affected even when air quality standards are met. By one estimate, there were close to 3000 deaths due to urban air pollution in 2003—nearly twice the national road toll.

Most Australians spend more than 90% of their time indoors, leading to concern over the possible impacts of indoor air quality on our health. Symptoms associated with poor indoor air quality can range from acute to chronic, and from mild and generally nonspecific (eyes, nose and throat irritation, and headaches and dizziness) to severe (asthma, allergic responses and increased cancer risk). Despite the potentially significant health effects of indoor air, data on indoor air quality in Australia are limited, and Australia has no specific guidelines for indoor air quality to provide a firm basis for forming assessments of overall status and trend.
Photosynthesis in many species of plants is impaired by UVB radiation, and overexposure can reduce yield and quality in some crop species, including varieties of rice, winter wheat, soybeans, corn and cotton. UVB radiation may also change the susceptibility of plants to insect and pathogen attack. In aquatic systems, photosynthesis in phytoplankton is more sensitive to UVB than in terrestrial plants, and short-term exposure to increased UVB levels can reduce productivity in such systems.\textsuperscript{101-103}

The ozone layer was threatened by human-produced ozone depleting substances (ODSs), principally chlorofluorocarbons (CFCs) and halons, which were widely used in refrigerators, air conditioners, fire extinguishers and electronic equipment, as solvents for cleaning (including dry cleaning) and as agricultural fumigants. These substances are stable and long lived in the lower atmosphere, but slowly drift up to the stratosphere, where they are subject to breakdown through the action of UV radiation. This releases highly reactive molecules (chlorine and bromine) that react with ozone molecules and break them apart.

Since peaking in the mid-1990s, levels of stratospheric chlorine and bromine from CFCs and other ODSs have declined. The latest World Meteorological Organization (WMO) \textit{Scientific assessment of ozone depletion}\textsuperscript{104} concludes that:

\begin{quote}
... the atmospheric abundances of nearly all major ODSs that were initially controlled [under the Montreal Protocol] are declining [Figure 3.19]. Nevertheless, ozone depletion will continue for many more decades because several key ODSs last a long time in the atmosphere after emissions end.
\end{quote}

This has important implications for climate, since all ODSs (except methyl bromide) are powerful GHGs, and the gradual recovery of the ozone layer is expected to interact with climate change through a complex series of linkages. These relationships may, for example, reduce the capacity of the oceans to absorb carbon dioxide and delay the recovery of stratospheric ozone.\textsuperscript{105}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{montreal_protocol_effect.png}
\caption{Effect of the Montreal Protocol on levels of ozone depleting substances in the atmosphere}
\end{figure}

\textbf{Figure 3.19} Effect of the Montreal Protocol on levels of ozone depleting substances in the atmosphere

\begin{flushright}
\textsuperscript{CFC} = chlorofluorocarbon; \textsuperscript{HCFC} = hydrochlorofluorocarbon; \textsuperscript{ppb} = parts per billion
\end{flushright}

\textbf{Source}: Krummel & Fraser,\textsuperscript{104} updated by P Krummel, Centre for Australian Weather and Climate Research, and Commonwealth Scientific and Industrial Research Organisation, unpublished data
The ozone hole

The impact of ODSs on the stratospheric ozone layer has been observed at all latitudes, except in the tropics (i.e. 20°N and 20°S), where ozone depletion is negligible. However, by far the most pronounced ozone losses are associated with the Antarctic ozone hole, which occurs each year over Antarctica between August and December. The ozone hole reaches its maximum extent in spring, when 60% of the total ozone in the vertical air column is lost. The depleted ozone layer then breaks up and disperses over the areas surrounding Antarctica during the summer and autumn months (see also Chapter 7: Antarctic environment). The break-up of the ozone hole during summer is the cause of reductions in stratospheric ozone in the Southern Hemisphere, as parcels of ozone-depleted polar air move north and mix with mid-latitude air. There is also increased evidence that the Antarctic ozone hole affects the Southern Hemisphere’s climate, acting as the driver of changes in pressure, surface winds and rainfall at mid-to-high latitudes during summer.

Images available from Environment Canada illustrate the break-up of the ozone hole and the dispersal of the depleted ozone layer across Tasmania and southern Australia (Figure 3.20).

Following a period of rapid growth from the late 1970s to the mid-1990s, the area of the ozone hole has remained relatively stable over the past 15 or so years (Figure 3.21), with October mean column ozone levels within the polar stratospheric vortex approximately 40% of 1980 values. The ozone holes of 2000 and 2006 were the most severe on record; the 2006 hole was the deepest and the 2000 hole the largest (in area). However, the hole can fluctuate markedly from year to year, with 2010 being one of the smallest on record in the past two decades.

The relative stability of the ozone hole reflects the fact that there have been only moderate decreases in stratospheric chlorine and bromine in the past few years. Since around 1997, ODS levels have been nearly...
constant, and the depth and magnitude of the ozone hole have been controlled by variations in temperature and climate dynamics. Although summer ozone levels over Antarctica have yet to show any statistically significant increasing trend, recent simulations of the effect of reductions in ODSs that are projected to continue to flow from controls under the Montreal Protocol indicate a return to pre-1980 benchmark values late this century. Modelling results suggest that this recovery may be accelerated by climate change in the form of stratospheric cooling, linked to increases in GHGs.

Ozone hole impacts

As noted above, the most recent WMO Scientific assessment of ozone depletion comments on the importance of the ozone hole as a driver of changes in Southern Hemisphere seasonal surface winds at mid-to-high latitudes. However, the influence of the hole extends to the whole of the hemisphere. Modelling by Son et al., which incorporates stratospheric chemical interactions and takes into account the likely influence of recovering ozone levels, indicates that the anticipated recovery of the hole may result in a reversal of the current acceleration of these seasonal surface winds (summer tropospheric westerlies) on the poleward side. The authors concluded:

... our analyses suggest that stratospheric processes, and ozone recovery in particular, may be able to affect SH [Southern Hemisphere] climate in major ways and thus should be included in predictions of SH climate in the 21st century.

In addition to its influence on climate, the ozone hole has been of concern in relation to UVB effects on health. The progressively more rigorous controls established under the Montreal Protocol during the 1990s are expected to lead to the avoidance of a significant increase in cases of skin cancer that would otherwise have been associated with large reductions in global stratospheric ozone (Figure 3.22). This is of particular importance in Australia, where high levels of UVB radiation combine with outdoor lifestyles to produce one of the highest incidence rates of skin cancer in the world. 

Figure 3.22 Effect of the Montreal Protocol and its amendments on ozone depleting substances and excess skin cancer cases

The top panel gives a measure of the projected future abundance of ozone depleting substances in the stratosphere, without and with the Montreal Protocol and its various amendments. The bottom panel shows similar projections for how excess skin cancer cases might have increased.
Ultraviolet (UV) radiation levels at ground level are principally an inverse function of the amounts of ozone in the upper atmosphere, the concentration of aerosols and water vapour in the atmosphere, and the extent of cloud cover. Long-term trends in UV radiation levels are measured at Lauder in New Zealand’s South Island and are modelled at a number of sites in Australia. UV is expressed as an erythemal UV index—a measure that describes the strength of the skin-burning component of UV radiation.

Figure A shows total column ozone levels over Melbourne and erythemal index values for Lauder and three Australian capital cities. The top panel shows January mean total ozone values, measured by the Bureau of Meteorology’s Dobson network at locations around greater Melbourne from 1979 to 2011. The green line shows a five-year running mean. Although year-to-year variability is evident—as is a clear signal of the 11-year solar cycle (which peaked around 1980, 1991 and 2002)—the underlying negative trend in ozone ceased in the mid-1990s. The long-term ozone behaviour closely follows the concentration of ODSs measured in the global atmosphere, which peaked in the mid-1990s (see Figure 3.19).
The middle panel shows summer-time peak UV index values in 1990–2010, as measured by UV spectroradiometer at Lauder by New Zealand’s National Institute of Water and Atmospheric Research. Although UV radiation values are affected by factors other than just ozone, the underlying trend quite closely follows the expected inverse relation to the ozone timeseries, with highest UV index values in the late 1990s when ozone was lowest.

The bottom panel shows modelled clear-sky UV index values for three Australian cities (Sydney, Adelaide and Melbourne), illustrating the effect of location on the amount of UV radiation received. The values were calculated using summer satellite measurements of ozone and meteorological fields from the Bureau of Meteorology forecast model, as input to the UV radiation code.

Some differences in the detail of panels 1 and 3 are evident. However, the overall pattern of rising UV through the 1980s and 1990s, followed by a stabilisation, corresponds to the decline and subsequent stabilisation of ozone during the same period. The differences are primarily due to the use of satellite-measured ozone values rather than ground-based values, a slightly different averaging period (all of summer in panel 3 compared with just January in panel 1) and some missing periods of satellite data in the late 1990s, when ozone values were low.

From the early 1980s to the early 2000s, Australian skin cancer rates for both sexes showed a generally increasing trend, after which rates appear to have stabilised (Figure 3.23). Most recent data for melanoma show a decline in both male (7.1%) and female (10.7%) rates from 2005 to 2007. However, the period involved is too short to tell whether the reduction indicates a genuine decline or is the result of fluctuations in the data.

3.1.2 Ambient air quality

Ambient air quality and health

Although air pollution can harm vegetation, erode the facades of historic stone buildings and limit visibility, the main focus of public concern over air pollution is its short-term and long-term effects on human health. Over the past decade, scientific studies have greatly expanded our understanding of the nature and extent of the effects of major air pollutants in our cities (e.g. Environment Protection Authority Victoria, Environment Protection and Heritage Council, Simpson et al.). On the basis of these and related studies, it is clear that urban air pollution is a significant cause of death and illness in the community. By one estimate, there were close to 3000 deaths due to urban air pollution in 2003. This was 2.3% of all deaths and nearly twice the national road toll. Two-thirds of these deaths were attributable to long-term exposure to air pollutants, with the elderly most affected. The health burden associated with urban air pollution was shared about equally between males and females (53% to 47%). Such deaths occur from a range of medical causes (Figure 3.24).
As shown in Table 3.4, a range of adverse health effects is associated with air pollution. The nature and severity of the effect are a function of the type and concentration of pollutant, the duration of exposure and the sensitivity of the individual. Individual sensitivity is influenced by factors such as age, general state of health and fitness, and prior illnesses.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Health effects</th>
<th>Population at risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>Mortality and increased hospital admission due to heart disease</td>
<td>People with ischaemic heart conditions</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>Hospital admissions for respiratory diseases, decreases in lung function, cardiovascular disease</td>
<td>Sufferers of respiratory disease, such as children with asthma; those with cardiovascular disease</td>
</tr>
<tr>
<td>Particulates</td>
<td>Mortality due to cardiovascular and respiratory diseases; hospital admissions due to respiratory and cardiovascular disease; decreases in lung function</td>
<td>Elderly people with respiratory and cardiovascular diseases; people with respiratory diseases, such as children with asthma</td>
</tr>
<tr>
<td>Ozone</td>
<td>Mortality due to respiratory and cardiovascular diseases; hospital admissions due to respiratory disease; decreases in lung function</td>
<td>Elderly people; people with respiratory diseases</td>
</tr>
</tbody>
</table>

Source: Adapted from Environment Protection and Heritage Council\textsuperscript{127}
Box 3.6 Pollens—the forgotten air pollutants

Many types of flowering plant depend on the wind to distribute their pollen, and the small, light, dry pollen grains that these plants produce are easily breathed in by humans. When inhaled, proteins and glycoproteins associated with these pollens can interact with the immune systems of sensitive individuals to produce an allergic response in the form of hayfever or allergic asthma. Acting on its own or in combination with fine particles, airborne pollen is known to influence the incidence and severity of hayfever and asthma in a population. A number of studies have suggested that the impact of the PM\textsubscript{2.5} size fraction may be most pronounced in relation to cardiovascular illness and mortality, whereas the coarse (PM\textsubscript{10}) fraction may be more important in worsening asthma and upper respiratory illnesses. The health effects of short-term exposure to elevated levels of PM\textsubscript{2.5} is an important area for further research.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging period</th>
<th>Maximum concentration</th>
<th>Goal (within 10 years) for maximum allowable exceedences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon monoxide</td>
<td>8 hours</td>
<td>9.0 ppm</td>
<td>1 day per year</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>1 hour</td>
<td>0.12 ppm</td>
<td>1 day per year</td>
</tr>
<tr>
<td></td>
<td>1 year</td>
<td>0.03 ppm</td>
<td>None</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>1 hour</td>
<td>0.20 ppm</td>
<td>1 day per year</td>
</tr>
<tr>
<td></td>
<td>1 day</td>
<td>0.08 ppm</td>
<td>1 day per year</td>
</tr>
<tr>
<td></td>
<td>1 year</td>
<td>0.02 ppm</td>
<td>None</td>
</tr>
<tr>
<td>Photochemical oxidants (as ozone)</td>
<td>1 hour</td>
<td>0.10 ppm</td>
<td>1 day per year</td>
</tr>
<tr>
<td></td>
<td>4 hours</td>
<td>0.08 ppm</td>
<td>1 day per year</td>
</tr>
<tr>
<td>Lead</td>
<td>1 year</td>
<td>0.50 µg/m\textsuperscript{3}</td>
<td>None</td>
</tr>
<tr>
<td>Particles (PM\textsubscript{10})</td>
<td>1 day</td>
<td>50 µg/m\textsuperscript{3}</td>
<td>5 days per year</td>
</tr>
</tbody>
</table>

PM\textsubscript{10} = particulate matter smaller than 10 micrometres; ppm = parts per million; µg/m\textsuperscript{3} = micrograms per cubic metre

Source: Office of Legislative Drafting

In 2003, the standards were amended to include advisory reporting standards for fine particulate matter smaller than 2.5 micrometres (PM\textsubscript{2.5}), reflecting growing concern over links between increases in PM\textsubscript{2.5} levels and mortality and morbidity associated with respiratory and cardiovascular disease (Table 3.6). A number of studies have suggested that the impact of the PM\textsubscript{2.5} size fraction may be most pronounced in relation to cardiovascular illness and mortality, whereas the coarse (PM\textsubscript{10}) fraction may be more important in worsening asthma and upper respiratory illnesses. The health effects of short-term exposure to elevated levels of PM\textsubscript{2.5} is an important area for further research.

Silver wattle (Acacia dealbata) flowers loaded with pollen, Victoria

Photo by Philippe Giraud
The standards are measured at locations that are generally representative of the level of exposure of the broad population, rather than at ‘hot spots’ (such as near major point sources or roads). Authorities have agreed on standardised monitoring methods, to ensure national comparability of results.136

The standards are set at levels intended to protect human health. They reflect the evidence available in the mid-to-late 1990s on links between the various pollutants and human health. The AAQ NEPM is currently being reviewed in light of new evidence on health effects and international trends in air quality standards. Analysis of such evidence confirms that a number of the criteria pollutants (e.g. ozone and particles) do not have a threshold level below which there is no health effect. This means that sensitive individuals, such as asthmatics and people with respiratory or cardiovascular disease, may be affected even when air quality standards are met.6

As well as setting standards for the criteria pollutants, the AAQ NEPM established goals, expressed in terms of ‘maximum allowable exceedences’, to be achieved within 10 years (i.e. by 2008). These goals reflected a broadly based consensus on the extent of improvements in air quality that would be practicable over the period.

Table 3.6 Advisory reporting standards and goal for PM$_{2.5}$ particles

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging period</th>
<th>Maximum concentration (µg/m$^3$)</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles (PM$_{2.5}$)</td>
<td>1 day</td>
<td>25</td>
<td>To gather sufficient national data to facilitate a review of the advisory reporting standards</td>
</tr>
<tr>
<td></td>
<td>1 year</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

PM$_{2.5}$ = particulate matter smaller than 2.5 micrometres; µg/m$^3$ = microgram per cubic metre

Source: Office of Legislative Drafting134

Box 3.7 The air quality index

In a number of states, the agency responsible for monitoring air quality reports results at each station in its network in terms of an air quality index (AQI) for all or a subset of the pollutants covered by the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM), apart from PM$_{2.5}$, which is not regularly reported. Often, the highest AQI is reported for each location. The AQI relates the observed level of a pollutant to the AAQ NEPM standard, expressed as a percentage. A given index level reflects the residual risks to public health.

$$\text{Index} = \frac{\text{Pollutant concentration}}{\text{Pollutant standard level}} \times 100$$

Five qualitative categories are used in public reporting of air quality. The categories and the AQI ranges that they represent are listed in Table A, together with a qualitative description of the associated health effects.

Table A Air quality index

<table>
<thead>
<tr>
<th>Category</th>
<th>Index</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very poor</td>
<td>150+</td>
<td>Air quality is unhealthy, and everyone may begin to experience health effects. People in sensitive groups may experience more serious health effects.</td>
</tr>
<tr>
<td>Poor</td>
<td>100–149</td>
<td>Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range.</td>
</tr>
<tr>
<td>Fair</td>
<td>67–99</td>
<td>Air quality is acceptable. However, there may be a health concern for very sensitive people.</td>
</tr>
<tr>
<td>Good</td>
<td>66–34</td>
<td>Air quality is considered good, and air pollution poses little or no risk.</td>
</tr>
<tr>
<td>Very good</td>
<td>0–33</td>
<td>Air quality is considered very good, and air pollution poses little or no risk.</td>
</tr>
</tbody>
</table>

Each category in the AQI corresponds to a different level of air quality and associated health risk.

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities6
Pollutant sources

Most pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide and PM2.5 particles) result from combustion (primary pollutants) (Table 3.7). Major sources include motor vehicles, industrial processes and domestic heating. Coarse particles (the PM10 fraction)—which include mineral dust, salt and soot—are also a form of primary pollutant, originating from both natural and human sources. Secondary pollutants (such as ozone) result from the action of complex photochemical processes on primary pollutants (oxides of nitrogen and volatile organic compounds), predominantly in the warmer months, forming photochemical smog.

Table 3.7 Major sources of criteria pollutants and fine particles (PM2.5)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Major sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary pollutants</strong></td>
<td></td>
</tr>
<tr>
<td>Nitrogen dioxide (NO2),</td>
<td>Combination of nitrogen and oxygen during high-temperature combustion of fossil fuels around 80% of urban NO2 is from motor vehicle exhaust. Other sources are petrol and metal refining, electricity generation from coal-fired power stations, other manufacturing industries and food processing.</td>
</tr>
<tr>
<td>together with nitric oxide (NO)</td>
<td></td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Combustion, including vegetation burning and wildfires, motor vehicles and metal manufacturing.</td>
</tr>
<tr>
<td>Lead</td>
<td>Road dust, metal manufacturing and metal ore mining.</td>
</tr>
<tr>
<td>PM10</td>
<td>In nonurban areas: vegetation burning, wildfires, soot, windblown dust from agriculture and other land uses, road dust. In urban areas: predominantly motor vehicles and secondary particles. Other sources are solid (domestic) fuel burning in winter and mining.</td>
</tr>
<tr>
<td>PM2.5</td>
<td>Combustion sources, secondary nitrates and sulfates, secondary organic aerosol and natural-origin dust.</td>
</tr>
<tr>
<td><strong>Secondary pollutants</strong></td>
<td></td>
</tr>
<tr>
<td>Ozone</td>
<td>Atmospheric photochemical reactions of primary pollutants, NO, and hydrocarbons (volatile organic carbons) from motor vehicles and industry. Naturally occurring ozone.</td>
</tr>
</tbody>
</table>

PM2.5/10 = particulate matter smaller than 2.5 or 10 micrometres

Sources: Australian Government Department of Sustainability, Environment, Water, Population and Communities; Environment Protection and Heritage Council; Goldstein & Galbally; Oltmans et al.
Although standards and monitoring strategies necessarily focus on individual pollutants, it is becoming increasingly clear that many of the health effects of air pollution are not due to single pollutants acting in isolation. This is hardly surprising, given that most major sources of urban air pollution (such as motor vehicle exhausts and domestic combustion heaters) emit a complex mix of gaseous and solid pollutants, some of which act as the building blocks for secondary pollutants such as ozone and some forms of fine particulate pollution.

**Ambient air quality trends**

Air quality in Australia’s urban centres is generally good, with levels of all the criteria pollutants usually falling well below the national standards. The latest national state of the air report showed that the levels of these pollutants (other than ozone and particles) declined or remained stable from 1999 to 2008. In some cities, peak ozone levels occasionally approached or exceeded the NEPM standard, whereas peak particle levels in nearly all regions exceeded the standard on a number of days. If, as seems likely, the yet-to-be-released review of the AAQ NEPM leads to a tightening of the current four-hour ozone standard (readings averaged over four hours) and to the establishment of an eight-hour standard (readings averaged over eight hours), the frequency of ozone exceedences is likely to increase significantly, particularly in Sydney.

Urban air quality varies both with short-term meteorological conditions—such as temperature inversions, which can trap pollutants near ground level—and seasonally, with summer temperatures promoting the formation of ozone and other photochemical pollutants. Extreme weather events are often associated with ‘peak’ pollution levels in Australian cities, where peak refers to the top 5% of measurements—which is distinct from the maximum (or highest) measurement. In addition, the frequency and severity of pollution events are strongly influenced in centres such as Sydney and Melbourne (Box 3.8) by the regional topography and the presence of the sea, which affect the circulation of air in those airsheds, recirculating polluted air and promoting the formation of photochemical smog. (An airshed is a body of air, bounded by meteorology and topography, in which substance emissions are contained. For example, the Bunbury Regional Airshed study area in Western Australia covers an area of 165 kilometres [east to west] by 234 kilometres [north to south] and contains a population of 270 000 people.)

**Box 3.8 The Melbourne eddy recorded by a weather satellite in February 1985 (the eddy is made visible by low cloud)**

Under a special set of meteorological conditions, air flowing from the north-east is funnelled by mountains to the north and east of Port Phillip Bay, creating a circular (clockwise), horizontal motion of air (about 100 kilometres in diameter). The eddy pushes air pollution out over the bay, initially taking it away from Melbourne before returning it in reacted form as photochemical smog.

Source: Satellite image originally processed by the Bureau of Meteorology from the polar-orbiting satellite NOAA-6, operated by the National Oceanographic and Atmospheric Administration (NOAA)
Ozone

The state of the air report shows ozone levels in the Sydney and the Illawarra regions to have been generally higher than in other Australian metropolitan and industrial regions, exceeding the one-hour and four-hour ozone standards in most years from 1999 to 2008. Expressed in terms of the air quality index (AQI), Sydney’s annual maximum four-hour ozone levels were generally classed as poor, whereas the 95th percentile levels were in the fair range. By comparison, annual maximum ozone levels in Melbourne, Brisbane, Perth, Adelaide and Canberra occasionally exceeded the standards, but generally rated as fair. Among these five cities, Melbourne’s annual peak ozone levels were the highest, exceeding the four-hour standard in some years, with a consequent AQI rating of poor (Figure 3.25). Median (50th percentile) levels in all regions were around 40% of the four-hour standard (in AQI terms, rating as good). Overall, across the 44 NEPM monitoring sites, the report discerned no trends in ozone levels.6

Particles (PM₁₀)

Peak PM₁₀ levels in both urban and nonurban areas tend to be seasonal. In summer, wildfires and dust storms associated with occasional extreme weather can lead to very high levels of particle pollution. In areas with a high dependence on solid fuel burning for domestic heating, the seasonal peak in particle levels usually occurs in winter. This is particularly the case in centres such as Launceston, where local topography can lead to a layer of cold polluted air being trapped near the ground by an overlying layer of warmer air (a situation referred to as a temperature inversion). In autumn, when most forest fuel-reduction burns occur, some areas, including metropolitan centres, can experience significant particulate pollution.

From 1999 to 2008, maximum PM₁₀ levels in Australian capitals and in some regional centres often exceeded the AAQ NEPM 24-hour standard, with levels up to 4 times the standard in the capitals and up to 14 times in some regional centres. However, annual state and territory reports on NEPM implementation reveal that in the capital cities such exceedences were generally limited in number and mainly related to extreme events, on which government air quality improvement programs have very limited effect.

In all capitals (other than Canberra and Hobart), 95th percentile PM₁₀ levels met the 24-hour standard (with levels falling in the fair or good AQI categories). In both Canberra and Hobart, the 95th percentile values exceeded the standard on one or two occasions early in the decade, subsequently declining and stabilising at levels comparable with the other capitals (Figure 3.26). These declines (along with a similar reduction in Launceston) largely reflect the success of programs to reduce wood smoke from domestic heaters. Setting aside these reductions, no trend is clear in the data for the other major cities.6

![Figure 3.25](image-url) For four major cities, the (a) average maximum four-hour average ozone concentrations and (b) average 95th percentile four-hour average ozone concentrations, 1999–2008.

µg/m³ = microgram per cubic metre; NEPM = National Environment Protection Measure; ppm = parts per million
Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities6
As the state of the air report notes, particle levels tend to be slightly higher in regional cities in southeastern Australia than in the capital cities. The most likely explanation is their greater seasonal exposure to the effects of bushfires, dust storms, planned burning and the use of wood for domestic heating.\(^5\)

\(\mu g/m^3 = \text{microgram per cubic metre; NEPM = National Environment Protection Measure; } PM_{10} = \text{particulate matter smaller than } 10 \text{ micrometres} \)

\(^5\) Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities\(^6\)

**Figure 3.26** Average 95th percentile 24-hour average \(PM_{10}\) concentrations in (a) Melbourne, Sydney, Brisbane and Perth, and (b) Adelaide, Hobart, Darwin and Canberra, 1999–2008

\(^5\) Early morning smog over Sydney, New South Wales

Photo by Barnaby Chambers
**Fine particles (PM$_{2.5}$)**

Fine particle levels are monitored at 18 sites around Australia, with Perth having the longest record, starting in 1994 (Figure 3.27). In 2008, the 24-hour advisory reporting standard (25 micrograms per cubic metre) was met at six sites (four in New South Wales, one in Queensland and one in South Australia). Peak levels are highly variable, being strongly influenced by extreme events such as bushfires and dust storms. This, together with a relatively short monitoring record at most sites, makes the identification of long-term trends problematic.6

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**Carbon monoxide**

National Pollutant Inventory data show that, apart from vegetation burning and wildfires, motor vehicles are the main source of carbon monoxide. Over the past two decades, levels of carbon monoxide have declined significantly. This has been part of a broader improvement in air quality associated with strengthened vehicle standards that required the exhaust systems of new vehicles to be fitted with catalytic converters, and legislation requiring the phase-in of unleaded fuel. Current peak carbon monoxide levels fall into the very good AQI category in all regions and are less than one-third to one-fifth of the national standard.6,140

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*Figure 3.27 Capital cities’ highest daily average PM$_{2.5}$ concentrations*
Nitrogen dioxide

Levels of nitrogen dioxide (both maximum and 95th percentile) are generally well below both the one-hour average and the annual average AAQ NEPM standards, rating good to very good (maximum) and very good (95th percentile) in terms of the AQI. Long-term records show a significant decline in maximum nitrogen dioxide levels, most notably in the 1990s. As is the case for carbon monoxide, the decrease was mainly driven by the introduction of tighter vehicle emission standards. During the past decade, although there has been a continued decline in nitrogen dioxide in some areas, levels have generally remained stable, despite an increase in vehicle numbers and distances travelled.6,141

Sulfur dioxide

Sulfur dioxide levels remain low in the capitals and most other urban areas. Between 1995 and 2000, there was an overall reduction in Australian sulfur dioxide emissions of almost one-third, due mainly to recovery of sulfur dioxide to produce sulfuric acid. However, over the past decade, levels across Australian cities have been relatively stable, despite the progressive tightening of standards for sulfur dioxide in fuel.6,142 Mount Isa and Port Pirie, with their large ore smelting operations, typically experience more than 20 exceedences of the one-hour sulfur dioxide NEPM standard, with Mount Isa recording more than three times and Port Pirie more than twice the standard—that is, in the very poor AQI category.6,107

Lead

Since the start of the national phase-out of leaded petrol in 1993, atmospheric lead levels in Australian cities have fallen markedly and are now below 10% of the national standard. The few exceptions are regional towns (such as Port Pirie) with large industrial point sources (Figure 3.28). This improvement is particularly welcome because lead (a persistent neurotoxin) is known to have adverse effects on children’s development of memory and motor abilities, even at low levels.143

Volatile organic compounds

Volatile organic compounds (VOCs) are primary pollutants that react with nitrogen oxides in complex photochemical processes to generate a range of secondary pollutants (notably ozone). Biogenic sources (vegetation and soil) form about three-quarters of the total VOC emissions from natural and human sources.144 Although emissions from biogenic sources are not hazardous themselves, they add to the background level of VOCs and thus can contribute to the formation of ozone. Figure 3.29 shows the main sources of VOCs other than vegetation and soil.

**Figure 3.28** Lead levels at two locations in Port Pirie, South Australia

| Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities |

| Source: National Pollutant Inventory |

**Figure 3.29** Total volatile organic compounds by source, excluding biogenics, 2009–10
Air toxics

Air toxics (also called hazardous air pollutants) are a broad group of pollutants found in ambient air, usually at relatively low levels. These hazardous air pollutants include known or suspected carcinogens and pollutants linked to other serious health impacts, including birth defects and developmental, respiratory and immune system problems. They include heavy metals and many types of volatile and semivolatile organic compounds. Some of these compounds (such as dioxins and furans) are highly persistent, tend to accumulate through food chains (bioaccumulation) and can be transported long distances through the atmosphere. These persistent organic pollutants are a focus of significant international concern and are controlled under the United Nations Stockholm Convention on Persistent Organic Pollutants, to which Australia is a signatory.

Air toxics are formed as products of combustion (motor vehicles are a significant source), as volatile emissions from paints and adhesives, and from various industrial processes.

In 2004, the National Environment Protection Council agreed on an additional air quality NEPM to address air toxics. This measure deals with five priority air toxics: benzene, toluene, xylene (collectively referred to as BTX), formaldehyde and benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons).

The NEPM adopts a nationally consistent approach to monitoring this initial group of air toxics at sites likely to experience elevated levels (such as near major roads and industrial areas) and establishes a series of benchmarks (‘monitoring investigation levels’ [MILs]) that, if exceeded, require further investigation and evaluation (see Table 3.8). A key aim of the NEPM is to develop a robust set of data on ambient levels of these priority air toxics to enable future ministerial councils to set national air quality standards that will protect human health.

A mid-term review of the air toxics NEPM summarised the results of five years’ monitoring. Benzene levels at nearly all sites were at or below the MIL. However, some sites near heavily trafficked roads and one in a mixed industrial area (where non-NEPM monitoring methods were used) recorded levels close to or above the MIL. A clear time trend could not be discerned. Toluene and xylene levels were (with a small number of exceptions) well below the MILs, with some signs of a reducing trend for toluene. Most formaldehyde measurements were significantly below the MIL, although the review notes that the dataset is much more limited than for BTX. Due to the limited amount of monitoring, results for benzo(a)pyrene were inconclusive. Overall, the review noted the limited extent of data collection at most sites, expressed caution in relation to interpreting the limited results, and argued for additional monitoring.

### Table 3.8 Monitoring investigation levels for air toxics

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Averaging period</th>
<th>Monitoring investigation level</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>Annual average</td>
<td>0.003 ppm</td>
<td>8-year goal is to gather sufficient national data to facilitate development of a standard</td>
</tr>
<tr>
<td>Benzo(a)pyrene (as a marker for polycyclic aromatic hydrocarbons)</td>
<td>Annual average</td>
<td>0.3 ng/m³</td>
<td>8-year goal is to gather sufficient national data to facilitate development of a standard</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>24 hours</td>
<td>0.04 ppm</td>
<td>8-year goal is to gather sufficient national data to facilitate development of a standard</td>
</tr>
<tr>
<td>Toluene</td>
<td>24 hours</td>
<td>1 ppm</td>
<td>8-year goal is to gather sufficient national data to facilitate development of a standard</td>
</tr>
<tr>
<td></td>
<td>Annual average</td>
<td>0.1 ppm</td>
<td>8-year goal is to gather sufficient national data to facilitate development of a standard</td>
</tr>
<tr>
<td>Xylenes (as total of ortho-, meta- and para-isomers)</td>
<td>24 hours</td>
<td>0.25 ppm</td>
<td>8-year goal is to gather sufficient national data to facilitate development of a standard</td>
</tr>
<tr>
<td></td>
<td>Annual average</td>
<td>0.2 ppm</td>
<td>8-year goal is to gather sufficient national data to facilitate development of a standard</td>
</tr>
</tbody>
</table>

ng/m³ = nanograms per cubic metre; ppm = parts per million

a For the purposes of this measure, the annual average concentrations in column 3 are the arithmetic mean concentrations of 24-hour monitoring results.

b For the purposes of this measure, monitoring over a 24-hour period is to be conducted from midnight to midnight.

Source: Adapted from Office of Legislative Drafting
Assessing the condition of ambient air

The qualitative assessment summaries 3.4–3.7 (below), based on the method outlined in Box 3.9, are generalised across periods of up to 11 years. The fact that these assessments indicate that overall air quality is good or very good should not be allowed to obscure the fact that, on a number of days each year, all of these cities experience air quality that does not meet the national health-based standards (i.e. air quality is in the poor or very poor categories). As a result, air pollution in our capitals and major regional centres remains a significant cause of death and illness in the community, particularly affecting the health of sensitive individuals and groups.

Box 3.9 Applying a graded report-card approach to Australia’s urban air quality

As part of the State of the Environment reporting process, a qualitative assessment was made of ambient air quality in the eight state and territory capitals and a small number of major regional or industrial centres. Of the seven pollutants for which national health-based standards have been set, photochemical oxidants (as ozone) and particulate matter smaller than 10 micrometres (as PM$_{10}$) were chosen as key pollutants potentially impacting on human health, reflecting the weight of scientific evidence.

The approach based the characterisation of an airshed from 1999 to 2009 on its worst performing monitoring station, rather than on the total number of exceedences across the airshed, since this is strongly influenced by the number of monitoring stations. Only data from monitoring stations established in accordance with an approved National Environment Protection Measure (NEPM) monitoring plan were considered. (In some cases, less than 10 years of NEPM monitoring data were available, and in one case—Perth—11 years of data were available.) Most large regional cities have only one NEPM monitoring station, and most monitor particles, but not ozone, since they lack the scale of industry and traffic likely to give rise to ozone as a secondary pollutant. In each state, the regional cities selected for analysis of PM$_{10}$ and ozone (where this was monitored) were the worst performing in the state.

It is recognised that the 10-year goals set in the Ambient Air Quality NEPM for ozone and particles allow for one exceedence per year for ozone and five exceedences per year for particles. Nevertheless, given the nature of the health-based standards, any exceedence may have a potentially adverse impact and should therefore be taken into consideration, even if the goal is met.

Ozone levels were evaluated against the four-hour exposure standard rather than the one-hour, as the four-hour standard is more likely to give a better indication of the impact on the general population, rather than on sensitive individuals who are likely to be affected by acute (i.e. shorter term) events.

Procedure

For each year, monitoring data for ozone and PM$_{10}$ from each of the selected stations were converted into air quality index (AQI) values. These were used as the basis for calculating the percentage of observations that fell in each of the five AQI-based qualitative categories (very good, good, fair, poor and very poor) commonly used by Australian environment protection agencies to report air quality.

Each of these yearly percentage distributions for each pollutant at each station was then assessed against the criteria set out in Table A, to assign a general AQI score to each pollutant. The results across the period were represented graphically to assist in identifying any trends. It must be emphasised that the criteria set out in Table A are essentially subjective in nature. In almost all cases, their application resulted in the most frequently occurring AQI category being selected to generalise the year as a whole. In a small number of years, the AQI distribution was bimodal, with the result being borderline between the very good and good categories.

Overall qualitative AQI scores for ozone and PM$_{10}$ were then assigned to each city, based on the most frequently occurring scores during the decade. A summary of the results is presented in assessment summaries 3.4 to 3.7, and the complete set of graphs is available on the State of the Environment website.
Table A  Criteria for assigning annual AQI-based qualitative scores

<table>
<thead>
<tr>
<th>Overall category</th>
<th>Very good (%)</th>
<th>Good (%)</th>
<th>Fair (%)</th>
<th>Poor (%)</th>
<th>Very poor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>&gt;50</td>
<td>&gt;20</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Good</td>
<td>&gt;20</td>
<td>&gt;30</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Fair</td>
<td>&lt;10</td>
<td>&lt;20</td>
<td>&gt;30</td>
<td>&gt;20</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Poor</td>
<td>&lt;10</td>
<td>&lt;20</td>
<td>&lt;20</td>
<td>&gt;30</td>
<td>&gt;20</td>
</tr>
<tr>
<td>Very poor</td>
<td>&lt;5</td>
<td>&lt;10</td>
<td>&lt;10</td>
<td>&gt;20</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>

**Supplementary rules**

If the percentage very good is greater than 45 and is also greater than the percentage good, the assessment grade is very good.

If the percentage good is greater than 75, then the percentage very good can be as low as zero and assessment grade is good.

a  www.environment.gov.au/soe
3.4 Assessment summary

Metropolitan cities’ score card for ozone (four-hour) NEPM standard, based on analysis of air quality index values, 1999–2008

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>In grade</td>
<td>In trend</td>
</tr>
</tbody>
</table>

**Adelaide**
- Average percentage frequency distribution:
  - very good 46; good 53; fair 1; poor 0; very poor 0
- In grade:  —
- In trend:  —
- Confidence:  —

**Brisbane**
- Average percentage frequency distribution:
  - very good 31; good 64; fair 55; poor 0; very poor 0
- In grade:  —
- In trend:  —
- Confidence:  —

**Canberra**
- Average percentage frequency distribution:
  - very good 43; good 55; fair 2; poor 0; very poor 0
- In grade:  ←
- In trend:  —
- Confidence:  —

**Melbourne**
- Average percentage frequency distribution:
  - very good 34; good 63; fair 3; poor 0; very poor 0
- In grade:  —
- In trend:  —
- Confidence:  —

**Perth**
- Average percentage frequency distribution:
  - very good 16; good 79; fair 4; poor 0; very poor 0
- In grade:  —
- In trend:  —
- Confidence:  —

**Sydney**
- Average percentage frequency distribution:
  - very good 17; good 72; fair 9; poor 2; very poor 0
- In grade:  —
- In trend:  —
- Confidence:  —

**Recent trends**
- Improving  
- Deteriorating  
- Stable  
- Unclear

**Confidence**
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Grades**
- Very good: Air quality is considered very good, and air pollution poses little or no risk
- Good: Air quality is considered good, and air pollution poses little or no risk
- Fair: Air quality is acceptable. However, there may be a health concerns for very sensitive people
- Poor: Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range
- Very poor: Air quality is unhealthy, and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects

**NEPM = National Environment Protection Measure**

Note: Melbourne assessment based on 2002–08; ozone is not regularly monitored in Darwin or Hobart.
### 3.5 Assessment summary

**Metropolitan cities’ score card for particles (PM$_{10}$) NEPM 24-hour standard, based on analysis of air quality index values, 1999–2008**

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adelaide</td>
<td>Average percentage frequency distribution: very good 42; good 51; fair 5; poor 1; very poor 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brisbane</td>
<td>Average percentage frequency distribution: very good 63; good 34; fair 3; poor 0; very poor 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canberra</td>
<td>Average percentage frequency distribution: very good 55; good 26; fair 11; poor 6; very poor 2 (Note: borderline very good – good)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Darwin</td>
<td>Average percentage frequency distribution: very good 56; good 42; fair 2; poor 0; very poor 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hobart</td>
<td>Average percentage frequency distribution: very good 73; good 26; fair 1; poor 0; very poor 0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melbourne</td>
<td>Average percentage frequency distribution: very good 36; good 50; fair 11; poor 2; very poor 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perth</td>
<td>Average percentage frequency distribution: very good 49; good 47; fair 3; poor 0; very poor 0 (Note: borderline very good – good)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Metropolitan cities’ score card for particles (PM$_{10}$) NEPM 24-hour standard, based on analysis of air quality index values, 1999–2008

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>Average percentage frequency distribution: very good 50; good 45; fair 4; poor 1; very poor 0 (Note: borderline very good – good)</td>
</tr>
</tbody>
</table>

- **Assessment grade**
  - Very poor
  - Poor
  - Fair
  - Good
  - Very good

- **Confidence**
  - Adequate high-quality evidence and high level of consensus
  - Limited evidence or limited consensus
  - Evidence and consensus too low to make an assessment

<table>
<thead>
<tr>
<th>Recent trends</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td>Stable</td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td>Deteriorating</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grades</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>Air quality is considered very good, and air pollution poses little or no risk</td>
</tr>
<tr>
<td>Good</td>
<td>Air quality is considered good, and air pollution poses little or no risk</td>
</tr>
<tr>
<td>Fair</td>
<td>Air quality is acceptable. However, there may be a health concerns for very sensitive people</td>
</tr>
<tr>
<td>Poor</td>
<td>Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range</td>
</tr>
<tr>
<td>Very poor</td>
<td>Air quality is unhealthy, and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects</td>
</tr>
</tbody>
</table>

**NEPM = National Environment Protection Measure; PM$_{10}$ = particulate matter smaller than 10 micrometres**

**Note:** Hobart assessment based on 2006–08; Melbourne assessment based on 2002–08; Perth assessment based on 2000–08
### Assessment summary

#### Regional cities’ score card for ozone (four-hour) NEPM standard, based on analysis of air quality index values, 1999–2008

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>New South Wales—Kembla Grange</strong></td>
<td>Average percentage frequency distribution: very good 35; good 62; fair 2; poor 1; very poor 0</td>
<td>Good</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Victoria—Moe</strong></td>
<td>Average percentage frequency distribution: very good 68; good 31; fair 1; poor 0; very poor 0</td>
<td>Poor</td>
<td>Limited evidence or limited consensus</td>
</tr>
</tbody>
</table>

**Recent trends**
- Improving
- Stable
- Deteriorating
- Unclear

**Grades**
- **Very good**: Air quality is considered very good, and air pollution poses little or no risk
- **Good**: Air quality is considered good, and air pollution poses little or no risk
- **Fair**: Air quality is acceptable. However, there may be a health concern for very sensitive people
- **Poor**: Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range
- **Very poor**: Air quality is unhealthy, and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects

NEPM = National Environment Protection Measure

Note: Ozone is regularly monitored in regional cities only in New South Wales, Queensland and Victoria. Of these states, only New South Wales and Victoria monitor ozone using both the NEPM one-hour and four-hour averaging periods. In Queensland, ozone is monitored at sites in Toowoomba and Townsville, but only using the one-hour averaging period. For this reason, only regional cities in New South Wales and Victoria were included in this assessment summary.
## 3.7 Assessment summary

Regional cities’ score card for particles (PM$_{10}$) NEPM 24-hour standard, based on analysis of air quality index values, 1999–2008

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>New South Wales—Wagga Wagga</td>
<td>Average percentage frequency distribution: very good 34; good 45; fair 13; poor 6; very poor 2</td>
<td>Very poor</td>
<td>In grade</td>
</tr>
<tr>
<td></td>
<td>(Note: Although the overall assessment is good, the distribution has a significant ‘tail’ of 29 days on which the national standard was exceeded)</td>
<td></td>
<td>In trend</td>
</tr>
<tr>
<td>Queensland—West Mackay</td>
<td>Average percentage frequency distribution: very good 30; good 61; fair 1; poor 0; very poor 2</td>
<td>Very good</td>
<td>In grade</td>
</tr>
<tr>
<td>South Australia—Port Pirie</td>
<td>Average percentage frequency distribution: very good 55; good 34; fair 8; poor 2; very poor 1</td>
<td>Poor</td>
<td>In trend</td>
</tr>
<tr>
<td>Tasmania—Launceston Ti Tree Bend</td>
<td>Average percentage frequency distribution: very good 65; good 30; fair 3; poor 2; very poor 1</td>
<td>Good</td>
<td>In trend</td>
</tr>
<tr>
<td>Victoria—Geelong South</td>
<td>Average percentage frequency distribution: very good 39; good 49; fair 9; poor 2; very poor 1</td>
<td>Good</td>
<td>In trend</td>
</tr>
</tbody>
</table>
### Component Summary

<table>
<thead>
<tr>
<th>Western Australia—Bunbury</th>
</tr>
</thead>
</table>

**Summary:** Average percentage frequency distribution:
- Very good: 46
- Good: 52
- Fair: 2
- Poor: 0
- Very poor: 0

**Assessment grade:**

<table>
<thead>
<tr>
<th>Very poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Very good</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Confidence:**

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Recent trends:**

- Improving
- Stable
- Deteriorating
- Unclear

**Grades:**

- Very good: Air quality is considered very good, and air pollution poses little or no risk
- Good: Air quality is considered good, and air pollution poses little or no risk
- Fair: Air quality is acceptable. However, there may be a health concern for very sensitive people
- Poor: Air quality is unhealthy for sensitive groups. The general population is not likely to be affected in this range
- Very poor: Air quality is unhealthy, and everyone may begin to experience health effects. People from sensitive groups may experience more serious health effects

**Notes:**

- NEPM = National Environment Protection Measure; PM$_{10}$ = particulate matter smaller than 10 micrometres
- Wagga Wagga assessment based on 2001–08; West Mackay based on 2000–08; Port Pirie based on 2003–10; Geelong South and Bunbury based on 1999–2008; Launceston based on 2006–08
3.1.3 Indoor air quality

Like citizens of other highly urbanised societies, most Australians spend more than 90% of their time indoors, leading to concern about the possible impacts of indoor air quality on our health. Such concern is heightened in situations where indoor pollutant concentrations equal or exceed outdoor levels and indoor exposure becomes the dominant form of exposure.\(^{150}\)

Symptoms associated with poor indoor air quality can range from acute to chronic, and from mild and generally nonspecific (eye, nose and throat irritation, and headaches and dizziness) to severe (asthma, allergic responses and cancer risk).\(^{95,151-152}\) Despite the potentially significant health effects of indoor air, data on indoor air quality in Australia are limited, providing no firm basis upon which to form assessments of overall status and trend.

Until recently, there has been no comprehensive study of indoor air quality in typical Australian dwellings; previous studies tended to focus on situations with particular air quality issues, such as emissions from unfuelled gas heaters and gas cooking appliances. The release in 2010 of a two-part report by CSIRO and the Bureau of Meteorology of 40 typical homes in Melbourne has filled that gap, at least for temperate urban areas.\(^{153}\) The study found concentrations of indoor air pollutants to be either lower than or comparable with concentrations found in previous Australian studies. The study showed weekly average concentrations of carbon dioxide, carbon monoxide, nitrogen dioxide, formaldehyde, other carbonyls, BTEX (benzene, toluene, ethylbenzene and xylene) and total VOCs to be higher indoors than outdoors, whereas PM\(_{10}\), ozone and fungi concentrations were higher outdoors. Across the 40 dwellings, the ambient 24-hour NEPM advisory reporting standard for PM\(_{2.5}\) was equalled or exceeded on 3% of days. In dwellings that relied on gas appliances for cooking, levels of carbon dioxide, carbon monoxide, nitrogen dioxide, PM\(_{2.5}\), formaldehyde, benzene and total VOCs were significantly higher than in households that solely used electric cooking appliances. The effect of proximity to major roads on indoor air quality was limited to an increase in nitrogen dioxide levels (accounting for around 20% of indoor nitrogen dioxide in these situations).\(^{153}\) Unfortunately, although the study has significantly expanded our knowledge of indoor air quality in Australian homes, as the authors note in a separately published overview of the study, ‘the absence of specific guidelines for indoor air quality in Australia prevents an objective assessment of the quality of observed indoor air’.\(^{154}\)
3.2 Pressures affecting Australia’s atmosphere

At a glance

Nitrous oxide, an ozone depleting substance and a greenhouse gas (GHG), is produced by a variety of natural and human-related sources (notably agricultural processes). Although its ozone depleting potential is low relative to chlorofluorocarbon-11 (CFC-11), human emissions are at such a large scale that it is recognised as currently the single most important form of ozone depleting emission, and can be expected to remain so throughout this century. Other GHGs not controlled under the Montreal Protocol, notably carbon dioxide and methane, are expected to significantly affect future stratospheric ozone levels. However, unlike nitrous oxide, the net effect of carbon dioxide and methane is expected to be positive for ozone recovery.

The air quality in Australia’s major cities is no longer principally influenced by emissions from industrial point sources. With the exception of a few centres dominated by one or two very large industrial facilities (such as Mount Isa and Port Pirie), widely spread, diffuse emissions now constitute the major source of pollutants in urban areas. Among these, motor vehicles are the single most important source, contributing a range of pollutants: carbon monoxide, particles, various toxic volatile organic compounds (VOCs) and nitrogen oxides (which, together with VOCs, act as precursors to the formation of ozone). In addition, diesel vehicles are an important source of particles. Commercial premises are another important diffuse source of pollutants (notably VOCs and particles) that affect air quality at an airshed scale as well as impacting on amenity at a neighbourhood level, generating complaints about odour, noise and smoke. Similarly, in many urban centres where wood heaters are widely used for home heating, domestic premises are an important diffuse source of particulate pollution during the colder months. A final broad source of diffuse pollution (with origins outside urban areas) is planned burning for purposes such as agriculture, forestry operations and land management. If not well planned, timed and executed, such burns can trigger health problems and loss of amenity in surrounding rural areas and urban centres.

Climate change is likely to also affect air quality. Rising temperature, which is expected to be a main feature of climate change in Australia, is likely to lead to the formation of more ozone by increasing the generation of both natural and human-generated VOCs. Hotter, drier conditions in many parts of the country, together with more extreme weather events (another likely result of climate change) can be expected to increase bushfires and dust storms, leading to short-lived, very high levels of particulate pollution, which, depending on location, may affect large urban populations.

The quality of indoor air is affected by many factors. The more important include building materials (particularly volatile materials like glues and paints), ventilation, furnishings, use of appliances (particularly cooktops, ovens and unflued gas appliances), environmental tobacco smoke and cleaning agents.
3.2.1 Stratospheric ozone

Global production of ODSs continues to decline (Figure 3.30). However, due to the long atmospheric lifetimes of a number of important ODSs, they will continue to impact levels of stratospheric ozone for many decades. In addition, future recovery of the ozone layer will be influenced by emissions of GHGs that are not controlled under the Montreal Protocol—notably carbon dioxide, methane and nitrous oxide—through their effects on temperature, wind and chemistry.104

Carbon dioxide has an indirect influence on stratospheric ozone through its effect on temperature, which affects the rates of chemical reactions that control the abundance of ozone. Increasing levels of carbon dioxide have been observed to cause cooling of the mid-to-upper levels of the stratosphere (via radiation to space), leading to a decrease in the rate of ozone loss in these parts of the atmosphere and an increase in the rate in the lower stratosphere. Increases in methane’s abundance in the troposphere will lead to more methane reaching the stratosphere. There, it interacts with compounds that contain active chlorine (which is able to destroy ozone) to produce inactive hydrogen chloride, which does not destroy ozone. Methane levels also influence stratospheric water vapour, which affects both ozone and climate. The net effects of carbon dioxide and methane are expected to be positive for the recovery of stratospheric ozone levels.104 However, this is not the case with nitrous oxide, which is produced by a variety of natural and human-related sources (notably agricultural processes).

As well as being a potent GHG, nitrous oxide from human sources is currently the single most important ODS and can be expected to remain so throughout this century.156 This reflects the fact that, although the ozone depleting potential of nitrous oxide is only about one-sixtieth that of CFC-11, human emissions are large and increasing. Even in 1987, when CFC emissions were at or near their peak, annual ozone depletion potential–weighted emissions of nitrous oxide were some 17% of the combined emissions of CFC-11, CFC-12 and CFC-112.156 In 2009, Australia’s emissions of nitrous oxide were 26.7 MtCO₂-e, which is approximately 0.7% of the world’s human-sourced emissions.38-39

![Figure 3.30](image_url)

Source: United Nations Environment Programme Ozone Secretariat

**Figure 3.30** Total reported global production of ozone depleting substances

As new countries ratify the Montreal Protocol, the number of countries reporting national production increases. Therefore, the number of countries is different in 1990 and 2009.
3.2.2 Ambient air quality

Point-source and diffuse-source pollution

As previously noted, air quality in Australia’s urban areas is strongly influenced by short-term meteorology (including extreme events), seasonal conditions, local topography and distance from the sea. The size of the urban centre and the presence of major industrial facilities also play a role in shaping the varying levels of air quality experienced in an urban airshed.

Historically, the most common image of air pollution has been a highly visible plume of unknown content being emitted from a power station or industrial plant. However, both state and national pollutant inventories show that, although industrial point sources still dominate some emission types (notably sulfur dioxide), with the exception of major industrial centres (such as Mount Isa and Port Pirie), diffuse or area sources tend to be the main factors affecting air quality at an airshed scale. These sources include motor vehicles, domestic and commercial solvents, service stations and domestic lawn mowers. The generalisation remains true whether the focus is on the key criteria pollutants (ozone and its precursors and particles) or on the main hazardous air pollutants (air toxics such as benzene, toluene and xylene) (Figure 3.31).139,157

It is the diffuse sources (motor vehicles, domestic solid fuel heating, bushfires and various types of planned burning, and dust from roads and agricultural activities) that are the most challenging for government policy makers, regulators and program managers working to improve air quality.

Among diffuse sources of air pollution, motor vehicles are the most pervasive and have the largest impact on urban air quality and human health. In our capital cities, they are the dominant source of NOx (a generic term for nitric oxide and nitrogen dioxide) and VOCs—the precursors of photochemical smog. Although the combined emissions from industry, electricity generation and wood heating are a larger source of PM10 than motor vehicles, because of their ubiquitous presence in our cities, motor vehicles tend to be a more important source of human exposure. Furthermore, discharges from major industrial and power-generation facilities are elevated and thus have less influence at ground level than corresponding ground-level emissions.

![Figure 3.31 Proportion of total estimated annual anthropogenic emissions from each anthropogenic source type in the Sydney region](image-url)
In addition, very fine particles (<1 micrometre) form a major part of vehicle particulate emissions. It is these, together with particles in the range 1 micrometre to less than 2.5 micrometres, that are the focus of increasing concern in relation to cardiovascular and respiratory disease, with which they are strongly correlated. The Australian Bureau of Transport and Regional Economics estimates that, in 2000, motor vehicle pollution was responsible for 900–4500 cases of respiratory and cardiovascular disease and bronchitis, and as many as 2000 premature deaths.

Within an airshed at a neighbourhood level, as state regulators and local government officials know only too well, a broad range of small-scale industrial and commercial activities have the potential to impact on local amenity and health, most often through emissions of odour, dust and noise. Such widespread diffuse-source problems are often historical in nature (the result of residential areas having developed in close proximity to incompatible land uses) and are particularly difficult to resolve.

An important diffuse source of particulate pollution in cool–temperate parts of Australia is domestic wood heaters and open fires. In autumn and winter, in cities such as Melbourne, Hobart, Canberra and Launceston, and in many smaller centres in Tasmania, Victoria and inland New South Wales, smoke from domestic wood heaters is the major source of particulate pollution. In inland centres such as Canberra, cold nights and clear skies frequently occur in autumn and winter, creating temperature inversions. These trap wood smoke near ground level, leading to particle levels above both the NEPM 24-hour PM$_{2.5}$ standard and the PM$_{2.5}$ advisory level. In centres such as Launceston, local valley topography can increase the frequency and strength of such inversions, leading to incidents of significant particulate pollution.

The term ‘planned burning’ encompasses a broad range of activities associated with forestry, public land management and agriculture. Depending on their location and scale, the smoke generated by such activities has the potential to impact on health and amenity, affecting areas such as tourism, viticulture and outdoor events if the burns are not well planned and executed. Recent work by the Environment Protection Division of the Tasmanian Department of Primary Industries, Parks, Water and Environment indicates that planned burns are a significantly more important diffuse source of particulate pollution than estimated by the National Pollutant Inventory. However, although the potentially adverse impacts of planned burns need to be recognised and managed, they should be considered in the context of potential benefits, such as a reduction in the risk of wildfires.

The term ‘planned burning’ could also be applied to burning carried out as a traditional management practice by Indigenous land custodians in tropical savanna grasslands in northern Australia. These low-impact burns have been employed by Aboriginal people for many thousands of years. Because they take place in remote areas away from population centres, these traditional practices do not raise concerns over impacts on health or amenity, such as are often associated with planned burning in the southern parts of the country.

Climate change and urban air quality

The combination of higher temperatures, more frequent bushfires and more raised dust associated with climate change can be expected to impact adversely on ambient air quality at an airshed scale. CSIRO modelling of the Sydney airshed has shown that higher temperatures, especially higher summer temperatures, can be expected to increase the formation of ozone by increasing the production of VOCs (including from leaves and other biogenic sources), thus impacting respiratory and cardiovascular health. Specifically, under a scenario of high carbon dioxide emissions growth, with air pollution emissions fixed at current-decade levels, Cope et al. found that projected numbers of ozone pollution–related hospital admissions would be 40% (2020–30) and 200% (2050–60) higher relative to 1996–2005. Tang et al. noted the potential for a similar temperature-related increase in emissions of NO, from some types of soil, which could lead to an increase in ozone formation.

In addition, climate change–driven shifts in atmospheric circulation, such as a change in the exchange between the stratosphere and the troposphere, could lead to relatively small but significant increases in background ozone levels in the troposphere. Such increases in background concentrations could be expected to add to
existing ozone pollution levels in urban areas, increasing the length of periods during which regulatory air quality standards are exceeded, with consequent effects on health.\textsuperscript{163} 

Analysis by Duc and Azzi\textsuperscript{164} indicates an increasing trend in background ozone levels in Sydney since the early 1990s. The authors note that this is similar to increasing trends reported from the United States and Europe. While they comment that the reason for the increasing trend in Sydney is ‘not entirely clear’, they note the possible influence of transfer from the stratosphere, along with increasing global emissions, particularly in north Asia.\textsuperscript{164} 

Existing monitoring data show strong links between extreme events such as bushfires and dust storms and very high levels of particulate pollution in metropolitan and regional centres. The expected climate change–driven increase in these events will therefore exacerbate episodes of severe particulate pollution. As in the case of ozone, this can be expected to lead to an increase in adverse respiratory and cardiovascular health outcomes, both acute and chronic.\textsuperscript{135} 

3.2.3 Indoor air quality

The quality of the air inside our homes, offices, public buildings, schools and so on is affected by many factors, including the quality of the outside air, building materials (particularly volatile materials like glues and paints), ventilation, furnishings, appliances (particularly unflued gas appliances), environmental tobacco smoke and cleaning agents.\textsuperscript{165-166} 

Of the factors impacting on indoor air quality, environmental tobacco smoke is of particular concern because it increases the risk of asthma in children and can worsen the symptoms. Environmental tobacco smoke is also known to trigger asthma symptoms in adults. Another focus of concern is nitrogen dioxide, the major sources of which are unflued gas heating and cooking appliances, and wood stoves and fireplaces. In winter, when homes are likely to be well sealed, even flued heaters and fireplaces can lead to high indoor levels of nitrogen dioxide due to leaks and poor chimney design.\textsuperscript{167-168} High nitrogen dioxide levels are associated with coughing, wheezing and asthma attacks. Prolonged exposure to such levels can contribute to the development of acute or chronic bronchitis.\textsuperscript{191}
### Assessment summary

#### Pressures affecting stratospheric ozone, ambient air quality and indoor air quality

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Greenhouse gases</strong></td>
<td>Emissions of nitrous oxide (N(_2)O), an ozone depleting substance and a greenhouse gas, together with other greenhouse gases (carbon dioxide [CO(_2)] and methane), are expected to have a significant effect on stratospheric ozone levels. CO(_2) and methane are expected to have a positive net effect on ozone recovery. That is not the case for N(_2)O</td>
<td>Insufficient information to assess likely extent of future impact of N(_2)O</td>
<td><img src="image" alt="Assessment" /></td>
</tr>
<tr>
<td><strong>Industrial point sources</strong></td>
<td>Local and airshed-wide impacts on health and aesthetics; localised effects on amenity and health near some major point sources</td>
<td><img src="image" alt="Assessment" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>Motor vehicles</strong></td>
<td>Metro-wide direct and indirect impacts of volatile organic compounds, NO(_x), ozone and particulates; localised impacts near ‘hot spots’ such as heavily trafficked roads in residential areas</td>
<td><img src="image" alt="Assessment" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>Domestic and commercial (urban)</strong></td>
<td>Local and airshed-wide impacts on health and aesthetics</td>
<td><img src="image" alt="Assessment" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>Planned burning</strong></td>
<td>Widespread evidence of generally localised effects on amenity and health</td>
<td><img src="image" alt="Assessment" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
</tbody>
</table>
### Component Summary Assessment grade Confidence

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change (airshed scale)</td>
<td>Higher temperatures will be associated with increased photochemical smog (ozone pollution events), and with an increase in serious particulate pollution events due to more frequent bushfires and dust storms. Both outcomes can be expected to adversely affect health</td>
<td>Very high impact</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td>Indoor air pollutants</td>
<td>A broad range of indoor pollutants is known to impact health</td>
<td>Very low impact</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
</tbody>
</table>

#### Recent trends

- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

#### Grades

- **Very low impact** Few or no impacts have been observed, and accepted predictions indicate that future impacts on values such as health and aesthetics are likely to be minor
- **Low impact** Impacts on values such as health and aesthetics have already been observed, most often localised
- **High impact** Significant impacts on values such as health and aesthetics have already been observed, mainly affecting more sensitive members of the community
- **Very high impact** Currently, a very serious impact on health and aesthetics for the broader population
3.3 Effectiveness of management

3.3.1 Stratospheric ozone

On the basis of the extent of international sign-on and results achieved, the Montreal Protocol is one of the world’s most effective international environment protection agreements. Various ‘world-avoided’ studies have demonstrated the importance of measures implemented under the protocol, not only in avoiding further damage to the ozone layer and allowing its gradual recovery, but also in significantly reducing the extent of climate change in coming decades. This is particularly important at high latitudes, where the avoided ozone depletion would have had a large effect on surface climate.\textsuperscript{104,169}

Based on analysis of historical ODS emissions and potential emission scenarios, Velders et al.\textsuperscript{170} reach a similar conclusion, noting that ‘the climate protection already achieved by the Montreal Protocol alone is far larger than the reduction target of the first

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At a glance

The Montreal Protocol on Substances that Deplete the Ozone Layer is one of the world’s most effective international environment protection agreements, orchestrating the phase-out of a broad range of ozone depleting substances (including some of the first generation of chlorofluorocarbon substitutes). Australia has ratified the protocol and, as a signatory, all subsequent amendments, and has reduced its use of controlled substances well ahead of its international obligations.

For more than a decade, Australia has had national standards and goals for ambient air quality—the National Environment Protection (Ambient Air Quality) Measure (AAQ NEPM)—based on strong empirical evidence about the health impacts of major pollutants. The measure mandates a consistent approach to air quality monitoring, which has been applied by all states and territories, but—recognising the different legislative arrangements in each jurisdiction—does not dictate the means to be applied to achieve the goals. The AAQ NEPM is supported by national emission standards for new vehicles, set in the Australian Design Rules, and by fuel quality standards, both of which are established through Australian Government legislation (the \textit{Motor Vehicle Standards Act 1989} and the \textit{Fuel Quality Standards Act 2000}, respectively).

During the past 30–40 years, state and territory environment protection agencies have employed a variety of regulatory measures (including works approval, licensing and notices) to control and greatly restrict emissions of air pollutants from industrial and commercial sources. More recently, nonregulatory measures (such as codes of practice, market-based mechanisms and cleaner production incentive schemes) have been increasingly used to complement regulatory controls. In some jurisdictions, local government has a role in controlling emissions (mainly of particles and odour) from commercial sources. Local government tends to be the main tier of government responding to complaints at the neighbourhood level about smoke from domestic wood heaters.

Although the size of the Australian vehicle fleet is continuing to grow (as are the distances travelled), emissions are expected to continue to decline over the next decade as a result of tighter national fuel standards and the mandating of improved emission-control technologies under the \textit{Motor Vehicle Standards Act 1989}. State and territory authorities are responsible for enforcing compliance with emission standards on in-service vehicles, and Australian Government officials monitor and enforce compliance with fuel standards.

Australian governments have actively sought to improve indoor air quality through a range of interventions (both regulatory and nonregulatory) targeting environmental tobacco smoke and unflued gas heaters. All states and territories prohibit smoking in cinemas and theatres (originally motivated by concern over risk of fire), in most types of public transport and in areas where food is prepared and consumed. Increasingly, similar bans are being applied to various outdoor public spaces. Unflued gas heaters are regulated in all states and territories; although the regulations vary between jurisdictions, they all require compliance with Australian standards. However, as various studies have shown, conformity with the Australian standards does not guarantee that emissions will not adversely affect health.
commitment period of the Kyoto Protocol’. Additional climate change mitigation could be achieved under the Montreal Protocol through management of substitute fluorocarbon gas emissions and by mandating gases with low global warming potentials as alternatives.

Other world-avoided studies have modelled decreases in ozone levels and resulting increases in ground surface solar UV radiation levels. The excess radiation would have had major adverse effects on terrestrial and aquatic ecosystems and on human health. For example, mid-latitude ozone losses in the Northern Hemisphere would have reduced the time taken to sunburn (under a clear sky at noon) from 15 to 5 minutes. The amount of DNA-damaging UV reaching Earth would have increased between 1980 and 2065 by 550%.

Table 3.9 Summary of Montreal Protocol measures

<table>
<thead>
<tr>
<th>Ozone depleting substance</th>
<th>Developed countries</th>
<th>Developing countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorofluorocarbons</td>
<td>Phased out end of 1995&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Total phase-out by 2010</td>
</tr>
<tr>
<td>Halons</td>
<td>Phased out end of 1993</td>
<td>Total phase-out by 2010</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>Phased out end of 1995&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Total phase-out by 2010</td>
</tr>
<tr>
<td>Methyl chloroform</td>
<td>Phased out end of 1995&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Total phase-out by 2015</td>
</tr>
<tr>
<td>Hydrochlorofluorocarbons</td>
<td>Freeze from beginning of 1996&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Freeze in 2013 at a base level calculated as the average of 2009 and 2010 consumption levels</td>
</tr>
<tr>
<td></td>
<td>35% reduction by 2004</td>
<td>10% reduction by 2015</td>
</tr>
<tr>
<td></td>
<td>75% reduction by 2010</td>
<td>35% reduction by 2020</td>
</tr>
<tr>
<td></td>
<td>90% reduction by 2015</td>
<td>67.5% reduction by 2025</td>
</tr>
<tr>
<td></td>
<td>Total phase-out by 2020&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Total phase-out by 2030&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Hydrobromofluorocarbons</td>
<td>Phased out end of 1995</td>
<td>Phased out end of 1995</td>
</tr>
<tr>
<td>Methyl bromide (horticultural uses)</td>
<td>Freeze in 1995 at 1991 base level&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Freeze in 2002 at average 1995–98 base level&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>25% reduction by 1999</td>
<td>20% reduction by 2005</td>
</tr>
<tr>
<td></td>
<td>50% reduction by 2001</td>
<td>Total phase-out by 2015</td>
</tr>
<tr>
<td></td>
<td>70% reduction by 2003</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total phase-out by 2005</td>
<td></td>
</tr>
<tr>
<td>Bromochloromethane</td>
<td>Phase-out by 2002</td>
<td>Phase-out by 2002</td>
</tr>
</tbody>
</table>

<sup>a</sup> With the exception of a very small number of internationally agreed essential uses that are considered critical to human health and/or laboratory and analytical procedures

<sup>b</sup> Based on 1989 hydrochlorofluorocarbon (HFC) consumption with an extra allowance (ozone depletion potential weighted) equal to 2.8% of 1989 chlorofluorocarbon consumption

<sup>c</sup> Up to 0.5% of base-level consumption can be used until 2030 for servicing existing equipment, subject to review in 2015.

<sup>d</sup> Up to 2.5% of base-level consumption can be used until 2040 for servicing existing equipment, subject to review in 2025.

<sup>e</sup> All reductions include an exemption for preshipment and quarantine uses.

Notes: The timetable set by the Montreal Protocol applies to bulk consumption of ozone depleting substances (ODSs). Consumption is defined as the quantities manufactured plus imported, less those quantities exported in any given year. Percentage reductions relate to the designated ‘base year’ for the substance. The protocol does not forbid use of existing or recycled controlled substances beyond the phase-out dates. Further information on these ODSs can be seen in the United Nations Environment Programme Ozone Secretariat’s *Handbook for the international treaties for the protection of the ozone layer* (see Section 1.2 of the handbook for links to graphs displaying ODS phase-out timetables). For Australia’s accelerated HCFC phase-out timetable, see Part IV of the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989*.

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities"
Australia was an early supporter of international efforts to protect the ozone layer and has ratified the Montreal Protocol and all subsequent amendments. It moved quickly to give legislative effect to its obligations under the protocol, establishing the Ozone Protection and Synthetic Greenhouse Gas Management Act 1989. Australia’s reduction in the use of substances controlled under the protocol (all of which are imported) has been well ahead of its international obligations (Figure 3.32). For example, Australia will essentially phase-out use of hydrochlorofluorocarbons four years ahead of 2020, the date scheduled under the protocol.107

3.3.2 Ambient air quality

National standards

At the national level, the Council of Australian Governments’ Standing Council on Environment and Water (previously the Environment Protection and Heritage Council) meets regularly to deal with issues of common concern, including ambient air quality. These ministerial meetings provide a forum for agreement on priorities and resourcing for the development of NEPM standards, policies and programs, and for related studies and other activities.

For more than a decade, Australia has had national standards and goals for ambient air quality (AAQ NEPM), which are based on strong empirical evidence about the health impacts of major pollutants. The standards are enshrined in law, and performance against them is regularly monitored in all our major cities and publicly reported. Achievement of the 10-year air quality goals established in the NEPM depends to a great extent on the effectiveness of actions (both regulatory and nonregulatory) taken by the states and territories to control point and nonpoint pollution sources. Although it is up to the individual state and territory governments how they go about achieving the NEPM

![Figure 3.32 Australia’s performance against Montreal Protocol obligations for controlled ozone depleting substance imports](source: Australian Government Department of Sustainability, Environment, Water, Population and Communities)
goals, the system of public reporting allows interest groups and members of the public to pressure governments and regulators if progress to improve air quality is judged to be lacking or too slow.

The Australian Government also plays an important role in achieving air quality goals, chiefly through its powers to set emission standards for new vehicles (through the Australian Design Rules—ADRs) and fuel quality standards. ADRs are established under the *Motor Vehicle Standards Act 1989*, while vehicle fuel quality standards are set through the *Fuel Quality Standards Act 2000*.

Responding to growing concern over particle and NOx pollution from diesel vehicles, the National Environment Protection (Diesel Vehicle Emissions) Measure was established in 2001. Unlike the ADRs that set standards for new petrol and diesel vehicles, the diesel emissions NEPM targets in-service vehicles (which are a state responsibility), establishing a range of strategies for governments to employ to reduce emissions.\textsuperscript{173-174}

Although, in the past, Australian emission and fuel quality standards have lagged behind equivalent overseas standards, they have been progressively tightened to require more sophisticated vehicle engine and emission-control systems and improved fuel quality. Recent improvements in fuel quality have focused on greatly reducing sulfur content (particularly important in diesel engines, where high sulfur levels prevent the use of catalytic particle filters and NOx adsorbers) and lowering the volatility of fuels to reduce evaporative losses (a major source of VOCs) (Figure 3.33).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{sulfur_levels.png}
\caption{Sulfur levels in premium unleaded petrol (PULP), unleaded or lead replacement petrol (ULP/LRP) and diesel, 2000–10}
\end{figure}

\textit{ppm = parts per million}

\textit{Source: Australian Government Department of the Environment, Water, Heritage and the Arts}\textsuperscript{50}
Point sources of pollution—industry

Environment agencies in the states and territories are responsible for controlling emission of pollutants from large industrial point sources, such as power stations, refineries, smelters, manufacturing plants, cement works and abattoirs. Various regulatory measures (including works approvals, licences and notices), together with emissions monitoring and modelling, and enforcement programs, are used to prevent emissions from individual point sources affecting health or amenity at the local level and to prevent such sources collectively leading to exceedence of national ambient standards at a larger scale. These tools are often supplemented by nonregulatory approaches, such as industry codes of best practice and programs to assist firms to identify and implement cleaner production approaches that provide both environmental and financial benefits.

Although discharges from industrial facilities are no longer the dominant source of most air pollutants in our metropolitan centres, a number of important regional centres host large-scale industrial facilities, such as metal smelters and petroleum refineries. Despite major gains in air quality achieved through improved pollution controls and cleaner forms of production, large industrial point sources still significantly affect air quality in some centres (e.g. Mount Isa and Port Pirie) and are therefore a focus for attention by environmental regulators.

Box 3.10 Major industrial point sources, Mount Isa

Mount Isa is home to one of Australia’s largest lead and zinc smelters. The lead–zinc and copper smelters, operated by the global mining company Xstrata plc since its 2003 takeover of MIM Holdings, have been a source of concern to the local community for decades, chiefly due to their emissions of sulfur dioxide and lead. In May 2011, the company announced that it would phase out copper smelting at Mount Isa by the end of 2016. Until 2008, the smelters operated under the Mount Isa Mines Limited Agreement Act 1985. This was one of a number of special agreement Acts applied to specific major industrial facilities that overrode stricter controls under the Environmental Protection Act 1994 and allowed much higher emission limits than elsewhere in Queensland.

The MIM/Xstrata facilities met the relaxed requirements of the 1985 Act, including standards for sulfur dioxide and lead (as PM$_{10}$—particulate matter smaller than 10 micrometres) in ambient air, as measured at monitoring stations around Mount Isa. However, despite a general downward trend in total sulfur dioxide air emissions from 2000–01 to 2006–07 (linked to improved pollution controls and cleaner production measures), the one-hour NEPM sulfur dioxide standard continues to be exceeded on a number of occasions each year at Mount Isa’s single NEPM monitoring station (Figures A and B).

![Figure A](https://example.com/figure_a.png)  **Figure A** Total sulfur dioxide emissions to air, Mount Isa

![Figure B](https://example.com/figure_b.png)  **Figure B** NEPM exceedences of sulfur dioxide, Mount Isa

Source: National Pollutant Inventory
Source: Queensland Department of Environment and Resource Management (Queensland air monitoring reports)
Figure C shows that Xstrata’s total lead emissions have fluctuated over the past decade. Available data show a downward trend since 2005–06, which may reflect improvement in pollution controls. Ambient lead monitoring results from five stations around Mount Isa (which record lead as PM$_{10}$) show no clear reducing trend over the past five years. During that period, the NEPM annual average standard for lead of 0.50 micrograms per cubic metre was exceeded at three stations in 2008 and at one in 2009 (Figures D and E).

The 2008 amendments to the environmental protection and related Acts established a three-year transitional period, during which the Mount Isa facilities (and other facilities covered by special agreement Acts) have to come in line with national ambient air quality standards. During this period, the Department of Environment and Resource Management has worked with Xstrata and the local community through the Living with Lead Alliance to define best-practice standards that the company will have to meet. These will include tighter emissions standards aimed at ensuring that Mount Isa’s ambient air quality meets the national standards for sulfur dioxide, lead and other pollutants, as required under Queensland’s Environmental Protection (Air) Policy.

**Figure C** Xstrata’s total lead emissions to air, Mount Isa

BSD = Base Supply Depot; µg/m$^3$ = microgram per cubic metre; RSL = Returned and Services League

Source: Queensland Department of Environment and Resource Management

**Figure D** PM$_{10}$ lead concentration

A running quarterly concentration is calculated monthly.
**Diffuse sources of pollution—motor vehicles**

The nature and scale of the impact of motor vehicles on air quality in our major cities is generally well understood (e.g. Bureau of Infrastructure, Transport and Regional Economics;\(^{180}\) Bureau of Transport and Regional Economics;\(^{188}\) Environment Protection Authority Victoria\(^{141,181}\)). Significant reductions in vehicular emissions followed the tightening of ADR emission limits for carbon monoxide and hydrocarbons in 1986, and the national introduction of three-way catalytic converters and unleaded fuel in the 1990s. These reductions have been maintained, despite increasing numbers of vehicles and distances travelled. By contrast, NO\(_x\) levels continued to rise through the 1990s, because ADR NO\(_x\) limits were not tightened until 1997–99, when ADR 37-01 was introduced. This, combined with continued growth in numbers of vehicles and distances travelled, resulted in a lag of several years before improved emission controls led to a plateauing of NO\(_x\) levels.

The Bureau of Infrastructure, Transport and Regional Economics has developed projections for metropolitan cities (Figure 3.34). These indicate continuing reductions in carbon monoxide, VOCs (evaporative and exhaust emissions), PM\(_{10}\) (exhaust emissions) and NO\(_x\) through to 2020, due to the increasing proportion of newer vehicles that meet the latest ADR requirements for engine and emission controls, and to improved fuel standards. However, the projections are based on a ‘business as usual’ case—that is, continued economic and population growth, no domestic carbon price in place, no further emission standards (after 2007–08 for diesel vehicles and 2008–10 for light-duty petrol vehicles), and only mid-range increases in future petrol prices (based on International Energy Agency reference case projections). As a result, they do not factor in further reductions in emissions that should follow the progressive introduction of tighter standards announced by the Australian Government in June 2011.\(^{182}\)
From 1 November 2013, Euro 5 emission standards for light vehicles will apply to all new-model vehicles, with existing models to comply from 1 November 2016. All new-model vehicles must comply with Euro 6 standards from 1 July 2017. Existing model vehicles must meet Euro 6 standards from 1 July 2018.\textsuperscript{183} As the regulation impact statement for the review of the Euro 5/6 light vehicle standards noted: ‘[adoption of the standards] would lead to significant reductions in NO\textsubscript{x} emissions from petrol vehicles, and HC and NO\textsubscript{x} emissions from diesel vehicles, and dramatic reductions in PM emissions from diesel vehicles’.\textsuperscript{183} Table 3.10 summarises the expected improvement in emissions.

These improvements, together with those associated with the earlier introduction of Euro 3 and Euro 4 standards, should continue to counter the effect of further growth in vehicle numbers and distances travelled.\textsuperscript{184,185} However, although the general outlook is therefore encouraging, it needs to be acknowledged that local vehicle pollution ‘hot spots’ continue to exist in our major cities. These are usually associated with very heavily trafficked roads, often carrying a significant proportion of heavy commercial vehicles through residential areas.\textsuperscript{186} There is a growing body of evidence that residents living on or near such roads not only experience loss of amenity, but also suffer a range of adverse health effects.\textsuperscript{187,188}

Although diesel-fuelled registered vehicles still constitute only a relatively small fraction of all registered vehicles (2.2 million, or 13.8%, at 31 March 2010), these figures represent an increase of 57.4% over the previous five years.\textsuperscript{186} The progressive tightening of diesel fuel standards is expected to contribute to a reduction in particle and NO\textsubscript{x} levels over time (Figure 3.34) by enabling the use of catalytic particle filters and NO\textsubscript{x} adsorbers. The case study in

![Graph showing projected growth in major pollutant emissions from motor vehicles for Australian metropolitan areas, 1990–2020 (index with 1990 = 100)](https://example.com/graph.png)

CO = carbon monoxide; NO\textsubscript{x} = nitrogen oxides; PM\textsubscript{10} = particulate matter smaller than 10 micrometres; SO\textsubscript{x} = sulfur oxides; VOC (evap + exhaust) = volatile organic compounds from evaporative and exhaust emissions

Source: Bureau of Infrastructure, Transport and Regional Economics; D Cosgrove, Principal Research Scientist, Bureau of Infrastructure, Transport and Regional Economics, pers. comm., May 2011

**Figure 3.34** Base-case projected growth in major pollutant emissions from motor vehicles for Australian metropolitan areas, 1990–2020 (index with 1990 = 100)

‘Metropolitan’ refers to all travel undertaken within the eight state and territory capital cities.
Box 3.12 describes how agencies in New South Wales are working to build on the gains flowing from improved diesel fuel standards by supporting the retrofitting of exhaust emission-control devices to diesel engines in both on-road and off-road situations.

**Diffuse sources of pollution—commercial and domestic**

In major urban centres, air quality is also affected by many small commercial sources whose size and large numbers generally make a licence-based approach to control inefficient and impracticable. Similarly, numerous small domestic sources, such as lawn mowers and solid-fuel heaters, add to the overall burden of urban air pollutants and are difficult to regulate.

When problems do arise with small commercial sources, they often take the form of a loss of local amenity due to emissions of odour, dust or noise. Environment protection regulators most often come in contact with these local problems as a result of complaints from neighbours. Responses can include regulatory tools, such as abatement notices and compulsory works orders, or requirements to carry out an environmental audit to clarify the source of the problem and identify the most effective solution.

**Table 3.10 Emissions reduction from adoption of Euro 5 and Euro 6 light vehicle standards**

<table>
<thead>
<tr>
<th>Vehicle fuel type</th>
<th>Emission reduction (%)a</th>
<th>Euro 4 → Euro 5</th>
<th>Euro 5 → Euro 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HCs</td>
<td>NOx</td>
<td>PM</td>
</tr>
<tr>
<td>Petrol/LPG</td>
<td>–</td>
<td>25</td>
<td>na</td>
</tr>
<tr>
<td>Diesel (and direct injection petrol)</td>
<td>25</td>
<td>30</td>
<td>80–90</td>
</tr>
</tbody>
</table>

– = no change; HCs = hydrocarbons; LPG = liquefied petroleum gas; na = not applicable; NOx = nitrogen oxides; PM = particulate matter

a To nearest 5%; a range indicates that the percentage reduction varies with vehicle category.

Source: Australian Government Department of Infrastructure and Transport

**Box 3.11 Nitrogen dioxide—a future concern?**

Although the outlook for the immediate future is for further reductions in motor vehicle emissions (primarily nitrogen oxides [NOx] and carbon monoxide), this is no basis for complacency, as the number of vehicles and total distance travelled continue to increase, potentially eroding past gains achieved through tighter standards and improved technology. In this context, it is worth noting increased concern in Europe over rising levels of nitrogen dioxide in urban air, attributable to vehicle emissions.

This increase is associated with an increase in the nitrogen dioxide: NOx emissions ratio from road traffic. A study of roadside nitrogen dioxide and NOx levels in London from 1997 to 2003 showed a statistically significant fall in NOx averaged across 36 sites, but no significant trend in nitrogen dioxide. The study concluded that the increasing use of certain types of diesel particle filters on buses contributed significantly to the observed change, along with the growth in numbers of diesel passenger cars, and new technologies and management approaches being applied to light and heavy engines. Although peak nitrogen dioxide levels in Australia’s cities are only half to one-third the NEPM standard, the importance of diesel vehicles in the Australian fleet is continuing to increase, so the possibility of unintended consequences flowing from some types of improved diesel engine controls will need to be considered.
Often, however, such problems are best addressed proactively and at a larger scale, working with industry associations to inform small to medium-sized firms of cost-effective ways of improving environmental performance. In Victoria, the Environment Protection Authority has combined with the Victorian Employers’ Chamber of Commerce and Industry to run Grow Me the Money\textsuperscript{b}.\textsuperscript{192} This program assists firms to carry out audits and develop and implement action plans that will improve environmental outcomes (and often their relations with the neighbours), while improving their ‘bottom line’. A number of states operate similar cooperative schemes—for example, the CleanBiz program in Tasmania.\textsuperscript{c}

Well-framed state land-use planning policies, together with local planning schemes and permits, also play an important part in preventing loss of local amenity due to emissions of odour, dust and noise from industrial and commercial premises. Use of planning controls to isolate offensive industrial and commercial operations from residential and other sensitive land uses is not an alternative to requiring such operations to comply with relevant environmental laws. However, planning controls have an important role to play by:

- preventing sensitive uses from ‘coming to the menace’ (i.e. locating near incompatible noxious or dangerous facilities)
- setting planning permit conditions that complement the requirements of environment protection regulators.\textsuperscript{193}

Since the banning of incinerators from suburban backyards during the 1980s and 1990s, smoke from solid-fuel home heating has been the focus of concern about particulate pollution from domestic premises. Open fires and heaters that do not meet the relevant Australian standards (notably AS/NZS 2918 relating to installation, AS/NZS 4012 relating to power and efficiency, and AS/NZS 4013 relating to the rate of particle emission) are the major source of the problem. When compared with noncompliant appliances, modern compliant wood heaters should generate less than half the particulate pollution per kilogram of wood burned and one-third the pollution of open fires.

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**Box 3.12 Diesel vehicles pollution reduction programs**

New South Wales (NSW) has been running two separate programs focusing on reducing exhaust emissions from diesel vehicles.

**Diesel vehicle retrofit program**

The NSW Office of Environment and Heritage, in conjunction with the NSW Roads and Transport Authority, has established a diesel vehicle retrofit program,\textsuperscript{191} which involves retrofitting engine exhausts with pollution reduction devices, primarily to reduce particulate pollution. Some devices can also reduce carbon monoxide and volatile organic compounds via a catalytic converter.

The program, which commenced in 2005, has had more than 70 vehicle fleets participate and has retrofitted 520 vehicles. As at April 2011, it is estimated that completed retrofits will result in 4.7 tonnes less particulate pollution per year.

**Clean Machine Program**

The NSW Clean Machine Program began in 2010. It aims to reduce diesel exhaust emissions from diesel plant and equipment used mainly in construction and industrial activities, such as cranes, dozers, loaders, graders, tractors and pumps.

The Office of Environment and Heritage partners with public sector and private sector organisations to implement the program through improved procurement practices, worksite guidelines and the subsidised retrofit of older engines with pollution reduction devices. As at April 2011, five organisations had formally joined the pilot program and committed to retrofit up to 35 machines.

\textsuperscript{b} www.growmethemoney.com.au
\textsuperscript{c} www.environment.tas.gov.au/index.aspx?base=3119
However, as Meyer et al.\textsuperscript{194} noted, measurement of in situ emission rates from some 20 households in Launceston showed that, when operated in homes, even compliant heaters do not meet the AS/NZS 4013 particle emission rate of four grams per kilogram of wood burned. The authors concluded that the main factor determining the rate of particle emissions is combustion efficiency, which depends on the rate of air flow. In most cases, they found that heaters were operated with dampers set to significantly reduce the air flow, thus generating higher PM\textsubscript{10} emissions. They further concluded that the test protocol specified in AS/NZS 4013 failed to accurately represent emissions performance in domestic usage and that it should be replaced by a test cycle that properly reflects actual domestic operational practices.

During the past decade, the Australian Government Department of Sustainability, Environment, Water, Population and Communities (and its predecessors) and environment agencies in affected states and the Australian Capital Territory have worked on a number of fronts to reduce domestic wood smoke in urban areas. In Launceston, which faced a chronic wood smoke problem, the Australian Government (working with the state government and the City of Launceston) made available $2.05 million in rebates to assist residents to replace open fires and older wood heaters with modern, less polluting heaters, including natural gas heaters. By its end in 2004, the program had achieved a reduction in wood heater use in households from 45% to 30%.\textsuperscript{195}

Federal, state and territory attention has also focused on:

- supporting research into factors affecting emissions
- further improving installation and emission standards
- ensuring that new wood heaters meet the Australian standards (e.g. Victoria has required this via a statutory policy)
- informing potential purchasers of the importance of buying a compliant heater and having it properly installed
- running public education programs providing advice on best operating practices.

**Planned burning**

As noted in Section 3.2.2, recent work by the Environment Protection Division in Tasmania indicates that smoke from planned burns is a more significant source of diffuse particulate pollution than previously thought. The case study in Box 3.13 describes work being done in that state to monitor the effects of planned burning on air quality and to use real-time monitoring data to inform decision-making and management of burns.

### 3.3.3 Indoor air quality

Whereas Australia has had national standards and goals set for key pollutants in outdoor (i.e. ambient) air, there are no standards or guidelines for pollutant levels in indoor air. There are regulations and codes that address indoor air quality, but (with the exception of regulations dealing with gas heating appliances) these apply to workplaces and to commercial premises and public buildings, rather than to residential dwellings.\textsuperscript{152} Despite these limitations, Australian governments have actively sought to improve indoor air quality through a range of interventions (both regulatory and nonregulatory) targeting environmental tobacco smoke and unflued gas heaters.

In the case of environmental tobacco smoke (also known as passive smoking), powers to control smoking in public places lie mostly with state and territory governments. All states and territories prohibit smoking in cinemas and theatres (originally motivated by concern over risk of fire), in most types of public transport and in areas where food is prepared. Over the past decade or so, most jurisdictions have extended such prohibitions to cover cars carrying children and a wide variety of public places, including government buildings, airports, premises where food is consumed, pubs and nightclubs, and shopping centres. Increasingly, similar bans are being applied to various outdoor public spaces. States and territories have also used occupational health and safety legislation to require smoke-free work environments.\textsuperscript{198}
A key pressure on air quality in Tasmania is smoke emissions from planned (prescribed) burning that can impact on human health, amenity, tourism and viticulture. Most of the concern surrounds burning by the forestry industry in autumn, although other sectors contribute both in autumn and at other times of the year.

According to National Pollutant Inventory (NPI) data, smoke from planned burning contributes only 3% of total particle emissions in Tasmania.\textsuperscript{a} However, a recent review indicates that the NPI methodology for estimating planned burn emissions is seriously deficient.\textsuperscript{159} It is now estimated that smoke from planned burning is responsible for approximately 50–80% of total particle emissions in Tasmania (the proportion varies from year to year, depending on the level of burning undertaken).\textsuperscript{196}

Tasmania’s Forest Practices Authority, in consultation with the Environment Protection Authority (EPA), has established the Coordinated Smoke Management System (CSMS).\textsuperscript{b} The CSMS provides for the coordination of planned burns to minimise the risk of high smoke levels in individual airsheds. It restricts the number of burns on days when weather forecasts and modelling predict poor smoke dispersal. Participation is voluntary and is currently limited to major forestry operators and the Tasmanian Parks and Wildlife Service.

To facilitate the assessment of the effectiveness of the CSMS and to provide real-time air quality data that can be fed into the CSMS decision-making process, the BLANkET (Base-Line Air Network of EPA Tasmania) smoke-monitoring network has been established by the EPA. BLANkET consists of a network of 17 indicative air quality monitoring stations (Figure A). Stations are located in regions away from the major centres of Launceston and Hobart, but in areas near where the forest industry and other sectors conduct planned burns.

Each BLANkET station consists of a low-cost optical particle counter that measures particulate matter smaller than 2.5 and 10 micrometres (PM$_{2.5}$ and PM$_{10}$), a meteorological station and a communications link. Real-time data are displayed on the EPA’s website.\textsuperscript{c} Performance of the stations has been very good, and there is high correlation between data from BLANkET and from reference low-volume air samplers at National Environment Protection Measure (NEPM) monitoring stations. The indicative data collected from the BLANkET network show that daily average particle levels above the NEPM PM$_{10}$ standard and the NEPM PM$_{2.5}$ reporting standard are sometimes measured in communities close to planned burn events.

The technology developed for the BLANkET network could also be used to facilitate the determination of population exposure to PM$_{2.5}$ and PM$_{10}$. For Tasmania, this approach is likely to provide a more realistic estimate of population exposure than inventory development and modelling, and at a lower cost.

Source: Tasmania Department of Primary Industries, Parks, Water and Environment (EPA Division)\textsuperscript{197}

\textsuperscript{a} www.npi.gov.au
\textsuperscript{b} www.environment.tas.gov.au/file.aspx?id=7583
\textsuperscript{c} www.environment.tas.gov.au
As noted in Section 3.2.3, there is concern about the impact of unflued gas heaters on indoor air quality and therefore health. Although these heaters are primarily known as a source of nitrogen dioxide, they also produce carbon monoxide and formaldehyde. Unflued gas heaters are regulated in all states and territories. Although the regulations vary between jurisdictions, they all require compliance with Australian standards AS 4553-2000 (AG 103-2000): Gas space heating appliances, and AS 5601-2002 (AG 601-2002): Gas installations. However, as various studies have shown, conformity with the Australian standards does not guarantee that levels of nitrogen dioxide will not adversely affect health.

In New South Wales, longstanding public concern over the use of unflued low-NOx gas heaters in schools led the government to commission a major independent review of respiratory health effects on children exposed to such heaters. The review, by the Woolcock Institute of Medical Research, found that, although exposure to these heaters was not linked to significant reductions in lung function, it did cause an increase in respiratory symptoms, especially in children with a predisposition towards developing allergic reactions. The review concluded that ‘it is important to seek alternative sources of heating that do not have adverse effects on health.’ In response, the New South Wales Minister for Education and Training announced in July 2010 that the use of unflued heaters would be phased out in all New South Wales public schools.
### Effectiveness of atmospheric management

#### Stratospheric ozone

**Understanding:** High level of understanding of nature and sources of ozone depleting substances (ODSs) and of the chemical processes through which they impact on stratospheric ozone. Likely future effect of greenhouse gases on recovery of stratospheric ozone is not as well understood. Links between reductions in ozone in the stratosphere, increased exposure to ultraviolet (UV) radiation and health effects (notably increased risk of skin cancer) are well understood.

**Planning:** Signatories to the Montreal Protocol have well-established planning, policy-setting and regulatory mechanisms to give effect to their obligations to phase out ODSs.

**Inputs:** The necessary public and private sector resources are being applied to achieve phase-out schedules agreed under the Montreal Protocol. Assistance is available to developing nations to implement agreed phase-outs.

**Processes:** A range of processes have been established under the Montreal Protocol to facilitate and monitor action by signatories to implement agreed phase-outs.

**Outputs and outcomes:** World production of ODSs continues to decline, and monitoring shows that atmospheric levels of ODSs peaked in the mid-1990s.

#### Pollution (industrial point sources)

**Understanding:** Very good understanding of air pollutants (types, sources and processes), of relevant industries and industrial processes, and of technologies and practices to prevent or control pollution.

**Planning:** States and territories have well-established plans, policies and regulatory systems to monitor and control these sources.

**Inputs:** Levels of resourcing to support regulatory and nonregulatory programs vary from jurisdiction to jurisdiction, generally reflecting the nature and extent of industrial sources in the state or territory.

**Processes:** All jurisdictions have well-established process to monitor and control these sources, including inspection and enforcement processes.

**Outputs and outcomes:** Jurisdictions apply works approvals, licensing and related regulatory mechanisms to limit types and quantities of pollutant emissions. Although performance levels vary, inspection and enforcement by environmental regulators, together with emissions monitoring and reporting, provide a sound basis for ensuring effective control of these sources.
### Atmosphere | Ambient air quality

#### Summary Assessment grade Confidence

<table>
<thead>
<tr>
<th>Understanding</th>
<th>Ineffective</th>
<th>Partially effective</th>
<th>Effective</th>
<th>Very effective</th>
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<tbody>
<tr>
<td>Pollution—diffuse sources (motor vehicles)</td>
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<tr>
<td>Understanding: Very good understanding of pollution types, sources and processes, and of interaction of fuels and control technologies</td>
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<tr>
<td>Planning: Australian Government and state governments cooperate in relation to planning introduction of improved fuel and technology standards. Appropriate policy and legislative standards in place at national and state and territory levels</td>
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<tr>
<td>Inputs: Adequate resourcing at national level for development and enforcement of standards for fuels and new-vehicle technology. Resourcing for in-service vehicle testing and enforcement at state and territory level is variable</td>
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<tr>
<td>Processes: Respective roles of Australian Government and state and territory governments are clear. Well-established national processes for promulgating and enforcing fuel and new-vehicle emission-control standards, and good coordination between Australian Government and state and territory governments via ministerial councils and officials’ working groups</td>
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<tr>
<td>Outputs and outcomes: National fuel and new-vehicle emission technology standards continue to be tightened. Bureau of Infrastructure, Transport and Regional Economics projections show continuing improvements in vehicle pollutant emissions until 2020</td>
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#### Summary Assessment grade Confidence

<table>
<thead>
<tr>
<th>Understanding</th>
<th>Ineffective</th>
<th>Partially effective</th>
<th>Effective</th>
<th>Very effective</th>
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<tbody>
<tr>
<td>Pollution—diffuse sources (commercial and domestic)</td>
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<tr>
<td>Understanding: Generally sound understanding of pollution types, sources and processes (chiefly via the National Pollutant Inventory [NPI] and state agency emissions inventories), although the reliance on United States data for some NPI emission factors (in the absence of verification) raises concerns about the accuracy of some NPI data</td>
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<tr>
<td>Planning: States and territories and (in some jurisdictions) municipalities have established plans, policies and regulatory systems to monitor and control these sources</td>
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<tr>
<td>Inputs: Resourcing levels to support regulatory and nonregulatory programs vary from jurisdiction to jurisdiction and among municipalities</td>
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<tr>
<td>Processes: All states and territories (and many municipalities) have well-established processes to monitor and control these sources, including inspection and enforcement processes</td>
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<tr>
<td>Outputs and outcomes: Generally effective control of diffuse emissions such as volatile organic compounds from commercial premises and particles (wood smoke) from homes benefits air quality at both the airshed and local level. Ambient monitoring against the National Environment Protection (Ambient Air Quality) Measure standards shows that the standards are met on the great majority of days in all major cities. However, complaints about smoke and odour at the local level continue to be a major focus for investigation and enforcement action by state and municipal officials</td>
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Continued next page
Effectiveness of atmospheric management *continued*

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<tr>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
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<tr>
<td></td>
<td>Ineffective</td>
<td>Partially effective</td>
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</table>

### Pollution—diffuse sources (planned burning)

**Understanding:** Recent work in Tasmania indicates that smoke from planned burns is a more significant source of diffuse particulate pollution than previously believed

**Planning:** Burning for forestry regeneration and related operations and for fuel reduction and habitat management purposes on public land is subject to various guidelines or codes of practice and is usually well planned and executed. Individual property managers make decisions on timing for planned agricultural burning, but must observe any local, regional and statewide restrictions

**Inputs:** Highly variable; unable to assess

**Processes:** In most, if not all, states and territories, authorities responsible for planned burns associated with forest operations and management burns on public land have formal arrangements with environment protection agencies, health agencies and local municipalities, which cover prior notification, suitability of local meteorological conditions, monitoring and public health warnings

**Outputs and outcomes:** Although the position is variable among jurisdictions, there is anecdotal evidence indicating improved cooperation between agencies responsible for planned burning and environment and health authorities. There is also improved notification and greater recognition of the significance of local impacts on health, amenity, tourism and so on
### Indoor air quality

**Understanding:** Although understanding is improving as a result of recent studies, most have focused on particular problems, such as unflued gas heaters or environmental tobacco smoke.

**Planning:** Although there are Australian standards for building materials and home heating devices, there is no national standard for indoor air quality.

**Inputs:** Variable across jurisdictions. Attention is largely restricted to unflued gas heaters and environmental tobacco smoke.

**Processes:** Unflued gas heaters are regulated in all jurisdictions. There has been significant growth in restrictions on smoking indoors.

**Outputs and outcomes:** Some areas of significant improvement (e.g. restrictions on indoor smoking in public venues and workplaces; New South Wales phase-out of unflued gas heaters in public schools), but overall highly variable.

<table>
<thead>
<tr>
<th>Recent trends</th>
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<tr>
<td>Improving</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td>Stable</td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td>Deteriorating</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
<tr>
<td>Unclear</td>
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<table>
<thead>
<tr>
<th>Grades</th>
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<tr>
<td>Very effective</td>
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<td>Effective</td>
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<tr>
<td>Partially effective</td>
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<tr>
<td>Ineffective</td>
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3.4 Resilience of Australia’s atmosphere

3.4.1 Stratospheric ozone

A number of the key ODSs persist in the atmosphere for long periods. Therefore, despite the success of the Montreal Protocol in phasing out CFCs and other major ODSs (apart from nitrous oxide), depletion of stratospheric ozone will continue for many decades.\textsuperscript{104} The World Meteorological Organization’s 2006 \textit{Scientific assessment of ozone depletion} concluded that, averaged across the whole of the global atmosphere, the decline in ozone stopped around 1996.\textsuperscript{202} The 2010 scientific assessment repeated this conclusion, noting that ‘average total [column] ozone values in 2006–09 have remained at the same level for the past decade, about 3.5% and 2.5% below the 1964–1980 averages, respectively, for 90°S–90°N and 60°S–60°N.’\textsuperscript{104} Similarly, monitoring of the maximum area of the Antarctic ozone hole (Figure 3.21) shows it to have been relatively stable since the mid-1990s. Recent simulations of the continuing effects of controls under the Montreal Protocol indicate that the time for total column ozone to recover to 1980 benchmark levels will vary with latitude and will occur last over Antarctica around 2045 to 2060.\textsuperscript{104}

3.4.2 Ambient air quality

Australia’s metropolitan cities all experience episodes of poor air quality (measured in terms of particulate pollution, or pollution by ozone and its precursors NO\textsubscript{x} and VOCs). The frequency, duration and severity of these episodes are strongly influenced by short-term meteorological conditions (principally temperature and wind conditions), in combination with local topography. Air quality is usually restored to acceptable levels once the immediate conditions change. In this context, our major urban airsheds are highly ‘resilient’, in terms of the common dictionary definition of the word. In contrast, application of the ecologically meaningful terms ‘resilience’, ‘sensitivity’ and ‘adaptability’ to the atmospheres of urban places is not particularly helpful in understanding either their dynamics or the effects of localised or widespread inputs of pollutants. However, if urban air pollution is considered from the perspective of the humans who cause most of it and are impacted by it, then resilience is a more useful concept.

Human resilience in the face of prolonged or recurring exposure to air pollutants is limited. Individuals vary in their sensitivity to exposure to particular air pollutants, with those most sensitive accounting for the great majority of the observed deaths and illness attributed to poor air quality. Unfortunately, our capacity to adapt to unacceptably high levels of air pollution is inherently limited. We can leave the affected area, shelter indoors (of limited value without effective air filtering), avoid strenuous exercise, wear face masks and, in the case of asthmatics and others with respiratory ailments, take prescribed medicines. Although necessary during periods of very poor air quality, these short-term adaptive strategies are not substitutes for action to mitigate the pollution at source through a range of regulatory and nonregulatory measures.
3.5 Risks to Australia’s atmosphere

3.5.1 Stratospheric ozone

As discussed in Sections 3.3.1 and 3.4.1, the prognosis for the future of the stratospheric ozone layer over the next half-century is one of continuing recovery. Over that period, GHGs (notably carbon dioxide, methane and nitrous oxide) that are not controlled under the Montreal Protocol are expected to significantly affect future stratospheric ozone levels.104,156

Unlike carbon dioxide and methane—whose net effects are likely to be positive for the eventual recovery of the ozone layer—human-sourced emissions of nitrous oxide will have a negative impact. (In terms of their weighted ozone depleting potential, nitrous oxide emissions are larger than any of the ODSs controlled under the Montreal Protocol and are growing.) Consequently, as Ravishankara et al.156 noted, ‘increases in anthropogenic N₂O [nitrous oxide] emissions or decreases due to abatement strategies would … affect the date for the recovery of the ozone layer’. A delay in the recovery date could delay realisation of certain health benefits (principally avoided cases of skin cancer) that are expected to accompany recovery. On the other hand, there is also the potential for reducing the recovery period through effective action to reduce nitrous oxide emissions.

Greenhouse gases (notably carbon dioxide, methane and nitrous oxide) that are not controlled under the Montreal Protocol are expected to significantly affect future stratospheric ozone levels. In the case of carbon dioxide and methane, the effect is expected to be positive, but human-sourced emissions of nitrous oxide could (in the absence of effective abatement strategies) slow the rate of recovery of stratospheric ozone levels. Should that occur, it could delay the full realisation of health benefits expected to accompany the recovery.

During the past 30 or so years, state and territory environment protection agencies (often working together with local government) have successfully employed regulatory and nonregulatory measures to greatly reduce threats to urban air quality from industrial and commercial activities. The risk of this situation changing markedly during the next decade is assessed as low, despite continuing growth of the economy. Similarly, the risk of a significant decline in local air quality due to increase in particle (wood smoke) pollution from domestic sources is assessed as low.

Motor vehicles are the main diffuse source of air pollution in urban areas, and the size of the Australian fleet is continuing to grow, as are the distances travelled. Despite this, projections to 2020 indicate a continued decline in vehicle emissions of the main air pollutants (carbon monoxide, nitrogen oxides [NOx], particles and volatile organic compounds [VOCs]). This positive outlook is strengthened by the Australian Government’s recent (June 2011) announcement of the progressive introduction of tighter emission-control standards, starting in 2013. Taking into account these competing factors, the risk of a marked deterioration in urban air quality over the next decade is conservatively assessed as medium.

The higher temperatures associated with climate change are expected to elevate ambient levels of VOCs, increasing the potential for ozone pollution in Australia’s larger metropolitan centres, where peak ozone levels already at times exceed national air quality standards. Climate change is also expected to affect the likelihood of bushfires, which, depending on location, can cause very serious particulate pollution in population centres. The level of risk associated with these outcomes is assessed as medium.

Rising domestic heating and cooling costs can be expected to promote better sealing of dwellings to reduce loss of heated and cooled air. This will lead to reduced air exchange rates and a deterioration in indoor air quality.
3.5.2 Ambient air quality

*Industrial point sources*

If not effectively controlled, emissions from industry can place health and amenity at risk, not only at the neighbourhood level, but more generally at the airshed level. During the past 30 or so years, state and territory environment protection agencies (working together with local government) have successfully employed a range of measures (both regulatory and nonregulatory) to greatly reduce the threat from industrial sources. As a result, apart from in major industrial centres or smaller centres with one or two significant industrial sources, diffuse sources (motor vehicles and commercial and domestic sources) tend to be the more important threats to urban air quality at an airshed scale.

A possible exception to this generalisation is the potential impact on urban air quality that could accompany any significant increase in local generation of electricity using cogeneration (i.e. combined heat and power) facilities. As noted by the Victorian Environment Protection Authority:

... cogeneration facilities can yield significant greenhouse emissions reduction benefits, but may pose a potential threat to air quality, as the burning of natural gas releases significant amounts of NOx. Air quality considerations will therefore be taken into account where cogeneration facilities are proposed in urban areas.203

*Diffuse sources—motor vehicles*

Motor vehicles are a significant source of anthropogenic carbon dioxide emissions in Australia, comprising some 90% of transport emissions, which in turn made up 15% of Australia's net carbon dioxide equivalent emissions in 2009.13,43 However, despite their contribution to climate change, the most immediate threat posed by motor vehicles is to air quality at the urban airshed scale, where vehicles typically account for around 80% of carbon monoxide emissions, two-thirds of NOx, 40% of VOCs and 30% of particles (as PM10).157 From 2005 to 2010, motor vehicle registrations increased by 15.4% (averaging 2.9% annually); the bulk of this growth was in passenger vehicles, which make up 76% of the total Australian fleet.186

If growth were to be maintained at this rate, the number of vehicles would double in 24 years. As noted earlier in this chapter, despite significant growth in vehicle numbers and distances travelled (which increased by 6.8% between 2003 and 2007), advances in motor vehicle engine and emission-control technology (together with improved fuel standards) have driven down emissions of carbon monoxide and VOCs.180,185 Projections to 2020 show these gains being maintained and levels of NOx declining. (These projections are based on a ‘business as usual’ scenario that does not factor in the progressive application of tighter emission-control standards starting in 2013, which should reinforce the projected gains.)

The threat, however, is that the combination of increasing vehicle numbers, distance travelled and congestion (which leads to more exhaust and evaporative emissions) may in future cancel out gains in technology, resulting in increased impacts on health and reduced amenity. For example, emerging concerns in Europe over increases in vehicle emissions of nitrogen dioxide accompanying technology-driven reductions in NOx could foreshadow similar concerns in Australia, if the proportion of diesel vehicles in the fleet continues to grow. (Data show diesel registered vehicles increasing from 10.1% of the fleet to 13.8% between 2005 and 2010.186)

*Diffuse sources—commercial and domestic*

Commercial premises can pose a threat to health and amenity at the local level, mainly through emissions of particles and VOCs. VOC sources include aerosols, surface-coating operations and solvents (the latter being a particular cause of odour complaints). Commercial food-processing operations can also place local amenity at risk due to odour emissions. As previously discussed, smoke from poorly designed and operated domestic wood heaters can pose a significant seasonal risk to amenity and health at both neighbourhood and airshed scales. Collectively, domestic and commercial sources annually contribute around one-third of VOCs to the Sydney and Melbourne airsheds, and approximately one-quarter to one-third to particulate pollution in Sydney and one-half in Melbourne. In the case of Melbourne, the contribution of both VOCs and particles is concentrated in winter, as it is strongly associated with domestic heating.157,204
Climate change poses a threat to urban air quality and health through increases in particulate pollution (associated with more frequent bushfires and dust storms) and increases in the formation of ozone and other components of photochemical smog. The latter phenomenon is driven by increasing temperatures, and long-range transport of pollutants associated with large-scale changes in atmospheric circulation.205

3.5.3 Indoor air quality

Despite significant reductions in the percentage of Australian homes using wood as a source of home heating,206 the cost of the main alternatives to wood (i.e. electricity and gas) have risen steeply in recent years and can be expected to continue to rise.207 Such rises may create pressure on households to return to open fires or wood heaters for domestic heating. Should that occur, the quality of indoor air in those homes can be expected to be adversely affected, since any form of fuel burning in a dwelling has been shown to be positively correlated with carbon dioxide, carbon monoxide, nitrogen dioxide and PM2.5.154

Similarly, increasing concern over heating efficiency and loss of heat through poorly fitting fixtures, such as doors and windows, is likely to lead to better home sealing to prevent loss of heat during winter and cool air in summer. If ventilation is reduced in this way, levels of indoor pollutants can be expected to rise.
### Assessment summary

**Current and emerging risks to Australia’s atmosphere**

<table>
<thead>
<tr>
<th>Possible</th>
<th>Catastrophic</th>
<th>Major</th>
<th>Moderate</th>
<th>Minor</th>
<th>Insignificant</th>
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<tbody>
<tr>
<td></td>
<td>Almost certain</td>
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<td>Likely</td>
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<tr>
<td></td>
<td>Increased deaths and illness associated with air pollution from growing motor vehicle fleet</td>
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<td></td>
<td>Adverse health impacts due to increased ground-level ozone linked to rising temperatures</td>
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<tr>
<td></td>
<td>Deterioration of indoor air quality due to better sealing of buildings</td>
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### Atmosphere | Ambient air quality

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<th>Moderate</th>
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<tr>
<td></td>
<td></td>
<td>Localised impacts on health and amenity due to increased air pollution from commercial and domestic sources</td>
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<td></td>
<td>Localised impacts on health and amenity due to increased air pollution from industry</td>
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<td></td>
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<td>Delayed recovery of stratospheric ozone layer, leading to a slowdown in expected reduction in skin cancer rates</td>
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| Unlikely       |       | Not considered |       |               |

| Rare           |       |               |       |               |

Note: Timeframes are within the next 50 years (stratospheric ozone) and within the next 20 years (urban air quality).

Explanation of terms:

- **Almost certain**: >90% probability of occurring during the specified timeframe
- **Likely**: >66% – ≤90% probability of occurring during the specified timeframe
- **Possible**: >33% – ≤66% probability of occurring during the specified timeframe
- **Unlikely**: >10% – ≤33% probability of occurring during the specified timeframe
3.6 Outlook for Australia’s atmosphere

Global observations of atmospheric levels of the major ODSs show that they peaked in the mid-1990s and have declined since then. This has led to a parallel decline in the stratospheric levels of the breakdown products of ODSs responsible for destroying ozone. The decline is expected to continue with the ongoing phase-out of these ODSs under the Montreal Protocol. As a result, the prospects for recovery of the stratospheric ozone layer to 1980 benchmark levels by around mid-century continue to be good.

Air quality in Australia’s major urban centres is generally good. Levels of carbon monoxide, lead, nitrogen dioxide and sulfur dioxide have decreased over the past two decades; however, ozone and particle levels have not declined. National health-based standards are rarely exceeded for prolonged periods, and very high levels of pollution are usually associated with short-lived extreme events such as bushfires and dust storms, which generate very high levels of particulate pollution.

Despite this broadly favourable situation, there is clear evidence that such periods of poor urban air quality have serious adverse impact on human health (particularly on the health of susceptible individuals). Research into the health effects of particles and ozone, along with pollutants such as sulfur dioxide, indicates that there is no threshold level below which they have no health effect. This means that sensitive individuals, such as asthmatics and people with respiratory or cardiovascular disease, may be affected even when air quality standards are met.

Emissions of air pollutants from major industrial point sources are generally well controlled in all Australian jurisdictions. Their effect on urban air quality is unlikely to increase, and may well diminish with the continued uptake of cleaner technologies. Similarly, there is no evidence to suggest that urban air quality will decline due to an increase in emissions from diffuse commercial sources. As is the case with industrial sources, continuing uptake of improved practices and technologies (driven by a desire for improved efficiency, as well as by the prompting of regulators) may see a reduction in emissions of some pollutants such as VOCs.

Air pollution from domestic sources (largely particulate pollution from wood smoke) can be expected to continue to reduce air quality at the neighbourhood level in areas where wood heaters are still widely used. However, unless rising costs of domestic heating prompt a marked increase in the use of wood as a fuel, domestic premises are unlikely to be a source of significant deterioration in urban air quality.

Motor vehicles are the main diffuse source of air pollution in urban areas, and the size of the Australian...
fleets is continuing to grow, as are the distances travelled. Despite this, and despite concerns about the effects of growing traffic congestion and continuing urban sprawl on air quality, projections to 2020 (based on a ‘business as usual’ scenario, which does not include further tightening of emission standards) indicate a continued decline in vehicle emissions of the main air pollutants (carbon monoxide, NOx, particles and VOCs). The recently announced progressive introduction of tighter emission controls (Euro 5 starts in 2013 and Euro 6 in 2017) should reinforce these projected gains.

There are reasonable grounds for optimism that reductions achieved in some urban air pollutants (carbon monoxide, nitrogen dioxide, sulfur dioxide, lead) during the past decade can be maintained or even extended. However, this is not the case with particles or the secondary pollutant, ozone. Monitoring results for these pollutants continue to show that peak ozone levels occasionally exceed the standard in some centres and that standards for particulate pollution are often exceeded for short periods in most metropolitan cities. Prospects of achieving significant reductions in peak levels of particles and ozone will be influenced by:

- the rate at which vehicles (particularly passenger vehicles) shift to hybrid, electric, or other forms of low-emission or no-emission propulsion
- improvements in public transport
- increased take-up of cleaner forms of production
- continuing reductions in the use of wood as a fuel for domestic heating
- urban sprawl.

Perhaps the largest influence will be the rising temperatures and more frequent extreme events associated with climate change.

The outlook for indoor air quality is difficult to assess because of the limited availability of Australian data upon which to form assessments of overall status and trend. Nevertheless, it is likely that increasing levels of restriction on smoking indoors will produce improvements in the quality of indoor air, at least in public venues and workplaces.
References


80 Zickfeld K, Fyfe J, Eby M, Weaver A. Comment on ‘Saturation of the Southern Ocean CO₂ sink due to recent climate change’. Science 2008;319:570.


References


References


188 Krzyzanowski M, Kuna-Dibbert B, Schneider J, eds. Health effects of transport-related air pollution. Copenhagen: World Health Organization Europe, 2005.


Junction Waterhole, Haasts Bluff, Northern Territory
Photo by Ken Duncan
Inland water
The past decade has been Australia’s most ambitious period of water policy reform. All states and territories have now committed to the principles of the National Water Initiative. This commitment includes providing secure water for sustaining the environment.

Withdrawing water for other uses changes our inland water ecosystems. Almost every inland ecological system in Australia is either permanently or seasonally limited by a shortage of water. Permanently withdrawing (abstracting) water from these systems will inevitably change their character in some way and degree. Conversely, this same water-limited ecology and our highly variable climate make these systems relatively resilient to small or short-term reductions in water availability.

Pressures caused by past human activities continue to affect our inland waters, and climate change poses our largest future threat. Most of the ongoing impacts on Australia’s inland water environments result from our historical legacy of land-use change, pest and weed introductions, and water resource development. The main risk to inland environmental health that remains poorly mitigated is the likelihood of a drying and warming climate in our southern catchments and warmer temperatures across Australia. Current water-sharing rules tend to favour water entitlement holders over environmental flows in dry times.

Recent droughts have had major effects on our southern inland water systems. Over the past decade or more, the southern half of Australia experienced the longest and most severe drought in our recorded history. The drought dramatically changed the character of inland water environments and there is evidence that this drought partly reflects a changing climate resulting from human activity. Northern Australia’s inland water systems are largely in good condition.

Remediation of catchment water quality is not yet well managed. While water abstraction pressures on inland water environments are increasingly better managed (and in places alleviated), there is less monitoring, coordination and effort applied to the remediation of catchment water quality. Planning and management of these two dimensions of catchment health are still largely separate.

Better understanding is needed about how well ecosystems can withstand changes in water regime. Except for the south-west corner of the continent, the southern drought ended in late 2010 with widespread flooding. Monitoring of the recovery of river and wetland ecosystems following these floods will provide crucial insights into how inherently resilient these systems are. Managing for extreme conditions is emerging as a vital issue for environmental flows, as the implications of a changing climate become more certain.
Meeting our population’s need for water will be a critical challenge for Australia.

Using water from our environment is fundamental to our national wellbeing and sustainability. Each year, Australian industries add about $1.2 trillion of gross value for the water we use. Demands for urban water will increase as Australia’s population grows; these demands are likely to be met without taking much more fresh water out of the environment (but potentially with other environmental costs, including increased energy use associated with desalination or wastewater recycling).

Water prices have risen, but Australia is using less water.

The average price of water nearly doubled from $0.40 per kilolitre (kL) in 2004–05 to $0.78 per kL in 2008–09. There was large variation in the average price paid for water in 2008–09—households paid $1.93 per kL and agriculture $0.12 per kL. Urban water prices have continued to increase across Australia, reflecting significant state and territory investments in new water infrastructure. However, due to long-term drought conditions, Australia’s water consumption fell 25%, from 18 767 gigalitres in 2004–05 to 14 101 gigalitres in 2008–09.

Water reforms, via the water market, will help secure environmental flows and support ecosystem services.

The establishment of efficient and effective water markets requires multijurisdictional collaboration. This includes effective administrative and regulatory arrangements and adequate monitoring and enforcement. In the future, once an efficient and effective water market model has been implemented, price signals will reflect the scarcity of water in Australia. As a result, water should flow to the economic, social and environmental uses of highest value.
# Contents

## 1 Introduction

1.1 A decade of change 193

1.2 Australia’s water resources and use 194
   1.2.1 Australia’s surface water resources, by drainage division 194
   1.2.2 Water availability and use 198

1.3 In this chapter 200

## 2 State and trends of inland water environments

2.1 Water flows and levels 202
   - Assessment summary 4.1—state and trends of inland water flows and levels 204

2.2 Water quality 206
   - Assessment summary 4.2—state and trends of water quality 212

2.3 Ecological processes and species populations 214
   2.3.1 State and trends of ecological processes 214
   2.3.2 State and trends of key species populations 217
   - Assessment summary 4.3—state and trends of inland water ecological processes and key species populations 222

## 3 Pressures affecting inland water environments

3.1 Recent climate 225
   3.1.1 The drought in south-eastern Australia, 2001–10 226
   3.1.2 The drought in south-western Australia, 1975–present 226

3.2 Water resource development 228

3.3 Changing land use and management 231

3.4 Pests and invasive species 232
   - Assessment summary 4.4—pressures affecting inland water environments 236

## 4 Effectiveness of inland water management 238

4.1 Water management in Australia 238

4.2 Recent national assessments of management performance 239

4.3 Reviews of state and regional management 243
   - Assessment summary 4.5—effectiveness of inland water management 244
5 Resilience of inland water environments 247

6 Risks to inland water environments 249

6.1 Climate change 249
   6.1.1 Murray–Darling division 249
   6.1.2 Northern Australia (Timor Sea and Gulf of Carpentaria divisions, and the northern part of the North-east Coast division) 250
   6.1.3 Tasmania division 250
   6.1.4 South-west Coast division 251

6.2 Water abstraction 251

6.3 Land use and management, including pollutants and nutrients 252
   • Assessment summary 4.6—current and emerging risks to inland water environments 255

7 Outlook for inland water environments 256

References 257
... speaking in penetrating dialects understood by all things—animal, vegetable or mineral—water travels intrepidly through four dimensions, sustaining ...

... destroying ... and creating ...

Tom Robbins, *Even cowgirls get the blues*, 1976
Introduction

Australia is the world’s driest inhabited continent. It is therefore not surprising that places where fresh water accumulates either permanently or seasonally—our aquifers, rivers and wetlands—are of particular ecological and cultural significance. These inland water environments are also the places where we get the water needed to sustain us, our way of life and our development as a nation. Perhaps no other single dimension of the Australian environment has such a ‘coming together’ of biological, cultural and economic values. This chapter assesses the state and trend of inland water environments resulting from historical development pressures, and the outlook for these environments given the emerging pressures we face.

1.1 A decade of change

The past decade has been the most dynamic and significant in modern Australia’s water history. It has been a period of ambitious water policy reform at the same time as the worst and longest droughts Australia has ever seen. There have also been massive public and private investments in water infrastructure, significant new foundations for water knowledge at a national scale, and the widespread acceptance by the public and by governments that Australia’s climate has changed and will continue to change. The decade ended with widespread, unprecedented flooding. All these factors have had, and will continue to have, a profound effect on the state of our inland water environment.

In 2004, the Council of Australian Governments agreed to a policy blueprint to improve the way Australia manages its water resources—the National Water Initiative. All Australian states and territories joined the agreement by 2006. The overall objective of the initiative is a nationally compatible water market—a regulatory and planning-based system of managing surface water and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes. Key environmental elements are:

- statutory provision for environmental and other public-benefit outcomes, and improved environmental water management practices
- completion of the return of all currently overallocated or overused water systems to environmentally sustainable levels of extraction
- inclusion of Indigenous representation in water planning; incorporation of Indigenous social, spiritual and customary objectives and strategies; and taking account of the possible existence of native title rights to water.

The National Water Commission established a national benchmark for Australia’s water resources, Australian Water Resources 2005, and has since assessed Australia’s performance against the objectives of the National Water Initiative; the assessment is a key input into this State of the Environment (SoE) report.

a www.water.gov.au
New arrangements for the management of the Murray–Darling Basin were put in place by the Australian Government through the Water Act 2007, which:

- established the Murray–Darling Basin Authority with functions and powers, including enforcement powers, to ensure that Basin water resources are managed in an integrated and sustainable way; and to prepare the Basin Plan—a strategic plan for the integrated and sustainable management of water resources in the Murray–Darling Basin
- established a Commonwealth Environmental Water Holder to manage the Australian Government’s environmental water, including protecting and restoring the environmental assets of the Murray–Darling Basin, and outside the Basin where the government owns water
- gave the Bureau of Meteorology water information functions in addition to its existing functions under the Meteorology Act 1955 (see Box 4.1).

In March 2008, the Australian Government announced Water for the Future, a $12.9-billon program to secure long-term water supplies for the nation and to better balance the water needs of communities, farmers and the environment. The initiative contains a suite of urban and rural policies and programs, including significant funding for water purchasing, modernisation of irrigation, desalination, recycling and stormwater capture. The initiative’s greatest focus is on the Murray–Darling Basin—it aims to increase the confidence of farmers and communities to plan for a future with less water, to put water use on a sustainable footing, to improve irrigation productivity, and to improve the health of rivers and wetlands.

Most states and territories have water strategies that include measures to manage and protect their inland water environments, and all major water utilities have programs to reduce demand for water and to minimise environmental impacts of supply.

### 1.2 Australia’s water resources and use

Australia’s water resources can be assessed, in part, according to drainage divisions and our withdrawal of water for other uses from the environment (abstraction).

#### 1.2.1 Australia’s surface water resources, by drainage division

The state and trend of, and outlook for, Australia’s inland water environments vary dramatically across the continent, at all scales of resolution. It is sensible to consider water issues by catchment or sets of catchments, so that the health of entire systems can be assessed. Australia’s 12 drainage divisions are the top level of our catchments (Figure 4.1).

Although the states or territories are usually responsible for environmental assessments (e.g. state SoE reports), some natural drainage lines cut across more than...
one jurisdiction—for example, the Murray–Darling extends across five jurisdictions. This creates a challenge in aligning environmental assessments by jurisdiction with specific divisions. In addition, because the drainage divisions are very large, the state and trend of the water environment and the pressures on it vary significantly within a division; this applies particularly to the North-east Coast, South-east Coast and Murray–Darling divisions. Where appropriate, the variations in assessments within a division are noted and discussed below.

Most drainage divisions are large enough to encompass most groundwater systems. That is, boundaries of recharge and discharge areas of aquifers are wholly contained within the boundaries of the drainage division. The major exception to this is the Great Artesian Basin, which lies under parts of the North-east Coast, Murray–Darling, Lake Eyre and Gulf of Carpentaria divisions.

A key feature of these drainage divisions is whether rivers are perennial (permanently flowing) or nonperennial (seasonally flowing) (Figure 4.2), and whether rivers or wetlands are protected or have special management status with respect to the environment (Figure 4.3). For example, the ecological character of each of the 64 Australian wetlands listed under the Ramsar Convention for Wetlands of International Importance is protected as a matter of national environmental significance by the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Wetlands of national importance are listed on the Directory of Important Wetlands in Australia, and in some states are protected by state
legislation or considered in planning processes. State-level legislation provides varying levels of protection for selected wetlands, lakes and rivers throughout Australia. Rivers and inland water bodies occurring within the boundaries of the National Reserve System may be protected to varying degrees by federal, state and territory governance arrangements. Rivers and wetlands may also be afforded protection through mechanisms such as market-based incentives, covenants and management agreements.

Unlike many other parts of the world, most of our rivers, streams and lakes do not always have flowing water in them, even in the tropics. Where water is permanent, large changes in flow regime can significantly alter ecosystems, yet these are the important historical sources of water for people and industry.
Figure 4.3  Australian rivers and wetlands that are protected or have special status under (a) the Ramsar Convention, (b) the Directory of Important Wetlands in Australia, (c) state legislation or (d) the National Reserve System

Water bodies mapped in Figure 4.3c are specifically protected by state-level legislation, including State Environmental Planning Policy No. 14—Coastal Wetlands (NSW), wild rivers as defined in the National Parks and Wildlife Act 1974 (NSW) Wild Rivers Act 2005 (Qld), Heritage Rivers Act 1992 (Vic), Environmental Protection (Swan Coastal Plain Lakes) Policy 1992 (WA), Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992 (WA), Environmental Protection (Gnangara Mound Crown Land) Policy 1992 (WA), Environmental Protection (South West Agricultural Zone Wetlands) Policy 1998 (WA), Environmental Protection (Western Swamp Tortoise Habitat) Policy 2003 (WA), and certain defined wetlands classified as environmentally sensitive areas under the Environmental Protection Act 1986 and Environmental Protection (Environmentally Sensitive Areas) Notice 2005 (WA, data supplied by the Department of Environment and Conservation). At the time of writing, maps for State Environmental Planning Policy No. 14—Coastal Wetlands (NSW) were in the process of being reviewed to improve their accuracy.
1.2.2 Water availability and use

Australia as a nation could not exist without taking water out of the natural environment and using it for domestic and productive purposes. Australia uses about 5% of its total renewable freshwater resources, compared with about 20% for the United States and 43% for Italy (based on 2006 data). The regional distribution of use is highly uneven across Australia, however, with some regions extracting half the available water. Per person, we use more than all other countries of the Organisation for Economic Co-operation and Development except New Zealand, Canada and the United States.

In the water year 2008–09, we extracted 59 839 gigalitres (GL) of water from the environment—of this, 9673 GL was extracted by water service providers and 50 166 GL was directly extracted by water users. Of the total, 47 459 GL was returned to the environment as regulated discharge. The majority of this discharge (44 484 GL) was in-stream use for hydro-electric power generation.

Australia’s water consumption was 14 101 GL in 2008–09, a decrease of 25% from 2004–05, when it was 18 767 GL (Table 4.1 and Figure 4.4). Agricultural activities accounted for 6996 GL (about 50%) of total Australian water consumption in 2008–09. This is a decrease from 2004–05 (12 191 GL; 65%), reflecting restricted supplies during southern Australia’s extended drought. This drought went from 2000 to 2010 (sometimes known as the millennium drought), although in some areas it began as early as 1997.

Somewhat remarkably, over the period 2006–09 the gross value of irrigated agriculture was maintained and even increased despite the decrease in water availability. The relationship between water availability for agriculture and economic sustainability at the farm, community, regional and national scales is clearly a complex one. The sources of water distributed for use across the jurisdictions appears in Table 4.2.

Table 4.1 Water consumption by industry sector; nationally for 2000–01, 2004–05 and 2008–09, and by state and territory for 2008–09

<table>
<thead>
<tr>
<th>Industry sector</th>
<th>Water consumption (GL), Australia</th>
<th>Water consumption (GL), by state and territory, 2008–09</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2000–01</td>
<td>2004–05</td>
</tr>
<tr>
<td>Agriculture</td>
<td>14 989</td>
<td>12 191</td>
</tr>
<tr>
<td>Electricity and gas</td>
<td>255</td>
<td>271</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>549</td>
<td>589</td>
</tr>
<tr>
<td>Forestry and fishing</td>
<td>40</td>
<td>47</td>
</tr>
<tr>
<td>Household</td>
<td>2 278</td>
<td>2 108</td>
</tr>
<tr>
<td>Mining</td>
<td>321</td>
<td>413</td>
</tr>
<tr>
<td>Water supplya</td>
<td>2 165</td>
<td>2 083</td>
</tr>
<tr>
<td>Other industriesb</td>
<td>1 106</td>
<td>1 063</td>
</tr>
<tr>
<td>Total</td>
<td>21 703</td>
<td>18 767</td>
</tr>
</tbody>
</table>

= nil or rounded to zero; ACT = Australian Capital Territory; GL = gigalitre; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a Includes sewerage and drainage services, and water losses

b Includes aquaculture and services to agriculture

Source: Australian Bureau of Statistics
Reuse water made up 348 GL (almost 4%) of total water supplied by water providers in 2008–09; of this, 98% (341 GL) was supplied through water utilities and 30% (102 GL) was used by agriculture.

The scarcity of water supplies that developed over the past decade and the resulting investment in new water infrastructure largely explain the increase in the average price of distributed water, from $0.40 per kilolitre (/kL) in 2004–05 to $0.78/kL in 2008–09. Urban water prices have continued to increase across Australia, reflecting significant state and territory investments in new water infrastructure. Households paid a national average of $1.93/kL and agriculture, $0.12/kL; this difference is partially explained by the higher level of treatment required for supplied drinking water. Water is, however, still a minor fraction (<2%) of household expenses and has not increased at the same rate as expenditure on housing or energy.3

### Table 4.2 Origin of distributed water by state and territory, 2004–05 and 2008–09

This includes water supply, sewerage and drainage industry only (excludes water provided by other industries). Almost half of national groundwater use in distributed water systems is in Western Australia, where groundwater makes up nearly 30% of total supply. Including self-supplied water, groundwater now makes up more than 75% of the water consumed in Western Australia.3

<table>
<thead>
<tr>
<th>Water origin</th>
<th>NSW</th>
<th>Vic</th>
<th>Qld</th>
<th>SA</th>
<th>WA</th>
<th>Tas</th>
<th>NT</th>
<th>ACT</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2008–09</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water</td>
<td>3439160</td>
<td>2399929</td>
<td>2024913</td>
<td>410235</td>
<td>417854</td>
<td>np</td>
<td>np</td>
<td>46625</td>
<td>8955501</td>
</tr>
<tr>
<td>Groundwater</td>
<td>68915</td>
<td>24564</td>
<td>67364</td>
<td>15461</td>
<td>183582</td>
<td>np</td>
<td>np</td>
<td>–</td>
<td>380376</td>
</tr>
<tr>
<td>Desalinated watera</td>
<td>–</td>
<td>–</td>
<td>na</td>
<td>na</td>
<td>33270</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>33270</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3508075</td>
<td>2424493</td>
<td>2092277</td>
<td>425688</td>
<td>634706</td>
<td>176618</td>
<td>60657</td>
<td>46625</td>
<td>9369147</td>
</tr>
<tr>
<td><strong>2004–05</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface water</td>
<td>3012717</td>
<td>3994520</td>
<td>2532418</td>
<td>444240</td>
<td>496838</td>
<td>111882</td>
<td>42182</td>
<td>77112</td>
<td>10711910</td>
</tr>
<tr>
<td>Groundwater</td>
<td>61130</td>
<td>9326</td>
<td>109116</td>
<td>16854</td>
<td>229461</td>
<td>443</td>
<td>21338</td>
<td>–</td>
<td>447668</td>
</tr>
<tr>
<td>Desalinated watera</td>
<td>–</td>
<td>–</td>
<td>85</td>
<td>61</td>
<td>85</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>231</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3073847</td>
<td>4003846</td>
<td>2641619</td>
<td>461155</td>
<td>726384</td>
<td>112325</td>
<td>63520</td>
<td>77112</td>
<td>11159809</td>
</tr>
</tbody>
</table>

- = nil or rounded to zero; ACT = Australian Capital Territory; ML = megalitre; na = not available; np = not available for publication but included in totals, where applicable; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a Includes sea water only

Source: Australian Bureau of Statistics

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**Figure 4.4 Water consumption by state and territory, 2004–05 and 2008–09**

The decreases in use are attributed to reduced availability of water due to drought.
The economic return for water used varies across industries. In 2008–09, the gross value added per gigalitre of water consumed was:

- agricultural production—$4 million
- mining industry—$226 million
- manufacturing industry—$164 million.

In total, Australian industries added about $1.2 trillion of gross value for the water used in 2008–09.

1.3 In this chapter

In this chapter, we paint a national picture of state, trend and outlook for the inland water environment. This is not intended as a substitute for state and territory statements on this environment, nor for local assessments. There are, however, no national databases for most water-related environmental data, nor a consistent, synchronised set of assessments with national coverage. A national-scale picture must be built in parts, based on uneven availability of data and uneven syntheses of information at the state/territory and local scales, at least until the Bureau of Meteorology completes its mission to bring together all water and water-related data across Australia.

This synthesis directly draws on primary data where available, as well as some key assessments, such as state, territory and regional SoE reports, catchment condition reports and strategies; the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Sustainable Yields assessments, 2007–09; the Sustainable Rivers Audit for the Murray–Darling Basin, 2008; and national-scale assessments of water resources and management by the National Water Commission.
State and trends of inland water environments

The concept of ‘environmental health’ of our inland water systems considers our rivers, wetlands and groundwater systems as ecological systems, including flora and fauna and their habitats, and the linkages between water systems and their catchments and climate. The health of inland water systems depends on their capacity to support key environmental functions (temperature regulation, nutrient and carbon cycling, salt balance and sediment transport) and to support communities and populations of native species.

A healthy system is one that has retained its character, biodiversity and functions over time and is more resilient than a system with deteriorated health to pressures and changes in environmental conditions, including climate change, resource use, pollution and invasive pests.7

The health of our inland water systems is relative. We need to ask: relative to what? There are no generally applicable benchmarks for the diverse ecosystem functions and species that make up inland water ecosystems. Instead, ecological assessments generally use a ‘reference condition’ with which actual conditions are compared. This reference is normally the state of the ecosystem with no history of human disturbance.8-9

The assessment in this report recognises that, since humans have shaped the condition of our inland waters for more than 50 000 years, it is not possible or appropriate to separate Aboriginal influences from such a reference condition. The same conclusion was drawn for a North American application, in which Native American influences on the ecosystem were considered as integral to the ecological reference condition.10 Therefore, for the purposes of this assessment, the reference condition of the health of our inland water systems is their condition before European settlement.

The use of this benchmark does not imply that we should restore inland water ecosystems to their near-original condition—it is simply the condition from which we measure change where we can.

A review of all state and national environmental programs determined that no suitable, single ecological indicator of water stress was readily available.11 In this assessment, we look at the major dimensions of the state and trend of our inland water ecosystems:

- how the flows and levels of water in our environment have changed
- how the quality of water in our environment has changed
- how ecological processes and species populations have changed.
2.1 Water flows and levels

Streamflow regime—the pattern of water flow through our rivers—is a major determinant of the environmental condition of inland waters. The regime can vary in frequency, duration and magnitude, and according to season. Natural flows are mainly altered by water resource development, such as the building of dams and weirs, diversion or extraction of in-stream flows, the alteration of flows on floodplains by levees and other structures, and the abstraction of groundwater.

Large variations in streamflow are characteristic of the Australian environment, but the past decade has seen much of the continent move from a period of water deficit to water surplus, in some cases over a short period of time. For example, in May 2010, Australia’s 231 large water storages were at 51% of capacity (total capacity is 78 449 gigalitres). One year later, they were at 73.7% of capacity and held the largest volume of water in Australia’s history: 57 817 gigalitres (Table 4.3).

Table 4.3 Dam water storage for Australia’s drainage divisions, May 2010 and May 2011

<table>
<thead>
<tr>
<th>Drainage division</th>
<th>Volume stored (GL) (% of capacity)</th>
<th>May 2010</th>
<th>May 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf of Carpentaria</td>
<td>95.6 (96%)</td>
<td>97.6 (98%)</td>
<td></td>
</tr>
<tr>
<td>Indian Ocean</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Lake Eyre</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Murray–Darling</td>
<td>7 141 (28%)</td>
<td>20 265 (80%)</td>
<td></td>
</tr>
<tr>
<td>North-east Coast</td>
<td>7 766 (91%)</td>
<td>8 267 (97%)</td>
<td></td>
</tr>
<tr>
<td>North-western Plateau</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>South Australian Gulf</td>
<td>117 (60%)</td>
<td>135 (69%)</td>
<td></td>
</tr>
<tr>
<td>South-east Coast</td>
<td>3 628 (34%)</td>
<td>5 412 (51%)</td>
<td></td>
</tr>
<tr>
<td>South-west Coast</td>
<td>368 (33%)</td>
<td>197 (21%)</td>
<td></td>
</tr>
<tr>
<td>South-western Plateau</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Tasmania</td>
<td>11 867 (54%)</td>
<td>12 852 (58%)</td>
<td></td>
</tr>
<tr>
<td>Timor Sea</td>
<td>9 086 (85%)</td>
<td>10 731 (100%)</td>
<td></td>
</tr>
</tbody>
</table>

GL = gigalitre; na = not available—there are no major dams to report on for the division

Australian Water Resources 2005 included a ‘snapshot’ of river and wetland health based on previous, relatively recent regional assessments. Key findings included confirmation that, in general, increasing diversions and extractions correlate with declining river health. Hydrological change (i.e. change related to water quality, movement and distribution) could be assessed in only 25% of the river length due to a lack of data; however, in about 20% of the regulated river length that was assessed, the flow regimes were largely unmodified from an ecological perspective.

Most rivers across northern Australia (Gulf of Carpentaria, Timor Sea and North-western Plateau divisions, and the northern third of the North-east Coast division) have unimpeded flows. The greatest diversion of water occurs in the Lower Ord system around Kununurra, to provide water for irrigation and hydro-electric power. The level of water diverted for irrigation is low, but hydro-electric power demand can require release of water from Lake Argyle of more than half the lake’s inflows. Less than 3% of the 200 000 gigalitres of mean annual streamflow discharging between Broome and Cairns is diverted for use. A similar low percentage of streamflow is used for irrigation in Tasmania, although a high percentage is used for hydro-electric power.

Historically, water resource development in the Murray–Darling division has caused major changes in the flooding regimes that support floodplain wetland systems in the Murray–Darling Basin. These environments are nationally and internationally important. Integrating the flow impacts through the connected rivers of the Basin shows that total flow at the Murray mouth has been reduced by 61%. The river now ceases to flow through the mouth 40% of the time; this figure would be 1% in the absence of water resource development. More than half the reaches of the Murray–Darling division assessed in 2001 and 2009 had modified hydrology, with the greatest changes found immediately downstream of dams and in lowland reaches used for irrigation supply.

In the South-west Coast division, about 20% of surface water resources are allocated for use. About 44% of annual groundwater recharge into supply aquifers is licensed for use, representing 74% of all water supplies to the south-west. There are concerns that complex interactions between climate (e.g. rainfall and temperature) and vegetation are magnifying the declines that are being seen in flows.
Box 4.2 CSIRO’s Sustainable Yields projects, 2007–10

The Australian Government commissioned the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to provide robust estimates of current and future water yield in several regions of Australia, under internationally agreed scenarios of climate change from the Intergovernmental Panel on Climate Change. These assessments provide the science to underpin sustainable planning and management of water resources.

The first project was in the Murray–Darling Basin. In March 2008, the Council of Australian Governments agreed to extend the assessment to three other areas: northern Australia, Tasmania and south-west Western Australia. These assessments were delivered in 2009.

With these assessments and those planned for other parts of the continent, Australia will have a comprehensive scientific assessment of water yields in most of its major water systems, providing a consistent analytical framework for national water policy decisions.

On average, only 3% of the surface water resources of the Tasmania division (not including the undeveloped west coast region and releases for hydro-electricity generation) are extracted for use; the main rivers are perennial and flow more than 95% of the time. About 3% of annual groundwater recharge is extracted (38 gigalitres per year). Some exceptionally dry conditions were experienced in 2003–08. This led to increased demands on surface waters, and significant declines in river flows and natural inflows to water storages. Water scarcity was an increasing problem in this period, despite Tasmania’s comparatively abundant water resources. A number of streamflow sites recorded their lowest flows since records started. There is evidence that groundwater use was unsustainable in some aquifers in Tasmania due to the increasing demands on water resources, constraints on surface water availability, reduced recharge due to drought conditions, and changes in land cover.

Stream hydrology was rated as poor to moderate across much of the southern section of the South-east Coast division, reflecting modified flow regimes. Groundwater management units generally had stable water levels—previous declines were arrested in four areas and continued in seven areas through the millennium drought. The hydrological state of coastal rivers in the northern half of the South-east Coast division was generally good.

Water use is generally stable, where licensed, across the South Australian Gulf division. Use of groundwater in the northern Adelaide Plains and parts of the south-east is considered to be above sustainable limits, and use of surface water in the Mount Lofty Ranges is above sustainable limits in some areas.

The degree of hydrological modification of surface water and groundwater systems varies greatly across the North-east Coast division. Groundwater levels in the northern and central parts of the division are generally stable; in the southern end, levels have been declining, mainly due to the millennium drought, which ended in 2010. The degree of modification of the hydrological flow regime has a similar north–south gradient.

A basin-wide coordinated approach to bore rehabilitation was proposed as part of the Great Artesian Basin Strategic Management Plan in 2000. This resulted in the development of the Great Artesian Basin Sustainability Initiative (GABSI). Under GABSI, the state and Australian governments and landholders agreed to work cooperatively over a 15-year period, and to invest significant public and private funds to repair uncontrolled artesian bores in the Great Artesian Basin and replace open bore drains with piped water reticulation systems. Pressure is recovering in artesian groundwater systems in many areas across the Great Artesian Basin. Around half of artesian bores monitored showed an increase in pressure; 341 bores in the Queensland portion of the Great Artesian Basin showed increases of pressure of up to 8 metres, and 31 bores have increased pressures of more than 8 metres. These results directly reflect programs to cap free-flowing bores.
## Assessment summary

### State and trends of inland water flows and levels

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf of Carpentaria</td>
<td>Very low levels of development, leaving flow regimes largely intact; information quite sparse</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Indian Ocean</td>
<td>Low levels of development, with mostly local self-supply abstraction or mine de-watering (extraction of water from underground mines); limited and sparse data</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Lake Eyre</td>
<td>Little monitoring data available, but low levels of development of surface and superficial aquifer water resources; natural flow regimes largely intact; progress on recovering pressures in the underlying Great Artesian Basin</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Murray–Darling</td>
<td>High level of development of both groundwater and surface water systems, apart from Paroo and Warrego rivers; drought-breaking floods and recovery of entitlements for the environment are positive</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td>North-east Coast</td>
<td>Low level of development in north; higher levels of development in central and south-east, with associated changes in flow regimes</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>North-western Plateau</td>
<td>Very low level of development, with mostly local self-supply abstraction or mine de-watering; very little (and sparse) data</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>South Australian Gulf</td>
<td>Flow regimes and groundwater levels strongly affected by high levels of development and flow regulation</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>South-east Coast</td>
<td>High levels of development in areas serving Sydney and Melbourne, and in areas east of Melbourne; less change in flow regime due to development in East Gippsland and north New South Wales coast</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>
### Inland Water | State and Trends

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>South-west Coast</td>
<td>Flow regimes greatly affected by high level of development and river regulation, and prolonged drought (changed climate); highly developed groundwater systems have widely lowered watertables beyond the reach of many dependent ecosystems on Swan Coastal Plain</td>
<td>Very poor</td>
<td>Adequate</td>
</tr>
<tr>
<td>South-western Plateau</td>
<td>Very low level of water resource development, with mostly local self-supply abstraction or mine de-watering; very little data</td>
<td>Poor</td>
<td>Limited</td>
</tr>
<tr>
<td>Tasmania</td>
<td>Low level of development relative to water availability; flow regimes changed by regulation of flows associated with hydro-electricity generation in places</td>
<td>Good</td>
<td>Adequate</td>
</tr>
<tr>
<td>Timor Sea</td>
<td>Apart from Ord River and Darwin water supply, very low levels of development, leaving flow regimes largely unchanged</td>
<td>Poor</td>
<td>Limited</td>
</tr>
</tbody>
</table>

**Recent trends**
- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

**Confidence**
- **Adequate high-quality evidence and high level of consensus**
- **Limited evidence or limited consensus**
- **Evidence and consensus too low to make an assessment**

**Grades**
- **Very good**: There are no significant changes in long-term water flows or levels as a result of human activities.
- **Good**: Some flows or levels have changed in some areas, but not to the extent that the changes are significantly affecting ecosystem function.
- **Poor**: Some flows or levels have changed substantially in some areas, to the extent that ecosystem function is significantly affected in some areas.
- **Very poor**: Flows or levels have changed substantially and over a wide area. Ecosystem function is seriously affected.
2.2 Water quality

On a national scale, nutrients and suspended sediment loads are higher than before European settlement in more than 90% of the river lengths assessed, and are substantially modified in at least one-third of the river lengths that were assessed in every drainage division, except Tasmania. A national comparison of water quality against the Australian water quality guidelines for fresh and marine waters and the Queensland water quality guidelines showed exceedences (of the slightly to moderately disturbed protection levels) in turbidity (Figure 4.5), electrical conductivity (salinity) (Figure 4.6), pH (Figure 4.7), total nitrogen (Figure 4.8) and total phosphorus (Figure 4.9) in parts of all drainage divisions. There is a general paucity of monitoring data on groundwater quality, except in places with very localised concerns; the emphasis here is therefore on surface water quality. River and wetland acidification does not appear to be a major national issue, although there are serious local acidification issues in some regions, such as that experienced by parts of the lower Murray River through the drought, and in waters draining salinised lands in the South-west Coast division.

![Compliance map](source: Sinclair Knight Merz)

**Figure 4.5** Compliance with the Australian water quality guidelines for fresh and marine waters and the Queensland water quality guidelines for turbidity, 2000–10

This map includes only sites with 30 or more samples collected over a minimum period of three years.
Poor and very poor ratings for turbidity predominantly occurred in the inland areas of the North-east Coast and Murray–Darling drainage divisions. Possible causes include low rainfall and subsequent low flow; increased extraction; and the impacts of urbanisation, land clearing and agriculture. Turbidity levels throughout the South Australian Gulf, South-east Coast and Tasmania drainage divisions have remained low for the majority of sites, with good compliance across the divisions.

Available data identified exceedence of salinity guidelines predominantly along the eastern margin of the Murray–Darling, south-eastern portion of the North-east Coast, eastern portion of the South Australian Gulf and south-west of the South-west Coast drainage divisions.

Salinity has been a significant issue in the Murray–Darling Basin for a number of years. The upper reaches of parts of the Basin have, in the past, exported much more salt than that which is delivered by rainfall, indicating that land clearing has increased the mobilisation of salts from these catchments. In 2009–10, the Independent Audit Group for Salinity, responsible for annual review of progress on implementing the Basin Salinity Management Strategy, reported that the Basin salinity target had been reached for the first time. Their report attributed this success to delivery of low salinity water from upstream storages down the Murray River and the operation of salt interception schemes to reduce salt inflows from regional watertables.
The report also noted that:

- The long-term drought in the southern Basin has significantly affected the salinity of the region. The low river flows have increased salinity levels in the Lower Lakes and the Coorong, and decisions had to be made to manage the risks salinity posed to critical human water needs and the ecology of the region over the short term.

- The lack of high river flows for 14 years in the Murray River has meant that salt was not exported from the Basin and has most likely built up along the river valleys. Based on previous drought–flood cycles, river salinities following a high river flow may increase significantly.

The majority of sites in Western Australia (Indian Ocean and South-west Coast drainage divisions) rated very poorly for salinity. Elevated salinity in this area is likely to be caused by a number of inherent characteristics, such as naturally occurring saline soils, combined with anthropogenic influences, especially the legacy effects of land clearing.

**Figure 4.7** Compliance with the Australian water quality guidelines for fresh and marine waters and the Queensland water quality guidelines for pH (acidity), 2000–10

This map includes only sites with 30 or more samples collected over a minimum period of three years. The 2001 State of the Environment report flagged river acidification as a potential future problem in some areas of the South-east Coast division.
The greatest contributors to degradation across the Murray–Darling division are disturbance to the catchment and changes to nutrient and suspended sediment loads; most reaches in the central and western part of the division were moderately modified. In contrast, an arc of reaches down the eastern side of the Basin were assessed as substantially modified. This was concluded to be largely the result of poor habitat, and nutrient and suspended sediment load conditions. For those parts of the division in New South Wales, mean daily salinity in streams was lower during 2006–09 than during the previous six years. This may have been due to the millennium drought, which limited the mobilisation of salts into streams. Stream phosphorus was regularly (>50% of the time) above trigger (guideline) values at most sites in the upper and middle reaches of the division’s major inland rivers in New South Wales. Trigger values are used in the Australian water quality guidelines to indicate a possible risk to the environmental value, with action needed to further investigate or fix the cause.

![Map showing compliance with water quality guidelines](image)

**Figure 4.8 Compliance with the Australian water quality guidelines for fresh and marine waters and the Queensland water quality guidelines for total nitrogen, 2000–10**

This map includes only sites with 30 or more samples collected over a minimum period of three years. Regional patterns are exceedingly difficult to interpret, and potentially reflect the applicability of standardised guidelines as much as real concerns over nutrient levels. At this scale, there is little evidence that the levels have changed from those reported in the 2001 State of the Environment assessment.

**Compliance for physical chemical parameters**

- **Good** (>75% of samples complied with guidelines)
- **Fair** (51–75% of samples complied with guidelines)
- **Poor** (25–50% of samples complied with guidelines)
- **Very poor** (<25% of samples complied with guidelines)
- **Drainage divisions**

Source: Sinclair Knight Merz
Within the Australian Capital Territory (ACT), reduced availability of water as a result of the drought, combined with the effects of the 2003 bushfire, led to poor surface water quality for the reporting period; however, the full extent of the water quality problem is unknown. The quality of water in the Murrumbidgee River leaving the ACT frequently failed the acceptable water quality limits. Water entering the ACT at Angle Crossing on the Murrumbidgee River is of a better standard, with minimal failures across the measured water quality parameters.\(^2^9\)

Across the southern section of the South-east Coast division, water quality reflected the degree of modification of the catchment. Improvements in total phosphorus and turbidity were attributed to drought rather than any long-term improvement.\(^1^9\) In the northern part of the division, some sites in the north-west of New South Wales exceeded the trigger values by an order of magnitude, with median total phosphorus levels of 0.5 milligrams per litre compared with a trigger value of 0.05 milligrams per litre.\(^1^9\)

Stream nutrient and turbidity levels in the South Australian Gulf division were generally in fair to poor condition, but stable since the previous SoE reporting period. Groundwater quality was stable throughout most of the division, although nutrient levels remained poor in many regions, and salinity increased in some.\(^2^0\)

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**Figure 4.9** Compliance with the Australian water quality guidelines for fresh and marine waters\(^2^5\) and the Queensland water quality guidelines\(^2^6\) for total phosphorus, 2000–10

This map includes only sites with 30 or more samples collected over a minimum period of three years.

---

**Compliance for physical chemical parameters**

- **Good** (>75% of samples complied with guidelines)
- **Fair** (51–75% of samples complied with guidelines)
- **Poor** (25–50% of samples complied with guidelines)
- **Very poor** (<25% of samples complied with guidelines)

*Source: Sinclair Knight Merz*\(^2^9\)
Box 4.3 Is salinisation still a major problem?

Saline land and water is a natural feature in many parts of Australia, but the changes we have brought about in land and water management caused large-scale increases in the salinisation of land and rivers across much of the continent. In the 2001 State of the Environment (SoE) report for Australia, salinisation of land and water was highlighted as an issue of growing concern—5.7 million hectares of land were identified as showing signs of salinisation, with 17 million hectares predicted to be at risk by 2050. The 2006 SoE report identified salinisation as a major pressure on biodiversity, with particular severity in the southern Murray–Darling, along the south-east coast and in catchments in south-west Western Australia. Through this period, a widespread belief developed that salinisation was among the greatest pressures on our environment, and major national programs (e.g. the National Action Plan for Salinity and Water Quality) were developed to mitigate or reverse these impacts.

In recent years, salinisation of land and water seems to have a lower profile in the national conversation about our environment. It does not appear among the priority outcomes for investment in the 2008–13 Caring for our Country program, and is only referred to in passing as a concern. Does this mean that the threat is diminished?

With the end of national-level support for salinity management, the close, coordinated watch that was kept on the issue and thus our ability to answer that question also ended. However, in regions with previously identified salinity risks, it is widely reported that shallow, saline groundwater levels (one of the fundamental drivers of secondary salinisation) are falling. There seem to be fewer reports of spreading land salinisation.

These changes, if real, are unlikely to be due to the success of the National Action Plan for Salinity and Water Quality or other investments in salinity management, according to an analysis by Pannell and Roberts.30 This program did, however, identify where we can expect to have ongoing salinity issues. Recent changes in salinity are most likely reflecting a changing balance between saline groundwater levels and dilution flows due to the widespread drought across southern Australia. Less rainfall can mean drops in local saline groundwater levels, thus reducing the delivery of salt to soil and streams. On the other hand, reduced river flows can mean local increases in salinisation, as occurred in the Lower Murray Lakes and the Coorong during the drought.

The Murray–Darling Basin Plan is still legislatively required to have a water quality and salinity management plan. There is also a Basin Salinity Management Strategy and an Independent Audit Group for Salinity. Dryland salinity is of greatest extent in the South-west Coast division, but public concern and government or community initiatives to redress the issue have diminished over the past five years.

It will be very important to monitor how the widespread floods in the south-east of Australia in 2010 and 2011 change the salt balances in soil and rivers.

Most surface water quality indicators across the North-east Coast division were assessed as good (or of concern), rather than poor; the proportion of sites in poor condition has decreased considerably since 2003. The reasons for this improvement are not clear. During the past 10 years, nitrogen values frequently exceeded ecosystem protection guidelines in northern aquifers and the sand islands, but did not exceed health guidelines.21

The majority of sampling sites across the Tasmania division (37 of the 52 stream gauging sites; 71%) experienced no exceedences of the upper guideline salinity (electrical conductivity) value of 482 microsiemens per centimetre. Most monitoring sites are at the bottom of the catchment and hence are affected by agricultural activities upstream. The majority of sites had more than 80% of samples above the guideline value for total nitrogen of 0.48 micrograms per litre.17

The 2008 Statewide river water quality assessment for Western Australia31 reported on the status and trends of nine key water quality parameters (total nitrogen, total phosphorus, total suspended solids, total dissolved salts, dissolved organic carbon, dissolved oxygen, pH, turbidity and colour readings) for 255 sites from 23 basins (out of a total of 44) in Western Australia. All basins in the South-west Coast division were represented by at least one site. In general, water quality failed national guidelines for nutrients and salinity in these rivers. Recent monitoring data are relatively lacking for most sites in the Indian Ocean, North-western Plateau and Timor Sea divisions, and virtually no water quality data are available for the South-western Plateau division, where flows are small and highly seasonal.
## 4.2 Assessment summary

### State and trends of water quality

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf of Carpentaria</td>
<td>Limited water quality data available</td>
<td>Very poor</td>
<td></td>
</tr>
<tr>
<td>Indian Ocean</td>
<td>Very little water quality data available</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>Lake Eyre</td>
<td>Very limited water quality data available; potential water quality issues around turbidity and nutrients arising from grazing and feral pests</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>Murray–Darling</td>
<td>Widespread, ongoing and serious issues of sedimentation, anoxia, eutrophication and salinisation</td>
<td>Very good</td>
<td></td>
</tr>
<tr>
<td>North-east Coast</td>
<td>Widespread concerns over water quality in rivers, particularly sediment and nitrogen; evidence of improved outcomes of land-use practices in northern and south-eastern catchments</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>North-western Plateau</td>
<td>Very little water quality data available</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>South Australian Gulf</td>
<td>Ongoing, widespread exceedences of nutrient and suspended solids</td>
<td>Very poor</td>
<td></td>
</tr>
<tr>
<td>South-east Coast</td>
<td>Ongoing, widespread exceedences of nutrient and suspended solids guidelines; little evidence of substantial, long-term improvements</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>South-west Coast</td>
<td>Ongoing exceedences of nutrient and salinity levels</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>South-western Plateau</td>
<td>Very little water quality data available</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
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<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very poor</td>
<td>Poor</td>
</tr>
</tbody>
</table>

**Tasmania**
Nitrogen levels of local concern; salinity generally within guidelines

**Timor Sea**
Very little water quality data except for Ord River and around Darwin; sedimentation issues arising from extensive land uses

**Recent trends**
- Improving
- Stable
- Deteriorating
- Unclear

**Confidence**
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Grades**
- Very good: There are no significant changes in long-term water quality as a result of human activities
- Good: Water quality has changed substantially as a result of human activities in some areas, but not to the extent that the changes are significantly affecting ecosystem function
- Poor: Water quality has changed substantially as a result of human activities, and these changes are significantly affecting ecosystem function in some areas
- Very poor: Water quality has changed substantially across a wide area of the region as a result of human activities, and ecosystem function is seriously affected in much of the region
2.3 Ecological processes and species populations

The health of our inland water systems can be assessed according to the modification of the systems and the state and trends of their ecological processes, including habitat and biodiversity, and of native species populations.

2.3.1 State and trends of ecological processes

Stream and wetland condition monitoring is resource intensive. Most states do not undertake comprehensive monitoring of rivers; very little and limited monitoring is done by some states. Apart from Victoria, there is very little broad-scale monitoring of wetland condition in states and territories. The available national picture of ecological health is particularly fragmented—more so than for other dimensions of our inland water environments.

The stream habitats in more than half the nation’s river length were assessed in 2005 as being modified from pre-European conditions. Degradation of habitat was largely attributed to changes in sediment loads, which alter channel morphology, and to the loss of riparian vegetation (i.e. vegetation on riverbanks). Scores for habitat were lowest in New South Wales, South Australia and Western Australia, largely reflecting the conditions of the Murray–Darling, South-east Coast and South-west Coast drainage divisions, respectively.

Repeated sampling of stream macroinvertebrates at sites across Australia indicates no significant trends in condition at a national scale over the past 15 years (Table 4.4). Most sites (51%) are similar to the reference condition, while 40% of sites are significantly impaired. These results relate to the sites sampled during the 2003–10 assessment period in each state and territory; they do not reflect an even coverage of Australia’s rivers and wetlands, but rather a consistent set of sites monitored over time. Australia is currently developing and testing a more national and comprehensive approach for assessing river and wetland health (Box 4.4).

Of all the drainage divisions, the most widespread concerns are about the ecological state and trend of the Murray–Darling. An assessment in 2001 found that 40% of the river length assessed in the Murray–Darling was impaired, having lost a significant number of aquatic macroinvertebrate species expected to occur there, and 10% of the river length was severely impaired, having lost at least 50% of the aquatic macroinvertebrate species expected to occur. More than 95% of the river length assessed had an environmental condition that was degraded, and 30% was substantially modified from the original condition.

In the Queensland portion of the Murray–Darling drainage division, the condition of rivers and wetlands reported for 2007 was of concern. The majority of the Victorian catchments in the division had less than 30% of their stream length in good condition as reported in 2007, and large areas in the central and western regions had less than 10% in good condition. In the New South Wales portion of the division, 7 of the 25 native freshwater fish species found in lowland rivers were listed as threatened with extinction—almost double the number reported in 2006. Three freshwater invertebrates were listed as endangered species, and the status of many other species was of concern for conservation purposes. Three aquatic ecological communities were listed as endangered under the New South Wales Fisheries Management Act 1994.

The health of rivers, streams and wetlands of the Murray River floodplain in South Australia is declining due to overextraction of water from the river system, increasing

| Table 4.4 Australian River Assessment System (AUSRIVAS) macroinvertebrate assessment at test sites for the 2001, 2006 and 2011 State of the Environment (SoE) reporting periods |
|---|---|---|---|---|---|---|
| Period of assessment | More biologically diverse than reference condition | Similar to reference condition | Significantly impaired | Severely impaired | Extremely impaired | Total |
| 2003–10 (SoE 2011) | 97 (3) | 1795 (51) | 1403 (40) | 213 (6) | 18 (0.5) | 3526 |
| 1990–2004 (SoE 2006) | 195 (4) | 2465 (52) | 1556 (33) | 433 (9) | 56 (1) | 4705 |
| 1994–99 (SoE 2001) | 154 (5) | 1702 (54) | 963 (31) | 254 (8) | 39 (1) | 3112 |

There is no clear trend over time.
Box 4.4 National Framework for the Assessment of River and Wetland Health

Australia has no national-level program for monitoring and reporting on aquatic ecosystem condition. The National Framework for the Assessment of River and Wetland Health (FARWH) was developed in 2005 to provide nationally comparable data on river and wetland health in Australia. It establishes a national monitoring, assessment and reporting system for river and wetland health that will allow comparable assessments within and between jurisdictions for future national reporting. It is based on the premise that ecological integrity is represented by all the major components of the environment that constitute the ecosystem. These components may be reported separately and brought together to provide an overall assessment of river and wetland condition, which is comparable across jurisdictions. The framework has been trialled in six jurisdictions. Assessments of two contrasting catchments in Queensland (the Pioneer and the Burdekin) are compared below (Table A).

The Pioneer is a relatively small, heavily cropped catchment in the wet tropics, with a large dam and numerous weirs. The Burdekin is a very large, mainly grazed catchment in the dry tropics, with only one large dam. These systems differ in both their biogeography (combination of landscape features and species) and in the pressures on their ecosystems arising from water resource development, clearing, land use and pollution. Although the overall scores from the FARWH assessments of these two systems are similar (i.e. in the same ecological condition band), the degree of impairment of indicators differs. For example, the fringing zone, catchment and physical form in the Burdekin seem to be in poorer condition, but the aquatic biota, water quality and soils, and hydrology seem to be in better condition.

Table A Comparison of FARWH assessments for the Pioneer and Burdekin stormwater management authorities for 2008

<table>
<thead>
<tr>
<th>Component</th>
<th>Pioneer</th>
<th>Burdekin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fringing zone</td>
<td>0.61</td>
<td>0.56</td>
</tr>
<tr>
<td>Catchment disturbance</td>
<td>0.62</td>
<td>0.56</td>
</tr>
<tr>
<td>Aquatic biota</td>
<td>0.82</td>
<td>0.89</td>
</tr>
<tr>
<td>Water quality and soils</td>
<td>0.84</td>
<td>0.86</td>
</tr>
<tr>
<td>Hydrological disturbance</td>
<td>0.33</td>
<td>0.48</td>
</tr>
<tr>
<td>Physical form</td>
<td>0.96</td>
<td>0.86</td>
</tr>
<tr>
<td>Overall score</td>
<td>0.63</td>
<td>0.66</td>
</tr>
</tbody>
</table>

These health indicators should help with diagnosing pressures and identifying appropriate management actions. In the case of the Pioneer, this would mean improving the hydrology (i.e. providing more natural flows) through water resource planning and management, improving the fringing zone (riparian) vegetation and reducing catchment disturbance.

A synthesis report on the national set of trial evaluations of FARWH methodology is expected in late 2011 as part of the Waterlines series of publications from the National Water Commission. This approach holds promise for improved national-scale reporting on river and wetland condition in future State of the Environment reports.

Source: Senior et al. [33]

Salt levels, drought and the non-delivery of environmental flows. [20] The health of floodplain vegetation is also declining. Macroinvertebrate communities of the Murray River are stable and typical of a large, permanent, slow-flowing, regulated river. The biodiversity of native fish species is declining as a result of loss of habitat as wetlands dry due to drought and management actions. [20]

Assessments over the period 2004–07 [6] reported on fish, macroinvertebrates and hydrology, which were chosen as criteria for their significance in river ecosystems, their sensitivities to interventions and their linkages to other features of river ecology. The assessments found the following:

- Only the Paroo was in good ecosystem health. The Border Rivers and Condamine were in moderate health. Seven valleys were in poor health, and 13 were in very poor health.
- Native fish populations had declined, particularly in the south. Many native fish species expected to occur in particular valleys were not recorded at all; overall, species were found in only 43% of valley zones where they were predicted to occur under reference conditions. Alien species rivalled or outnumbered native fish in 9 of 23 valleys; 10 alien species contributed 43% of abundance and 68% of biomass. Three alien species (common carp, gambusia and goldfish) were present in all rivers—carp alone were 58% of all fish biomass.
- Most macroinvertebrate communities showed lower diversity than the reference condition.
- One-third of sites fell short of the hydrology reference condition; these were mostly sites in the main channels of the division’s principal rivers.
The report on the reassessment of the Sustainable Rivers Audit for the Murray–Darling division for 2008–10 is anticipated in late 2011. Given that most of the data was collected during a drought, it is unlikely that the above results will have greatly improved.

The decline of ecosystems across the Murray–Darling as a result of diminished water flows has been documented in many areas of ecological science (Figure 4.10). Many of the wetlands of the northern part of the division (some of which are listed under the international Ramsar Convention) are highly degraded. About half of the river red gums (Eucalyptus camaldulensis) and river coobas (Acacia salicina) have died. The northern nature reserve of the Macquarie Marshes lost about three-quarters of the cumbungi (Typha spp.) and water couch (Paspalum distichum) over the 10 years to 2007. Three-quarters of the association between water couch and spike rush (Eleocharis obicis) and more than half of the marsh club-rush (Bolboschoenus spp.) were lost between 1996 and 2005.

Impacts on waterbird and shorebird populations of loss of freshwater habitat due to abstractions and extended drought were evident by 2008. The annual survey of waterbird communities at the Living Murray icon sites in 2008 found a 48% decrease in bird numbers from the previous year. No waterbird breeding was recorded at the Lower Lakes, Coorong and Murray mouth, and only minimal breeding of white ibis and black swans occurred at Chowilla Floodplain and Lindsay–Wallpolla islands. The decline of inland wetlands was identified as a significant contributor to the drastic decline in shorebirds (73% and 81% declines for migratory and resident shorebirds, respectively) over the period 1983–2006.

The floods in late 2010, following years of drought, were beneficial for floodplain forests, wetlands and rivers. The prolonged drought had led to a significant build-up of leaf litter on the floodplains, which in turn led to an extensive blackwater event. Blackwater events are a natural phenomenon associated with the rapid breakdown of accumulated leaf litter on the forest floor, which causes water discolouration. The breakdown of leaf litter plays an important ecological role in delivering nutrients back into the river system, thereby supporting the growth of many aquatic organisms. However, this process can result in very low dissolved oxygen levels, which can be severe enough to cause fish deaths. By mid-December 2010, a blackwater event extended across the Murray River in the Edward and Wakool river system and the Goulburn–Broken, Lower Darling anabranch and Loddon rivers. The Victorian Environment Protection Authority reported the death of hundreds of Murray cod later that month.

In the southern part of the South-east Coast division, less than 30% of stream length was found in good condition; only the catchments in eastern Gippsland had more than half their stream length in good condition. River health did not demonstrably change over the period 1999–2004. The condition of fish populations in coastal rivers in the northern part of the division was generally poor to moderate, while macroinvertebrate communities in most coastal river catchments were in fair to good condition.
River health in the South Australian Gulf division, as indicated by macroinvertebrates, declined due to the effects of the prolonged drought. Wetland areas have been extensively modified, filled and drained since European settlement, and close to 90% of those in south-eastern South Australia have been lost. Along the Fleurieu Peninsula, approximately 30% of wetlands existing before European settlement remain, and just 1% of the original extent of wetlands remains in a pristine condition.20

Queensland lost more than 7000 hectares per year of wetlands from 1997 to 2003, mostly in the North-east Coast division. However, the river condition was good at almost 70% of sites monitored, based on macroinvertebrate communities. Northern regions tend to be in better condition than southern regions, with condition generally good in the wet tropics and the central region, and potentially of concern in south-east Queensland. Approximately 27% of the total length of streambank assessed for riparian vegetation condition was in poor condition (based on sampling in three catchments only). The number of native fish species across catchments remained the same as in 2003, but the number of exotic species increased by one in the Herbert, Mary and Warrego catchments. The major pressures on river condition were identified as changes in land-use and land-management practices, and changes to the natural flow regime. The Stream and Estuary Assessment Program report on the central freshwater biogeographic province of Queensland concluded that the overall river ecosystems in Central Province are in slightly disturbed condition (as measured by the ecological responses); the same study found that riparian condition was moderately disturbed, partly due to habitat removal and partly due to weeds.

Rivers and wetlands of the Gulf of Carpentaria division are in generally good condition.21

In Tasmania, an assessment of the ‘naturalness’ of inland waters of the Tasmania division found 114 175 kilometres (75%) of the state’s river length to be in near natural condition and 24 478 kilometres (16%) to be severely altered from the natural condition. Base levels of stream aquatic health were determined in 2003–04; approximately 49 of the 60 sites (82%) were in good condition (unimpaired), 10 sites (17%) were significantly impaired and 1 site (2%) was severely impaired. There was a small overall change in site condition between 2003–04 and 2005–06.

Assessment of lake naturalness in Tasmania indicated that 580 lakes (43%) are still in a natural or near-natural condition. However, only 6176 hectares (5%) of their total area has not been altered. Up to 110 274 hectares (81%) of the total lake area has been severely altered, and 20 591 hectares (15%) has been significantly altered. The discrepancy between the number and area of lakes altered is related to several large lakes that have been regulated and/or modified for hydro-electricity and/or abstraction.

More than half of Tasmania’s wetlands (12 171 hectares; 59%) and nearly three-quarters of their total area (153 604 hectares; 74%) are still in natural or near-natural condition, 7150 wetlands (35%) and 30 432 hectares (15%) of wetland area have been severely altered, and 1276 wetlands (6%) and 22 754 hectares (11%) of wetland area have been significantly altered.

A number of threatened species were associated with inland waters in Tasmania, including 14 species of freshwater plant, more than 30 riparian plant species and 76 species of freshwater fauna (including 12 native fish and 5 crayfish).

Only about 30% of Western Australia’s major rivers are in good condition, and most of these lie outside the South-west Coast division (Figure 4.11). Thirty-two per cent of major river basins (i.e. 12 of the 38 that are monitored) are in a largely unmodified state; most of these are in the North-western Plateau and Timor Sea divisions. Only 17% of remaining wetlands on the Swan Coastal Plain have high conservation significance, and wetland vegetation is being lost or degraded at the rate of more than 300 hectares per year. Information about the condition of other Western Australian wetlands is extremely limited.

The rivers and catchments of the Lake Eyre Basin are in generally good condition. In particular, the low level of hydrological modification means that critical aquatic ecosystem processes remain intact.41

2.3.2 State and trends of key species populations

The Eastern Australian Waterbird Survey provides the longest and largest scale dataset on wetland extent and waterbird populations. The survey, which began in 1983, covers one-third of Australia on up to 2000 wetlands, using a consistent methodology. Data from the survey were used to evaluate the relationships between water availability and waterbird numbers for the 10 wetlands with highest waterbird numbers, plus the Macquarie Marshes.
Figure 4.11  River basin condition, Western Australia
Across the whole survey area, there was a significant decline in wetland extent over a 27-year period (1983–2010). Consistent decline below the long-term mean occurred after 1999, associated with the millennium drought and long-term effects of river regulation.

Waterbird abundance declined significantly over this period, with numbers dropping below the long-term mean in 1998 and remaining there (Figure 4.12). The number of breeding waterbirds and the number of breeding species also fell significantly. There was a clear relationship between the extent of wetlands and the abundance of waterbirds, demonstrating the importance of wetland areas. The relationship between the status of native species populations and the condition of rivers and wetlands, at a national scale, is not always so clear (Figures 4.13 and 4.14).

**Figure 4.12** Waterbird abundance during annual aerial surveys of waterbirds across eastern Australia, 1983–2010

The graph shows changes relative to the long-term mean (dashed line). Some of the long-term changes are related to effects of river regulation, reducing the frequency and extent of flooding on large wetlands systems. For example, wetland extent over this period peaked in 1984, associated with the peak in waterbird numbers.
Figure 4.13  Number of frog species listed as threatened under the EPBC Act, by drainage division

Frogs are often proposed as a general indicator of ecosystem health. There are approximately 208 species of frog in Australia. The Australian Action Plan for Frogs suggests that pressures on populations include aerial insecticide spraying, drainage of wetlands, the conversion of temporary ponds for stock use and the introduction of mosquito fish (*Gambusia holbrooki*). However, some declines or disappearances cannot be linked with any obvious causes.

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities. 2011
Figure 4.14 Number of freshwater fish species listed as threatened under the EPBC Act, by drainage division

There are approximately 280 species of freshwater fish in Australia.
## 4.3 Assessment summary

### State and trends of inland water ecological processes and key species populations

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulf of Carpentaria</td>
<td>Ecological processes largely intact; populations of native aquatic and riverine species generally healthy</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Indian Ocean</td>
<td>Ecological processes largely intact</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Lake Eyre</td>
<td>Few ecological processes affected, apart from influences of introduced species and access of livestock to river pools</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Murray–Darling</td>
<td>Ecological processes and native fauna populations significantly impaired from reference condition, apart from north-western catchments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North-east Coast</td>
<td>Ecological processes largely intact in north, with limited degradation of ecological condition and healthy native fauna populations; ecological processes of southern region compromised; continuing loss of wetlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North-western Plateau</td>
<td>Limited ecological data available</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>South Australian Gulf</td>
<td>Rivers and wetlands strongly modified; macroinvertebrates in decline; biodiversity of native fish in decline</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South-east Coast</td>
<td>Macroinvertebrates in fair state; fish populations in relatively poorer state</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South-west Coast</td>
<td>Fish populations in decline; macroinvertebrate populations in some high-rainfall areas still in good condition, but seriously affected by low flows and salinity in drier areas</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>
## Inland water | State and trends

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>South-western Plateau</td>
<td>Very little ecological data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tasmania</td>
<td>Most rivers and almost half of lakes and wetlands in relatively natural state; however, a number of fish species threatened</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timor Sea</td>
<td>Ecological processes largely intact, with limited degradation of ecological condition outside Ord catchment; populations of native aquatic and riverine species largely healthy</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Recent trends
- **Improving**: Adequate high-quality evidence and high level of consensus
- **Stable**: Limited evidence or limited consensus
- **Deteriorating**: Evidence and consensus too low to make an assessment

### Grades
- **Very good**: There is no evidence of significant change in ecological processes; few if any populations of species have declined
- **Good**: Some ecological processes have changed in some areas, but not to the extent that the changes are significantly affecting ecosystem function; populations of a number of species have declined significantly
- **Poor**: Ecological processes have changed substantially in some areas to the extent that ecosystem function is significantly affected in some parts of the region; populations of many species have declined significantly
- **Very poor**: Ecological processes have changed substantially over a wide area; ecosystem function is seriously affected in much of the region; populations of a large number of species have declined significantly
Pressures affecting inland water environments

A range of pressures on our inland water environments arise from the drivers identified in Chapter 2 of this report (population and economic growth, and climate change). Impacts from pressures include global changes, such as reduced rainfall as a result of changes in climate and recent droughts; more regional impacts, such as the abstraction of water and changes in flow from water resource development; changes to drainage patterns and pollution from land use; changed land management, including fire regimes and forest practices; damage to riparian areas; and impacts on native ecosystems from invasive animals and plants.

3.1 Recent climate

Assessing the state of inland water environments in 2011 is difficult, due to the effects of recent droughts. Long, dry periods are a natural feature of the continent. We have seen the millennium drought that south-eastern Australia experienced between late 2000 and 2010, as well as the much longer drying period in south-western Australia from 1975 to the present. The Bureau of Meteorology has summarised the modern history of major droughts since the late 19th century.43

To what degree can we attribute the changes in inland water environments to the ‘natural’ process of drought, and to what degree are recent droughts themselves ‘natural’?

There is no absolute answer to the first question. There are, however, reasons that a river or wetland might be made more vulnerable to a drought than it would naturally have been before European settlement. In ‘regulated’ river systems (like the Murray–Darling Basin, the Ord River or the Onkaparinga River), where dams and other control structures are managed to provide long-term water security, the rules of operation often do not favour maintaining environmental flows over water security during times of water scarcity. This was highlighted in the CSIRO Sustainable Yields assessment of the Murray–Darling Basin; under current arrangements, although allocations drop in times of drought, environmental flows drop relatively more in all valleys except the Gwydir.

Even unregulated inland systems may be made more vulnerable to drought through the cumulative impacts of other stresses on the system—such as sedimentation, eutrophication (excessive nutrients in a body of water), pests, weeds and the removal of streamside vegetation—and damage to the connectivity of river and wetland systems, which might otherwise provide regional refuges for aquatic species during dry times.
The other question of drought versus human-induced climate change is considered in Chapter 3: Atmosphere. The possible effects of emerging pressures resulting from climate change are discussed in Section 6 of this chapter.

3.1.1 The drought in south-eastern Australia, 2000–10

By late 2000, it was clear that much of south-eastern Australia was in drought. In early 2008, the Bureau of Meteorology stated that the drought that was devastating south-eastern Australia was ‘very severe and without historical precedent’, with rainfall totals at record lows in many regions, including many critical to the Murray River. At that point in the drought, rainfall figures were similar to the severe drought that lasted from 1939 to 1945, and the Federation drought, which ran from 1895 to 1903, although average daily temperatures were higher by about 1 °C.

The drought eventually broke, dramatically, with widespread flooding in the Murray–Darling, southern Victoria and south-east Queensland by late 2010; 2010 was Australia’s wettest year since 2000 (690 millimetres of rainfall compared with the long-term average of 450 millimetres; Figure 4.15). Exemplifying how fast the water resource situation turned around, in late December 2009, total water in storage in the Murray–Darling was at 26.1% of capacity (6575 gigalitres); at the same time a year later, it was at 80.8% (20 358 gigalitres).

CSIRO concluded that the drought in at least the northern part of the affected region (south-east Queensland) was probably associated with decadal variability rather than climate change. However, further south, there is evidence that observed changes in the large-scale circulation affecting south-eastern Australia are associated with global warming, which is therefore likely to have contributed to the drought.

3.1.2 The drought in south-western Australia, 1975–present

Rainfall in the south-west has been ‘stepping down’ since 1975, deepening into major short-term meteorological droughts in 2001, 2002, 2004,
2006 and 2010. CSIRO has concluded that at least half the observed decrease in regional rainfall is due to anthropogenic forcing of the atmosphere (human-induced climate change).46

Despite Australia having its wettest spring on record in 2010, this rainfall again missed the south-west corner of the continent, and much of the region had the lowest annual rainfalls on record (Figure 4.16). In late December 2010, flooding rains had reached the Gascoyne and northern Murchison catchments, but the drought was unrelieved for the rest of the region south of Geraldton. Inflow to the surface water supply catchments for 2010 was less than 10 gigalitres, compared with the annual average inflow before 1975 of more than 338 gigalitres (Figure 4.17).
3.2 Water resource development

The pressure on the natural environment from human needs is clearly seen in the need for water. The Water Services Association of Australia report card 2009–2010 predicted residential water demand in the capital cities, based on population projections by the Australian Bureau of Statistics and projected per capita consumption. Relative to actual consumption in 2009, the estimates across all capital cities ranged from increases of 39–49% in 2026 to 64–107% in 2056. In response to both widespread drought and projected increases in demand, Australia invested $8.1 billion in capital expenditure by water utilities in 2008–09, compared with $4.5 billion in the previous year.

From 2006 to the present, several major water resource developments taking fresh water out of the environment were considered by governments around Australia, with some proceeding and some being rejected due to environmental concerns:

- In 2007, the Western Australian Government rejected the Water Corporation’s application to annually extract 45 gigalitres of groundwater from the south-west Yarragadee Aquifer, because of concerns about the potential impact on agriculture and biodiversity.

- A proposed dam on the Mary River at Traveston Crossing that would have added 70 gigalitres of supply for south-east Queensland was rejected by the Australian Government in 2009 on the basis of unacceptable impacts on the environment, including threatened species such as the Mary River turtle and the Australian lungfish.
• The Sugarloaf Pipeline was completed in 2010, connecting Melbourne’s water supply system with the Goulburn River system to deliver 75 gigalitres of water each year. This water resource was expected to result from improvements in irrigation system efficiencies of some 225 gigalitres per year, to be shared with the environment in northern Victoria (within the Murray–Darling Basin). In November 2010, the Victorian Government announced that the water resource would only be used to bring water to Melbourne during critical water shortages, due to concerns about potential impacts on regional development (including agriculture).

• A new dam wall is under construction to increase the capacity of the Cotter Reservoir, near the headwaters of the Murrumbidgee River, from 4 gigalitres to 78 gigalitres. This option to increase Canberra’s water supply was considered to have relatively minimal impact because the dam wall will be constructed in an area already affected by the existing reservoir, on land that was badly affected by the 2003 fires and previous forestry plantations.

• Tasmania is advancing plans for expanding irrigation across 13 schemes, totalling some 190 gigalitres of new water supplies, with a commitment to proceed only if the proposal is proven to be economically and environmentally sound.

• Queensland has completed the 30-gigalitre Wyaralong Dam on Teviot Brook, about 90 kilometres south-west of Brisbane, which began filling in December 2010. Before Wyaralong, the last major dam built in Australia was the Paradise Dam in central Queensland in 2005. Wyaralong is the region’s fifth largest dam and is connected to south-east Queensland’s new water grid. The grid, an interconnected network of dams, water recycling plants and the Tugun Desalination Plant, is capable of supplying 58 megalitres per day to residents.

Queensland has also introduced the Wild Rivers Act 2005. The Act aims to preserve a river that has all, or almost all, of its natural values intact by regulating development activities that have the potential to impact on the river’s natural values. As at June 2010, nine rivers had wild river declarations: the Archer, Fraser, Gregory, Hinchinbrook, Lockhart, Morning Inlet, Settlement, Staaten and Stewart rivers. The Wenlock Basin also had a declaration, and the Cooper Creek Basin was under proposal. A declaration sets out caps on resources (including water) that can be taken in the declared wild river area, rules or limits that must be complied with when undertaking new development activities (such as quarrying, agriculture and mining) and development assessment codes that must be applied. Both agricultural and Indigenous interests, wanting further access to water for productive uses, expressed strong opposition to this program.

As part of its 50-year vision to meet water demand in the Perth region, the Water Corporation of Western Australia established Australia’s first groundwater replenishment trial for drinking water using treated wastewater at its Advanced Water Recycling Plant in November 2010. The trial recycles wastewater to drinking water standards, and can treat up to 0.5 megalitres per day before recharging it deep into the groundwater below. The current plant has the capacity to recycle 1.5 gigalitres per year; however, if a full scheme were to proceed, as much as 25–35 gigalitres per year (about 10% of current water demand) could be recycled from the Beenyup Wastewater Treatment Plant alone.

In Victoria, construction started in October 2009 on an upgrade of the Altona Treatment Plant to purify wastewater from the plant and pipe it to nearby industrial manufacturing sites, sporting clubs and councils. The plant was commissioned in April 2011 and will produce 2.5 gigalitres of class A recycled water per year, reducing the amount of wastewater discharged from the Altona Treatment Plant into Port Phillip Bay.

Most Australians live in metropolitan areas, and 2005–10 saw major transformations in how the water industry will meet future metropolitan demand. This was in response to drought, climate uncertainty, climate change, population increase and a new understanding of the need to provide water flows to the environment. The most salient features were moves towards demand management (reducing per capita water consumption) and ‘manufactured’ sources of water, such as seawater desalination and recycling, to complement historical sources of fresh water taken out of the environment. For instance, in 2004–05, Australia desalinated 231 megalitres of sea water; by 2008–09, this had grown to 33 270 megalitres. Desalination plants were commissioned in Sydney and at Tugun in south-east Queensland in 2010; others are under construction in Melbourne (completion 2011), Perth (completion 2011) and Adelaide (completion by 2013) (Table 4.5).

‘Water security through diversity’ has become the new dominant water management paradigm for our cities.
### Table 4.5 Planned and constructed desalination plants since 2005

Built capacity is 35% of capital city water consumption in 2008–09; the ability to increase capacity inherent in these plants is 49% of capital city water consumption in 2008–09.

<table>
<thead>
<tr>
<th>Area</th>
<th>Location</th>
<th>Capacity (ML/year)</th>
<th>Ability to increase capacity (ML/year)</th>
<th>Completion date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>Kurnell</td>
<td>90 000</td>
<td>180 000</td>
<td>Completed</td>
</tr>
<tr>
<td>Melbourne</td>
<td>Wonthaggi</td>
<td>150 000</td>
<td>Up to 200 000</td>
<td>2011</td>
</tr>
<tr>
<td>South-east Queensland</td>
<td>Tugun</td>
<td>49 000</td>
<td></td>
<td>Completed</td>
</tr>
<tr>
<td>Perth</td>
<td>Kwinana</td>
<td>45 000</td>
<td></td>
<td>Completed</td>
</tr>
<tr>
<td></td>
<td>Binningup</td>
<td>50 000</td>
<td>100 000</td>
<td>2011</td>
</tr>
<tr>
<td>Adelaide</td>
<td>Port Stanvac</td>
<td>100 000</td>
<td></td>
<td>December 2012</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>484 000</strong></td>
<td><strong>674 000</strong></td>
<td></td>
</tr>
</tbody>
</table>

ML = megalitre
Source: Water Services Association of Australia

#### 3.3 Changing land use and management

There is a strong consensus among Australian jurisdictions that:

- Point sources of pollution are no longer significantly affecting the Australian environment; discharges of this type of pollution are tightly regulated, licensed and monitored.
- Current and future diffuse pollution to catchments often results from historical land clearing and land-use changes; these legacy issues, which affect water quality and flow regimes, are difficult and expensive to reverse.

Large-scale land clearing for agriculture has been largely curtailed in Australia, but the legacy of sedimentation, nutrient enrichment and salinisation of rivers is ongoing. Although the millennium drought slowed some of these degrading processes in places, it is likely that subsequent flooding will bring these issues back to the forefront of environmental concerns.

Bushfires are a natural and common feature of the Australian environment. When extensive and intense, and in our higher rainfall areas (such as the fires in Victorian catchments in 2003 and 2009), they can have serious short-term impacts on water quality and very long-term impacts on water supplies. Following the 2003 bushfires, which burned 1 million hectares of Victorian high country, studies showed that the maximum reduction in water yield (at about 25–30 years after the fires) was 692 gigalitres for the Murray River and 155 gigalitres for the Gippsland Lakes. Analyses estimated that, one year after the fires, the Ovens, Kiewa, Hume and Snowy catchments would deliver approximately 30 times more total suspended solids, 5 times more total nitrogen, and 8 times more total phosphorus than before the fires. Following the bushfires of January 2009 (which affected catchments of five of Melbourne’s nine major dams), Melbourne Water had to shift some 10 gigalitres of supplies out of storages made vulnerable to contamination from ash and debris. The effects of bushfires on water quality, and the measures that can be taken before, during and after bushfires to minimise these impacts, have been recently and comprehensively reviewed.

Land drainage and clearing for urban expansion place obvious pressures and, in some cases, irrevocable impacts on local wetlands and rivers. For example, the Southern River catchment is one of the fastest developing areas of Perth, but development is impeded by shallow groundwater and multiple wetlands of high conservation value. It is likely that future alterations in land use may significantly affect the current water balance. As inundation and shallow watertables are incompatible with urban infrastructure, it is expected that the urban development will include watertable control measures. Consequently, development is likely to increase the export of nutrients to the Canning River and Swan River estuary. These urbanisation effects have been closely modelled to support urban design that will minimise such impacts.

![Russell Falls, Tasmania](Photo by Nick Rains)
3.4 Pests and invasive species

At least 80 introduced animal species have established populations on the Australian continent. Assessing invasive animals in 2008\textsuperscript{11} stated that invasive animal species are one of the top three greatest threats to threatened species and ecosystems—mainly by competing for, or destroying, habitat and food resources—and that they continue to colonise new areas. Some of these species were initially established in past centuries and continue to expand their ranges (e.g. the cane toad spreading into Western Australia in February 2009; Figure 4.18), but new threats have also emerged, such as red-eared slider turtles and tilapia. Carp were found to occur in 11.5% of Australian rivers. In addition to carp and cane toads, feral pigs were identified as nationally significant invasive animals by the Australian Vertebrate Pests Committee, due to their impact on inland river systems (especially wetlands).

Predicted final distribution of *Bufo marinus*

Present distribution of *Bufo marinus*

Source: Reid Tingley, University of Sydney, unpublished data; Kearney et al.\textsuperscript{26}

**Figure 4.18** Current and predicted distribution of the cane toad (*Bufo marinus*)

In February 2009, cane toads expanded into the Kimberley region of Western Australia. Predictions of the cane toad’s future range were based on long-term monthly averages of daily maximum and minimum air temperature, wind speed, cloud cover and relative humidity, rainfall totals and a solar radiation model, which were used to drive mechanistic models of microclimatic conditions and their physiological consequences for cane toad activity, development, survival and reproduction.
Southern Australia and New Zealand, considered together, represent one of six major invasion ‘hot spots’, where non-native freshwater fish species represent more than one-quarter of the total number of fish species in river systems, and where the proportion of native fish species that have a high risk of extinction in the wild is the highest. In New South Wales, three alien species—common carp, gambusia and goldfish—are present in all inland rivers. Redfin perch, brown trout and rainbow trout are also widespread. Carp are overwhelmingly dominant (Figure 4.19), making up 87% of alien fish biomass and 58% of total fish biomass. Carp and gambusia were the dominant species in all lowland rivers in the Murray–Darling Basin.

Source: National Land & Water Resources Audit

**Figure 4.19** Distribution of common carp (*Cyprinus carpio*)
The climate of most of southern and central Australia is considered highly suitable for carp.
Australia has about 30,000 species of legally imported plants; of these, about 2700 species have become naturalised. About 300 species are declared weeds,\(^5\) which alter the natural environment and subsequently destroy habitat for native species. Of the Weeds of National Significance,\(^3\) nine invasive plant species are of particular concern to inland water ecosystems (Figure 4.20):

- alligator weed (*Alternanthera philoxeroides*)
- cabomba (*Cabomba caroliniana*)
- salvinia (*Salvinia molesta*)—see Figure 4.21
- hymenachne (*Hymenachne amplexicaulis*)
- mimosa (*Mimosa pigra*)
- pond apple (*Annona glabra*)
- willow (*Salix spp.*)
- blackberry (*Rubus fruticosus*)
- athel pine (*Tamarix aphylla*).

Alligator weed, cabomba, salvinia and hymenachne are all aquatic weeds.

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**Figure 4.20** Number of the nine weed species of national significance found in each river basin, which are of particular concern to inland water ecosystems
Salvinia is a floating aquatic weed that can cover entire water surfaces with a thick mat of vegetation, shading submerged plant life and impeding oxygen exchange, making the water unsuitable for fish and other animals. The national response to this introduced weed shows what can be accomplished with an effective control option (in this case developed by CSIRO using a natural biological agent—*Cyrtobagous salviniae*), and national strategy and commitment. Nevertheless, complete eradication has not yet been possible.
### 4.4 Assessment summary

## Pressures affecting inland water environments

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressures resulting from climate variability and climate change</td>
<td>Widespread and unprecedented drought across southern Australia over the past decade or more has greatly affected inland water ecosystem condition. Flooding since 2009 has broken the drought in the south-east of the continent, but the drought continued (as of early 2011) in the south-west. There is substantial scientific evidence of a component of change towards a drier climate across southern Australia and a warmer climate nationally. Drier landscapes have the potential for increased rates of sedimentation due to decreased vegetative cover, exacerbated by the potential for more frequent and intense storms.</td>
<td>Low impact</td>
<td>Very high impact</td>
</tr>
<tr>
<td>Water resource development</td>
<td>Historical allocations of surface water and groundwater have changed the ecological character of many river and wetland systems across southern Australia; development pressures are generally much less in the northern half of the continent. Recovery of water for increased environmental flows in the Murray–Darling and Snowy basins has reduced this pressure on some inland water ecosystems. Most new water for Australian metropolitan areas will come from resources other than development of new inland resources—sources will include reuse and seawater desalination, improving run-off and recharge into existing infrastructures, and trading with existing users.</td>
<td>Low impact</td>
<td>Low impact</td>
</tr>
<tr>
<td>Land use and management</td>
<td>For most of Australia, historical land clearing for dryland agriculture and locally intensive agricultural land uses continue to place river systems under pressure from nutrient run-off, sedimentation and salinisation. The growth of the peri-urban fringe around major metropolitan areas places great pressure on local waterways and can involve the irreversible drainage of local wetlands. Riparian degradation by livestock and feral pests is an ongoing impact.</td>
<td>Low impact</td>
<td>Very low impact</td>
</tr>
</tbody>
</table>
### Pests and invasive species

Vertebrate pests continue to impact most inland water systems across the continent, through grazing-related impacts, direct ecological competition or as a hazard to native predators (as in the case of cane toads). Waterway and floodplain weed infestations are widespread but of variable local impact.

<table>
<thead>
<tr>
<th>Recent trends</th>
<th>Grades</th>
<th>Confidence</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving</td>
<td>Very low impact</td>
<td>Adequate high-quality evidence and high level of consensus</td>
<td>There are few or negligible impacts, and predictions indicate that future impacts on the environmental values of regions are likely to be negligible.</td>
</tr>
<tr>
<td>Deteriorating</td>
<td>Low impact</td>
<td>Limited evidence or limited consensus</td>
<td>There are minor impacts in some areas, and predictions indicate that future impacts on the environmental values of regions are likely to occur, although they will be localised.</td>
</tr>
<tr>
<td></td>
<td>High impact</td>
<td>Evidence and consensus too low to make an assessment</td>
<td>The current and predicted environmental impacts are significantly affecting the values of regions, and predictions indicate serious environment degradation within 50 years.</td>
</tr>
<tr>
<td></td>
<td>Very high impact</td>
<td>Stable</td>
<td>The current and predicted environmental impacts are widespread, irreversibly affecting the values of regions, and predictions indicate widespread and serious environment degradation across the region within 10 years.</td>
</tr>
<tr>
<td></td>
<td>Stable</td>
<td>Unclear</td>
<td></td>
</tr>
</tbody>
</table>

In grade | In trend
---|---
Very high | High impact
High impact | Low impact
Low impact | Very low impact
Very low impact |

Confidence

- **Adequate high-quality evidence and high level of consensus**: There are few or negligible impacts, and predictions indicate that future impacts on the environmental values of regions are likely to be negligible.
- **Limited evidence or limited consensus**: There are minor impacts in some areas, and predictions indicate that future impacts on the environmental values of regions are likely to occur, although they will be localised.
- **Evidence and consensus too low to make an assessment**: The current and predicted environmental impacts are significantly affecting the values of regions, and predictions indicate serious environment degradation within 50 years.
Effectiveness of inland water management

Australia is not alone in trying to meet the simultaneous challenges of protecting inland water environmental quality and providing water for human needs. Vörösmarty et al. assessed the stressors posing risks to water security and river biodiversity at a global scale. The higher rainfall areas of southern and eastern Australia, and the northern part of Australia, had high and low risks to biodiversity, respectively. However, Australia is the only continent without serious risks to water security, at least from the point of view of meeting essential human needs. In part, this is because we have the means to meet metropolitan water demand (even in a drying climate) through relatively expensive water supply technologies such as seawater desalination.

4.1 Water management in Australia

The Australian constitution gives the Australian Government no express legislative power over water—management of water is vested in the states and territories. By 2006, all jurisdictions had agreed to the provisions and objectives of the National Water Initiative (NWI). The state and territory governments determine access to water resources through water plans and the issuing of entitlements, now under an agreed NWI framework that is intended to deliver:

- secure ecological outcomes, by describing the environmental and other public benefit outcomes from water systems and defining the appropriate water management arrangements to achieve those outcomes.
- Resource security outcomes, by determining the shares in the consumptive pool and the rules to allocate water during the life of the plan.

For the most part, ‘water for the environment’ is secured by the rules set out in a water plan that in some way limits how much water can be diverted into the consumptive pool (allocated for human use). In a few highly hydrologically stressed systems like the Murray–Darling Basin, additional water for the environment has been sourced from within the pool of water entitlements (Box 4.5).

In addition, the NWI has set out guidelines for a more efficient and effective water market in Australia. The National Water Market System project will help improve water market operations, such that price signals reflect the scarcity of water in Australia. As a result, water should flow to the highest value economic, social and environmental uses.

Although Australian research has documented the ecological consequences of diminished flows of water, the challenge remains of quantitatively relating changes in flow regime (or the benefits of increased environmental flows) to the expected ecological response. Flow recommendations still mainly rely on expert ecological opinion, based on incomplete ecosystem models or limited data. The growing assertion and development of Indigenous land and water management, and associated recognition of traditional environmental knowledge, is significant in this regard (Box 4.6).
One of the NWI's aims is to ensure that the flows and levels of water deliver positive environmental outcomes. Since 1992, Australia has also been developing a national approach to improve water quality in our inland waterways under the National Water Quality Management Strategy (NWQMS). The goal is to achieve sustainable use of the nation’s water resources by protecting and improving their quality, while maintaining social and economic development.

The NWQMS provides guidelines for water quality policies and benchmarks, including fresh and marine water quality, drinking water quality, water quality monitoring and reporting, groundwater protection, rural land use and water quality, urban stormwater management, sewage effluent management, industrial waste management, agricultural waste management and water recycling.

Water quality improvement plans are a significant vehicle for implementing the NWQMS guidelines. These plans seek to significantly reduce the discharge of pollutants by setting water quality objectives and target loads for pollutants of concern, and through catchment-based management, including control of diffuse and point sources of pollution.

4.2 Recent national assessments of management performance

The National Water Commission reviewed the environmental water management arrangements around Australia at 30 June 2010. The aim was to establish a consolidated and agreed baseline to improve national environmental water reporting and management. Key findings included the following:

- Environmental water management is a complex task that has developed in response to vastly different water resources around the country and a range of historical demands on those resources.
- Although the determination of environmental water requirements and the commitment of such water flows are improving, the detail, frequency and geographic coverage of monitoring, reporting and review of environmental water use and outcomes vary around Australia.
- Water plans are becoming clearer with regard to their environmental objectives. However, it is difficult to review the effectiveness of environmental water commitments because monitoring of outcomes is not widespread or consistent due to cost. As well, the timeframes involved in detecting ecological responses and changes in condition are longer than for annual reporting.
Water management is old business for Indigenous people, and offers new ways of thinking for water planning. The 2009 assessment of the National Water Initiative found that it is ‘rare’ for Indigenous water requirements to be explicitly included in water plans, and most jurisdictions are not yet effectively engaging Indigenous people in water planning processes. A similar conclusion was reached at the 2010 National Indigenous Land and Sea Management Conference. In 2010, the National Water Commission appointed seven members to the First Peoples’ Water Engagement Council—a new group formed to provide advice on national water issues relating to the National Water Initiative and biennial assessments, including engagement in planning processes, the allocation of cultural flows in water plans, Indigenous access to the consumptive pool for economic development and appropriate entitlement regimes to meet Indigenous needs.

Regionally, there have been significant developments in Indigenous land and water management. The North Australian Indigenous Land and Sea Management Alliance supports practical Indigenous management by traditional owners across northern Australia; this includes significant research and natural resource management projects, in a broad alliance of groups and communities involved with Indigenous management of land and sea on their country. In August 2009, the alliance convened about 80 Indigenous water experts from across northern Australia on the banks of the Mary River to discuss their water interests and issues. This resulted in the Mary River Statement on the seriousness of Indigenous peoples’ contribution and participation in policy decision-making:

As traditional owners we have an inherent right to make decisions about cultural and natural resource management in Northern Australia. In accordance with Article 19 of the United Nations Declaration on the Rights of Indigenous Peoples we must have a central role in the development, implementation and evaluation of policy and legislative or administrative measures that may affect us concerning water.

The Murray Lower Darling Rivers Indigenous Nations (MLDRIN) is a confederation of Indigenous nations or traditional owners in the southern part of the Murray–Darling Basin, formed in 1998 during the historic Yorta Yorta native title case. MLDRIN advocates the participation of 10 Indigenous nations in decisions on natural resource and water management. MLDRIN has a partnership project under the Living Murray initiative to ensure that its advice and knowledge contribute to the management of significant ecological assets, with culturally appropriate outcomes.

The Northern Basin Aboriginal Nations was established in 2009 in Moree. It is a confederation of 21 Indigenous nations in the northern part of the Murray–Darling Basin. Like MLDRIN, it advocates for the right of Indigenous people to be part of water markets and natural resource management decisions within the Murray–Darling Basin. Its key objective is to encourage scientific research towards the quantification of a cultural flow. Volume 1 of the recent guide to the Murray–Darling Basin Plan states that both the MLDRIN and the Northern Basin Aboriginal Nations have developed their definition of cultural flows as:

Water entitlements that are legally and beneficially owned by the Aboriginal nations and are of a sufficient and adequate quantity and quality to improve the spiritual, cultural, environmental, social and economic conditions of those Aboriginal nations; this is our inherent right.

The South West Aboriginal Land and Sea Council is the native title representative body of the Noongar people, traditional owners of south-west Western Australia. The council has active programs of cultural and environmental audits with traditional owners to improve land and water management strategies.

The 2011 biennial assessment is the National Water Commission’s third assessment of progress in the implementation of the NWI. The biennial assessment is the most comprehensive source of information for assessing the quality and robustness of Australia’s water policies and management, and therefore the degree to which we mitigate the likelihood and consequence of pressures on our inland water environment. Key findings with respect to inland water environmental management included the following:

- All jurisdictions have environmental water management and institutional arrangements in place. However, approaches to implementation vary considerably, and the past few years have seen a large increase in water recovery activities outside water plans.
• Transparency and accountability have increased, but reporting remains patchy and does not always clearly link environmental outcomes to environmental management actions.

• Failure to provide the same level of security of water for the environment as for other consumptive water access entitlements is a threat to the integrity of NWI water management structures. This is likely to inhibit the ability of environmental water holders to use water trade to improve environmental outcomes.

• In each state and territory other than Western Australia and the Northern Territory, legislation has been enacted that enables delivery of NWI-compliant water plans. All jurisdictions have made significant progress in establishing or revising plans for the management of water resources. However, no jurisdiction has fully implemented NWI-consistent planning except for the Australian Capital Territory, which has only one plan.

• Currently, there is no national strategic and coordinated approach to the planning and funding of science to support water planning and management. As a result, we still lack the level of scientific understanding and predictive capability that is required to guide sustainable water management. In 2008, the Council of Australian Governments agreed to develop a National Water Knowledge and Research Plan to establish priority water research and knowledge themes, ensure coordinated research effort and ensure the best possible returns from new knowledge investments. Extensive consultation on the draft plan is currently taking place.

• A central requirement of water reform—to return all currently overallocated or overused systems to environmentally sustainable levels of extraction—will not be met in the timeframes envisaged under the NWI, although significant progress has been made and further investment and initiatives are under way.

An additional finding by the biennial assessment is an increased recognition of the cultural values of water resources and the importance of the engagement of Indigenous Australians in water management. While most jurisdictions have established consultative mechanisms intended to engage Indigenous people in water planning, many water plans do not consider Indigenous cultural values and economic development, leaving the cultural and economic expectations of Indigenous Australians as an unmet demand on the water system.

A review of the implementation of the NWQMS across Australia (and New Zealand) found that:

• the NWQMS framework has provided a good, consistent process for water quality management, which has been incorporated into jurisdictions’ legislation and policies and then used as a basis for catchment management plans

• most water quality management issues have been covered by NWQMS guidelines

• point sources of pollution are well managed

• water quality benchmark guidelines provide sound technical underpinning for management plans

• the NWQMS has reacted to emerging issues associated with water quality, such as water recycling and water-sensitive urban design

• there is now a good range of water quality management plans for rivers and coastal catchments

• there is a need to link water quality management with water reform assessments under the NWI.

The Organisation for Economic Co-operation and Development (OECD) assessed Australia’s environmental performance since 1998 in 2008. The report recognised that Australia’s economy has grown faster than the OECD average, and our environmental policy response has also strengthened over a similar period. This includes stronger environmental impact assessment of major development proposals, improved and expanded load-based licensing of pollution discharges, and effective voluntary and partnership approaches with industry and communities. However, the OECD concluded that the capacity of environmental agencies is insufficient to meet all of their responsibilities, including inspection, assessment and enforcement of compliance. With respect to water resource management, the OECD concluded that:

• the NWI, backed by significant government investment, represents real progress towards reform, including setting environmental flow regimes and largely curtailling widespread land clearing

• catchment management bodies successfully integrate land and water management (however, the National Water Commission’s biennial assessment in 2011 recommends that greater coordination of water management and natural resource management initiatives would yield significant gains, for example by better aligning the development, implementation and review of water plans and catchment plans)
salinity in the Murray River is being held in check

important challenges remain, including climate change mitigation and adaptation, weeds and invasive species, overallocation of water resources (e.g. Box 4.7), blue–green algae blooms, and the pollution of nearshore coastal waters—many of these reflect the legacy of historical land and water management.

In the past decade, programs to ensure river and estuary health in metropolitan areas of Australia (e.g. Hobart and Brisbane) have set inspirational benchmarks for effective and efficient use of evidence to guide investment, management and policy; and to communicate the condition, trend and potential futures of these systems (see Box 4.8). Key features of these programs include:

- a stable organisational platform for monitoring, modelling and reporting
- the ability to incorporate innovations in monitoring and modelling, and to provide robust, auditable results, including forecasts and scenarios
- effective reporting and communication with the community, industry and government
- stable and effective partnerships among local government, state government, industry, nongovernment organisations and research providers, all working towards an agreed strategy.

Progress against the Aquatic Weeds of National Significance strategic plans in 2003–08 was reviewed by the National Aquatic Weeds Management Group. Control, eradication and research were found to be well coordinated, with targeted efforts and protocols appropriate to each of the three aquatic weeds now in place. In the Lake Eyre basin, athel pine (Tamarix aphylla) has been brought under control along approximately 420 kilometres of the Finke River. Follow-up treatment and monitoring continue in the upper Finke River system. Control work has also begun on infestations in the Mount Isa area that threaten the Georgina River. Research is in progress on the potential for native biocontrol to assist with long-term management of this weed.

No introduced animal species that has become widespread has ever been eradicated in Australia, even with serious and long-term efforts. Such an objective is unrealistic with current technology. The highest priority of the Australian Pest Animal Strategy for protecting ecosystems is preventing further introductions or spread; setting priorities for, and investment in, the management of established pest animals should be informed by a risk management approach.

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**Box 4.7 Restoring the Snowy River**

The construction of the Snowy Mountains Scheme between 1955 and 1967 severely altered flows in the Snowy River. In the years following completion of the scheme, less than 1% of mean annual natural flow was recorded in the river at Jindabyne, and 4% of mean annual natural flow at Dalgety. This radical change in flow regime has had significant effects on stream and streamside ecology.

To improve river health, water was released to the Snowy River via the Mowamba River in 2002–06, and from Jindabyne Dam in 2006–10; during this period, an average of 131 megalitres per day was recorded in the Snowy River at Dalgety, compared with 41 megalitres per day before the program of ecological flow releases.

An additional 24.2 gigalitres of water was made available to the Snowy River during 2010–11 through a joint commitment of environmental water made by the New South Wales and Victorian governments and funded by the Australian Government. This allowed the largest environmental flow delivered to the Snowy River since the completion of Jindabyne Dam in 1967 to be made during November 2010. Approximately 17 gigalitres were released over 10 days, to mimic the annual flushing flows from snow melt experienced in the river prior to development of the Snowy Scheme. It is anticipated that up to 21% of mean annual natural flow at Jindabyne will eventually be released to the Snowy River.
Box 4.8 South East Queensland Healthy Waterways Partnership

The South East Queensland Healthy Waterways Partnership is a collaboration between state and local government, industry, research organisations and community groups. It aims to improve the management of catchments and the health of the waterways in south-east Queensland, using sound science, rigorous monitoring and adaptive learning. The partnership’s vision is that, by 2026, waterways and catchments will be healthy ecosystems supporting the livelihoods and lifestyles of people in south-east Queensland.

The strategy contains more than 500 actions to maintain and improve the health of the waterways of south-east Queensland through reductions in urban and nonurban diffuse source pollution, protecting and conserving waterways with high ecological value, and decreasing point-source pollution. Local governments in recent years have invested $300 million on sewage treatment plant upgrades alone.

The Ecosystem Health Monitoring Program, which is managed by the partnership, is one of the most comprehensive environmental monitoring programs in Australia. It delivers a regional assessment of ambient ecosystem health for each of south-east Queensland’s 19 major catchments, 18 river estuaries, and Moreton Bay, highlighting where the health of waterways is getting better or worse.

4.3 Reviews of state and regional management

The State of the environment report: Western Australia 2007 noted that 33 actions were identified for inland waters in response to the 1998 report. Of these, 18 were incomplete, 12 were complete but had not been evaluated, and only three were both complete and evaluated. Progress with, and evaluation of, actions were complicated by a gradual decline in monitoring, reduced funding for rehabilitation projects, and other perceived priorities for water resource management agencies. Improved monitoring and evaluation of inland waters is urgently required.

The New South Wales state of the catchments reports for 2010 assessed the capacity of natural resource managers to contribute to regionally relevant natural resource management for each of the state’s major catchments. Most assessments showed room for improvement in effectiveness.

The Victorian Catchment condition report 2007 roughly estimated an investment of $305 million in natural resource management projects over the previous five years. However, condition and impact analysis indicated that investment in responses is not keeping pace with the scale of degradation occurring across the state. The framework set out in Securing Our Water Future Together (the Victorian Government’s 2004 white paper), which has been further developed though regional sustainable water strategies, emphasises water-use efficiencies and legal recognition of the amount of water set aside to provide environmental benefits to water-dependent ecosystems.

Where river or groundwater systems are overcommitted with respect to environmental requirements, programs such as the Murray–Darling Basin Plan and Water for the Future are intended to restore the balance between consumptive use and environmental health. The Australian Government purchased 426 gigalitres of water entitlements for additional water for the environment in 2008–09, and an additional 415 gigalitres in 2009–10. This was part of the $3.1-billion commitment over 10 years to buy water in the Murray–Darling Basin for environmental purposes. A significantly larger volume of water was allocated against these entitlements in 2009–10 than in 2008–09, increasing the opportunity for environmental watering; 154 gigalitres were delivered to wetlands and floodplains in the Murray, Murrumbidgee and Macquarie catchments; the Lowbidgee Floodplain and Lake Albert; the Warrego, Moonie, Darling and Ovens rivers; and Nebine Creek. Some recovery of vegetation as a result of these flows has already been observed.

In assessing the effectiveness of management, it is also useful to look at how management is dealing with the identified pressures on the inland water environment.
## Effectiveness of inland water management

### Water resource development

**Understanding:** There is reasonable accounting of water resources across jurisdictions, and this is improving through water information initiatives with the Bureau of Meteorology. There is an improving picture of where overallocation is occurring, but with limited quantification of environmental flow requirements.

**Planning:** Although progress towards the objectives of the NWI has been somewhat limited, there is strong evidence that the principles are increasingly reflected in water resource planning and decisions. Water resource planning is not yet meeting NWI targets, and consultations with key stakeholders are uneven. The commissioning of regional studies of sustainable yield in advance of potential developments in northern Australia and Tasmania is positive. In fast-expanding urban areas, consideration and integration of innovations in urban water management are still poor.

**Inputs:** Large financial resources have been made available for recovery of water for the environment, particularly in the Murray–Darling Basin. Resources available for community-based water management and monitoring have decreased.

**Processes:** Ongoing commitment to restoring environmental flows in previously overallocated systems is substantial.

**Outputs and outcomes:** Recent decisions on proposed developments of new water resources reflect increasingly effective consideration of NWI principles, but the full objective of the NWI will not be met on the agreed timetable. The final outcomes of the Murray–Darling Basin Plan will be a crucial and difficult test of these principles and commitment.

### Land-use and water quality management

**Understanding:** There is a reasonable understanding of the types and sources of pollution and their environmental impacts. Most of these impacts are the legacy of historical land-use change and planning.

**Planning:** There is relatively poor national coordination of programs to improve water quality, and poor integration with the management of environmental flows and abstraction.

**Inputs:** The present level and approach to investment in improving catchment-scale water quality do not generally match requirements to meet water quality guidelines. Fewer resources are available to redress water quality issues than for the parallel issue of environmental flows.
SUMMARY ASSESSMENT GRADE

<table>
<thead>
<tr>
<th>Ineffective</th>
<th>Partially effective</th>
<th>Effective</th>
<th>Very effective</th>
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<tbody>
<tr>
<td>In grade</td>
<td>In trend</td>
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Land-use and water quality management continued

**Processes:** National community-based programs to improve catchment health have diminished since the previous State of the Environment report, without any substantial and effective alternative in place at a national scale.

**Outputs and outcomes:** Australia has achieved good control over point-source pollution. There are few local examples of programs to control diffuse pollution delivering significantly improved water quality outcomes at the catchment scale.

Adaptation to climate variability and change

**Understanding:** The potential implications are broadly and reasonably well understood; climate forecasts are becoming more confident in direction (e.g. warmer and drier in south) but still have significant uncertainties in the magnitude and timing of change.

**Planning:** Source and supply planning for metropolitan water utilities is now based on best available climate science and reflects movement towards sources that do not depend on climate. Water resource planning increasingly takes into account climate projections, but many water resource plans are structured in ways that maintain the security of water entitlements over environmental flows.

**Inputs:** Support for good science to underpin adaptation is being maintained or increased. The full cost and scale of adapting water policy and management to this challenge are, however, still uncertain.

**Processes:** Jurisdictions are effectively incorporating climate forecasts into water supply planning.

**Outputs and outcomes:** Water policy and management are largely staying abreast of the climate challenge as it unfolds, with most metropolitan water suppliers now anticipating a greater fraction of demand being met by sources that are not sensitive to climate and by demand management.

Continued next page
Effectiveness of inland water management

### Summary

<table>
<thead>
<tr>
<th>Understanding:</th>
<th>Planning:</th>
<th>Inputs:</th>
<th>Processes:</th>
<th>Outputs and outcomes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is good national and regional awareness of threats from weeds and pests, including potential new invasive species.</td>
<td>Planning for managing and monitoring significant threats is good and nationally coordinated.</td>
<td>The potential costs of effective control on such a large scale are enormous. With present technology, resourcing will never be sufficient to eradicate threats.</td>
<td>There is excellent national coordination and a strong commitment to effective biosecurity across jurisdictions.</td>
<td>There has been some local success in limiting or eliminating some invasive weeds.</td>
</tr>
</tbody>
</table>

### Assessment grade

<table>
<thead>
<tr>
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<th>Partially effective</th>
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<th>Very effective</th>
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### Confidence

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### Recent trends

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<th>Stable</th>
<th>Deteriorating</th>
<th>Unclear</th>
<th>Confidence</th>
</tr>
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</table>

**NWI = National Water Initiative**
Resilience of inland water environments

It is beyond the scope of this report to meaningfully assess the general resilience (resilience to a range of potential disturbances) of Australia’s inland water environments. Many of the pressures on these systems result from historical actions (e.g. land clearing, water resource development) that have left a long-term legacy of ongoing pressure and impact. Some systems have been affected by certain pressures for many decades, and yet still retain a significant degree of their original environmental character.

With respect to specific resilience (resilience to certain disturbances) to changes in flow regimes, water quality and invasive species, much conceptual material has been written about Australia’s inland water systems. However, very little empirical scientific work directly and clearly connects the ecological response of a severely impacted river or wetland to the restoration of flows or improvement in water quality. In recent years, opportunities to correct this knowledge gap have been limited by drought, the short period over which initially small releases of environmental water have been happening, and the lack of sufficient monitoring of response to these releases. There is a general absence of long-term, careful, detailed observations of rivers or wetlands following restored watering regimes or pollution remediation, making robust statements and attributions of response difficult.

Programs have now begun that use a suite of on-ground and remotely sensed techniques to monitor trends in riparian and groundwater-dependent ecosystems over time; it is hoped that more comprehensive statements will be possible in future about the ability of our water ecosystems to recover from disturbances, or to simply withstand pressures.

The best available example of an evaluation of restoration and resilience with respect to flow regimes is a study of the Yanga National Park floodplain along the Murrumbidgee River. Researchers set out to determine how long a floodplain can retain its ecological character between flood events. They concluded that, even after nine years of drought and substantial red gum mortality, tree genetics had not shifted. Aquatic macrophytes regenerated after nine dry years following flooding. The microflora, meioflora and bacteria (which represent most of the biodiversity and ecological function) were found to be highly resistant to drought. The researchers concluded that floodplain communities are resilient to drought and that, if there is a major ‘tipping point’, it must be more than nine years of drought. Floodplains consist of a huge number of species (mostly inconspicuous) that collectively perform fundamental nutrient cycling and can withstand both inundation and extended periods of drought. Thus, floodplains are naturally highly changeable, dynamic and resilient to flow regime change.

Long-term recovery from secondary (dryland) salinisation of streams has few examples. The salinisation of Mundaring Weir east of Perth due to forest clearing in the early decades of the 20th century was reversed through complete reforestation. Similarly, high levels of highly targeted reforestation with commercial eucalypt plantations in the upper Denmark River catchment in Western Australia appear to have reversed salinity trends in that river system. Recovery from land salinisation may not be possible at all in places where soil structure has been lost.
The impact of invasive species is well documented, but in most cases the specific pathways and mechanisms for impact or ecosystem resilience to these invasions are poorly understood. An exception to this is our study and understanding of the consequences of cane toad spread. Early research identified the specific mechanism of ecosystem impact (the potentially lethal ingestion of toxin by predators) and extrapolated from initial impacts on predator populations to severe and irreversible consequences on ecosystems (i.e. extinctions). Subsequent research has discovered a variable response, even within the same predator species, from place to place—some affected populations recover within a few decades following invasion of cane toads, due to aversion learning and longer term adaptive changes. Other predator species that were considered at risk have not been affected, either due to a tolerance to the toxin or to a natural or learned aversion. Some native predator populations have declined because of cane toads; some native species populations have increased; for others, the impacts have been minor. No native species have become extinct as a result of cane toad invasion. This realisation that ecosystems may be more resilient to an ostensibly catastrophic specific pressure than we initially thought only emerged as a result of careful, long-term monitoring and ecological analysis.

The widespread floods of 2010 in drought-affected areas offer a tremendous opportunity to observe the response of extremely drought-stressed inland water systems, as do the releases of environmental flows in the Murray–Darling Basin and the Snowy River.
Risks to inland water environments

It is important to separate the legacy of ongoing impacts on our inland water systems associated with historical land and water management decisions from risks posed by future pressures. Chief among these future risks are climate change, further development of freshwater resources, and future changes in land use, including those that give rise to additional pollution. In Section 3 of this chapter, we considered the current risks to the inland water environment from these pressures. In this section, we will look at the projected impacts into the future of unmitigated pressures.

6.1 Climate change

The best available projections for Australia’s future climate are presented in Chapter 2 of this report. These projections indicate that warming of the continent is highly likely. Rainfall projections are less certain, but the ensemble results of the global climate models and emissions scenarios in the fourth assessment report of the Intergovernmental Panel on Climate Change suggest that the southern part of the continent is likely to be drier than the past. The whole continent is expected to warm.

CSIRO projected the likely future yields of surface water and groundwater systems for large and important regions of Australia, based on the same climate scenarios (see Box 4.2). These analyses characterised the impacts of water diversions on flow regimes under the historical climate, and the likely future impacts on flow regimes under conditions of planned developments and future climate. The key findings, by region, are outlined below.

6.1.1 Murray–Darling division

- The impacts of climate change by 2030 are uncertain; however, surface water availability across the entire division is more likely to decline than to increase (Figure 4.22). A decline in the south is more likely than in the north. In the south, a very substantial decline is possible. In the north, significant increases are possible. The median decline among climate projections for the entire division is 11% (9% in the north of the Murray–Darling Basin and 13% in the south).

• The median water availability decline would reduce total surface water use by 4% under current water-sharing arrangements. It would reduce flow at the Murray mouth by 24%, to be 30% of the total pre-development outflow. In volumetric terms, most of the impact of climate change would be borne by the environment rather than by consumptive water users.

• The relative impact of climate change on surface water use would be much greater in dry years. Under the median 2030 climate, diversions in driest years would fall by more than 10% in most New South Wales regions, around 20% in the Murrumbidgee and Murray regions, and from around 35% to more than 50% in the Victorian regions. Under the dry extreme 2030 climate, diversions in driest years would fall by more than 20% in the Condamine–Balonne, around 40–50% in New South Wales regions (except the Lachlan), more than 70% in the Murray, and 80–90% in the major Victorian regions.
Figure 4.22 Current and likely future surface water availability across the 18 regions of the Murray–Darling Basin

Grey bars indicate the uncertainty inherent in the climate change projections for 2030. The current total surface water resource across the 18 regions is 23,417 gigalitres per year on average; under the median 2030 climate projections, this reduces to 20,936 gigalitres per year, with a range of 26,047–15,524 gigalitres per year.

6.1.2 Northern Australia (Timor Sea and Gulf of Carpentaria divisions, and the northern part of the North-east Coast division)

- Climate modelling indicates that future rainfall will be similar to historical averages. Evapotranspiration (transfer of water to the atmosphere from evaporation and plant transpiration) may be slightly higher.

6.1.3 Tasmania division

- Under the median modelled future climate, rainfall would increase by 1% under the wet extreme and decrease by 3% and 7% under the median and dry extremes, respectively. Run-off would increase by 1% under the wet extreme and decrease by 5% and 10% under the median and dry extremes, respectively.
- Climate change between now and 2030 is expected to have only a very minor impact on groundwater levels.
- About 1–2% of the area’s subcatchments and 6–15 of the 150 key ecological sites would potentially be impacted under future climate and current levels of development.
6.1.4 South-west Coast division

- The appropriate historical climate baseline for future projections is the period 1975–2007 because a climate shift occurred in the region in the mid-1970s—rainfalls after this time have been 10–15% lower than the long-term mean going back to 1900 (associated with a 50% decrease in run-off into local supply dams). The post-1975 rainfall is currently used by Western Australian water managers and suppliers for planning.

- Almost all combinations of global climate models and emission scenarios indicate at least some reduction in rainfall for the area by 2030. However, current models account for only about half of the drying experienced in the region since 1975, and water yield projections may therefore be conservative.

- Future mean annual surface water yields in the region are likely to be 24% lower, on average, by 2030 (with a possible range of 4–49%), compared with 1975–2007.

- Groundwater demonstrates greater resilience to climate change where watertables are now within a few metres of the surface. As these watertables fall, evaporative and drainage losses are reduced, which results in increased net recharge. Groundwater yields are projected to fall significantly under areas of native vegetation. Yields would decrease by a third to a half in places such as the Gnangara Mound, which provides Perth with most of its drinking water. Groundwater levels are expected to continue to rise under dryland agriculture, which covers more than 56% of the Perth Basin. Future groundwater yields in the region are likely to be 2% lower, on average, by 2030, with a range of +2% to –7%. Many groundwater-dependent ecosystems have already been severely impacted by the drying climate since 1975.

- The environmental impacts are most significant for ecological river functions that require high river flows, and where falling groundwater levels affect wetlands that are dependent on groundwater levels being at or above the land surface.

There have been equivalent studies of the water supply catchments of Sydney, Melbourne and Adelaide, based on similar climate modelling inputs and local hydrological modelling. These form crucial inputs into metropolitan supply planning for those regions.

6.2 Water abstraction

The commitment of all states and territories to the National Water Initiative (NWI) placed clear and limiting criteria on the abstraction of additional fresh water from the environment. Under these criteria, it is recognised that water resources across southern Australia are already either fully committed or overcommitted. On the basis of current planning, Australia’s major metropolitan areas will meet future urban demand through a combination of water conservation and new sources, based on either sea water or recycled water. The Sustainable development panel report concluded that a larger future population (and an increasing ‘footprint’ of cities extending out into the surrounding regions) means increased water prices and less water for the environment. Based on a review of current metropolitan water planning, the former is highly likely but the latter will not necessarily occur. However, meeting increased demand without taking more fresh water from the environment almost certainly will mean increased energy inputs to our water supply (e.g. for water recycling).

Groundwater currently represents 16% of total water use in the Murray–Darling Basin. Under current water-sharing arrangements, groundwater use could increase by 2030 to be more than a quarter of total water use. A quarter of current groundwater use will eventually be sourced directly from induced streamflow leakage, which is equivalent to about 4% of current surface water diversions. Current groundwater use is unsustainable in 7 of the 20 high-use groundwater areas in the Murray–Darling Basin and will lead to major falls in groundwater levels in the absence of management intervention.

Across northern Australia, rainfall and run-off are highly variable and decrease away from the northern coast. This pattern of run-off, combined with the generally low relief of much of the coastal area, provides little opportunity for significant increases in surface water storages. Potential new dam sites are mainly in the upper reaches of catchments, where rainfall is lower and more sporadic, and potential evapotranspiration is higher. Large storages are needed to compensate for evaporative losses, and storage volumes need to be much larger than in southern Australia, all things being equal. There are few large-scale opportunities to increase surface water storage that satisfy all these requirements. On the basis of changes to flow regimes only, existing plans by jurisdictions to increase water use will have little impact on water resources at the region scale in the next two decades.
Under the future projected climate of Tasmania, of the 24 proposed irrigation schemes considered, 10 can be supplied with their full demand for water in all years. Another 5 can be supplied with their full demand for water in more than 80% of years, 4 can be supplied with their full demand in 50–80% of years, and the remaining 5 can be supplied with their full demand in less than 50% of years. Future development of groundwater to extractions of 25% of recharge in the Mella, Togari, Wesley Vale and Scottsdale groundwater assessment areas is expected to have only localised impacts on groundwater levels and streams in irrigated parts of these areas. Between 2% and 4% of the area’s subcatchments and between 12 and 15 of the 150 key ecological sites are potentially impacted under the likely future climate and levels of development.16

In the south-west of Western Australia, significant gaps between water yields and demands are expected by about 2020 in the areas where surface water resources are used for irrigation. Significant gaps between groundwater yields and demands are expected by about 2020 for areas around Perth. The Water Corporation’s Water Forever strategic plan74 is designed to meet the challenge to provide water in an even warmer and drier climate, for twice as many people, and with less environmental impact. For the purposes of this plan, a climate scenario that projects a 20% decline in rainfall by 2030 from the 1990 baseline was adopted. A rainfall reduction of this magnitude is estimated to reduce yields from existing dams and groundwater sources to about 165 gigalitres per year, from average yields of 260 gigalitres per year since 2001. Further, the scenario considers a 40% decline in average annual rainfall by 2060 from the 1990 baseline, to less than 500 millimetres per year. This would further reduce yields from existing dams and groundwater sources, to an estimated 55 gigalitres per year. At these levels, dams would cease to be a reliable part of Perth’s water supply (in 2010, there was almost no usable run-off into Perth’s dams). Water Forever provides a portfolio of options to manage Perth’s demand and supply balance to 2060 by reducing water use by 25%, increasing wastewater recycling to 60% and developing new sources.

Many of Australia’s recent water resource decisions reflect the commitment to the principles of the NWI. An optimistic assessment of future risks from water resource development relies on continuing adherence to these principles through times of high development pressure and pressing needs to recover water for the environment.

6.3 Land use and management, including pollutants and nutrients

Less than 1% of northern Australia (the drainage divisions between Broome and Cairns) is cleared or intensively used. Not only has widespread land clearing greatly decreased in Australia, but the re-establishment of woody vegetation for a variety of purposes continues. The increasing demand for wood and the increasing attractiveness of tree planting for carbon offsets can bring benefits to catchment health, but can also lead to decreases in catchment yield from higher rainfall areas. In the Murray–Darling Basin, expansion of commercial forestry plantations is expected to occur; projections indicate only very minor impacts of these developments on the total run-off reaching rivers, although local streamflow impacts may be significant.75 In Tasmania, the area of commercial plantation forest is currently about 15 000 square kilometres. Under future development, this is expected to increase by about 730 square kilometres (5%), which would lead to a decrease in run-off of 0.3%. However, in the Mersey–Forth region, where the area of commercial forest is expected to increase by 16%, decreases in run-off are likely to be up to 1.5%. The increase in commercial forest area is expected to reduce inflows to rivers by 138, 148 and 159 gigalitres per year (around 0.7%) under the wet extreme, median and dry extreme future climates, respectively. It may also have a small impact on inflows to, and outflows from, hydro-electric power stations (mostly concentrated in the Mersey–Forth region).

With the loss of streamflows in the South-west Coast division, a trial has begun in the Wungong catchment to see whether catchment thinning in the jarrah forest can increase water yields while reducing the likelihood of forest collapse due to climate change and improving streamflow for in-stream fauna.15 Thinning using increased fuel reduction burns in banksia woodland on the Gnangara Mound has also been investigated as a means of increasing recharge and groundwater levels that support through-flow wetlands. The increases in recharge are modest and may not justify the increase in risk to species that are sensitive to fire.
Australia has had only very limited success in the local control of animal pests that threaten inland water ecosystems, with no complete eradications from the continent. There has been more success in controlling local populations of weeds, but eradication is again elusive and depends on early identification of infestations and prompt action. It is difficult to foresee any significant reduction in the risks to water ecosystems from pest and weed species with current technologies.

The emerging developments of coal-seam gas resources in Queensland and New South Wales involve the extraction of water from coal seams. The discharge and management of this (often saline) water presents an immediate issue for land and water environmental health. In the longer term, reduced regional groundwater levels have the potential to result in diminished streamflows. Given that Australia has little experience with large-scale development of these resources, uncertainty surrounding the potential environmental impacts and their effective mitigation hampers both community confidence and environment approvals. Coal-seam gas already supplies a significant fraction of the natural gas market of eastern Australia and most of the Queensland market. Agreements are in place for exports of more than 3.6 million tonnes of liquid natural gas per year, worth more than $60 billion over the next 20 years. In June 2010, Queensland established a Coal Seam Gas Water Management Policy to ensure salt resulting from developments does not contaminate the environment.
## Assessment summary

### Current and emerging risks to inland water environments

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<tr>
<th>Catastrophic</th>
<th>Major</th>
<th>Moderate</th>
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<th>Insignificant</th>
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<td>Almost certain</td>
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<td><strong>Warming climate and/or increased water extractions leading to changed flow regime or groundwater level</strong></td>
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<td><strong>Urbanisation leading to loss of wetland habitat</strong></td>
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<td><strong>Agricultural run-off leading to nutrient pollution and sedimentation of rivers</strong></td>
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<td><strong>Minor chemical pollution event</strong></td>
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<td><strong>River or aquifer salinisation due to historical land clearance</strong></td>
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<td><strong>Changed fire frequency or intensity</strong></td>
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<td><strong>Salinisation or contamination of rivers due to development of underground mineral and energy resources</strong></td>
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<td><strong>Warming climate increasing aquatic habitat temperatures</strong></td>
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<td><strong>Blue–green algae outbreak</strong></td>
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<td><strong>Livestock damage to riparian areas</strong></td>
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<td>Possible</td>
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<td><strong>Extreme weather events under a drying climate leading to sedimentation of rivers</strong></td>
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<td><strong>Major chemical pollution event</strong></td>
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<td><strong>Disease outbreak</strong></td>
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Not considered
Outlook for inland water environments

Australia can potentially meet the projected growth in population and maintain its overall prosperity while improving the protection of inland water environments and, in places, reversing historical and detrimental flow regime changes. This will require that we continue to progress towards full realisation of the principles in the NWI, and that metropolitan water strategies continue to emphasise an increasing mix of demand management, water recycling and desalination to meet future needs. A major uncertainty in this outlook is the complex hydrological consequences of a changing climate. A second serious uncertainty is the degree to which river, wetland and floodplain environments will recover after an unprecedented drought followed by extensive floods in south-eastern Australia. These are two key points to take into account for future specification and protection of environmental flows.

Australia’s history of land clearing and extensive land-use practices have left us with a challenging legacy of ongoing impacts on our water quality. Redressing these impacts is not a prominent feature of the NWI, and there is uneven commitment across jurisdictions to reduce diffuse pollution and salinisation. There is little evidence that water quality is generally further deteriorating, but, with some notable local exceptions, relatively low levels of investment are being made to improve water quality.

Australia is good at identifying and monitoring the spread of weeds and pests affecting inland water environments, but has had only limited success in controlling their spread and impact. It is not clear whether further investment of resources in tackling these issues with current strategies and tools would improve control.

Many of Australia’s inland water environments are in a degraded condition. Nutrient levels exceed guidelines in all metropolitan and agricultural regions, and ecological processes have been altered across most parts of the continent. However, some areas of northern and central Australia and Tasmania largely retain their original character despite widespread pressures from pests and weeds and changed fire regimes. Water ecosystems supporting many of our irrigation areas and near our cities are likely to remain under significant pressure, and maintaining or improving their ecological condition remains a serious national challenge. This is particularly true for two regions: the Murray–Darling Basin, where the need to rebalance use and environmental flows is widely recognised but difficult; and the south-west of the country, where the remaining inland water ecosystems are generally in poor condition as a result of salinisation, agricultural run-off, water diversions and an unbroken 36-year drought.
References


Newman, Western Australia
Photo by Christian Fletcher
Key findings

Our land use is changing in response to new priorities and new pressures.

Major trends in land use and management during the reporting period are the expansion of the area managed for conservation and by Indigenous Australians—each of which now accounts for more than 20% of Australia’s land area—and a reduction in agricultural production during the recent extended drought in southern Australia.

The rate of land clearing, one of the most significant pressures affecting the land environment, averaged around 1 million hectares annually over the decade to 2010.

Land clearing and ecosystem fragmentation are associated with the expansion of both agriculture and settlements, and are concentrated in a relatively small number of regions, some of which are coastal. By the end of the decade, the continental extent of land clearing was balanced by the extent of regrowth—although the character and values of the original and regrowth vegetation are often different.

Widespread landscape-scale pressures, particularly those due to invasive species and inappropriate fire regimes, continue to threaten environmental values across much of Australia’s land environment.

The level of environmental impact from grazing—Australia’s most widespread land use—appears to be mixed, with diminished impacts in some regions but increased impacts in others. Invasive species, fire regimes and grazing are having a significant impact on much of our land environment.

Soil processes, including acidification, erosion and loss of soil carbon, will increasingly affect Australia’s agriculture unless they are carefully managed.

Acidification and erosion currently affect significant areas of land, although wind erosion has decreased in response to more effective land cover. Soil carbon is central to maintaining soil health and can also be a significant source or sink (depending on land management) for greenhouse gases.

Climate change is expected to bring about profound changes in the Australian land environment, particularly native vegetation and production systems.

Our understanding of the probable impacts of climate change on Australia’s land environment deepened substantially during the reporting period. Some native vegetation communities are likely to disappear completely; the extent and distribution of others are likely to change significantly; and novel ecosystems are expected to arise. These changes will affect other environmental and production values.
Management effectiveness of the land environment varies.

The effectiveness of our management of the land environment varies with land use and the nature of the pressures on the environment. The nature of widespread, landscape-scale pressures and resource constraints often make it difficult to manage more extensive land uses and pressures as effectively as we would wish. A notable exception during the past decade is the large and widespread reduction in tillage intensity across the cropping lands of Australia.

Governance and institutional arrangements for management of the land environment need improvement, and levels of investment are inadequate.

Governance and institutional arrangements have changed significantly during the reporting period, and are not yet optimal in a number of important respects. Although substantial, the levels of investment in management of the land environment—and in the research, development, knowledge and information systems that underpin management—remain inadequate for soundly based adaptive management.

There is a serious capacity gap in the professional and technical human resources necessary for effective land management, including both a growing shortage of qualified people and a lack of relevant skills and experience among the next generation of land managers.

This gap is already becoming evident in agriculture, forestry and related specialisations. It will increase, and its consequences will become more acute as we face the challenges to land environmental values and production systems associated with climate change.

The outlook for Australia’s land environment is mixed.

We have much of the knowledge and experience required to manage our land environment better, and have been doing so in many respects. However, the trends in many indicators of land environmental values are negative, and are likely to be exacerbated by climate change. Realising a more positive outlook for Australia’s land environment will require renewed resolve, effort and investment.
Contents

1 Introduction
1.1 Soil 267
1.2 Vegetation 268
1.3 In this chapter 268

2 State and trends of the land environment 270
2.1 Land use and management 270
2.1.1 Land-use trends 273
2.2 Soil 274
2.2.1 Baseline 275
2.2.2 A framework for understanding soil 275
2.2.3 Key indicators of soil condition 277
2.2.4 Carbon dynamics 277
Assessment summary 5.1—state and trends of soil carbon 282
2.2.5 Soil acidification 287
Assessment summary 5.2—state and trends of soil acidification 290
2.2.6 Soil erosion 294
Assessment summary 5.3—state and trends of soil erosion by water and wind 302
2.3 Vegetation 305
2.3.1 Native vegetation 305
2.3.2 Non-native vegetation 312
Assessment summary 5.4—state and trends of vegetation 315

3 Pressures affecting the land environment 317
3.1 Climate change–induced pressures 318
3.1.1 Native vegetation 318
3.1.2 Diseases, pests and weeds 318
3.1.3 Agricultural and forestry production systems 318
Assessment summary 5.5—continental-scale pressures affecting the land environment 321
3.2 Regional and landscape-scale pressures 322
3.2.1 Bushfire 322
3.2.2 Land clearing 323
3.2.3 Invasive species 327
Assessment summary 5.6—regional and landscape-scale pressures affecting the land environment 330
3.3 Land uses 331
3.3.1 Grazing 331
3.3.2 Nature conservation reserves, other protected areas, ‘minimal use’ land and Indigenous land 334
3.3.3 Agriculture 334
3.3.4 Production forestry 335
3.3.5 Urban and rural residential use 336
3.3.6 Mining 336
3.3.7 Waste disposal and contamination 337
Assessment summary 5.7—contemporary land-use pressures on the land environment 338
Effectiveness of land management 340

4.1 Management context 340
4.2 Resources and capacity for management 341
4.3 Knowledge and institutional arrangements 342
  4.3.1 Institutional arrangements for environmental information 343
  4.3.2 Market failure 343
  4.3.3 The changing nature of mapping, monitoring and forecasting 345
  4.3.4 Reform and integration 345
4.4 Human capital 346
  Assessment summary 5.8—effectiveness of land management 348

Resilience of the land environment 355

5.1 Landscape and soil 355
5.2 Vegetation 356

Risks to the land environment 359

- Assessment summary 5.9—current and emerging risks to the land environment 360

Outlook for the land environment 362

References 364
With the first day light this morn the Land was seen ...

Joseph Banks, 
The Endeavour journal of Joseph Banks, 
August 1768 – July 1771

Dairy cows, Queensland
Photo by John Dick
Introduction

The land—and the social, economic and ecological values it provides—is fundamental to Australian identity and purpose. Our predominantly harsh and nutrient-poor landscapes have shaped life for hundreds of generations of Australians. These generations have in turn dramatically changed the land.

Australians use land in many different ways. Livestock grazing and management for nature conservation are the two land uses of greatest extent, together accounting for nearly 90% of Australia’s land area. We also use our land for agriculture, forestry, urban and residential development, mining, waste disposal and infrastructure. The land provides our food, fibre and minerals, and much else that we consume. It also generates the ecosystem services on which human, animal and plant life depend—clean air, biodiversity and fresh water. The state of our land matters for all Australians.

1.1 Soil

Our soils, landforms and vegetation have co-evolved over millions of years. Their health and condition are inextricably linked. Soil health has a strong influence on the growth and condition of all types of vegetation. Conversely, changes to vegetation caused by fire, clearing, grazing or harvesting affect the condition of our soils.

The soil system performs many functions. It:

- produces biomass
- stores and filters water
- stores and cycles nutrients
- is a large carbon store
- hosts biodiversity
- provides raw materials (e.g. clay, sand, gravel)
- stores our geological, palaeontological and archaeological heritage.

Soil is essentially a nonrenewable resource, because it forms and regenerates very slowly, but can degrade rapidly. Some types of degradation, such as nutrient exhaustion, can be corrected, but this correction may be very costly. However, other forms of degradation, such as soil erosion, are difficult to remedy. Prevention is the key.

Soil is effectively privately owned across much of Australia. However, the influence of healthy soils on the environment as a whole—such as improving water quality, protecting biodiversity and mitigating excess greenhouse gases (GHGs)—means that soil is also a large public good.
Most of Australia’s soils are ancient, strongly weathered and infertile. Some areas have younger and more fertile soils; these mainly occur in the east. Australian soils have many distinctive features. Surface layers have low levels of organic matter, and are often poorly structured, a condition made worse by historical agricultural practices. Soils affected by salt—either now or in earlier geological times—cover large portions of the arable lands of our continent. We also have large areas of cracking clays, which are relatively fertile but have physical limitations that reduce agricultural options and affect key infrastructure. These constraints and their interactions with climate have made it difficult to develop sustainable systems of land use.

1.2 Vegetation

Like the soil that supports it, vegetation is fundamental to ecosystem processes and human survival. Vegetation is vital for:

- producing oxygen for animal and human life
- maintaining air quality by trapping particulates such as dust and pollutants
- biodiversity, both through plants themselves and through the habitat that vegetation provides for other species
- regulating the climate, from the continental scale down to the micro scale
- ecosystem processes, such as producing energy through photosynthesis
- hydrological processes involving surface water and groundwater, such as maintaining the porosity of soils and their capacity to retain water
- maintaining soil integrity and stability, including through protection from water and wind erosion
- producing food, fibre, medicines and shelter.

Australia’s vegetation includes both native and introduced plant species. Our native vegetation is globally unique: 85% of Australian plant species are endemic (found nowhere else on Earth). The rich biodiversity of our vegetation (see Chapter 8: Biodiversity) is attributable to the continent’s geological and environmental history, and to the diversity of Australia’s climate and physical environment.

The most extensive types of Australian native vegetation are grasslands, woodlands dominated by eucalypts, and shrublands dominated by acacias. Non-native vegetation includes a diverse array of annual, perennial and horticultural crops from which we derive almost all our food, and plantation forests from which we source most of our wood. It also includes many weed species that have adverse impacts on environmental values.

Australia’s native vegetation has been modified to varying degrees by different land uses and management practices throughout the country’s human history. Since European settlement, some 13% has been completely converted to other land uses, and a further 62% is subject to varying degrees of disturbance. The cumulative impacts of land uses and management practices on the environmental values of Australia’s soils and native vegetation are a central concern for the assessments reported in this chapter.

1.3 In this chapter

This chapter provides an account of the most significant and recent human impacts on our land. It highlights improvements in land management over some parts of Australia, as well as several adverse trends. Our focus is relatively narrow—primarily on land use, vegetation and soil. In particular, we focus on the land-management practices and landscape processes that, in our view, warrant most attention.

The chapter starts with an introduction to Australia’s soils, vegetation and systems of land use. An assessment is then made of the condition and trends in soil and vegetation across the country. This is followed by an analysis of major pressures on soils and vegetation, and the potential threats to the services and products they provide.

The effectiveness of management for sustaining and protecting our soils and vegetation under different land uses is then considered. The chapter describes the resilience (ability to cope with change) of the land and the current risks to land function, and concludes with an assessment of the outlook for Australia’s land resources.
The larger context for this chapter is the magnitude of the pressures emerging globally on land use. Stated simply, the world needs to increase food production as the population grows, but there are significant constraints to achieving this, including:

- water scarcity
- limited increases in available arable land
- apparent plateaus in yield for major crops
- the need for reduced emissions of GHGs from agriculture
- increasing costs of energy and nutrients
- widespread land degradation
- risks from contaminants
- the likely implications of climate change for biodiversity and current land-use systems.

Wheat harvesting near Burra, South Australia
Photo by Jeff Drewitz
State and trends of the land environment

Australia’s land use, soils and vegetation are linked. Each is considered in this section through an examination of its history and current state.

2.1 Land use and management

The absolute and relative extent of Australia’s principal land uses are summarised in Table 5.1 (2005–06 data). The dominant land use, in terms of extent, is livestock grazing of native vegetation (46%); grazing of modified pastures accounts for another 9%. Nature conservation and other forms of protection are the second most common land use—together with minimal use, they are the principal use for some 36% of Australia’s land area. Dryland cropping is practised on about 3% of our land area. Other uses—production forestry, various forms of intensive agriculture, urban and residential, mining and waste, and water bodies—each account for less than 2% of Australia’s land area.

At a glance

Land-management practices have improved during the past few decades, but soil management has to improve significantly to build soil carbon, control acidification and prevent erosion.

The management and monitoring of soil carbon is a matter of national and international importance. Depending on how soils are managed, they can be a significant source or sink for greenhouse gases. Few regions have increasing levels of soil carbon, although the potential in the savanna landscapes of northern Australia is significant.

Soil acidification affects about half of Australia’s agriculturally productive soils. Its severity and extent are increasing, and large areas will become unproductive and degraded unless they are treated. Soil acidification also looms as a major constraint on Australia’s capacity to increase carbon in agricultural soils.

Current rates of soil erosion by water across much of Australia now exceed soil formation rates by a factor of at least several hundred and, in some areas, several thousand. The latter areas will be severely degraded in less than a century. However, the rate of wind erosion during the recent drought in southern Australia was less than 20% of that during the ‘dust bowl years’ of the 1940s.

The longer settled agricultural and coastal zones have the highest concentration of impacts on native vegetation. In most of these regions, less than 50% of native vegetation remains, and vegetation condition generally deteriorates with diminishing remnant extent. Approximately 13% of native vegetation nationally has been completely converted to other uses.

Annual rates of native vegetation clearing averaged around 1 million hectares in the decade to 2010, balanced by the extent of regrowth by the end of the decade. The condition of much native vegetation is deteriorating, particularly that remaining as fragmented remnants in intensive and settled land-use zones, and that subjected to persistent pressures such as inappropriate grazing or fire regimes.

Assessment of land, soil and vegetation condition over the past decade is complicated by the impacts of drought in much of the south and east of the continent. Drought affected these areas from 2000 to 2010 (sometimes known as the millennium drought), although in some areas it began as early as 1997. Furthermore, nationally consistent metrics for assessment of vegetation condition are still under development.
Table 5.1 Australian land use, 2005–06

<table>
<thead>
<tr>
<th>Land use</th>
<th>Area (million hectares)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• native vegetation</td>
<td>356</td>
<td>46</td>
</tr>
<tr>
<td>• modified pasture</td>
<td>72</td>
<td>9</td>
</tr>
<tr>
<td>Nature conservation and other protected areas (includes Indigenous uses)</td>
<td>159</td>
<td>20</td>
</tr>
<tr>
<td>Minimal use</td>
<td>124</td>
<td>16</td>
</tr>
<tr>
<td>Dryland cropping</td>
<td>26</td>
<td>3</td>
</tr>
<tr>
<td>Production forestry&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• native forests</td>
<td>11</td>
<td>1.5</td>
</tr>
<tr>
<td>• plantation forests</td>
<td>2</td>
<td>0.3</td>
</tr>
<tr>
<td>Water</td>
<td>13</td>
<td>1.6</td>
</tr>
<tr>
<td>Irrigated and intensive agriculture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• irrigated cropping</td>
<td>1.3</td>
<td>0.2</td>
</tr>
<tr>
<td>• irrigated pastures</td>
<td>1.0</td>
<td>0.1</td>
</tr>
<tr>
<td>• irrigated horticulture</td>
<td>0.4</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>• intensive animal and plant production</td>
<td>0.3</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>• dryland horticulture</td>
<td>0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Urban and rural residential</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• intensive (mainly urban) uses</td>
<td>1.6</td>
<td>0.2</td>
</tr>
<tr>
<td>• rural residential</td>
<td>0.9</td>
<td>0.1</td>
</tr>
<tr>
<td>Mining and waste</td>
<td>0.2</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Total</td>
<td>769</td>
<td>100</td>
</tr>
</tbody>
</table>

<sup>a</sup> Production forestry data have subsequently been updated in Montreal Process Implementation Group.<sup>1</sup>
Source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES);<sup>2</sup> ABARES is an independent research agency of the Australian Government.

The distribution of these land uses (Figure 5.1) reflects the history and pattern of European settlement of Australia and the intersection of that settlement with climate and resources relevant to primary production. These factors have been reviewed in previous national State of the Environment (SoE) reports.<sup>1</sup> In brief, urban settlements and the majority of Australia’s population are concentrated along the eastern, south-eastern and south-western coastal fringes (see Chapter 10: Built environment and Chapter 11: Coasts). Intensive agriculture is generally located in higher rainfall zones within 200 kilometres of the coast, with some exceptions in irrigation areas. Most dryland agriculture is located south of latitude 21°S on the western slopes of the Great Dividing Range in the east, between the 300–600-millimetre isohyets (maplines joining points of equal precipitation); and largely within the confines of that isohyet in South Australia and Western Australia, extending closer to the 250-millimetre isohyet in some areas.<sup>4</sup> These three groups of land uses define what is often described as the ‘intensive land-use zone’. Land managed for nature conservation and protection is located primarily in central and northern Australia, and in the forested ranges of the east and south-west of both mainland Australia and Tasmania.
Australian land is managed by:

- approximately 136,000 agricultural businesses, who manage around 52% of the total land area\(^5\)
- Australian, state and territory governments, which manage national parks, state forests and other public land totalling around 25% of the total land area\(^1\)\(^2\)
- Indigenous Australians, who have formal ownership and management or co-management responsibility for 23% of the total land area (Box 5.1)\(^6\)
- mining companies, water authorities and others with particular interests or responsibilities, who manage a small proportion of the total land area
- residents of urban or peri-urban (between the suburbs and the countryside) settlements, who have responsibility for their residential land.
2.1.1 Land-use trends

While the general pattern of land use is well established across Australia, significant changes have occurred since the 2006 SoE report. Estimates of the areas affected are imprecise in some cases, but the most important trends are described below.

Conservation

- Areas managed for conservation continued to expand, to around 25% of Australia’s land area. Over the past decade, Australia’s terrestrial conservation estate (International Union for Conservation of Nature categories I–VI) expanded...
by more than 50% to nearly 100 million hectares. Land under conservation management now includes a rapidly growing area dedicated to, and managed for, conservation by private owners (e.g. conservation trusts). The extent of private conservation lands is now more than 4 million hectares.8

Indigenous land

- The area of land formally owned and managed by Indigenous Australians continued to increase, to 23% of Australia’s land area.6

Agriculture

- The millennium drought (affecting southern Australia from 2000 to 2010, although starting in 1997 in some areas) had a profound impact on agricultural industries. It reduced agricultural production and caused a reappraisal of risks in irrigation regions. However, the shift to higher value irrigated crops on smaller areas meant that the total value of production per unit of water increased significantly in the Murray–Darling Basin.9

- The sophistication of agricultural land management increased, with significant reductions in the intensity of agricultural chemical use in the cotton industry, due largely to the adoption of genetically modified cotton;10 more careful use of fertilisers in sensitive environments (e.g. catchments of the Great Barrier Reef); and more flexible approaches to grazing management to reduce erosion and increase productivity.

- The trend of significant expansion of horticulture was curtailed with the demise of the managed investment scheme taxation arrangements supporting this industry.

- Global concerns about food security, triggered initially by the 2008 spike in food prices (e.g. von Braun11), started a debate about Australian agriculture and land-use policy, which will undoubtedly intensify in the future.

Forestry

- The area of public native forest managed for wood production declined by nearly 20%, to around nine million hectares, and there was a corresponding increase in the extent of public native forest in conservation reserves.12

- Plantation forests funded by managed investment schemes expanded significantly to around 1 million hectares, but expansion has now ceased and a contraction of up to 50% is expected in the coming decade.

- The extent and severity of wildfires in south-eastern Australia rekindled debate on strategies for fire suppression, how best to balance protection of life and property with that of environmental assets, residential expansion in forested regions, and the future viability of some native forest–based industries.13

Carbon sequestration

- The use of land and vegetation for carbon sequestration became a mainstream interest for industries and governments.14-15 The comparative advantages and risks of biosequestration compared with other forms of sequestration (e.g. geological capture and storage) may have a very large impact on future rural land use and management.

Mining

- The dramatic expansion of coal mining and the coal-seam gas industry in some prime agricultural regions caused conflict because of competition for land, and concerns about contamination of, and competition for, water resources. The associated infrastructure and expansion of export facilities are also placing pressure on some coastal environments.

Built environment

- Australian cities and coastal settlements continued to sprawl, despite some successful attempts by local, state and territory governments to manage development to protect biodiversity, good-quality agriculture lands and areas prone to flooding.

2.2 Soil

Understanding the current state and condition of Australian soils requires an appreciation of their diversity and capability to support different forms of land use. It also requires an appreciation of human impacts, not only in recent years and decades, but also on longer timescales of centuries and millennia. This is because the effects of some forms of land use are long lasting, some rates of change are very slow, and remediation can take decades.
2.2.1 Baseline

The environmental baseline adopted throughout much of this report is that preceding European settlement (1750). However, this is problematic for soils, because there is limited evidence about the physical, chemical and biological conditions at this time. There is generally a much better understanding of soil changes associated with land clearing and conversion to land uses such as agriculture and forestry. Most assessments of soil change presented here relate to the condition before clearing, unless otherwise stated. Even then, it is instructive to start with the context set by Aboriginal land management.

At the time of Aboriginal arrival more than 50 000 years ago, the vegetation in many parts of Australia was quite different from now. Many of the widespread species were those that we now associate with dry rainforest environments—eucalypts did not have their present dominance. Although fire was a natural feature of the landscape, it appears to have been both less frequent and less widespread. The Australian megafauna were common at this time, becoming extinct 40 000–50 000 years ago. While there has been great debate over the cause of megafauna extinction, the loss of large herbivores from the Australian landscape and the subsequent changes in vegetation and fire had an undoubted effect on soil properties and processes. There is still much to learn, but it is clear that Aboriginal impacts on Australian soil must have been profound.

There is a clearer understanding of the impact of European land use. The resulting soil degradation, particularly in the 100 years after 1850, was extreme in some regions. Scott provides an instructive historical account for the Murray–Darling Basin. Rates of soil change were dramatic, with severe erosion, organic matter loss and nutrient depletion commonplace across large areas. Fragile soils were cleared of vegetation, and land-management practices were crude. Today’s controls on clearing and more enlightened land management have made this gross form of land degradation uncommon. Although major threats to soil health remain in many regions, these are less visible, very persistent and widespread. We only have a rudimentary understanding of baselines and current rates of change.

2.2.2 A framework for understanding soil

The major soil types in Australia are summarised from the Australian Soil Classification in Table 5.2.

A generalised map of the major soil types (orders) is provided in Figure 5.2.

Table 5.2 Australia's main types of soil

<table>
<thead>
<tr>
<th>Soil order</th>
<th>Simplified description</th>
<th>Proportion of Australian soil (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthroposols</td>
<td>Soils formed by humans</td>
<td>No data</td>
</tr>
<tr>
<td>Calcarosols</td>
<td>Soils dominated by carbonate</td>
<td>9.2</td>
</tr>
<tr>
<td>Chromosols</td>
<td>Neutral to alkaline soils with a sharp increase in texture with depth</td>
<td>3.0</td>
</tr>
<tr>
<td>Dermosols</td>
<td>Structured B horizons (having a concentration of silicate clay, iron, aluminium and organic material) and gradational to minor changes in texture with depth</td>
<td>1.6</td>
</tr>
<tr>
<td>Ferrosols</td>
<td>High iron levels and gradational to minor changes in texture with depth</td>
<td>0.8</td>
</tr>
<tr>
<td>Hydrosols</td>
<td>Wet soils</td>
<td>2.2</td>
</tr>
<tr>
<td>Kandosols</td>
<td>Strongly weathered earths with minor changes in texture with depth</td>
<td>16.5</td>
</tr>
<tr>
<td>Kurosols</td>
<td>Acid soils with sharp increases in texture with depth</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Continued next page
Table 5.2 continued

<table>
<thead>
<tr>
<th>Soil order</th>
<th>Simplified description</th>
<th>Proportion of Australian soil (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organosols</td>
<td>Organic soils</td>
<td>0.1</td>
</tr>
<tr>
<td>Podosols</td>
<td>Soils with accumulated organic matter, iron and aluminium</td>
<td>0.4</td>
</tr>
<tr>
<td>Rudosols</td>
<td>Minimally developed soils</td>
<td>14.0</td>
</tr>
<tr>
<td>Sodosols</td>
<td>Soils with sodic subsoils, which are often alkaline, and with a sharp increase in texture with depth</td>
<td>13.0</td>
</tr>
<tr>
<td>Tenosols</td>
<td>Slightly developed soils</td>
<td>26.3</td>
</tr>
<tr>
<td>Vertosols</td>
<td>Cracking clays</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Source: CSIRO Land and Water, 2011

Figure 5.2 Generalised map of soil orders for Australia
In this chapter, we use the hierarchical stratification of Australia’s landforms from the Australian Soil Resource Information System (ASRIS).\(^a\) The ASRIS mapping hierarchy divides Australia into three physiographic divisions, which are further subdivided into 23 provinces and 220 regions. These broadscale mapping units have similar geological origins and a characteristic suite of soils and landforms. Even then, a diversity of soils and land-management systems often occurs within each region. It is therefore only possible to reach general conclusions about the state of the soil for each region—there are always local exceptions.

2.2.3 Key indicators of soil condition

Many physical, chemical and biological processes occur in soils, and they operate at different rates across the landscape according to the climate, land use and soil type. The following processes are key indicators of soil condition:

- carbon dynamics
- acidification
- soil erosion.

These processes have major environmental and economic consequences for Australia. Other aspects of soil change are also important, but they are dwarfed by the significance of these three.

A fourth key process affecting soil condition in Australia is dryland salinity. A large proportion of Australia’s agriculture is undertaken in areas with a rainfall of 450–800 millimetres per year. In their natural condition, these landscapes had minimal deep drainage (generally less than 20 millimetres per year), and natural stores of salt brought in by rain and dust had accumulated in the soil in many regions. The removal of native vegetation changes the hydrological cycle, because trees and shrubs intercept significant quantities of rain—often 10–20% of rainfall fails to reach the soil surface. When vegetation is removed, more water either infiltrates or runs off the surface. If the original vegetation has been replaced by more shallow-rooted species that use less water (e.g. annual crops and pastures), even more water passes through the soil. This may lead to rising groundwater levels and, in some cases, dryland salinity.

Dryland salinity has been one of Australia’s most costly forms of land degradation. The assessment by the National Land & Water Resources Audit (NLWRA)\(^b\) provides a comprehensive overview. Assuming no changes in water imbalance, the NLWRA expected dryland salinity to increase from 5.7 million hectares to 17 million hectares by 2050. However, the millennium drought appears to have halted the spread of dryland salinity in most of the worst affected regions, especially in south-west Western Australia. Chapter 4: Inland water, Box 4.3 summarises the current status of salinity and its impact on inland waters.

The outlook outlined by the NLWRA\(^b\) will need further moderation if current projections are correct for a drying of southern Australia. However, the long-term outlook for more recently cleared land in the northern Murray–Darling Basin and central Queensland is unclear. Large areas are yet to reach a new hydrological equilibrium after clearing.

Given the effects of drought over the reporting period, this report does not provide an update on previous SoE reports or the NLWRA assessment\(^b\) regarding salinity. However, close surveillance of groundwater systems is essential, particularly in regions that returned to wetter conditions in 2010–11. A key requirement for understanding the state of dryland salinity in Australia will be to maintain the groundwater monitoring network established under the National Action Plan for Salinity and Water Quality.

2.2.4 Carbon dynamics

The management and monitoring of soil carbon has become a matter of national and international importance. Soil carbon can be a significant source or sink for GHGs depending on how land is managed. The management of soil carbon is also central to maintaining soil health and ensuring global food security.\(^b\) However, there are complex trade-offs between reducing GHG emissions and producing food.

At the global scale, the amount of carbon contained in terrestrial vegetation \((550 ± 100\) petagrams \([1\) billion tonnes]—Pg)\) is of a similar order to that in the atmosphere \((800\) Pg). However, the organic matter in soils is two to three times this amount. Approximately 1500–2000 Pg of carbon is in the top metre, and as much as 2300 Pg in the top three metres.\(^b\)

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\(^a\) [www.asris.csiro.au](http://www.asris.csiro.au)
The carbon content of soil is a key indicator of its health, and is a master variable that controls many processes (e.g. nutrient cycling, development of soil structure, water storage). The carbon derives primarily from plant materials created through the capture of atmospheric carbon dioxide via the process of photosynthesis. These organic materials are cycled through the soil and used by organisms as a source of energy and nutrients. A significant amount of carbon dioxide is returned to the atmosphere as a result of respiration. Increasing soil organic carbon leads to an increase in:

- energy supply for biological processes
- direct nutrient supply to plants (particularly nitrogen, phosphorus and sulfur)
- capacity to retain and exchange nutrients
- aggregation of soil particles and stability of soil structure
- water storage and availability to plants
- beneficial thermal properties
- pH buffering (helping to maintain acidity at a constant level).

The maximum equilibrium carbon content for a soil at a given location is determined by environmental factors such as rainfall, evaporation, solar radiation and temperature. For example, soil carbon content is generally larger in cool, wet environments. A lack of nutrients and a limited capacity to store and supply water in a soil can reduce this potential maximum, as can other constraints to plant growth (e.g. toxicities). Within these constraints, the actual amount of organic carbon contained in a soil will be determined by the balance between carbon inputs and losses, which are strongly influenced by land management and soil type. Agricultural practices that alter rates of carbon input (e.g. plant residues, compost, mulch) or loss (e.g. removal of crops, cultivation) change the stock of soil organic carbon.

**Soil carbon stocks in Australia**

Soil carbon stocks are low in many Australian agricultural systems. Conversion from native vegetation to agriculture typically reduces soil carbon by 20–70%. This reduction is often associated with declining soil health and significant emissions of GHGs. It is generally acknowledged that more conservative forms of land management can increase soil carbon stocks, and have a significant impact on national and global emissions. This opportunity is the motivation behind many schemes around the world that aim to restore soil carbon stocks, including the Australian Government’s Carbon Farming Initiative.

**Carbon resilience and land management**

There are different types of carbon in soils. It is useful to recognise three primary fractions:

- particulate organic carbon (POC): organic carbon associated with particles larger than 0.05 millimetres (excluding charcoal carbon)
- humus organic carbon (HUM): organic carbon associated with particles smaller than 0.05 millimetres (excluding charcoal carbon)
- resistant organic carbon (ROC): organic carbon found in the soil particles smaller than 2 millimetres having a chemical structure similar to charcoal.

The three primary fractions have contrasting dynamics. POC can be readily increased in a soil, but it also breaks down quickly. In contrast, ROC takes much longer to increase unless it is added via an amendment such as biochar.

The relative amount of each fraction in a soil determines the resilience of the soil’s carbon stocks. Figure 5.3 shows a typical pattern of soil carbon loss for each fraction after conversion from native vegetation to a cropping system in southern Australia. The system is converted back to pasture after 33 years of cropping, to restore soil carbon. This results in a quick increase in POC, but only a small increase in HUM and ROC. After 10 years, the pasture is converted back to a cropping system (year 43), and it experiences a quick decline. It only takes 9 years to return to the pre-pasture low point. In the first period, this amount of decline took 18 years (years 15 to 33) because the soil had proportionally more HUM. The key message is that, even under improved systems of land management, carbon stocks can be less resilient than those developed over long periods under native vegetation.
Sanderman and Baldock\textsuperscript{28} recently reviewed replicated Australian field trials with timeseries data, providing an important new insight into carbon dynamics in agricultural systems. They concluded that, although the implementation of more conservative land-management practices will lead to a relative gain in soil carbon, absolute soil carbon stocks may still be on a trajectory of slow decline (Figure 5.4). Their results showed that many soils used for agriculture are somewhere between scenario A and B.

Analysis by Sanderman et al.\textsuperscript{24} of major management options for sequestering carbon in agricultural soils (Table 5.3) highlights the inevitable tradeoff between agricultural production (i.e. carbon exports in the form of crops, fibre and livestock) and carbon sequestration (capture and storage) in soils.

Figure 5.3 Dynamics of soil carbon associated with clearing, cultivation and pasture phases after conversion from native vegetation to a cropping system in southern Australia

Figure 5.4 Results from a hypothetical field trial comparing conventional and improved management practices initiated at three different times (A, B and C) after converting a natural ecosystem to agricultural production in year 0

All three points show the same relative gain of 5 megagrams of soil organic carbon (SOC) per hectare over a five-year period from improved management practice; however, the actual rate of change for the improved management ranges from –1.9 to +1.0 megagrams of SOC per year.

Assessment of state and trends in soil carbon across Australia

A group of experts in soil carbon and land resource assessment was convened to provide an assessment of the state and trends in soil carbon across Australia. The assessment summary provides ratings for regions where the most significant issues are apparent (Figure 5.5). The ratings for all physiographic regions are available on the SoE website.\textsuperscript{b} A more comprehensive assessment of soil carbon across a range of agricultural systems will be available at the end of 2012 when a major national collaborative study is completed.

\textsuperscript{b} www.environment.gov.au/soe
### Table 5.3 Summary of major management options for sequestering carbon in agricultural soils

<table>
<thead>
<tr>
<th>Management</th>
<th>SOC benefit</th>
<th>Confidence</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 Shifts within an existing cropping/mixed system</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Maximising efficiencies</td>
<td>0/+</td>
<td>L</td>
<td>Yield and efficiency increases do not necessarily translate to increased C return to soil</td>
</tr>
<tr>
<td>i. Water use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Nutrient use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Increased productivity</td>
<td>0/+</td>
<td>L</td>
<td>Potential trade-off between increased C return to soil and increased decomposition rates</td>
</tr>
<tr>
<td>i. Irrigation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Fertilisation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Stubble management</td>
<td>+</td>
<td>M</td>
<td>Greater C return to soil should increase SOC stocks</td>
</tr>
<tr>
<td>i. Eliminate burning and grazing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Tillage</td>
<td>0</td>
<td>M</td>
<td>Reduced till has shown little SOC benefit</td>
</tr>
<tr>
<td>i. Reduce tillage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Direct drilling</td>
<td>0/+</td>
<td>M</td>
<td>Direct drill reduces erosion and destruction of soil structure, thus slowing decomposition rates; however, surface residues decompose with only minor contribution to SOC pool</td>
</tr>
<tr>
<td>e. Rotation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Eliminate fallow with cover crop</td>
<td>+</td>
<td>M</td>
<td>Losses continue during fallow without any new C inputs—cover crops mitigate this</td>
</tr>
<tr>
<td>ii. Increase ratio of pasture to crops</td>
<td>+/+</td>
<td>H</td>
<td>Pastures generally return more C to soil than crops</td>
</tr>
<tr>
<td>iii. Pasture cropping</td>
<td>++</td>
<td>M</td>
<td>Pasture cropping increases C return with the benefits of perennial grasses (listed in 2c, below) but studies lacking</td>
</tr>
<tr>
<td>f. Organic matter and other offsite additions</td>
<td>++/+</td>
<td>H</td>
<td>Direct input of C, often in a more stable form, into the soil; additional stimulation of plant productivity</td>
</tr>
<tr>
<td><strong>2 Shifts within an existing pastoral system</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Increased productivity</td>
<td>0/+</td>
<td>L</td>
<td>Potential trade-off between increased C return to soil and increased decomposition rates</td>
</tr>
<tr>
<td>i. Irrigation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Fertilisation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Rotational grazing</td>
<td>+</td>
<td>L</td>
<td>Increased productivity, including root turnover and incorporation of residues by trampling, but lacking field experience</td>
</tr>
<tr>
<td>c. Shift to perennial species</td>
<td>++</td>
<td>M</td>
<td>Plants can use water throughout the year; increased below-ground allocation but few studies to date</td>
</tr>
<tr>
<td><strong>3 Shift to different system</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Conventional to organic farming system</td>
<td>0/+</td>
<td>L</td>
<td>Likely highly variable, depending on the specifics of the organic system (e.g. manuring, cover crops)</td>
</tr>
<tr>
<td>b. Cropping to pasture system</td>
<td>+/+</td>
<td>H</td>
<td>Annual production, minus natural loss, is now returned to soil; active management to replant native species often results in large C gains</td>
</tr>
</tbody>
</table>

0 = nil; + = low; ++ = moderate; +++ = high; C = carbon; H = high; L = low; M = medium; SOC = soil organic carbon

a Qualitative assessment of the SOC sequestration potential of a given management practice

b Qualitative assessment of the confidence in this estimate of sequestration potential based on both theoretical and evidentiary lines

Source: Sanderman et al.24
However, it is possible to draw the following conclusions from the currently available evidence:

- The time since clearing is a key factor determining current trends. For example, large parts of Queensland are on a declining trend because widespread clearing for agriculture was still occurring in the 1990s.
- Few regions have increasing soil carbon stores.
- Regions with intensifying systems of land use (e.g., northern Tasmania) have decreasing stores.
- Most regions with a projected drying climate have declining trends.

- The savanna landscapes of northern Australia have significant potential for increasing soil carbon stores, but this requires changes in grazing pressures and fire regimes.

Some of the extensive cropping lands in southern Australia with weathered and naturally infertile soils are rated as good (i.e., 30–70% loss) or very good (i.e., <30% loss) because they had small carbon stores at the time of European occupation and have not changed substantially (although soil biodiversity has undoubtedly changed). Many of these soils have also benefited from the addition of fertiliser and the correction of trace element deficiencies.

**Figure 5.5** Rating of condition for soil carbon

The definition of each grade is provided in Assessment summary 5.1. Numbered regions have significant changes or trends (up or down), and are described in more detail in the assessment summary.
### 5.1 Assessment summary

#### State and trends of soil carbon

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Paroo Plain and Warwick Lowland</td>
<td>Rangelands with extensive grazing and soil erosion caused by wind, particularly on sandplains</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Warrego Plains</td>
<td>Rangelands with minor opportunity cropping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Tenterfield Plateau</td>
<td>Land used for grazing of modified and natural pastures and nature conservation. Significant losses of soil carbon, particularly in the east</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Clarence Lowlands</td>
<td>Infertile coastal lowlands used for forestry, grazing, cropping and some nature conservation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Cobar Plains</td>
<td>Significant declines in soil carbon, mostly associated with historically poor management. Overgrazing by feral goats is causing further decline, despite improving land management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Barrier Ranges</td>
<td>Surface content of carbon declining due to grazing and prior clearing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Gunnedah Lowlands</td>
<td>Declining trend due to intensification of cropping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Macleay Barrington Fall</td>
<td>Area used for nature conservation and production forestry, with some grazing. Possible decline due to logging</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Merriwa Plateau</td>
<td>Mixed farming on fertile Ferrosols and Vertosols</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Condobolin Plains</td>
<td>Sodosols and Vertosols used for cropping and grazing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Bathurst Tablelands</td>
<td>Grazing of modified and natural pastures dominates. General improvement in land-management practices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
</tr>
<tr>
<td>----------------------------</td>
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</tr>
<tr>
<td>12 Hawkesbury Shoalhaven Plateaus</td>
<td>Diverse landscape with natural conservation, forestry, grazing, horticulture and urban land uses. Fire regime and land-management practices are most likely causing a decline</td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td>13 Cumberland Lowland</td>
<td>Mostly urban and industrial land use</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>14 Werriwa Tablelands</td>
<td>Relatively infertile lands used for grazing. Suspected slight decline</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>15 Monaro Fall</td>
<td>Forestry, nature conservation and grazing. Land management is improving</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>16 Australian Alps</td>
<td>Mostly used for nature conservation. Controls on grazing and reduced erosion stabilised early losses, but the increased intensity and extent of fires are likely to be causing a slight decrease, particularly in Organosols</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>17 Mallee Dunefield</td>
<td>Cropping, grazing and nature conservation with irrigated agriculture along the Murray River. Improved farming practices have improved soil condition in some areas, but soil carbon levels are probably still declining</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>18 Wimmera Plain</td>
<td>Mainly cropping and grazing. Former grazing lands now used for nature conservation may still be experiencing declining carbon content. Changing farming practices to no-till may reduce soil carbon loss in some areas, especially on heavier soils. Soil carbon is still likely to be declining in this region</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>19 Riverine Plains</td>
<td>Dryland cropping, irrigated agriculture and grazing, with the latter dominant in the west. Slight declines under dryland cropping systems, although farming practices may halt this</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

Continued next page
### State and trends of soil carbon continued

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 West Victorian Plains</td>
<td>Grazing, cropping and expanding plantation forestry. Areas converted from pasture to cropland are probably declining, as are soils used for continuous cropping</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td>21 Midlands Plain</td>
<td>Dryland cropping, grazing and increasing irrigated cropping. Intensification of cropping is causing the decline</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td>22 Lakes Plateau</td>
<td>Nature conservation reserves where wildfire and grazing have initiated sheet erosion over large areas, with very limited potential for recovery</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td>23 West Tasmanian Ridges</td>
<td>More frequent and/or hotter fires in conservation reserves are causing losses, especially in Organosols. Northern areas dominated by production forestry, with no potential for soil carbon sequestration</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td>24 East Tasmanian Hills</td>
<td>Production and plantation forestry, with minor declines due to erosion. Irrigated cropping in the southeast and northeast is causing declines</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td>25 North West Ramp</td>
<td>Decline is associated with irrigated cropping</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td>26 Roe and Carlisle Plains, Coonana–Ragged and Bunda Plateaus</td>
<td>Mainly grazing of native vegetation. Shift from perennials to annuals and possible increase in fire frequency may lead to nominal decline</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td>27 Southern Goldfields Plateau</td>
<td>Soil carbon decline restricted to pastoral areas</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td>28 Swan Plain</td>
<td>Urban areas and intensive agriculture. Declines due to tillage. Irrigated pasture systems for dairy may be stable or increasing</td>
<td>Poor</td>
<td>Neutral</td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
</tr>
<tr>
<td>-------------------------------</td>
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</tr>
<tr>
<td>29 Woodramung Hills</td>
<td>Low input cropping and grazing. Drying trends have compounded effects of clearing and cropping on soil carbon</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>30 Murchison Plateau, Leemans and Yaringa Sandplains, Carnegie and Glengarry Hills, Augustus Ranges</td>
<td>Areas with extensive grazing of native vegetation, with declines in more heavily grazed areas. Drying trends are an additional factor</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>31 Carnarvon Plain</td>
<td>Nature conservation, extensive grazing and small areas of intensive irrigated horticulture. Episodic removal of surface soil carbon in horticultural areas</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>32 Fitzroy Plains</td>
<td>Extensive grazing of native vegetation</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>33 Daly Basin</td>
<td>Small areas of intensive agriculture likely to have declining carbon. Remainder is used for extensive grazing</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>34 Whirlwind Plain and Birrundudu Plain</td>
<td>Extensive grazing with small areas of more intensive development on better soils. Possible minor decreases in soil carbon due to high seasonal stocking rates</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>35 Barkly Tablelands</td>
<td>Extensive grazing on clay plains. Some impacts on soil carbon due to grazing</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>36 Toowoomba Plateau</td>
<td>Ferrosols used for cropping and pasture, with increasing agroforestry. Slow increases occurring under pasture and agroforestry</td>
<td>Poor</td>
<td></td>
</tr>
</tbody>
</table>

Continued next page
### State and trends of soil carbon continued

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>37 Central Uplands</td>
<td>Partially cleared grazing country. Soil carbon is likely to be declining where cleared recently, otherwise stable</td>
<td>Good</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td>38 Atherton Tableland</td>
<td>Fertile land with high rainfall. Diverse land uses, with soil carbon now increasing under pastures and tree crops. Stable under rainfed crops but still decreasing under small crops</td>
<td>Good</td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td>39 Garnet Uplands</td>
<td>Recently intensified land use after clearing. Soil carbon likely to be declining</td>
<td>Poor</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
</tbody>
</table>

**Recent trends**
- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**

**Grades**
- **Very good**: Carbon stocks have either remained the same or increased (<30% loss or increase)
- **Good**: Carbon stocks have changed in some areas (30–50% loss)
- **Poor**: Carbon stocks have decreased (50–70% loss)
- **Very poor**: Carbon stocks have decreased substantially (>70% loss)
2.2.5 Soil acidification

Soil acidification is an insidious process that develops slowly. If not corrected, it can continue until the soil is irreparably damaged. Acidification affects about half of Australia’s agriculturally productive soils. The severity and extent of acidification are increasing in many regions, due to inadequate treatment, intensification of land management, or both.

Soil acidification is of greatest concern in situations where:

- agricultural practices increase soil acidity (e.g. use of high-analysis nitrogen fertilisers, large rates of product removal)
- the soil has a low capacity to buffer the decrease in pH (e.g. infertile, light-textured soils)
- the soil already has a low pH.

The process of acidification considered in this report is distinct from that associated with acid sulfate soils. Such soils occur primarily in coastal settings, and naturally contain iron sulfides that severely acidify when oxidised. This can occur through drainage of coastal wetlands, or exposure due to drought, as was the case in the Lower Lakes of South Australia during the millennium drought.

The main onsite effects of acidification include:

- loss or changes in soil biota involved in nitrification (fixing nitrogen, a key nutrient, within the soil)
- accelerated leaching of plant nutrients (manganese, calcium, magnesium, potassium and anions)
- induced nutrient deficiencies or toxicities
- breakdown and subsequent loss of clay materials from the soil
- development of subsoil acidity
- reduced net primary productivity and carbon sequestration
- erosion as a result of decreased groundcover that may follow acidification.

The potential offsite effects include:

- acidification of waterways as a result of leaching of acidic ions
- increased siltation (where there are fine sediments suspended in the water and deposited on the floor) and eutrophication (where a high concentration of nutrients typically triggers excess growth of algae) of streams and water bodies.

Soil acidification in Australia

In 2001, the NLWRA estimated that soil acidity affected 50 million hectares of surface layers and 23 million hectares of subsoil layers of Australia’s agricultural zone. The estimated annual value of lost agricultural production due to soil acidity was $1.585 billion, about eight times the estimated cost of soil salinity at that time. More recent studies have confirmed the scale of the problem (e.g. Lockwood et al. 2003; Wilson et al. 2003), but there have been only a few detailed quantitative investigations.

Ultimately, soil acidification restricts options for land management, because acid-sensitive crops and pastures cannot be grown. It also looms as a major constraint on Australia’s capacity to increase carbon in agricultural soils.

It is relatively straightforward to reverse short-term soil acidification through the application of lime. However, it is much harder to reverse the problem if the acidification has advanced deeper into the soil profile, because incorporating lime at depth is prohibitively expensive. Prevention rather than cure is essential.

While rates of lime application appear to be increasing, they still fall far short of what is needed to arrest the problem. Western Australia has one of the best programs for combating acidification in Australia, but the rates of lime application are still much lower than what is needed to avoid irreparable damage (Figure 5.6). Around $400–500 million is already being lost in annual productivity in the state.

A similar situation exists in South Australia (Figure 5.7). The average quantity of lime sold annually over the past decade (113 000 tonnes) is only 53% of that needed to balance the estimated annual soil acidification rate.
Assessment of state and trends of soil acidification across Australia

A group of experts in soil acidification and land resource assessment was convened to provide an assessment of the state and trends of soil acidification across Australia. Assessment summary 5.2 provides ratings for regions where the most significant issues are apparent. The ratings for all physiographic regions are available on the SoE website.\textsuperscript{c}

Australia does not have an organised monitoring system for soil acidification, which accounts for the significant uncertainty in many regions. However, the following conclusions can be drawn from the evidence available to the expert group:

- Soil acidification is widespread in the extensive farming lands of southern Australia (Figure 5.8).
- Rates of lime application are well short of those needed to arrest the problem.
- Acidification is common in intensive systems of land use (tropical horticulture, sugar cane, dairying).
- Acidification is limiting biomass production in some regions, but the degree of restriction is difficult to estimate.
- Trends in the tropical savannas are uncertain. If acidification is occurring, it will be a difficult problem to solve.
- Carbon losses are most likely occurring across regions in poor condition, and soil acidification is a major constraint on storing carbon in soils in the future.

\textsuperscript{c} www.environment.gov.au/soe
Soil acidification grade
- **Very poor**
- **Poor**
- **Good**
- **Very good**

**Figure 5.8  Soil acidification in Australia**

Large areas of Australia are affected by soil acidification. The definition of each grade is provided in Assessment summary 5.2. Numbered regions have been assessed as changing (mostly acidifying) and are described in more detail in the summary.
## State and trends of soil acidification

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Toowoomba Plateau</td>
<td>Naturally fertile land with widespread intensive use. Insufficient lime application</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>2 Maryborough Lowland</td>
<td>Soils under pine plantations are acidifying, but improved practices for sugar cane and horticulture appear to be effective</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>3 Atherton Tableland</td>
<td>Improved practices across diverse land uses, but localised subsoil acidification under banana cropping</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>4 Garnet Uplands</td>
<td>Recently intensified land use after clearing</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>5 Tenterfield Plateau</td>
<td>Grazing of modified and natural pastures, with widespread declines in pH</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>6 Clarence Lowlands</td>
<td>Coastal lowlands with a variety of soil types. Significant decline in pH on the floodplains due to intensive agriculture</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>7 Cobar Plains</td>
<td>Cropping and grazing of modified and natural pastures in the east, with declines in pH evident</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>8 Mitchell Slopes</td>
<td>Diverse landscape, but pH has declined markedly, especially on soils with a long history of mixed farming</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>9 Merriwa Plateau</td>
<td>Fertile Ferrosols and Vertosols, mostly used for mixed farming. Slow decline in pH likely due to management systems</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>10 Goulburn Corridor</td>
<td>Minimal evidence, but declines in pH are expected due to lack of liming</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>11 Hunter Valley</td>
<td>Mined areas and Hunter River floodplains are mostly managed sustainably for acidification, but declines in pH are expected on the Singleton Valley floodplains</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>12 Riverine Plain</td>
<td>Diverse region, with declines in pH in irrigation districts and in soils used for dryland cropping and grazing of annual pastures, especially in the south</td>
<td>Very poor</td>
<td>In trend</td>
</tr>
<tr>
<td>13 Hume Slopes</td>
<td>Mostly mixed farming. Widespread and significant declines in soil pH</td>
<td>Poor</td>
<td>In trend</td>
</tr>
<tr>
<td>14 Condobolin Plains</td>
<td>Declines in pH restricted to irrigation districts</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>15 Bathurst Tablelands</td>
<td>Diverse soils used for grazing of modified and natural pastures</td>
<td>Poor</td>
<td>In trend</td>
</tr>
<tr>
<td>16 Hawkesbury Shoalhaven Plateau</td>
<td>Substantial declines in pH in soils used for agriculture</td>
<td>Very poor</td>
<td>In trend</td>
</tr>
<tr>
<td>17 Cumberland Lowland</td>
<td>Declining pH in soils used for vegetable production and intensive agriculture</td>
<td>Poor</td>
<td>In trend</td>
</tr>
<tr>
<td>18 Werriwa Tablelands</td>
<td>Declining pH in soils used for grazing of native and improved pastures</td>
<td>Poor</td>
<td>In trend</td>
</tr>
<tr>
<td>19 Tinderry Gourock Ranges</td>
<td>Declining pH in soils used for grazing of natural and modified pastures</td>
<td>Good</td>
<td>In trend</td>
</tr>
<tr>
<td>20 Monaro Fall</td>
<td>Declines in pH in soils used for grazing</td>
<td>Very poor</td>
<td>In trend</td>
</tr>
<tr>
<td>21 Monaro Tableland</td>
<td>Declining pH in soils used for grazing of natural and modified pastures</td>
<td>Poor</td>
<td>In trend</td>
</tr>
</tbody>
</table>

Continued next page
### State and trends of soil acidification

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>22</strong> Australian Alps and East Victorian Uplands</td>
<td>Grazing lands outside conservation reserves are showing declines in pH</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>23</strong> West Victorian Uplands</td>
<td>Areas used for grazing of dryland annual pastures are acidifying</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>24</strong> West Victorian Plains</td>
<td>Diverse lands with evidence of acidification restricted to poorly drained Sodosols and Vertosols used for dryland cropping and the grazing of annual pastures</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>25</strong> Lincoln Hills, Eyre Dunefield and Yorke Peninsula</td>
<td>Mainly dryland agriculture. Rates of liming are not sufficient to balance rates of acid addition for most soils. Generally stable pH in Calcarosols</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>26</strong> Flinders–Lofty Ranges</td>
<td>Diverse lands with stable pH in the arid north. Declines in pH are occurring in the temperate central area under dryland cropping and viticulture. Lands in the cool temperate south used for viticulture, horticulture and grazing are acidifying</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>27</strong> Mallee Dunefield</td>
<td>Mainly cropping in rotation with pastures. Trend to more cropping. Declining pH in surface soil layers over calcareous subsoils. Significant declines in pH in horticulture areas along the Murray River</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>28</strong> Wimmera and Millicent Plains</td>
<td>Diverse soils used for dryland cropping, grazing, some irrigation and forestry in the south. Declining trend in pH due to insufficient lime use</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>29</strong> Warren–Denmark Slopes, Leeuwin Peninsula and Donnybrook Lowland</td>
<td>Forestry, intensive agriculture and dryland cropping. Significant declines in pH in intensively used areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>30</strong> Albany Esperance Sandplain</td>
<td>Grazing and cropping systems are acidifying, particularly on lighter soils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
</tr>
<tr>
<td>-----------</td>
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<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td>31 Avon Plateau and Northam Slopes</td>
<td>Diverse soils. Widespread surface and subsurface soil acidity. Inadequate application of lime</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>32 Darling Range</td>
<td>Mostly forested, but areas used for cropping and grazing are acidifying</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>33 Swan Plain</td>
<td>Urban areas and intensive agriculture, with declines in pH in the latter</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>34 Dandaragan Tablelands</td>
<td>Declines in pH restricted to areas used for cropping and grazing systems</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>35 Greenough Hills</td>
<td>Significant acidification of both surface and subsurface horizons on noncalcareous soils used for cropping</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>36 Woodramung Hills</td>
<td>Significant acidification and low pH in the western part of the region used for cropping</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>37 Carnarvon and Top End Coastal Plains</td>
<td>Declining pH in agricultural areas used for intensive irrigation and horticulture</td>
<td>Poor</td>
<td>Low</td>
</tr>
<tr>
<td>38 Daly Basin</td>
<td>Declining pH in areas used for horticulture and more intensive pastoral development</td>
<td>Poor</td>
<td>Low</td>
</tr>
</tbody>
</table>
2.2.6 Soil erosion

The rate of soil formation is typically very slow. The fastest rates occur in dune sands in moist environments, where weakly developed soils can develop over decades or centuries. In river alluvium, a strongly developed soil (Chromosol) can develop in 20,000–30,000 years. Soil formation from weathering rock is much, much slower and varies with the environment and rock type. An average of 1 millimetre per 1000 years or slightly less is typical.

Water erosion

Current rates of soil erosion by water across much of Australia now exceed soil formation rates by a factor of at least several hundred and, in some areas, several thousand. As a result, the expected half-life of soils (the time for half the soil to be eroded) in some upland areas used for agriculture ranges from less than a century to several hundred years.

The latest assessment concluded that soil erosion by water in Australia is still at unsustainable rates, but there are large uncertainties about the time until soil loss will have a critical impact on agricultural productivity. Environmental impacts of excessive sedimentation and nutrient delivery on inland waters, estuaries and coasts are already occurring (see Chapter 4: Inland water).

Up to 10 million hectares of land have less than 500 years until the soil’s A horizon (effectively the more fertile ‘topsoil’) will be lost to erosion. Most of this land is in humid subtropical Queensland. Integrated studies of soil formation and erosion using a variety of techniques will be needed to better understand the extent, severity and significance of the problem. However, it is clear that a concerted program of soil conservation is essential to control this chronic form of land degradation across large areas of Australia.

The key to controlling soil erosion by water is the maintenance of a protective cover on the soil surface (e.g. living plants, litter, mulch). Other soil conservation practices—such as contour banks, filter strips and controlled traffic—are important, but secondary to the maintenance of cover.

Land-management practices have improved significantly during the past few decades, due to better grazing practices, adoption of conservation tillage, enforcement of forestry codes and soil conservation measures in engineering (e.g. relating to road construction and urban development).

An ability to monitor land cover provides a key input to assessments of erosion risk across the landscape. Three significant developments in this regard have occurred since the last SoE report:

- Ground-based monitoring of management practices and land cover has been under way for long enough to identify trends.
- New data on land-management practices are available from the Australian Bureau of Statistics (ABS).
- Remote sensing has advanced to the point where monitoring of bare soil and surface cover is possible. This will eventually lead to more reliable estimates of erosion rates.

The ground-based surveys and ABS data reveal a pattern of:

- more careful grazing and maintenance of effective land cover at critical times of the year
- improved adoption of conservation practices, especially across the cropping lands of southern Australia
- an associated large decline in the amount of tillage in farming systems (Figure 5.9).

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**Figure 5.9** Change in the percentage area of all land prepared for crops and pastures under different tillage practices, 1996–2010

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Figure 5.10 shows two images of Australia derived from remotely sensed data. The images show the proportion of bare soil and surface cover that is either photosynthetically active (i.e. growing vegetation) or inactive (e.g. crop residues, plant litter). Figure 5.10a shows the Australian continent in 2006, during the millennium drought. Figure 5.10b shows the same seasonal period in 2011, when the drought had broken. Large reductions in the area of bare soil are evident, especially in the north, east and south-east of the continent. The intense rainfall and floods associated with the breaking of the drought resulted in widespread erosion, especially in south-east Queensland. A full timeseries showing seasonal averages for the past decade is available on the SoE website,\(^d\) illustrating the pervasive effect of fire, especially across northern Australia.

**Wind erosion**

Climate is by far the strongest determinant of wind erosion. Land management can either moderate or accelerate wind erosion rates. Unravelling these two influences has been difficult, but the millennium drought provided an excellent opportunity to gauge the effectiveness of improvements in land management that have occurred in recent decades.

It has been well documented in historical accounts of land degradation in Australia that wind erosion was very active during the drought periods of the late 19th and early 20th centuries (e.g. Ratcliffe\(^37\)). While these anecdotal reports present dramatic images of huge dust storms engulfing rural towns, and sand drifts burying fence lines and blocking rural roads, until now it has never been unequivocally established whether the ‘dust bowl years’ of the 1940s were due to extreme drought, poor land management or both.

The millennium drought resulted in large dust storms and other wind erosion activity. Two extreme dust storms hit eastern Australian cities on 23 October 2002 and 23 September 2009. Wind erosion has environmental impacts at the source where soils are eroded (onsite wind erosion), and much greater economic and human health impacts downwind from the source where air quality is reduced (offsite wind erosion). The extreme dust storms increased public awareness of both these impacts, and also raised the question of whether this recent period of wind erosion was more or less active than that of the 1940s, and whether changes in land management have played a role.

\(^d\) www.environment.gov.au/soe

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**Figure 5.10** Images of Australia derived from remotely sensed data, showing the proportion of bare soil, photosynthetically active vegetation and nonphotosynthetically active vegetation, averaged for March–April–May in (a) 2006 and (b) 2011. White areas are either lakes (salt or fresh water, including exposed lake beds) or cloud.
McTainsh et al. have analysed wind erosion activity during the 1940s and 2000s. They used archived meteorological data to calculate the dust storm index (DSI) for both periods. The DSI, which provides a measure of the frequency and intensity of wind erosion activity, is the accepted measure of wind erosion activity, and has been used in past SoE reports and reports on the rangelands.

Wind erosion activity for the 1940s and 2000s was compared using the highest DSI year for each available station within each decade (decade maximum DSI) (Tables 5.4 and 5.5; Figure 5.11). Overall, mean onsite wind erosion in the 1940s was almost six times higher (mean DSI = 11.4) than in the 2000s (mean DSI = 2.0), and the mean maximum DSI for the 1940s was four times that of the 2000s (Table 5.4). There were also significant regional differences (Table 5.4). Wind erosion was much higher in the Mulga, Riverina and central Australia than in the South Australian and Western Australian rangelands, and the decrease in wind erosion in the 2000s is much more pronounced in the east and centre of the continent. For example, in the Mulga, the mean 1940s DSI is 21.3, compared with only 0.5 for the 2000s. Similarly, in the Riverina region, the mean decadal DSI decreases from 17.7 to 2.9. The 1940s erosion rate in central Australia is large, but the decrease in the 2000s is less.

The offsite wind erosion record at 11 coastal cities (Table 5.5 and locations in Figure 5.11) during the 1940s demonstrates that wind erosion across the inland had a very significant impact on the coast. This is especially so from Brisbane to Adelaide. Although the south-east coast DSI levels in the 1940s are around 40% of those inland, the mean DSI in the 2000s is less than 5% of the 1940s value (Table 5.5). There has been a large decrease in dust storms reaching the coastal cities.

As noted above, previous national SoE reports have provided updates on the DSI across the continent. Maps for the continent from 2001 to 2009 are shown in Figure 5.12.

Assessment of state and trends in erosion across Australia

Figure 5.13 and Assessment summary 5.3 provide an assessment of soil erosion by wind and water across Australia. The assessment draws heavily from the NLWRA, Bastin et al., Leys et al., Bui et al. and McTainsh et al.
Table 5.4 Dust storm index at six onsite wind erosion regions for the 1940s and 2000s

<table>
<thead>
<tr>
<th>Region and station</th>
<th>1940s mean DSI</th>
<th>1940s mean DSI range</th>
<th>2000s mean DSI</th>
<th>2000s mean DSI range</th>
<th>1940s maximum DSI</th>
<th>2000s maximum DSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qld: Mulga</td>
<td>21.3</td>
<td>19.0–23.6</td>
<td>0.5</td>
<td>0.5–0.6</td>
<td>39.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Charleville</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NSW: Riverina</td>
<td>17.7</td>
<td>16.9–18.5</td>
<td>2.9</td>
<td>2.89–2.93</td>
<td>51.5</td>
<td>9.2</td>
</tr>
<tr>
<td>Wagga Wagga</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Central Australia: Alice Springs</td>
<td>13.7</td>
<td>11.3–16.2</td>
<td>3.5</td>
<td>3.4–3.5</td>
<td>37.3</td>
<td>15.0</td>
</tr>
<tr>
<td>Southern SA: Ceduna</td>
<td>6.0</td>
<td>5.95–5.98</td>
<td>2.5</td>
<td>2.3–2.6</td>
<td>17.6</td>
<td>7.8</td>
</tr>
<tr>
<td>WA: Southern Rangelands</td>
<td>5.4</td>
<td>2.19–8.6</td>
<td>1.6</td>
<td>1.4–1.8</td>
<td>21.6</td>
<td>5.9</td>
</tr>
<tr>
<td>Kalgoorlie</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA: Northern Rangelands</td>
<td>4.4</td>
<td>3.4–5.5</td>
<td>1.3</td>
<td>1.1–1.4</td>
<td>20.0</td>
<td>7.4</td>
</tr>
<tr>
<td>Port Hedland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>11.4</strong></td>
<td><strong>2.0</strong></td>
<td><strong>31.2</strong></td>
<td><strong>7.8</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DSI = dust storm index; NSW = New South Wales; Qld = Queensland; SA = South Australia; WA = Western Australia
Source: McTainsh et al.38

Table 5.5 Dust storm index at 11 offsite locations for the 1940s and 2000s

<table>
<thead>
<tr>
<th>Location</th>
<th>1940s mean DSI</th>
<th>1940s mean DSI range</th>
<th>2000s mean DSI</th>
<th>2000s mean DSI range</th>
<th>1940s maximum DSI</th>
<th>2000s maximum DSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cairns</td>
<td>2.3</td>
<td>1.7–2.9</td>
<td>0.0</td>
<td>–</td>
<td>7.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Townsville</td>
<td>1.1</td>
<td>0.8–1.3</td>
<td>0.3</td>
<td>–</td>
<td>8.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Rockhampton</td>
<td>3.6</td>
<td>–</td>
<td>0.2</td>
<td>–</td>
<td>21.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Brisbane</td>
<td>3.8</td>
<td>0.17–6.8</td>
<td>0.1</td>
<td>0.05–0.15</td>
<td>21.0</td>
<td>1.2</td>
</tr>
<tr>
<td>Sydney</td>
<td>3.3</td>
<td>0.7–5.9</td>
<td>0.3</td>
<td>–</td>
<td>16.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Canberra</td>
<td>7.8</td>
<td>–</td>
<td>0.1</td>
<td>–</td>
<td>15.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Melbourne</td>
<td>5.0</td>
<td>4.3–5.6</td>
<td>0.1</td>
<td>–</td>
<td>11.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Adelaide</td>
<td>8.2</td>
<td>7.0–9.4</td>
<td>0.6</td>
<td>–</td>
<td>29.2</td>
<td>5.2</td>
</tr>
<tr>
<td>Perth</td>
<td>1.3</td>
<td>–</td>
<td>0.0</td>
<td>–</td>
<td>4.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Broome</td>
<td>0.2</td>
<td>–</td>
<td>0.3</td>
<td>–</td>
<td>1.3</td>
<td>0.6</td>
</tr>
<tr>
<td>Darwin</td>
<td>8.1</td>
<td>7.9–8.2</td>
<td>0.2</td>
<td>–</td>
<td>20.1</td>
<td>1.1</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>4.1</strong></td>
<td><strong>0.2</strong></td>
<td><strong>14.0</strong></td>
<td><strong>1.2</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DSI = dust storm index; – = data not available
Source: McTainsh et al.38
Figure 5.11  Maximum dust storm index across Australia for the (a) 1940s and (b) 2000s
**Figure 5.11 continued**

Maximum dust storm index

Source: McTainsh et al.24
Figure 5.12 Dust storm activity across Australia based on 356 stations, 2001–09

Source: McTainsh et al.
Figure 5.13  Grade of soil erosion for the physiographic provinces of Australia

Soil erosion grade
- Very poor
- Poor
- Good
- Very good

See Assessment summary 5.3 for commentary and assessments of trends.
## 5.3 Assessment summary

### State and trends of soil erosion by water and wind

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>102 Peninsular Province</strong></td>
<td>Land management in the grazing and cropping lands is improving, although localised erosion continues at unsustainable rates</td>
<td><img src="image" alt="Assessment grade" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>103, 104 Burdekin and Fitzroy Provinces</strong></td>
<td>Land management in the grazing and cropping lands is improving, although erosion continues at unsustainable rates</td>
<td><img src="image" alt="Assessment grade" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>105, 106 New England–Moreton and Macquarie Uplands Provinces</strong></td>
<td>Management of surface cover has improved in most areas, but erosion from less fertile grazing lands is significant</td>
<td><img src="image" alt="Assessment grade" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>107 Kosciuszkan Uplands Province</strong></td>
<td>Diverse lands experienced severe gully and sheet erosion after clearing. Increasing extent of wildfire is likely to increase erosion</td>
<td><img src="image" alt="Assessment grade" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>108 Tasmanian Uplands Province</strong></td>
<td>Unsustainable rates of erosion under intensive agriculture in the north, and widespread hillslope erosion in the west and south-west due to wildfire</td>
<td><img src="image" alt="Assessment grade" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>201 Carpentaria Lowlands Province</strong></td>
<td>Hillslope erosion primarily in the east and south associated with clearing and grazing</td>
<td><img src="image" alt="Assessment grade" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>202 Central Lowlands Province</strong></td>
<td>Large and diverse province, with widespread wind erosion in the centre and west. Hillslope erosion associated with grazing by stock and feral animals. Rate of erosion has slowed</td>
<td><img src="image" alt="Assessment grade" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>203 Murray Lowlands Province</strong></td>
<td>Extensive wind erosion associated mainly with dunefields. Increased surface cover has slowed previously severe erosion</td>
<td><img src="image" alt="Assessment grade" /></td>
<td><img src="image" alt="Confidence" /></td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------------------------------------------------------------------------</td>
<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td><strong>301 North Australian Plateaus Province</strong></td>
<td>Sheet and gully erosion in areas cleared for grazing or agriculture. Vulnerable to severe erosion due to intensity of rainfall and erodibility of the soils</td>
<td>![Very poor] ![Poor] ![Good] ![Very good]</td>
<td>![In grade] ![In trend]</td>
</tr>
<tr>
<td><strong>302 Kimberley Province</strong></td>
<td>Fast rates of sheet and gully erosion have slowed, but remain unsustainable in areas with poor surface cover</td>
<td>![Very poor] ![Poor] ![Good] ![Very good]</td>
<td>![In grade] ![In trend]</td>
</tr>
<tr>
<td><strong>303 Carpentaria Fall Province</strong></td>
<td>Erosion rates have slowed, particularly in the south-east of the province</td>
<td>![Very poor] ![Poor] ![Good] ![Very good]</td>
<td>![In grade] ![In trend]</td>
</tr>
<tr>
<td><strong>304 Barkly–Tanami Plains Province</strong></td>
<td>Sheet and gully erosion in areas cleared for grazing or agriculture. Vulnerable to severe erosion due to intensity of rainfall and erodibility of soils</td>
<td>![Very poor] ![Poor] ![Good] ![Very good]</td>
<td>![In grade] ![In trend]</td>
</tr>
<tr>
<td><strong>305 Central Australian Ranges Province</strong></td>
<td>Extensive wind erosion, with gully and sheet erosion in areas subject to grazing by stock and feral animals</td>
<td>![Very poor] ![Poor] ![Good] ![Very good]</td>
<td>![In grade] ![In trend]</td>
</tr>
<tr>
<td><strong>306 Sandland Province</strong></td>
<td>Gully and sheet erosion in areas subject to grazing by stock and feral animals</td>
<td>![Very poor] ![Poor] ![Good] ![Very good]</td>
<td>![In grade] ![In trend]</td>
</tr>
<tr>
<td><strong>307 Pilbara Province</strong></td>
<td>Gully and sheet erosion in areas subject to grazing by stock and feral animals</td>
<td>![Very poor] ![Poor] ![Good] ![Very good]</td>
<td>![In grade] ![In trend]</td>
</tr>
<tr>
<td><strong>308 Western Coastlands Province</strong></td>
<td>Gully and sheet erosion in areas subject to grazing by stock and feral animals</td>
<td>![Very poor] ![Poor] ![Good] ![Very good]</td>
<td>![In grade] ![In trend]</td>
</tr>
</tbody>
</table>
### State and trends of soil erosion by water and wind continued

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>309 Yilgarn Plateau Province</strong></td>
<td>Extensive wind erosion, particularly in the north</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>310 Nullarbor Plain Province</strong></td>
<td>Erosion rates are relatively stable, unless there is a loss of surface cover due to grazing or fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>311, 312 Eyre Peninsula and Gulfs Ranges Provinces</strong></td>
<td>Diverse lands with a history of unsustainable rates of wind and water erosion. Land-management practices are improving</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Recent trends**
- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**

**Confidence**
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Grades**
- **Very good**
  - Current management adequate—low level of monitoring required
- **Good**
  - Significant erosion at the time of clearing (>5 tonnes/ha/year). Rates are 1–5 tonnes/ha/year. Needs management and monitoring, otherwise the system of land use will be threatened in the long term
- **Poor**
  - The majority of the landscape has been eroded to the extent that plant growth has been affected and, in agricultural systems, yields and returns are compromised. Erosion rates are unsustainable (>5 tonnes/ha/year)
- **Very poor**
  - Current rates of erosion are unsustainable, with large areas reaching exhaustion within 50 years
2.3 Vegetation

Australia’s vegetation comprises native and exotic species, in assemblages that vary from essentially natural to completely modified. The year 1750 has been widely adopted as the reference point for comparison of pre-European vegetation with subsequent extent of Australian vegetation, and is used for that purpose here.

The continental extent of all forms of vegetation is summarised in Table 5.6 and mapped in Figure 5.14.

2.3.1 Native vegetation

Australia’s native vegetation can be classified into 23 major vegetation groups (MVGs), the majority of which are dominated by just two woody plant genera—*Acacia* and *Eucalyptus*.

**Extent**

Three MVGs each occupy more than 10% of continental land area—hummock grasslands (18%), eucalypt woodlands (12%) and *Acacia* shrublands (11%). Seven MVGs together occupy less than 2% of continental land area—rainforests and vine thickets, eucalypt tall open forests, callitris forests and woodlands, low closed forests and tall closed shrublands, mangroves, heathlands and eucalypt low open forests.

The pre-1750 and current extent of MVGs are summarised in Figure 5.15 and mapped in Figures 5.16 and 5.17.

Since European settlement, 13% of Australia’s native vegetation has been cleared and converted to other land uses, predominantly agriculture. The extent of loss varies greatly between vegetation types (Figure 5.16). The greatest areal loss of vegetation since European settlement has been in the eucalypt woodlands (MVG 5), which have been reduced by one-third, to around 84 million hectares. Each of eucalypt open forests (MVG 3), mallee woodlands and shrublands (MVG 14), and other grasslands, herblands, sedgelands and rushlands (MVG 21) have suffered a similar proportional loss, from smaller original extents. The greatest proportional losses, to around 60% of their original extent, have been in casuarina forests and woodlands (MVG 8), and low closed forests and tall closed shrublands (MVG 15).

Table 5.6 Continental extent of Australian vegetation

<table>
<thead>
<tr>
<th>Vegetation category</th>
<th>Area (million hectares)</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native shrublands and heathlands</td>
<td>283</td>
<td>37</td>
</tr>
<tr>
<td>Native grassland and minimally modified pastures</td>
<td>257</td>
<td>33</td>
</tr>
<tr>
<td>Native forests and woodlands</td>
<td>148</td>
<td>19</td>
</tr>
<tr>
<td>Annual crops and highly modified pastures</td>
<td>66</td>
<td>9</td>
</tr>
<tr>
<td>Ephemeral and permanent water features</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Intensive uses (includes urban, peri-urban, mining)</td>
<td>3</td>
<td>0.4</td>
</tr>
<tr>
<td>Plantation forests</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>Perennial crops</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Bare</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Horticultural trees and shrubs</td>
<td>0.7</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>769</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Source: Australian Bureau of Agricultural and Resource Economics and Sciences
Figure 5.14 Extent of all forms of vegetation across Australia, 2009

Source: Australian Bureau of Agricultural and Resource Economics and Sciences
Current and pre-1750 extent of Australian major vegetation groups

Source: Australian Government Department of the Environment and Water Resources
Rainforest and vine thickets
Eucalyptus tall open forest
Eucalyptus open forest
Eucalyptus low open forest
Eucalyptus woodlands
Acacia forests and woodlands
Callitris forests and woodlands
Casuarina forests and woodlands
Melaleuca forests and woodlands
Other forests and woodlands
Eucalyptus open woodlands
Tropical eucalyptus woodlands/grasslands
Acacia open woodlands
Mallee woodlands and shrublands
Low closed forest and tall closed shrubland
Acacia shrublands
Other shrublands
Heath
Tussock grasslands
Hummock grasslands
Other grasslands, herblands, sedgelands and rushlands
Chenopod shrublands, samphire shrubs and forblands
Mangroves
Inland aquatic—fresh water, salt lakes, lagoons
Unclassified native vegetation
Naturally bare—sand, rocks, claypan, mudflat
Sea and estuaries
Unclassified forests
Other open woodlands
Mallee open woodlands and sparse shrublands
Unknown/no data

Source: Australian Government Department of the Environment and Water Resources

Figure 5.16 Estimated pre-1750 distribution of major vegetation groups in Australia
Current distribution of major vegetation groups in Australia

Source: Australian Government Department of the Environment and Water Resources

Figure 5.17
The pattern of native vegetation loss is illustrated by Figure 5.18. This shows the proportion of native vegetation remaining in each of Australia’s 18 agroclimatic regions (an agroclimatic region is defined by particular climatic parameters relevant to farming systems).45 The greatest reductions in native vegetation extent have been in eastern, south-eastern and south-western Australia, where post-1750 human settlement and agricultural land uses are greatest. More than 50% of native vegetation has been lost in six agroclimatic regions, and one-third or more in two other regions. As discussed in Section 2.1, this pattern of vegetation loss reflects that of European settlement and land use.

**Condition**

The condition of native vegetation depends on a suite of factors operating at a range of spatial and temporal scales. As discussed in Section 3, the most important of these are the extent of vegetation clearing and resultant patterns of fragmentation; the impacts of climate variability such as that manifested through drought, and of particular climate events such as cyclones; the effects of both historical and current management practices, such as grazing and harvesting; and the impacts of fire events and regimes.46–47

In general, vegetation condition deteriorates with diminishing remnant extent. The national rate of native vegetation clearing is now balanced by the extent of regrowth (see Section 3.2.2).48 However, the condition of much native vegetation is likely to be deteriorating, particularly fragmented remnants that are in intensive land-use areas and subjected to pressures such as grazing.

Historically, vegetation condition has been assessed at a range of scales and with a variety of approaches. Progress has recently been made towards developing a nationally consistent approach to assessing vegetation condition, built around state-level approaches and assessments;46 however, national-level results from this work are not yet available. In the interim, related parameters that provide insights into native vegetation condition at a continental scale are:

- the degree of fragmentation of native vegetation (see Chapter 8: Biodiversity, Section 3.7.1)
- annual and seasonal variation in green vegetation cover (mean annual greenness fraction—the fraction of land surface covered by photosynthesising green vegetation), which reflects variation in net primary productivity as a proxy for vegetation condition (e.g. Donohue et al.49); see Section 2.2.6 and Figure 5.10
- the degree of vegetation modification, as assessed under the ‘Vegetation Assets, States and Transitions’ (VAST) framework developed by the Bureau of Rural Sciences.50

The VAST framework ‘classifies vegetation condition by degree of anthropogenic modification from a benchmark condition state’;51 the VAST classification framework is summarised in Table 5.7. The degree of modification of Australia’s native vegetation across Australia’s land area as assessed by VAST is illustrated in Figure 5.19. This classification is provided by continental-scale remotely sensed data, and is most useful for broad regional assessments rather than fine detail.51

Again, the continental pattern of vegetation modification reflects Australia’s history of European settlement, land clearing and agricultural land uses. The greatest extent of least-modified vegetation is in the north and centre of the continent, along the eastern and south-western ranges of mainland Australia, and in the eastern ranges and south-west Tasmania. In these zones, an average of 80% (range 70–96%) of vegetation is classified as VAST category I or II (residual or modified; for definitions, see Table 5.7). Conversely, the greatest extent of most-modified or replaced vegetation is in the intensive-use zones of the eastern and southern mainland, and in the midlands and north of Tasmania. In these zones, an average of only 40% (range 15–69%) of vegetation is classified as VAST category I or II.

Figure 5.20 illustrates the extent of modification of each of the MVGs as assessed by VAST.
Figure 5.18 Percentage of Australian native vegetation remaining, by agroclimatic region

Letters indicate agroclimatic categories; numbers indicate subcategories for each region.45

Vegetation remaining (%)  
- 90–100
- 70–90
- 50–70
- 40–50
- 0–40

Agroclimatic region  
- B  Cold
- D  Cool, wet
- E  Warm, seasonally wet/dry
- F  Warm, wet
- G  Warm to hot, very dry
- H  Hot, dry
- I  Hot, seasonally wet/dry
- J  Hot, wet

Source: Environmental Resources Information Network, Australian Government Department of Sustainability, Environment, Water, Population and Communities, 2011
<table>
<thead>
<tr>
<th>Vegetation cover classes</th>
<th>Criteria</th>
<th>Native vegetation cover</th>
<th>Non-native vegetation cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 0: residual bare</td>
<td>Areas where native vegetation does not naturally persist</td>
<td>Dominant plant species indigenous to the locality and spontaneous in occurrence, i.e. a vegetation community described using definitive vegetation types relative to estimated pre-1750 types</td>
<td>Dominant structuring plant species indigenous to the locality but cultivated, alien to the locality and cultivated, or alien to the locality and spontaneous</td>
</tr>
<tr>
<td>Class I: residual</td>
<td>Native vegetation community structure, composition and regenerative capacity intact—no significant perturbation from land-use or land-management practice. Class I forms the benchmark for classes II to VI</td>
<td>Native vegetation community structure, composition and regenerative capacity intact—perturbed by land-use or land-management practice</td>
<td>Native vegetation replaced with species alien to the locality and spontaneous in occurrence</td>
</tr>
<tr>
<td>Class II: modified</td>
<td>Native vegetation community structure, composition and regenerative capacity intact—perturbed by land-use or land-management practice</td>
<td>Native vegetation community structure, composition and regenerative capacity significantly altered by land-use or land-management practice</td>
<td>Native vegetation replaced with cultivated vegetation</td>
</tr>
<tr>
<td>Class III: transformed</td>
<td>Native vegetation replaced with species alien to the locality and spontaneous in occurrence</td>
<td>Vegetation removed</td>
<td></td>
</tr>
</tbody>
</table>

Source: Thackway & Lesslie

### 2.3.2 Non-native vegetation

Non-native vegetation includes that comprised solely of exotic species, such as many annual and perennial crops, and native vegetation assemblages that have been significantly altered through management or invasion by exotic species. There is currently no generally agreed threshold for the level of alteration at which vegetation ceases to be classified as ‘native’, so there may be some imprecision in classification between, for example, VAST categories III and IV.

The dominant forms of non-native vegetation are annual crops and highly modified pastures, together comprising around 9% of Australia's land area (Table 5.1). All other forms of non-native vegetation each comprise less than 1% of continental land area: plantation forests comprise 0.22%, perennial crops 0.14%, and horticulture 0.08% of our land area.

The major trends in non-native vegetation over the reporting period were discussed in Section 2.1. These reflected climatic, market and policy factors.
VAST class

0  Bare
I  Residual
II  Modified
III  Transformed
IV–V  Replaced
VI  Removed

Source: Lesslie et al.¹¹

Figure 5.19  VAST classification of Australian vegetation
Figure 5.20 Extent of modification of major vegetation groups, as assessed by VAST
## 5.4 Assessment summary

### State and trends of vegetation

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Native vegetation extent—outside intensive land-use zones</td>
<td>More than 90% of the original native vegetation remains in central and northern mainland Australia, and in Tasmania’s central highlands and south-west</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native vegetation extent—within intensive land-use zones</td>
<td>Less than 50% of the original native vegetation remains in most of Australia’s major primary production regions, and in many settled coastal regions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native vegetation condition—outside intensive land-use zones</td>
<td>Although there are exceptions associated with invasive species or management regimes, the degree of modification of most vegetation outside the intensive land-use zones is relatively small. The proportion of each major vegetation group classified in VAST categories I or II (residual or modified) averages 80%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Native vegetation condition—within intensive land-use zones</td>
<td>The proportion of each major vegetation group classified in VAST categories I or II (residual or modified) averages 40%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Recent trends**

- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

**Confidence**

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Grades**

- **Very good** The environmental values of native vegetation are, or approximate, those that would be found in undisturbed vegetation; community structure, composition and regenerative capacity are intact
- **Good** The environmental values of native vegetation are suboptimal, but community structure, composition and regenerative capacity remain largely intact
- **Poor** The environmental values of native vegetation are significantly compromised and are unlikely to recover without intervention
- **Very poor** The environmental values of native vegetation have largely been lost
Pressures affecting the land environment

Pressures affecting Australia’s land environment derive from each of the drivers discussed in Chapter 2: Drivers, as well as from the interactions between them. The growing human population and levels of consumption, both domestically and globally, will increase demand for more food and fibre. Expanding settlements and infrastructure will continue to impact on the environment. Economic growth places more demands on natural resources, as well as generating financial resources and new technologies for environmental management.

Changed climate regimes and sea level rise associated with global warming are expected to place new pressures on both the human environment and primary production systems (see Chapter 2: Drivers). These drivers interact—for example, fire regimes are influenced by both climate change and changing patterns of settlement and land use associated with population and economic growth. Coastal ecosystems will be affected by the interaction between sea level rise and human settlements.

The major pressures impacting on Australian soils and vegetation have been identified in previous SoE reports, and in a series of assessments and reviews over the past decade. These pressures are:

- those resulting from climate change, which include increased average temperatures, warmer minimum and maximum temperatures, less rainfall in much of Australia, and more extreme weather events
- vegetation clearing and associated habitat fragmentation, with consequences for ecosystem services such as carbon sequestration, and for biodiversity
- changed fire patterns for both wildfires and managed fires
- land uses and land-management practices, including farming and forestry systems
- invasive diseases, pest and weeds
- urban expansion
- mining
- waste disposal
- water diversions, and changed hydrology and salinity.

At a glance

The impacts of climate change on the land environment are expected to be profound. By 2070, many environments will differ markedly from those that currently exist. As a result, some vegetation communities will disappear, others will change significantly in extent and distribution, and novel ecosystems will arise. Many agricultural and production systems are likely to be adversely affected.

Rates of land clearing averaged around 1 million hectares annually over the period 2000–10, and were balanced by the extent of regrowth—although the character and values of the original and regrowth vegetation are often different. Land clearing and ecosystem fragmentation associated with the expansion of both agriculture and settlements are concentrated in a relatively small number of regions.

Widespread landscape-scale pressures—particularly those due to invasive species and inappropriate fire regimes—continue to threaten environmental values across much of Australia’s land environment. These pressures are likely to be exacerbated by climate change. The impacts of these pressures are particularly pronounced on the extensively managed environments of northern Australia.

Pressures on the land environment associated with livestock grazing—Australia’s most extensive land use—are mixed; they appear to be diminishing in some regions, but increasing in others. Although better management of many agricultural systems has reduced their impacts on the land environment, a number of issues around nutrient and soil management remain. Management of both native and plantation production forests has become more regulated, and landscape-scale impacts are generally small.

The widespread adoption of minimum tillage in agriculture during the past decade is a major achievement by Australian farmers that reduces pressures affecting the land environment.

Urban and peri-urban expansion, particularly around major cities and in some coastal regions, continues to impact adversely on land environmental values.

New forms of mining are generating pressures on the land environment, and conflicting with other land uses, notably agriculture, in some regions.
Each pressure, except water diversions, which are discussed in Chapter 4: Inland water, is discussed below.

3.1 Climate change–induced pressures

The millennium drought and subsequent floods in eastern Australia are recent examples of the high levels of variability that typify the Australian climate, in cycles ranging from seasons to centuries. Australia’s soils and native vegetation have evolved under, and are adapted to, the pressures of such climatic variability. However, the pressures exerted by climate change are expected to change both the distribution and occurrence of native and exotic plant species. This will progressively change Australian landscapes.29

3.1.1 Native vegetation

The impacts of climate change on Australia’s native vegetation are expected to be profound.52 Some native vegetation communities will no longer exist, the extent and distribution of others will change, and novel ecosystems of variously native and exotic species will arise.53 The extent of likely change can be assessed as dissimilarity from the current condition,52 which is shown for each of the 23 MVGs in Figure 5.21. Figure 5.22 depicts the possible extent of new environments by 2070 under a medium-impact scenario; e it is evident that these may be very extensive.

3.1.2 Diseases, pests and weeds

Climatic changes will also alter the occurrence and distribution of diseases, pests and weeds, and their impacts on vegetation communities. Only preliminary work has been conducted to investigate these possible impacts. The case of buffel grass (Cenchrus ciliaris), a major weed in arid and semi-arid zones, is illustrative. This weed may become less problematic in its current environment, and more problematic in southern and eastern Australia, where it does not currently occur or is just becoming established.52 Diseases and pests are likely to move south as temperatures increase, impacting on both native vegetation and production systems.54

3.1.3 Agricultural and forestry production systems

Both favourable and adverse impacts on agricultural and forestry production systems are expected. For example, there may be growth benefits from additional carbon dioxide fertilisation, but adverse impacts from changes in temperature extremes, precipitation, pests and nutrient availability.54

Rainfall, evaporation and the water storage capacity of soils are finely balanced in some parts of Australia, and relatively small shifts in climate can have a large impact on the viability of various land uses. For example, in northern cropping regions, large areas of heavy-textured soils stand to benefit from an increase in summer rainfall. Conversely, light-textured soils in southern cropping lands have small water storage capacities, and cropping is only possible because rainfall is light but regular throughout the growing season. Any reduction in the frequency of cold fronts across southern Australia during the growing season will adversely affect yields in these southern regions.

Cropping and livestock production is expected to decline by 2030 over much of southern Australia, due to increased drought and limited availability of nutrients; heat and drought are also likely to reduce the quality of grain, grape, vegetable, fruit and other crops.54 Both native and plantation forests are likely to be at greater risk of fire, and productivity is likely to be diminished by decreased rainfall and soil water availability.

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e https://wiki.csiro.au/confluence/display/ozclim/Science provides the basis and assumptions of these scenarios; those used were scenarios A1B with medium sensitivity, and A1F1 with high sensitivity
Figure 5.21  Artificial neural network–based predicted environmental dissimilarity in different environment types, under 2070 medium-impact and high-impact scenarios, averaged across all grid cells in each major vegetation group

Source: Dunlop et al.10
Figure 5.22 Novel biotically scaled environments under the 2070 medium-impact scenario, based on generalised dissimilarity modelling of vascular plants

The colours depict the biotically scaled environmental difference between the future environment at each point and the most similar current environment from anywhere on the continent. In biotically scaled environments, ‘the environmental change assessed is meaningful to biodiversity’. Higher values (dark pinks) indicate potential locations of future environments for which no analogue currently exists anywhere on the continent.

Source: Dunlop et al.32
## 5.5 Assessment summary

### Continental-scale pressures affecting the land environment

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate change–induced impacts on native vegetation</strong></td>
<td>Some native vegetation communities will no longer exist, the extent and distribution of others will change, and novel ecosystems will arise</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Climate change–induced impacts on diseases, pests and weeds</strong></td>
<td>Climate change will alter the occurrence and distribution of diseases, pests and weeds, and their impacts on vegetation communities. Specific impacts remain largely speculative</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Climate change–induced impacts on agricultural and forestry production systems</strong></td>
<td>Both favourable and adverse impacts on agricultural and forestry production systems are expected, but the latter are expected to outweigh the former</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

### Recent trends

- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**

### Grades

- **Very low impact**
  - There are few or negligible impacts on land environmental values
- **Low impact**
  - Expected impacts are not widespread and may affect only a small number of land environmental values
- **High impact**
  - Expected impacts are widespread and may irreversibly affect land environmental values
- **Very high impact**
  - Expected impacts are widespread and will irreversibly affect land environmental values

### Confidence

- **Adequate high-quality evidence and high level of consensus**
- **Limited evidence or limited consensus**
- **Evidence and consensus too low to make an assessment**
3.2 Regional and landscape-scale pressures

3.2.1 Bushfire

Australia’s fire regimes—the frequency, intensity and timing of bushfires—have major consequences for vegetation distribution, composition and condition, and soil bareness and erosion.

The pattern of fire occurrence over the Australian continent (illustrated by Figure 5.23 for 1997–2009) is generally of:

- frequent fires in the tropical savannas, half or more of whose area may burn in any one year
- regular fires in the arid and semi-arid grasslands following years of above-average rainfall
- major fires in the south-east and south-west of the continent and in Tasmania associated with major drought cycles.

These characteristic patterns of fire occurrence in different parts of the continent are evident in the decadal record of vegetation, which is available on the SoE website.

A review of bushfires in Australia over the seven years to 2004 demonstrates these patterns, and the much greater average area burned annually by bushfires across northern Australia outside the wet tropics (Figure 5.24). Over 1997–2004, the average extent of fire-affected area in the three northern zones ranged from 19% to 35%, while elsewhere in Australia the extent ranged from 1% to 5%. Conversely, the greatest impacts on life and property of intense wildfires occur in southern Australia, tragically exemplified by the 2009 Victorian fires.

Fire regimes in all parts of Australia impact on environmental values. For example, frequent high-intensity fires impact on the recruitment and persistence of obligate seeder plant species—that is, plants with large, fire-activated seed banks that germinate, grow, and mature rapidly following a fire. This happens in environments as diverse as the Arnhem Land Plateau savannas and the tall, wet eucalypt forests of south-eastern Australia. One consequence of the millennium drought in south-eastern Australia was the frequent occurrence of high-intensity wildfires in parts of Victoria’s alpine region. This led to the repeated burning of some areas of *Eucalyptus delegatensis* and *E. regnans* that were too young to have seed crops adequate for stand replacement. Conversely, an insufficient frequency of low-intensity fires will also impact adversely on the environmental values of ecosystems adapted to relatively frequent low-intensity fires.

Weather conditions favouring more severe bushfires appear to be becoming more frequent. The past 30 years have seen an upward trend in the cumulative forest fire danger index (a measure of predicted fire severity), exemplified by the change at one recording station in Victoria (Figure 5.25). This reflects the effects of both progressively increasing temperatures and, in the latter period, the millennium drought. This trend is expected to continue under predicted climate change conditions; the average number of ‘extreme’ fire danger days in 2020 is predicted to increase by 5–25% and 15–65% compared with 1990 levels, for 0.4 °C and 1.0 °C temperature increases, respectively.

Figure 5.23 Fire frequency map of Australia, 1997–2009
3.2.2 Land clearing

Land clearing represents a fundamental pressure on the land environment, causing the loss and fragmentation of native vegetation. Depending on subsequent management, land clearing can lead to a variety of impacts on soils, including erosion and loss of nutrients.

Loss of native vegetation

The pattern of forest cover change over 2002–06 (the most recent years for which full continental data are available) shows woody vegetation loss concentrated in the north of the Northern Territory, southern Western Australia, northern and eastern Tasmania, and inland central and northern Queensland (Figure 5.26). This general pattern continued in the latter part of the decade—a small number of surveyed bioregions lost more than 10% of their extent of woody vegetation from 2000 to 2010. These regions were along the coastal plain of Western Australia, from Geraldton to Cape Naturaliste; in the Northern Midlands of Tasmania; and in the northern Brigalow Belt of central Queensland. These changes primarily reflect urban and peri-urban expansion in the coastal areas, and clearing for agriculture in others.
Figure 5.26 Continental pattern of Australia’s forest cover change, 2002–06

Negative values represent a decrease between 2002 and 2006, while positive values represent an increase between 2002 and 2006.

The best nationally consistent data on land clearing are available from the Australian Government Department of Climate Change and Energy Efficiency’s monitoring of change in Australia’s forest vegetation for international reporting under the United Nations Framework Convention on Climate Change. There are some caveats to these data: they do not correspond exactly to vegetation clearing in toto, because the monitoring system is directed at measuring changes in the carbon stocks of forests and woodlands, which are defined as woody vegetation with a minimum of 20% canopy cover, a minimum height of 2 metres, and a minimum area of 0.2 hectares. The monitoring system does not assess change in nonwoody native vegetation, and may report the impacts of events such as intense fires or cyclones as loss of forest, and...
of natural regeneration and recovery following those events as expansion (regrowth) of forest.

Before 2007, monitoring was conducted for the whole continent; since 2007, monitoring has focused on mapping the intensive land-use zone shown in Figure 5.27. Approximately 80% of Australia’s forest vegetation, and most human-induced forest cover change, occur in this zone. Forest loss, forest regrowth and net forest cover change for those regions assessed continually since 1972 are shown in Figure 5.28. Annualised data for the decade to 2010 are shown in Figure 5.29.

The annual rate of forest loss in the mapped intensive-use zone over the decade to 2010 averages 1.1 million hectares (range 0.7 million – 1.5 million hectares) (Figure 5.27). This loss has been offset by forest expansion averaging 1 million hectares annually (range 0.6 million – 1.3 million hectares). As a consequence, there was a small net gain of forest in Australia in 2007–10, for the first time since the early 1990s. The overall average net rate of forest change in the area mapped over the decade to 2010 was a loss of around 160 000 hectares annually. As the 2006 SoE report noted, ‘regrowth’ vegetation and its environmental values are generally different in many respects from the vegetation that has been cleared.
Fragmentation of native vegetation

The fragmentation of remnant vegetation that follows land clearing may impact adversely on the quality and persistence of that vegetation, because of the disruption to essential ecosystem processes such as pollination, seed dispersal and regeneration. This is most acute in the case of paddock trees and small remnant patches of vegetation. As discussed by the Assessment of Australia’s terrestrial biodiversity 2008, no nationally consistent data to characterise fragmentation are yet available, although analyses have been conducted for some states (e.g. Tasmania) and are under way elsewhere. The VAST assessment reported in Section 2.3 currently provides the best continental-scale information, but only at a relatively coarse scale. In general, fragmentation impacts will be greatest where land clearing has been greatest, both historically (Figure 5.18) and recently (Figure 5.26).

Fragmented vegetation is also subject to ‘edge effects’, which are a diverse range of ecological changes occurring at the abrupt artificial margins of uncleared and cleared land. Increased light levels and wind at the edges can change the local habitat, and the fragmented vegetation is usually more prone to colonisation by invasive species.

Impacts on soils

Soils and vegetation have co-evolved across the Australian landscape over millennia. Clearing of the predominantly deep-rooted native vegetation has many impacts on soil, changing the cycling of water, nutrients, sediments and solutes. Soils take decades, and in some cases centuries, to adjust to the new conditions. Many soils across Australia are therefore still equilibrating to European land use.
The initial disruption to soil usually results in a significant loss of nutrients. Organic matter is oxidised, and the removal of surface cover (litter and protective vegetation) makes the soil more prone to erosion. Stores and cycles of nutrients adjust under the new land use, but in most cases the net loss of nutrients and leakage are greater than under natural conditions. As noted in Section 2.2.4, soil carbon typically reduces to 20–70% of the pre-clearing amount. Restoring this very large stock of carbon is now a key focus in programs for mitigating GHGs around the world, and nationally (e.g. the Australian Government’s Carbon Farming Initiative).

The removal of native vegetation also results in major changes to the hydrological cycle, including dryland salinity (see Section 2.2.3). The soil also experiences more rapid leaching, and this can change soil properties and processes (e.g. clays may disperse and reduce permeability). A less widely appreciated effect of clearing is that the land surface becomes more uniform—the patchiness of the native system is lost. For example, removing mounds of litter, grass tussocks and rough surfaces leaves a relatively smooth soil surface. This almost invariably leads to more rapid run-off and erosion, less effective water infiltration, and a loss of the micro-environments necessary for many species.

3.2.3 Invasive species

Invasive species impacting on the land environment comprise disease-causing organisms such as fungi and parasites, insects and other invertebrates, pest animals and weeds. Invasive species put pressure on land environmental values in a variety of ways, as well as impacting on biodiversity (see Chapter 8: Biodiversity). Some invasive species, such as rabbits, are long-established pressures. Others, such as foxes, are long established in some environments but new to others; yet others, such as the fungus that causes myrtle rust, are only recently established. The risk of invasive species incursions into Australia is increasing with the growth of international travel and trade.
Fungi

Among the numerous introduced fungi affecting plant health, two are of particular concern at a national scale.

The first is Phytophthora cinnamomi, which causes root rot that can significantly alter plant communities and lead to local and perhaps complete species extinctions.68 Its impacts have been recognised since the 1960s. *P. cinnamomi* now occurs widely across Australia, but its most severe impacts are in vegetation communities in the south-west and south-east of the country. Many genera of endemic taxa have a high proportion of susceptible species—many of which are rare and threatened.69 Consequently, the disease caused by *P. cinnamomi* is listed as a key threatening process under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).68

In contrast, the fungus that causes myrtle rust, *Uredo rangelii*, is a recent introduction. It was first detected in 2010 in central coastal New South Wales, and is now established in most of coastal New South Wales70 and in south-east Queensland.71 Myrtle rust affects trees and shrubs in the Myrtaceae family of plants. This family includes many iconic Australian plant genera, including bottlebrush (*Callistemon*), eucalypts (*Eucalyptus*) and affiliates (e.g. *Corymbia*), lilly pillies (*Syzygium*) and tea tree (*Melaleuca*). Because of the dominance of the Myrtaceae in the Australian flora and the high mobility of plant rusts, the potential impacts of myrtle rust are profound. However, little is known of the behaviour and impacts of myrtle rust under Australian conditions.72

Pest animals

Some 73 invasive pest animal species (amphibians, birds, fish, mammals and reptiles) have established populations in Australia. In many cases—such as feral cats, foxes, rabbits and wild dogs—these populations are long established and distributed over much of the continent. In other cases, such as foxes in Tasmania, introductions are recent, and populations are still small. The highest concentration of significant pest animal species is along the eastern seaboard, and many coastal and offshore islands suffer significant impacts.73 Some newly established pests, such as the Asian honeybee, may ultimately have significant impacts on ecosystem processes and thus vegetation.74

Pest animals with the greatest impacts on the land environment, in terms of damage estimates, are foxes, feral cats, rabbits, feral pigs, wild dogs, house mice, goats, cane toads, wild horses and camels.75 Their impacts are expressed as environmental damage, such as that caused to soil and vegetation by pigs or camels; as loss of production in agricultural systems; and as loss of biodiversity. Land degradation by goats, pigs and rabbits, and the impacts of cane toads, are formally listed as threatening processes under the EPBC Act.

Weeds

Invasive weeds present serious threats to Australia’s environmental values. They displace native species, contribute significantly to land degradation, and reduce farm and forest productivity.76 The Australian and state and territory governments have identified the worst of these (currently, 20 species) as Weeds of National Significance for coordinated management action (Table 5.8). The impacts of gamba grass and four other introduced grasses in northern Australia, and of escaped garden plants nationally, have been listed as threatening processes under the EPBC Act. A further 28 species have been identified as being at an early stage of establishment, but with the potential to become significant threats.77 The potential of weeds to transform the land environment is very significant; for example, ‘eleven plant species have the capacity to permanently alter ecosystems across Australia’s rangelands’.41
Table 5.8  Weeds of National Significance, July 2011

<table>
<thead>
<tr>
<th>Common name(s)</th>
<th>Scientific name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prickly acacia, blackthorn, prickly mimosa, black piquant, babul</td>
<td><em>Acacia nilotica</em></td>
</tr>
<tr>
<td>Alligator weed</td>
<td><em>Alternanthera philoxeroides</em></td>
</tr>
<tr>
<td>Pond apple, pond-apple tree, alligator apple, bullock’s heart, cherimoya,</td>
<td><em>Annona glabra</em></td>
</tr>
<tr>
<td>monkey apple, bobwood, corkwood</td>
<td></td>
</tr>
<tr>
<td>Bridal creeper, bridal veil creeper¹, smilax, florist’s smilax,</td>
<td><em>Asparagus asparagoides</em></td>
</tr>
<tr>
<td>smilax asparagus</td>
<td></td>
</tr>
<tr>
<td>Cabomba, fanwort, Carolina watershed, fish grass, Washington grass,</td>
<td><em>Cabomba caroliniana</em></td>
</tr>
<tr>
<td>watershield, carolina fanwort, common cabomba</td>
<td></td>
</tr>
<tr>
<td>Boneseed⁰</td>
<td><em>Chrysanthemoides monilifera subsp. monilifera</em></td>
</tr>
<tr>
<td>Bitou bush⁰</td>
<td><em>Chrysanthemoides monilifera subsp. rotundata</em></td>
</tr>
<tr>
<td>Rubber vine, rubbervine, India rubber vine, India rubbervine,</td>
<td><em>Cryptostegia grandiflora</em></td>
</tr>
<tr>
<td>palay rubbervine, purple allamanda</td>
<td></td>
</tr>
<tr>
<td>Hymenachne, olive hymenachne, water stargrass, West Indian grass,</td>
<td><em>Hymenachne amplexicaulis</em></td>
</tr>
<tr>
<td>West Indian marsh grass</td>
<td></td>
</tr>
<tr>
<td>Lantana, common lantana, Kamara lantana, large-leaf lantana,</td>
<td><em>Lantana camara</em></td>
</tr>
<tr>
<td>pink-flowered lantana, red-flowered lantana, red-flowered sage,</td>
<td></td>
</tr>
<tr>
<td>white sage, wild sage</td>
<td></td>
</tr>
<tr>
<td>Mimosa, giant mimosa, giant sensitive plant, thorny sensitive plant,</td>
<td><em>Mimosa pigra</em></td>
</tr>
<tr>
<td>black mimosa, catclaw mimosa, bashful plant</td>
<td></td>
</tr>
<tr>
<td>Chilean needle grass</td>
<td><em>Nassella neesiana</em></td>
</tr>
<tr>
<td>Serrated tussock, Yass River tussock, Yass tussock, nassella tussock</td>
<td><em>Nassella trichotoma</em></td>
</tr>
<tr>
<td>(New Zealand)</td>
<td></td>
</tr>
<tr>
<td>Parkinsonia, Jerusalem thorn, jelly bean tree, horse bean</td>
<td><em>Parkinsonia aculeata</em></td>
</tr>
<tr>
<td>Parthenium weed, bitter weed, carrot grass, false ragweed</td>
<td><em>Parthenium hysterophorus</em></td>
</tr>
<tr>
<td>Mesquite, algaroba</td>
<td><em>Prospis spp.</em></td>
</tr>
<tr>
<td>Blackberry, European blackberry</td>
<td><em>Rubus fruticosus aggregate</em></td>
</tr>
<tr>
<td>Willow (except weeping willow, pussy willow and sterile pussy willow)</td>
<td><em>Salix spp. (except S. babylonica, S. ×calodendron and S. ×reichardtii)</em></td>
</tr>
<tr>
<td>Salvinia, giant salvinia, aquarium watermoss, kariba weed</td>
<td><em>Salvinia molesta</em></td>
</tr>
<tr>
<td>Athel pine, athel tree, tamarisk, athel tamarisk, athel tamarix,</td>
<td><em>Tamarix aphylla</em></td>
</tr>
<tr>
<td>desert tamarisk, flowering cypress, salt cedar</td>
<td></td>
</tr>
<tr>
<td>Gorse, furze</td>
<td><em>Ulex europaeus</em></td>
</tr>
</tbody>
</table>

¹ May also refer to *Asparagus declinatus*

² The Weeds of National Significance listed show bitou bush and boneseed separately—these two taxa together are treated as one of the 20 Weeds of National Significance.

### Regional and landscape-scale pressures affecting the land environment

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bushfire</td>
<td>Bushfire is an inherent component of many Australian ecosystems. Fire regimes have a pervasive impact on environmental values. The extent, frequency and intensity of bushfires are expected to increase as temperature increases due to climate change</td>
<td>Very high impact</td>
<td>In grade</td>
</tr>
<tr>
<td>Land clearing</td>
<td>Although land clearing is now balanced by the extent of regrowth, both its immediate and legacy effects continue to threaten environmental values</td>
<td>In trend</td>
<td>In trend</td>
</tr>
<tr>
<td>Invasive species—diseases</td>
<td>Both long-established and newly introduced plant diseases threaten the composition of Australian vegetation communities and the survival of particular species</td>
<td>In trend</td>
<td>In trend</td>
</tr>
<tr>
<td>Invasive species—animals</td>
<td>Pest animals are widespread; many are well established and difficult to control. New pest species are becoming established</td>
<td>In trend</td>
<td>In trend</td>
</tr>
<tr>
<td>Invasive species—plants</td>
<td>Weeds are ubiquitous across the Australian landscape, and have major impacts on environmental values</td>
<td>In trend</td>
<td>In trend</td>
</tr>
</tbody>
</table>

### Recent trends and Grades

- **Improving**: Adequate high-quality evidence and high level of consensus
- **Stable**: Limited evidence or limited consensus
- **Deteriorating**: Evidence and consensus too low to make an assessment

- **Very low impact**: There are few or negligible impacts on land environmental values
- **Low impact**: Current and expected impacts are not widespread and may affect only a small number of land environmental values
- **High impact**: Current and expected impacts are widespread and may irreversibly affect land environmental values
- **Very high impact**: Current and expected impacts are widespread and will irreversibly affect land environmental values
3.3 Land uses

This section considers the pressures associated with each of the major land uses identified in Section 2.1.

3.3.1 Grazing

Livestock grazing is the most widespread Australian land use (Table 5.1). It is overwhelmingly based on native pastures, principally in the rangelands of central and northern Australia. More intensive production systems are found in the mixed farming wheat–sheep belt of southern Australia, and are based on improved pastures and fallow rotations. In addition to domestic livestock, native and feral animals also exert grazing pressure on vegetation and soils. These can be very significant, such as in the case of kangaroos in the southern rangelands, camels in central Australia, or rabbits across much of the Australian landscape.41,73

The Assessment of Australia’s terrestrial biodiversity 200846 noted that, depending on the intensity and management of grazing pressure, grazing can be associated with:

- direct removal of some species
- changes in the relative proportions and mixtures of species in ecosystems, including by facilitating weed invasion
- alteration to habitat in mid-storeys and lower storeys of forests and grasslands
- altered fire regimes
- impacts on soil structure and water infiltration.

Intensive grazing by domesticated livestock, native fauna and feral animals can damage soil quickly, because removal of too much cover leads directly to erosion. Grazing can also permanently remove nutrients unless they are replenished with fertiliser. Heavy grazing inhibits plant growth, which affects biological activity in the soil by reducing inputs of energy and organic materials to soil food webs.

Wild rabbits deserve particular mention when discussing overgrazing. Introduced to Australia in 1860, they reached plague proportions within a decade. Their main effect was to exacerbate overgrazing caused by stock, leading to bare ground and erosion by water and wind. In semi-arid lands, rabbits also ringbarked edible trees and contributed to the loss of perennial grasses and shrubs. Rabbit plagues continued throughout the first half of the 20th century and were particularly devastating to the environment during the 1940s. Numbers of rabbits were reduced greatly from 1950, when the myxomatosis virus was introduced. The significant changes in wind erosion presented in Section 2.2.6 are attributable in part to this reduction in grazing pressure. Wild rabbit populations gradually increased in the decades following 1950, decreased when the calicivirus was released in the 1990s, and are now increasing again.

The impacts of grazing on environmental values can be inferred from the assessment of seasonally adjusted landscape function (a measure of the landscape’s capacity to capture rainfall and nutrients) across Australia’s pastoral regions, reported and discussed by Bastin et al.41 (Figure 5.30). The assessment is confounded by the impacts of other factors, notably fire. However, there is evidence that grazing impacts on environmental values are diminishing in some regions (Figure 5.30a), while increasing in others (Figure 5.30b). These impacts reflect the interactions between initial landscape condition, total grazing pressure from both native and exotic animals, and available levels of forage. Each of these parameters varies geographically and over time.41
Figure 5.30  Seasonally adjusted changes in landscape function for Australia’s rangelands: (a) increase in landscape function following below-average seasonal quality; (b) decrease in landscape function following above-average seasonal quality

For New South Wales, South Australia, the Northern Territory and Western Australia, mapped change applies to the local area represented by monitoring sites. Any value above 0% in Figure 5.30a is a positive result. The colour scheme is reversed between the two maps so that, in each case, the blue–purple end of the colour scheme represents the most substantial improvement; for example, where landscape function increased despite below-average seasonal quality.
Figure 5.30 continued
3.3.2 Nature conservation reserves, other protected areas, ‘minimal use’ land and Indigenous land

The principal pressures on the environmental values of land under conservation, land not formally protected but subject to minimal use, and land formally owned and managed by Indigenous Australians are the continental, regional and landscape-scale factors discussed in Section 3.3.2—grazing by pest animals, and grazing by domestic livestock on those tenures where it is allowed. These pressures have been comprehensively reviewed by the Assessment of Australia’s terrestrial biodiversity 2008 and, for the rangelands where much of the minimal use and Indigenous lands are located, by Bastin et al.

3.3.3 Agriculture

The major impacts of agriculture relating to carbon, acidification and erosion were considered in Section 2.2. Here, we also consider those impacts relating to soil nutrients, cultivation and compaction.

**Nutrient management**

The nutrient balance of Australian landscapes (i.e. net gains and losses of nitrogen, phosphorus, sulfur, potassium and other essential nutrients) depends on the system of land use. As a generalisation, the most sustainable systems of land use tightly cycle nutrients, with limited leakage to the atmosphere, streams and groundwater. The NLWRA provides an extensive summary of nutrient balances across Australia.

Careful nutrient management is an important determinant of profitability and sustainability in agriculture and forestry. The environmental aspects of nutrient management of greatest relevance to this report occur when:

- nutrient leakage to the atmosphere contributes to GHGs
- nutrient leakage to inland waters, estuaries and coastal waters results in eutrophication and adverse environmental impacts
- nutrient availability decreases (e.g. due to insufficient nutrient inputs or acidification) and options for future land use are lost
- nutrient availability constrains net primary productivity and limits carbon sequestration in soils.

The environmental impact of leakage from soils to inland waters and estuaries is considered in Chapter 4: Inland water, and emission of GHGs from the land sector is summarised in Chapter 3: Atmosphere. The degree to which nutrient availability constrains agriculture and forestry is closely monitored by organisations involved in primary industries (e.g. producer groups, research and development corporations). Two aspects of nutrient management relevant to this report are phosphorus and the nutrient capital needed to increase soil carbon stocks across Australia (see Section 2.2.4).

Recent concerns that the world’s supply of phosphorus was being rapidly depleted and that ‘peak phosphorus’ was only a few decades away have been dispelled, due to recent upward revisions of world phosphate rock reserves and resources. However, the world supply of phosphorus is limited, and rising prices and market volatility are inevitable. More efficient use of phosphorus is therefore essential, especially in Australia, where the majority of soils used for agriculture are naturally deficient in phosphorus.

From phosphorus audits of Australian agricultural industries and farming systems it is clear that the use of phosphorus fertilisers in Australia is relatively inefficient. Most phosphorus is applied in the higher rainfall areas of southern Australia, and around 40% is applied to pastures. Nationally, approximately 20% of the phosphorus applied as fertiliser is extracted in food and fibre products for export, and about 5% is consumed domestically. The remaining 75% of the phosphorus applied in Australian agriculture accumulates in the soil and some of this is lost to the environment, with detrimental impacts on waterways. The accumulation of phosphorus is greatest in soils across southern Australia. Apart from the environmental risks caused by this accumulation, the inefficiency has an economic cost that will increase as fertiliser prices rise. In contrast, many grazing systems in northern Australia have pastures and animal production that are limited by phosphorus availability. Careful fertiliser strategies and supplements will be needed in these systems.

**Cultivation**

Cultivation benefits agriculture by controlling weeds and creating suitably sized soil aggregates for a good seed bed. However, cultivation also disrupts microbiological activity and causes oxidation of organic matter. Its effect on soil organisms and
organic matter has been likened to a fire through ploughed soil. Cultivation causes a decline in organic matter, which can lead to a general loss of fertility, unless counteracted by actions such as using fertilisers and rotating crops or pastures to restore organic matter levels. Loss of organic matter often leads to soil structural problems such as surface sealing and hard-setting.

Excessive cultivation was widespread during the first half of the 20th century, and it still remains a problem in some locations. During recent decades, techniques of conservation farming have been developed that emphasise retention of crop residues, appropriate rotations with legumes and reduced tillage. Maintaining soil cover on sloping land is especially important to protect against erosive rainfall. These changes are having a major influence on soil condition and trend (see Sections 2.2.4 and 2.2.6). Figure 5.9 provides a succinct summary of the great progress made by Australian farmers in reducing the intensity of tillage. This achievement required changes to agricultural machinery, crop rotations and methods for controlling pests, diseases and weeds. The transition to minimum tillage across most cropping lands during the past decade is a major advance by Australian farmers that reduces pressures on the land environment.

Compaction

Heavy machines such as tractors, harvesters and trucks drive over most agricultural areas, compacting soils. Damage is greatest when the soil is wet. Some of the compaction can be undone through cultivation, although it is common for plough pans (a soil layer that is hard, compacted and roughly horizontal) to develop just below the depth of cultivation. The distribution of pressure under a heavy vehicle also results in a zone of compaction halfway between the wheels, usually at a depth of around 0.5 metres. This type of compaction is difficult to remove. Heavy animals can also compact wet soil, leading to a decline in pasture production. Most of the damage occurs in the upper part of the soil profile. The degree to which soil compaction limits plant growth and the efficient functioning of soils across Australia is not known with any certainty, although there are sufficient studies to suggest that it may be significant. Soil compaction affects landscape processes (e.g. carbon sequestration, water-use efficiency of vegetation) and the general state of the environment. Controlled-traffic farming, which addresses compaction by confining it to the smallest possible area, is being widely adopted and has the potential to alleviate further damage.

3.3.4 Production forestry

Forestry production systems comprise the harvesting of wood and nonwood products from native forests, and their regeneration after harvesting; the establishment, management, harvesting and re-establishment of plantation and other forms of planted forests; and sometimes other forest uses, such as apiary and domestic livestock grazing. Forestry production systems also require the management of bushfire risk, invasive species and other forest uses, and the delivery of ecosystem services.

Historically, the majority of native forest wood production has been in public forests. The area of public forest available for timber harvesting decreased by almost 50% nationally in the decade to 2008, as tenure was transferred to conservation reserves. No public native forests are harvested for wood production in the Australian Capital Territory, the Northern Territory or South Australia, and harvesting in south-east Queensland is being phased out by 2025. Further reductions in the extent and level of native forest harvesting in publicly managed forests are occurring in other states—for example, under the Tasmanian Forests Intergovernmental Agreement.

Commercial timber harvesting is now limited to specified zones within the 6% (9.4 million hectares) of Australia’s native forests in public multiple-use tenures, private native forests, and plantations and other forms of planted forests. Firewood harvesting also takes place on these tenures. All native forest harvesting and most plantation practices are governed by codes of forest practice. Both wood and nonwood products are harvested from forests owned by Indigenous Australians, but typically at relatively small scales for art, handicraft products and local and cultural uses. Apiary and grazing are generally allowed on all tenures from which harvesting of forest products is permitted; each is specifically regulated.

g  www.controlledtrafficfarming.com
The rapid expansion of plantation forests over the past decade noted in Section 2.1 has placed a number of pressures on land environmental values in regions where expansion was concentrated. These regions are parts of coastal Queensland, south-western Victoria, south-east South Australia, south-west Western Australia, and eastern, northern and southern Tasmania. The pressure of most widespread concern has been the possible impact on catchment water yields, which can be locally significant, but is limited at a major catchment scale. The other major pressure was that of land clearing (see Section 3.2.2) associated with conversion of native to plantation forest, which occurred principally in Tasmania and, to a lesser extent, in the Northern Territory. However, at a continental scale, conversion of native forest to plantation accounted for only around 1% of all land clearing in the decade to 2010 (from Australia’s state of the forests: five yearly report 2008 and interpretation of data reported in Section 3.2.2).

The emergence of markets for carbon and other ecosystem services is likely to alter management objectives and regimes of both native and planted forests. Preliminary work (e.g. Keith et al., Polglase et al., Wentworth Group of Concerned Scientists) has identified some of the possibilities, but further research is required to clarify optimum management regimes that account for other forest values and products, and for risks.

3.3.5 Urban and rural residential use

Each year, new areas of land are covered with roads, car parks, buildings and other structures (see Chapter 10: Built environment, Section 3.1). When soil is capped with an impermeable layer, it effectively ceases to function as a biological entity. The consequences are more than a loss of land for agriculture, conservation or other uses. Capping soil changes the water balance of catchments (more run-off is produced from rainstorms over a shorter period) and reduces the area available for soil respiration and carbon sequestration.

During the 19th century, many urban centres were established on, or adjacent to, land highly suited to horticulture and cropping. The encroachment of urban and peri-urban development has seen the capping of this land. For economic reasons, it is highly unlikely that these good-quality soils will ever regain their biological function.

The loss of strategically valuable agricultural lands is a significant challenge for most state, territory and local governments. Various policies and planning mechanisms are now in place to protect and maintain remaining areas. However, the broader challenge posed by mining and coal-seam gas development in New South Wales and Queensland has heightened public debate and government engagement. The lack of detailed soil surveys that identify the location of the best agricultural soils impedes planning. The current information base does not allow optimal decision-making about where to locate development projects, due to the generally deficient information accessible to local planning authorities. The need to accurately map our best agricultural land has been recognised for decades.

3.3.6 Mining

Compared with most countries, the mining industry in Australia is large, and it is responsible for much of the nation’s economic prosperity. Mining is a major industry in many regions, including Peel (bauxite, mineral sands), the Western Australian Goldfields (gold and nickel), the Pilbara (iron ore), the Hunter Valley (coal), the La Trobe Valley (coal) and the Bowen Basin (coal and gas). Australia has notable mining towns (e.g. Broken Hill, Mount Isa) and large mines (e.g. Ranger Uranium, Olympic Dam).

Environmental management in the mining industry before the 1970s was inadequate, and the legacy included contaminated and degraded land with chronic environmental problems (e.g. Victorian goldfields in the 19th century, Queenstown, Captains Flat mine).

Environmental impacts are now more actively managed, due to tighter environmental regulation and the need for companies to obtain a social licence to operate. However, the rapid expansion of the industry is continuing, and the scale of disturbance in some regions is transforming the landscape and causing profound environmental change. Notable examples include the Hunter and La Trobe valleys and the Bowen Basin. The scale of the current expansion, particularly for gas in eastern and north-western Australia, is resulting in conflicts over land use and the environment. These are set to continue and most likely intensify.
3.3.7 Waste disposal and contamination

Soil has a remarkable ability to absorb and filter contaminants. As a result, most human waste is either buried in landfills or spread across the soil surface (land-based effluent disposal). However, it has been realised for some time that many contaminants cannot be safely disposed of in this manner, because they either do not break down into safe substances or they move from the disposal site (either to groundwater or as a gas to the atmosphere). The sophistication and regulation of waste disposal have improved markedly in recent decades. The Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) estimates that 160 000 contaminated sites potentially exist across Australia, containing as many as 75 000 different contaminants (R Naidu, CRC CARE, pers. comm., 2011). The centre quotes industry sources that estimate clean-up costs to be $2 billion per year, with the total remediation cost being much greater. While uncertainties remain about the scale of the problem, significant advances have been made in the development of remediation technologies that replace ‘dig and dump’ methods of disposal with a more effective, efficient, risk-based approach.

Some examples of soil contamination are described below:

- **Fertiliser impurities**—Impurities in fertilisers and soil amendments such as lime and gypsum can include cadmium, fluorine, lead and mercury. Cadmium has been of most concern, because it can move from soil to the edible portions of plants. In recent years, levels of cadmium in fertilisers have been reduced, and farming systems have been modified to lessen the problem. However, large areas of land that once received heavy applications of superphosphate over decades now have elevated levels of cadmium.

- **Pesticides and herbicides**—Many of the more harmful pesticides and herbicides have been banned or more tightly controlled. However, some can persist and adversely affect the environment, notably in areas that were, or still are, used for growing potatoes, tomatoes, cotton, bananas and sugar cane. Copper, arsenic and lead are contaminants associated with orchards and market gardens.

- **Organochlorines**—Soil at thousands of former cattle and sheep-dip sites are contaminated with organochlorines such as dichlorodiphenyltrichloroethylene (DDT) and other pesticides such as arsenic-based compounds. Urbanisation and the construction of dwellings on or near such sites pose a serious threat to human health. Most of these sites have been identified and registered.
### 5.7 Assessment summary

**Contemporary land-use pressures on the land environment**

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grazing</td>
<td>Grazing impacts on environmental values are decreasing in some regions but increasing in others</td>
<td>![Assessment grade icon]</td>
<td>![Confidence icon]</td>
</tr>
<tr>
<td>Nature conservation, other protected areas, minimal use and Indigenous land</td>
<td>The extent of these areas is increasing, but active management of various forms is needed to protect or maintain their environmental values</td>
<td>![Assessment grade icon]</td>
<td>![Confidence icon]</td>
</tr>
<tr>
<td>Dryland and irrigated agriculture</td>
<td>Local and landscape-scale impacts in agricultural regions may be high, and appear to be diminishing for some factors but increasing for others</td>
<td>![Assessment grade icon]</td>
<td>![Confidence icon]</td>
</tr>
<tr>
<td>Native production forests</td>
<td>The extent and scale of commercial wood harvesting from public native forests have diminished substantially, and harvesting and other activities are strongly regulated</td>
<td>![Assessment grade icon]</td>
<td>![Confidence icon]</td>
</tr>
<tr>
<td>Plantation forests</td>
<td>The expansion of plantation forests was significant in some regions, but impacts on environmental values were generally limited, unless the site was converted directly from native vegetation. The area of plantation forests remained small as a proportion of land area, and plantation forestry became more strongly regulated</td>
<td>![Assessment grade icon]</td>
<td>![Confidence icon]</td>
</tr>
<tr>
<td>Urban and rural residential</td>
<td>The impacts of urban and rural residential development are substantial in the areas in which they are concentrated (i.e. around major cities and along parts of the coastline), and are increasing. The scale of development is increasing in these areas</td>
<td>![Assessment grade icon]</td>
<td>![Confidence icon]</td>
</tr>
<tr>
<td>Waste disposal</td>
<td>The impacts of waste disposal are generally low because of management systems and the small relative area affected. However, the volume of waste is increasing, and impacts are concentrated around major settlements or industrial centres</td>
<td>![Assessment grade icon]</td>
<td>![Confidence icon]</td>
</tr>
</tbody>
</table>
### Mining

The scale of mining is increasing rapidly, and the potential impact on environmental values from new forms of mining is substantial in those regions where it is occurring.

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td></td>
<td>High impact</td>
<td></td>
</tr>
</tbody>
</table>

**Recent trends**: Improving, Stable, Deteriorating, Unclear

**Confidence**: Adequate high-quality evidence and high level of consensus, Limited evidence or limited consensus, Evidence and consensus too low to make an assessment

**Grades**: Very low impact, Low impact, High impact, Very high impact

- Very low impact: There are few or negligible impacts on land environmental values.
- Low impact: Current and expected impacts are not widespread and may affect only a small number of land environmental values.
- High impact: Current and expected impacts are widespread and may irreversibly affect land environmental values.
- Very high impact: Current and expected impacts are widespread and will irreversibly affect land environmental values.
Effectiveness of land management

Most of Australia’s land environment is managed by one of three groups: state and territory agencies responsible for public land of various tenures, family and corporate agricultural and pastoral businesses, and Indigenous Australians. The Australian Government and local governments manage smaller, but significant, areas. Private landowners manage many small peri-urban and rural properties, primarily for lifestyle rather than farming purposes. Various forms of co-management have emerged, particularly between governments and Indigenous communities for conservation.

The management of any particular area of land depends on its tenure and the objectives of the owner or manager—subject to regulatory, knowledge, information and resource constraints. The management objectives of almost all public land are now formally documented in management plans, which are generally subject to public comment and review processes. Many private property owners, and some areas of Indigenous land, also have documented management plans. Management of Indigenous lands is reviewed in Box 5.1 (p. 272).

In this section, we discuss management effectiveness in terms of factors that underpin management of the land environment generally: governance and institutional arrangements, levels of investment, the knowledge and information base, and capacity. In Assessment summary 5.8, we assess management effectiveness in relation to each of the major pressures on the land environment and the major land uses identified in Section 3. Although many aspects of management effectiveness are improving in most sectors, the key issue is whether the rate of improvement is sufficient to meet the environmental challenges facing each sector and region.

4.1 Management context

Legislative arrangements for the management of public lands are relatively stable, notwithstanding periodic changes in institutional arrangements, such as changes to the names, roles and structures of government agencies with land management responsibilities. Similarly, while private and Indigenous landowners may be subject to increasing levels of regulation and constraint (e.g. in the terms under which they are permitted to clear or harvest native vegetation; see McDermott et al.86 for a national review), the institutional arrangements under which they manage land are also relatively stable. At the national level, the development in 2009 by the then Natural Resource Management Ministerial Council of a consultation draft of Australia’s Native Vegetation Framework (to complement existing national strategies such as the National Strategy for the Conservation of Australia’s Biodiversity and the National Forest Policy Statement) provides an important national foundation for future management of Australia’s land environment.
The discussion here therefore focuses on those arrangements that have been most volatile over the past decade—the ‘natural resource management arrangements’ under which the Australian Government directs funding to state and territory governments, private landowners and the community to improve management of the environment. There have been significant changes in these arrangements associated with development and implementation of the regional model of natural resource management (NRM), established by the Australian Government in 2002. Under this model, policies and programs focused on developing regional-level strategic plans through which to channel joint federal–state NRM funding; ... a designated network of 56 regional NRM organisations governed by community-based boards of management were given significant responsibilities to deliver more strategic NRM outcomes under the aegis of national programs. The arrangements that prevailed from 2002 to 2008 were a more devolved and community-based form of NRM governance than had applied previously in Australia, under which the regional NRM organisations had a substantial role in both setting and helping to deliver NRM investment priorities.

These institutional and funding arrangements changed in 2008, with the introduction of the Australian Government’s Caring for our Country program. Partly as a response to criticisms from the Australian National Audit Office and others that it was difficult to assess the outcomes and impacts of NRM investments, Caring for our Country centralised decisions over NRM investment funding under six priority areas, and focused on measurable, short-term outputs. There is now a body of literature discussing the advantages and disadvantages of various models of institutional arrangements for Australian NRM.

The Australian Government is conducting a review of the Caring for our Country program to assess its effectiveness and achievements and future options for NRM arrangements. The key themes that emerge from the literature are well characterised by those emerging from consultations under the Caring for our Country review, which include the need to consider:

- alignment of national, regional and local NRM priorities
- recognition and alignment of the roles of governments and regional NRM organisations
- continued strong support for community skills, knowledge and engagement activities
- quality and accountability in NRM decision-making
- funding certainty for NRM delivery agents, including community groups
- improved efficiency of funding arrangements, and the potential to leverage funding from industry, the private sector and philanthropic individuals and groups
- national environmental accounting to support monitoring progress in NRM delivery
- integration of the successful elements of the Working on Country and Indigenous Protected Area programs (i.e. well-funded, multiyear contracts, alignment with Indigenous caring for country needs and aspirations) with other Caring for our Country programs.

4.2 Resources and capacity for management

Investment in management of the land environment includes financial and in-kind commitments by all levels of government, private landowners and businesses, nongovernment organisations, Indigenous Australians and communities. Each of these is considerable, and some—particularly the commitment of time by individuals, groups and communities—are difficult to quantify.

Estimates of volunteered and private time and resources are indicative rather than complete. For example, nearly 4000 individual volunteers contributed time worth more than $2 million to activities in partnership with Tasmania’s Parks and Wildlife Service in 2009–10. The level of private expenditure is exemplified by that reported for weed, pest, and land and soil management by agricultural businesses of $3 billion and three million person-days in 2006–07.

Australian governments’ NRM expenditure includes that on public lands, such as national parks, state forests and lands under local government control, as well as on NRM in the sense discussed in Section 4.1. Whole-of-government environment expenditure is not routinely reported in most jurisdictions. It was last reported for the Australian Government for 2006–07, when it was around $4 billion.
Australian Government expenditure on the land environment is mostly delivered through the government’s flagship environment program, Caring for our Country, which has a budget of $2.25 billion over five years from 2008–09 to 2012–13 (an annual average of $450 million). The Australian Government also proposes to commit a further $1.7 billion to NRM investments over five to six years from 2012 (an annual average of $286 million) under its Clean Energy Future plan.14

NRM expenditure at the state and territory level includes that on the management of public lands under various tenures, as well as expenditure on policy development and implementation. For example, in 2009–10, Victoria’s Department of Sustainability and Environment spent $133 million on management of public land (including coastal and marine environments), $180 million on management of forests and parks, $276 million on bushfire management (including risk reduction, fire fighting, and recovery), $47 million on biodiversity programs, $107 million on natural resource–related research and $76 million on environmental policy and climate change.107

Expenditure by regional NRM bodies derives principally from Australian and state or territory government funding, and so is included in those totals. Similarly, much of the land environment–related expenditure by local governments derives from the higher levels of government. Australian local governments spent $2.6 billion on environmental management and $1.9 billion on NRM in 2002–03, the most recent year for which data are available.108

Although these investments are substantial, they appear to be less on a per-hectare basis (of agricultural land) than in Europe or the United States,109 and are generally regarded as inadequate to meet Australia’s environmental management needs. For example, the investment estimated in 2000 as necessary to address the then national NRM targets was $65 billion over the following decade.110 Sparks et al.111 reported a present-value cost of $854 million over 30 years to protect (only) the 30 most highly valued biodiversity assets in south-west Western Australia from salinity, and Roberts et al.112 estimate the cost of meeting targets for reducing nutrient inputs from agricultural land into the Gippsland Lakes at around $1 billion over 25 years.

Investment in research and development for management of the land environment is also likely to be insufficient in relation to expected needs. The level of investment in rural research and development, including that on production systems and environmental management, was recently reviewed by the Productivity Commission.113 The commission estimated a total annual expenditure on rural research and development of $1.5 billion, 48% of which was Australian Government funding, 28% from state and territory governments, and 24% from the private sector.113 The commission noted the widespread view that state and territory governments were progressively withdrawing from rural research and development investments, although it could not substantiate this for all jurisdictions. It also noted that the level of private sector investment is low by international standards, although variable across sectors. The commission recommended the establishment of a publicly funded, public good–oriented research and development entity—Rural Research Australia—with an annual budget of $50 million. This entity would replace and expand the role of Land & Water Australia, which was disbanded by the Australian Government in 2009.

4.3 Knowledge and institutional arrangements

National SoE reporting began in 1996. In 2006, the third national SoE report concluded that, because of the lack of accurate, nationwide environmental data, the SoE Committee was still not in a position to give a clear national picture of the state of Australia’s environment. The lack of information not only affects the assessment of our environment, but also limits management effectiveness by restricting accurate planning and monitoring of management strategies. The situation has improved for some aspects of the environment since then; for example, in the terrestrial carbon, water and marine systems. However, it is now widely acknowledged that Australia has a fragmented, incomplete and inefficient set of systems for mapping, monitoring and forecasting the condition of our land.114–116 The problems are particularly acute for components that require field–based measurement (e.g. soil and regolith). The reasons for this situation are complex, but two important factors are current institutional arrangements and market failure.
4.3.1 Institutional arrangements for environmental information

In Australia, most environmental information relating to the land is collected by public agencies through short-term projects; very few enduring programs have a strategic focus. There have been losses of capacity in relevant Australian Government initiatives, such as the end of the NLWRA in 2008. The exceptions are in weather, climate, economics and, to a lesser extent, the geosciences. Significant quantities of environmental data are collected by individual land managers, community groups and private companies (e.g. to support environmental impact statements), but the data are rarely captured in information systems for others to use.

State and territory agencies have traditionally had the primary responsibility for acquiring and maintaining land resource data, although the Commonwealth Scientific and Industrial Research Organisation (CSIRO) has also had a significant role. The scientific capacity of state and territory agencies has declined during the past two decades, despite intermittent programs for surveys of vegetation, land use, salinity and soil resources. These programs have been initiated and funded to a large extent by Australian Government programs.

The consequences of intermittent and project-based funding were discussed by Campbell,114 among others, and are now very clear:

- Few agencies have been able to maintain the core scientific and technical capabilities necessary to build robust environmental information systems.
- Corporate memory is poor. As a result, resources are wasted, because lessons learnt are forgotten as teams are disbanded and then reformed several years later to continue work on the same problem (e.g. monitoring of land condition).
- The lack of stable career paths causes a high rate of turnover in the professional ranks, and a consequent loss of capacity. Most field scientists develop skills during programs of survey and monitoring, but they are then forced to move when short-term funds cease (see Section 4.4).
- Most agencies have not been able to maintain the critical mass necessary for building and maintaining the sophisticated databases and geographic information systems that are now essential for web-based delivery of information.
- Those commissioning programs of land resource survey and monitoring are often separated from associated technical programs, and they rarely have long-term custodianship of the resulting information.
- Large, short-term investments in acquisition or analysis of environmental information have not returned the expected benefits. Some of the best quality information on soil, vegetation and land use has been produced by small, enduring teams with a sound strategy, and good scientific and technical credentials.
- There are blurred distinctions between investments in environmental research and operational environmental management. Research agencies (e.g. universities, CSIRO) are not resourced or judged on their ability to provide routine environmental information, although they are important sources for innovation and new technology.

Investment has increased in monitoring, evaluation and reporting, such as through the Monitoring, Evaluation, Reporting and Improvement initiativeh under the Caring for our Country program, and state programs such as that conducted by the Natural Resources Commission of New South Wales.117 However, inadequate investment in monitoring to inform adaptive management remains a major constraint across the land environment.118

4.3.2 Market failure

Investments in land resource information (e.g. soil and vegetation surveys, monitoring networks) have a very high return on investment.114 In Australia and many other countries, the demand for this information is strong and increasing. This is because of the urgency of the issues, and the opportunities for information collection and data analysis presented by new technology. Despite this, many programs of primary data collection have come to a virtual standstill. Figure 5.31 shows one indicator of the dramatic decline for soil information.

h www.nrm.gov.au/me/index.html
Demand and supply are disconnected, and market failure appears to be distorting both public and private investment in environmental information. There are several factors at play:

- The beneficiaries of environmental information are many and varied, but individual users rarely buy the information from those who bear the cost.
- There is often a mismatch between the time needed to gather appropriate data (years) and the timescale of the decision-making process (days to months).
- Environmental information has a long life, and the stream of benefits is unpredictable; all costs are incurred at the beginning, but benefits are not. For example, maps produced by land resource surveys across northern Australia 50 years ago are still used today.
- Purchasers of environmental information may not appreciate how valuable the environmental information is, particularly when it comes to costs avoided. For example, land management may change as a result of new information, but the user may never be aware of the full extent of environmental costs that have been avoided.
• The benefit from environmental information is greatly increased when surveys and monitoring programs fit together to form a broader regional or national view. These benefits are rarely considered when funding is allocated to individual projects.

The absence of clear market signals to investors has resulted in governments at all levels failing to have effective strategies for obtaining environmental information. Similarly, private sector and community efforts are generally fragmented, and the substantial amount of environmental information they collect remains underused.

4.3.3 The changing nature of mapping, monitoring and forecasting

Environmental information has traditionally been supplied as static maps and reports. This is inadequate for many contemporary problems, because most require insight into rates of change. Measuring and forecasting landscape dynamics involves integrating data from field observations, mapping and monitoring programs and, in many cases, applying computer simulation models to provide forecasts on a range of timescales (e.g. daily, weekly, seasonal and decadal intervals). Decision-makers also need to understand trade-offs—for example, can revegetation strategies in rural landscapes be optimised to resolve often conflicting objectives of conserving biodiversity, storing carbon, securing stream flows, and maintaining viable agriculture and forestry? Other examples of important questions requiring technically demanding analyses are:

• What changes are likely in species distributions (e.g. pests, disease vectors, threatened species) and how will these affect the national reserve system?

• Will large-scale revegetation achieve desired outcomes relating to carbon sequestration and biodiversity?

• How secure is Australia’s food supply system, and can it help alleviate problems with food security in our region and globally?

• How serious are existing threats to ecosystem services (e.g. soil acidification, biodiversity decline, soil erosion by wind and water)?

• What are the trade-offs between biofuels and other forms of agriculture?

Addressing each of these questions demands good-quality environmental information. The information needs to be collected according to consistent standards to enable integrated analysis. While this need may seem obvious, accessing such environmental information is difficult in Australia.

Technological advances (e.g. the advent of generally accessible imagery, such as that provided by Google Earth) have transformed the acquisition, analysis and potential use of environmental information. However, taking full advantage of the digital revolution again requires discipline and adherence to standards in the collection and management of environmental information. This is the Achilles heel of Australia’s current environmental information system. Although anecdotal evidence suggests that lack of consistent and standardised information is a constraint on economic efficiency and environmental performance, these costs have not been quantified in any systematic way.

4.3.4 Reform and integration

The Australian Government’s announcement in May 2010 of a new initiative to address the environmental information needs of the nation represents a significant and welcome development to address the issues discussed above. The National Plan for Environmental Information is the beginning of a long-term commitment to reform Australia’s environmental information base. It establishes the Bureau of Meteorology as the Australian Government authority for environmental information. The initiative will produce environmental information standards, build national environmental datasets and provide the infrastructure to deliver information online. The Terrestrial Ecosystem Research Network, established in 2009, and other recent initiatives in water information and carbon accounting provide an indication of what could be done for other aspects of the environment.

The need for reform goes beyond our national boundaries. For example, the carbon dynamics of Australian landscapes and our capacity to produce food are part of much larger global considerations. Our information systems need to be integrated with the emerging Global Earth Observation System of Systems if we are to measure global environmental trends and provide a basis for analysis and informed policy.

i www.environment.gov.au/npei
j www.tern.org.au
k www.earthobservations.org
4.4 Human capital

Section 4.3 focused on the systems that inform management about the land environment. Management effectiveness also depends heavily on the quality and overall capacity of the human resources, networks and infrastructure involved in land planning and management. In large measure, improvements in land use during recent decades have been due to:

- increased land literacy in the community (e.g. through the Landcare movement and other community-based programs)
- improved levels of environmental education, due to a greater focus on the environment in school curricula, and professional learning and development programs
- a better understanding of the intrinsic suitability of particular areas of land for different uses (e.g. based on land resource and ecological surveys)
- effective adoption of outcomes from research and development (e.g. better crop varieties and fertilisers, conservation cropping strategies)
- more formalised management practices that result in better planning and timing of operations (e.g. grazing systems, farm planning, forest codes of practice)
- better access to information on sustainable systems of land management (e.g. through industry groups, Landcare networks and the Internet).

Although the improvements in land use are to be applauded, it is clear from this report that, in many regions, the decline in land condition has not been completely arrested. The significance of this problem is sharpened when we consider the scale of the global land and water challenge (see Section 1.3). Another worrying trend is an apparent weakening of relevant human capital—knowledge, education and experience—in Australia. There are several dimensions to this problem, with interlinked causes and impacts:

- Loss of connection to the land—Australia is becoming increasingly urbanised, and many Australians now have minimal direct contact with people in rural and remote regions. This affects both the awareness and sophistication of public discourse on land-related issues (e.g. debates on the management of feral animals, fire policy and genetically modified organisms).

- Higher education—Numbers of students taking higher degrees in agricultural science and forestry have diminished significantly over the past decade. The same trend applies to NRM-related degrees more generally and relevant vocational education and training programs. As a result, there is now a growing professional and technical capacity gap in land and NRM. The reasons for this are complex, but reflect in part a decline in the status of these fields, perceptions that primary industries are in decline, and an apparent lack of career paths for graduates.

- Career paths for land managers—Many of the traditional career paths for land managers no longer exist, as a consequence of agency downsizing and shifts to shorter term, project-based funding. Despite large investments in programs such as the Natural Heritage Trust and Caring for our Country, there has been limited consideration of workforce planning and career development for the thousands of people employed through these programs.

- Scientific and technical capability—This is closely related to the career-path problem and the issue of investment in research and development discussed above. Many committed and capable scientists and technicians have been trained in land-related disciplines in the past 20 years. For example, the survey programs during the Decade of Landcare (an Australian Government initiative aimed at addressing land degradation, conducted in 1990–2000) resulted in a cohort of experts in vegetation science, rangeland ecology, soils, salinity, regolith and applied ecology. However, the shift to project-based funding resulted in many of these young and mid-career professionals leaving their chosen field. Rebuilding this capability requires career pathways that offer opportunities for around five years’ field experience in a range of landscapes subsequent to degree completion.
• **Indigenous capacity**—As Indigenous Australians assume formal responsibility for managing or co-managing more of Australia’s land environment, and as their interests in, and potential contributions to, land management are recognised more widely, there is a corresponding need to build their capacity in both traditional and scientific management. There is also a need to build the capacity of Indigenous and non-Indigenous Australians to work effectively together in managing the land environment.6,122-123

• **Scientific and professional inputs into policy and planning**—The weakening of human capital has a direct impact on the level of scientific and professional advice provided to governments. The likelihood of informed policy and planning outcomes is reduced accordingly.

![Footpath through forest to Newdegate Cave, Hastings Caves State Reserve, Tasmania](image)

Photo by David Wall
## Effectiveness of land management

### Climate-induced pressures

**Understanding:** The general nature and pattern of climate-induced pressures are becoming clearer, although many uncertainties remain at finer scales

**Planning:** Most planning remains at an early stage, in part reflecting the rapidly evolving understanding of how climate-induced pressures are likely to impact on the land environment

**Inputs:** There have been substantial initial investments in national and state-scale research on likely impacts and possible management responses

**Processes:** National and state-level bodies and industry sectors are now engaging with the issues of climate change. However, there is not yet consensus at the highest political levels about strategies to address and mitigate climate change

**Outputs and outcomes:** Outputs focus on the knowledge and information base necessary to inform management responses to the likely impacts of climate change

### Bushfire

**Understanding:** There is a generally high level of understanding of the impacts of bushfires on environmental values, strategies for mitigating adverse impacts, and the responsibilities of land managers

**Planning:** There is generally a high level of planning for bushfire risk mitigation

**Inputs:** The overall level of inputs for bushfire risk mitigation and management has increased, particularly for public land in southern Australia. In general, there are insufficient inputs to minimise the impacts of bushfire on environmental values of the extensively managed rangelands and tropical savannas of all tenures

**Processes:** There are well-developed processes for evaluating the impacts of bushfire management strategies on environmental values, and for adaptive management

**Outputs and outcomes:** In general, the greater recognition and understanding of bushfire impacts on environmental values means that these are less impacted by planned fire. The impacts of wildfire are more difficult to manage, and more variable
## Land clearing

**Understanding:** The impacts of land clearing on environmental values are well understood

**Planning:** All states and territories, other than the Northern Territory, where legislation is now being enacted, have legislation to control land clearing

**Inputs:** Timely monitoring and reporting systems and tools are key inputs; the availability and quality of these have improved nationally and within jurisdictions

**Processes:** Processes vary between jurisdictions, but all are more effective than they have been in the past

**Outputs and outcomes:** The national rate of land clearing is now balanced by that of regrowth, but land clearing continues to threaten environmental values in some regions

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## Invasive species

**Understanding:** There are well-established, coordinated national arrangements for identification of, minimisation of and response to biosecurity risks, and national and state strategies for managing priority pest animal and invasive plant species

**Planning:** There are high levels of national, state and regional-level planning for priority invasive species

**Inputs:** Australian Government inputs are focused on national priority species or on listed threatening processes. In addition, state and territory governments and regional natural resource management organisations commit resources to local priorities; these are complemented by considerable voluntary community and landowner commitments of time and resources. However, in general, financial resources available to manage established invasive species are less than those that would be necessary to substantially impact on pest populations. In some cases, this is because control measures that are effective and feasible have not been identified

**Processes:** Management processes vary widely, depending on the nature of the invasive species or threat. There is generally an emphasis on integrated management responses, drawing on a range of control measures. Processes are public, and stakeholders are appropriately engaged

**Outputs and outcomes:** Containment, rather than elimination, is the feasible goal of most invasive species management strategies. The success of strategies for individual invasive species varies, both spatially and temporally, but overall, invasive species are expected to become more, rather than less, threatening for land environmental values

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### Effectiveness of land management

#### Management of conservation reserves

**Understanding:** The objectives of the national reserve system, and for management of conservation reserves, are explicitly specified in national and state-level policy statements and in management plans for reserves.

**Planning:** Management plans are the basis of planning for individual reserves. Planning to adapt to the impacts of climate change, and to improve the resilience and effectiveness of the national reserve system, is under way.

**Inputs:** Resource inputs across the conservation system as a whole are insufficient for the realisation of management objectives.

**Processes:** Processes governing management of conservation reserves are generally clear and transparent, draw on stakeholder input, and report to stakeholders.

**Outputs and outcomes:** Management outcomes are usually realised in the short term, but the longer term outcomes sought of conservation reserves depend also on the impacts of processes, such as those described in this table, that threaten maintenance of their values.

#### Indigenous-managed lands

**Understanding:** Indigenous Australians have formal management rights to increasing areas of their country under a number of tenure regimes.

**Planning:** Planning processes are best developed for Indigenous protected areas, and for areas in which Indigenous ranger groups are active.

**Inputs:** Financial inputs derive predominantly from government programs, and are threatened by planned changes to workforce programs. Significant resources have been committed from the private and philanthropic sectors for some projects.

**Processes:** Processes respect Indigenous culture and interests as well as the interests of funding entities.

**Outputs and outcomes:** The outputs of Indigenous land management include cultural, social and economic elements, as well as land management itself. The outcomes of greater Indigenous land management include a more effective conservation reserve system, and more sustainable land management.
Production forests

**Understanding:** Management of both public and private native forests harvested for wood production is regulated by codes of forest practice in all states and territories. Plantation forestry practices are regulated similarly in some states, but less prescriptively in others. Many large-scale forest owners in both public and private sectors have sought and received third-party forest certification.

**Planning:** Intensive planning of forest operations is required for native forests in all states and territories, and for plantation forests in most jurisdictions.

**Inputs:** High levels of inputs, funded on a commercial basis, are associated with production forestry.

**Processes:** Processes for public native forest management have high levels of stakeholder engagement; those for private native forests and plantation forests are generally more limited.

**Outputs and outcomes:** Outputs are typically assessed against planning and commercial objectives. Outcomes are intended to ensure that forestry operations comply with the principles of sustainable forest management and forest certification systems.

Grazing lands

**Understanding:** There is a good understanding of climate variability, trade-related matters and greenhouse gas abatement, and these directly affect grazing practices. Animal welfare issues are prominent.

**Planning:** The standard of property planning continues to improve, especially in larger integrated grazing operations.

**Inputs:** Monitoring of grazing systems has improved. Insufficient resources are available to protect ecosystem services, due to the absence of a funding mechanism for these public goods. Survey and monitoring programs are poorly resourced.

**Processes:** These have advanced significantly through Landcare and related activities.

**Outputs and outcomes:** Good progress, but chronic forms of land degradation are widespread in the grazing lands of Australia.
## Effectiveness of land management continued

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### Dryland cropping

**Understanding:** There is a good understanding of climate variability, trade-related matters and the potential impacts of climate change

**Planning:** Sophistication continues to increase, and leading farmers use sophisticated modelling and forecasting tools to plan operations

**Inputs:** Weakening human capital and patchy information systems constrain economic efficiency and environmental management

**Processes:** Weakening investment in research and development and ongoing changes to extension services are significant matters

**Outputs and outcomes:** By international standards, dryland cropping in most regions is very efficient, although environmental performance is often difficult to assess

### Irrigation and intensive agriculture

**Understanding:** The industry is in the middle of a major water reform process, which is leading to improved efficiency but inevitable disruptions. These changes are strongly contested, although a much clearer view is emerging about future development pathways (e.g. northern Australia, Murray–Darling Basin)

**Planning:** This has improved significantly at the farm and district scale, but regional and national planning has not been able to resolve competing contemporary and future needs for agriculture and the environment

**Inputs:** Weakening human capital and patchy information systems constrain current performance and capacity to adapt

**Processes:** Generally good at the local and district scale, but processes for dealing with reduced water allocations are only partly effective

**Outputs and outcomes:** Irrigated agriculture has improved its environmental performance (e.g. salinity management, reduced pesticide use, improved nutrient management), and the economic return per unit of water has increased
## Mining

**Understanding:** Unprecedented industry expansion is a profound development for Australia. Most of the industry has a much greater sensitivity to the need for environmental management and a social licence to operate. The local impacts of mining on the land environment are nearly always major, and conflict with stakeholders is inevitable. The scale of expansion is now a major issue because of emerging regional impacts (e.g. Hunter and La Trobe valleys, northern New South Wales, central Queensland)

**Planning:** Existing mechanisms are being tested, particularly when mining and agriculture interests are at odds

**Inputs:** Insufficient environmental information is hampering decision-making and policy (e.g. mapping of prime agriculture land, assessing groundwater dynamics and contamination risks)

**Processes:** Management of mine sites has generally improved, as has mine site rehabilitation. Processes for some types of mines and mining continue to be contested

**Outputs and outcomes:** Significantly improved, but the scale of expansion and related environmental impacts are now the key issues

## Urban and residential use

**Understanding:** Impacts on the land environment are acknowledged

**Planning:** The incremental nature of expansion rarely translates into an event or conflict that results in major change to planning systems. Strategic planning is only partially successful. The planning profession has lost ground in recent decades, and the need for innovation in planning is now stronger than ever

**Inputs:** Large private sector investment, with modest public sector investment

**Processes:** Many innovations to improve urban environments are occurring (e.g. through landscape architecture, community initiatives, urban agriculture), and urban development has less of an impact (e.g. erosion and sediment control, water-sensitive design)

**Outputs and outcomes:** Urban sprawl continues. The demand for land on the eastern seaboard will result in the loss of prime agricultural land and continuing environmental impact, unless major changes are made in urban design and planning
Effectiveness of land management *continued*

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**Understanding:** Global, national and local imperatives to reduce waste and recycle are now widely supported

**Planning:** Still evolving, but future constraints are significant and improvements are needed. For example, rehabilitation of existing contaminated sites and shortage of landfill sites are major challenges

**Inputs:** Industries and public agencies have invested in waste disposal and recycling technologies

**Processes:** Surveillance of existing and potentially new contaminated sites is inadequate given the potential economic costs, environmental impacts and consequences for human health

**Outputs and outcomes:** Much improved

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**Recent trends**

- **Increasing:** Adequate high-quality evidence and high level of consensus
- **Stable:** Limited evidence or limited consensus
- **Deteriorating:** Evidence and consensus too low to make an assessment

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Resilience of the land environment

The resilience of Australia’s land, soil and vegetation can be assessed in two stages: firstly, in terms of the interaction of land with land use and the maintenance of environmental values under particular land-use regimes; and secondly, in terms of how well land regains these values after major disturbances such as clearing, flood or fire.

5.1 Landscape and soil

Given enough time, the land (i.e. landforms, soils, drainage networks of streams and rivers, vegetation and other biota) comes into equilibrium with the climate and the regime of land management. This rarely happens, because land management is always being adjusted and shifts in climate occur before the land has had time to equilibrate. As a result, the land is always changing. The rates of change are often difficult to detect if we rely on unaided human observation and memory. Furthermore, the slow changes (e.g. habitat loss, soil acidification and erosion) often present the biggest environmental problems in the long run.

The degree to which the land provides a long-term, optimal mix of ecosystem services depends on its overall quality and resilience to these changes. In general, good-quality and resilient land has these related features:

- Leakage of nutrients is low.
- Biological production is high relative to the potential limits set by climate.
- Levels of biodiversity are relatively high.
- Rainfall is efficiently captured and held within the root zone.
- Rates of soil erosion and deposition are low, with only small quantities transferred out of the system (e.g. to the marine environment).
- Contaminants are not introduced into the landscape, and existing contaminants are not concentrated to levels that cause harm.
- Systems for producing food and fibre for human consumption do not rely on large net inputs of energy.

At a glance

Australia has large areas of ancient and weathered soils. Their resilience to change is lower than the younger landscapes of parts of Europe and North America.

Soils are prone to serious degradation when they have insufficient resilience and when particular thresholds are exceeded. Unless agricultural management practices change, these thresholds may soon be exceeded for soil acidity and organic carbon. Thresholds for salinity have already been exceeded in significant areas from Western Australia to Queensland.

Lands managed for nature conservation and for minimal use are generally resilient. In contrast, resilience of vegetation is likely to be poor and often diminishing in much of the intensive land-use zone—increasingly so in peri-urban and coastal zones, where most vegetation occurs as disconnected remnants.

Principles to restore resilience in native vegetation are well established. They focus on maintaining or restoring connectivity across the landscape; maintaining vegetation composition, structure and regeneration processes; managing key and threatened plant and animal species; and managing threatening processes such as invasive species and inappropriate fire regimes.

The resilience of land to disturbances such as intense storms, clearing of vegetation or changes in land management depends on the age and character of the soils and landforms. In general, ancient, strongly weathered landscapes have different responses to disturbance from young landscapes. When young landscapes are disturbed, they tend to return to something similar to their previous state, because there are sufficient nutrient reserves for vegetation to re-establish. Old, weathered landscapes are unlikely to return to the pre-disturbance state or to a functionally similar variant. Their smaller reserves of nutrients mean that any loss through leakage (e.g. leaching and erosion after clearing) will constrain biomass production when vegetation re-establishes. Australia has large areas of ancient and weathered soils with less resilience to change than young landscapes such as Europe and North America.
Other factors can also affect the resilience of soils. The presence of clays that shrink and swell with drying and wetting allows soils (e.g. Vertosols) to recover from compaction and physical degradation. Soils without this capacity are less resilient and can be permanently compacted. Some of Australia’s best soils for horticulture and intensive agriculture (e.g. Ferrosols on the east coast) have excellent physical and chemical fertility but, because they do not shrink and swell, once compacted by poor land management they are extremely difficult, if not impossible, to repair. Some soils are naturally fertile because of the parent material type (e.g. basalt, most forms of river alluvium), and the reserves of nutrients generated by this material confer resilience.

Soils are prone to serious degradation when they have insufficient resilience and when particular thresholds are exceeded. The most important thresholds highlighted in this report are described below:

- Organic carbon declining past a threshold below which physical and chemical fertility effectively collapse. The precise carbon content varies with soil type, but is usually between 1% and 2% for surface layers. Management is improving in most regions, but some are likely to pass below this threshold unless more conservative forms of land management are implemented (see Section 2.2.4).

- Soil pH decreasing below 4.2 (increasing acidity). This is a critical threshold, because it triggers aluminium toxicities and the soil becomes very difficult to remediate. Many plants are affected before this threshold is reached. Unless land management changes in Australia, the time before this critical pH is reached across large areas used for agriculture is only two or three decades and, in some regions, only a matter of years (see Section 2.2.5).

- Surface cover declining past a threshold below which storm rainfall causes hillslope erosion or wind erosion. Most regions have locally appropriate targets for surface cover, based on rainfall intensity, soil erodibility and land-management practices (see Section 2.2.6).

5.2 Vegetation

The resilience of vegetation to pressures depends on the extent to which essential ecological processes have been, and can be, maintained. Resilience to current pressures is relatively high where vegetation is largely intact on a landscape scale, connectivity between landscape elements has been maintained, and levels of disturbance are within ecological thresholds.

Therefore, land managed for nature conservation generally has a relatively high level of resilience, although this may be affected by pressures that are difficult to manage, such as invasive species. Conversely, in much of the intensive land-use zone, and increasingly in peri-urban and coastal zones where most vegetation occurs as disconnected remnants, resilience is likely to be poor or diminishing because of both legacy effects and current pressures. Proactive restoration may be necessary to rebuild resilience in these landscapes.

Measures to improve the resilience of biodiversity (see Chapter 8: Biodiversity) also apply more generally to vegetation. A set of principles has emerged to foster resilience in landscapes managed for production; these also apply to landscapes fragmented by other forms of development.

The principles encompass both pattern and process-oriented management strategies:

- Landscapes should include structurally characteristic patches of native vegetation, corridors and stepping stones between them, a structurally complex matrix, and buffers around sensitive areas. Management should maintain a diversity of species within and across functional groups. Highly focused management actions may be required to maintain keystone species and threatened species, and to control invasive species. Fischer et al.

Implementation of these principles has also been discussed in the context of strategies that will improve the resilience of Australian ecosystems to climate change. As noted in Section 3.1, recent assessments suggest that climate change may cause profound changes in the character and spatial distribution of many Australian vegetation communities. Some communities—such as those at higher elevations in the wet tropics—are at risk of disappearing completely.
Partly for this reason, the maintenance or re-creation of vegetation corridors that provide connectivity across landscapes is one of the most important means of improving the resilience of vegetation to both current and future pressures, as long as the potential drawbacks of corridors, such as facilitating the movement of invasive species, are managed. Other components of the management strategies identified by Fischer et al. include maintaining vegetation composition, structure and regeneration processes; managing key and threatened plant and animal species; and managing threatening processes such as invasive species and inappropriate fire regimes. Implementation of each of these is necessary to improve the resilience of vegetation to current and future pressures, including climate change.52

Aspirations and initiatives to establish connectivity on a large scale in Australian landscapes have been described by Worboys and Pulsford (Box 5.2), and are represented in Figure 5.32.

Box 5.2 Connectivity conservation in Australian landscapes

Connectivity conservation is an increasingly important conservation approach to land use and management in Australia, as elsewhere. Connectivity conservation areas interconnect protected areas, help maintain large-scale natural Australian landscapes and ecosystem processes, and are a natural and critical partner in biodiversity conservation to the National Reserve System. These areas are a critical conservation response to climate change. They provide opportunities for species to move, interact, adapt and evolve as higher temperatures and changed rainfall patterns cause ecosystem shifts at a landscape scale.

By 2011, seven large-scale connectivity conservation areas had been initiated to help protect the integrity and resilience of many Australian ecosystems. Major large-scale connectivity conservation areas are found in the east (the 2800-kilometre Great Eastern Ranges Corridor); in the north and north-west (the 3000-kilometre Northern Australia Tropical Savannah Lands Corridor, including the Kimberley Landscape Conservation Area); the south-west (the 1000-kilometre Gondwana Link); and through the centre (the 3500-kilometre Trans-Australia Ecolink Corridor) of the Australian continent. Other important large-scale corridors are located in the borderlands of South Australia, Victoria and New South Wales (Habitat 141) and in the Victorian alps (Biolinks).

The connectivity areas have been initiated by grassroots organisations, nongovernment conservation organisations, governments or a combination of these. The connectivity areas are managed to varying degrees. A central guiding vision has provided management direction, with management actions helping to maintain biodiversity and critical ecosystem processes, and respond to threats. Management has also included strategies for retaining opportunities for long-distance biological movements, retaining the integrity of hydro-ecological systems, sustaining resilience to global climate change, minimising human disturbances at local and regional scales, and protecting opportunities for species interactions and maintaining evolutionary processes. Connectivity conservation management frameworks are providing a systematic approach to conservation assessment, planning and management, and over time will include evaluation of effectiveness.

Governance of these large-scale corridors has favoured decentralised approaches that include multiple partnerships, and a shared vision has been developed for the corridor as a whole and within component links. This is important, given the needs of local areas relative to the entire corridor. On-ground management has been achieved through conservation programs and multiple individual efforts. The positive involvement of people from all walks of life in connectivity conservation work has been a small social phenomenon that can only be expected to grow, and reflects important changes in attitudes to the environment throughout the community. A connectivity conservation management approach, however, requires reliable resourcing, and supportive planning and policies, to consolidate its role in facilitating biodiversity conservation.

Source: Worboys & Pulsford
The discussion in Section 4 of this chapter, and the corresponding discussion in Chapter 8: Biodiversity reviewed the effectiveness of current approaches to managing Australia’s land environment. In essence, we are succeeding in managing some parts of our land environment and some of our production systems for resilient outcomes. In others, however, our efforts seem to be having little impact, and the resilience of the land environment will decline unless our management changes or becomes more effective. Ultimately, the outcomes of our management strategies will determine the outlook for Australia’s land environment, which we discuss in Section 7.

Figure 5.32 Australian connectivity conservation corridors, 2010
Risks to the land environment

Risks to the land environment reflect the conjunction of historical, contemporary and expected pressures in particular regions and locations. Some of these risks are a consequence of the now low resilience of soils and vegetation in those parts of Australia that have been longest and most intensively settled and used. Others reflect pressures that are difficult to manage on a landscape scale, such as fire and invasive species. Climate change is expected to exacerbate many of the risks to the land environment. Some of the risks relate to the possibility of inadequate investment and lack of capacity to manage the land environment adequately (see Section 4). The risks identified in Assessment summary 5.9 emerge from those that have been identified in assessments and reviews over the past decade (notably the Assessment of Australia’s terrestrial biodiversity 2008, Bastin et al., Burgman et al. and Cleugh et al.).

At a glance

The predicted impacts of climate change pose major risks to the values of the land environment. These include changes in vegetation communities and the impacts of invasive species.

Acidification and loss of soil carbon are major risks to our agricultural production systems, and climate change is a major risk to agricultural and forestry production systems.

Inadequate investment in monitoring and adaptive management, a lack of capacity for good management, and major land contamination events represent possible major risks to the land environment.
## 5.9 Assessment summary

### Current and emerging risks to the land environment

<table>
<thead>
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<th>Risk</th>
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<th>Probability</th>
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- **Almost certain**
  - Catastrophic: Profound changes in vegetation communities due to higher temperatures, changed rainfall patterns, and more extreme weather events associated with climate change.
  - Major: Invasive species, including new introductions and distributions.
  - Moderate: Further vegetation fragmentation by urban development.
  - Minor: Changes in coastal vegetation communities due to sea level rise associated with climate change.
  - Insignificant: Loss of good agricultural land to urban sprawl.

- **Likely**
  - Catastrophic: Decrease of soil carbon stores due to drying climate and acidification.
  - Major: Widespread acidification of agricultural lands.
  - Moderate: Altered fire regimes associated with climate and land-management changes.
  - Minor: Changes to agricultural and forestry production systems associated with climate change.
  - Insignificant: Hillslope erosion continuing at current rates or increasing due to intensification of storm events due to climate change.
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<td>▪ Major land contamination event with direct impacts on humans or food-supply chains</td>
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<td>□ Not considered</td>
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Outlook for the land environment

The outlook for Australia’s land environment—and the risks to it—will depend on the combination of three factors. These are the impacts of historical legacies, such as land clearing and land use since human settlement; the effectiveness of management regimes, such as our capacity to manage invasive species; and the development of future contexts, principally those associated with the drivers discussed in Chapter 2: Drivers.

In the past, the processes that determined the outlook for Australia’s land environment were dominated by land clearing for agriculture and settlement, and by land-use practices in agricultural and forested landscapes. As land clearing slows and the management of production systems improves, other processes become more important in determining the future character of the vegetation component of the land environment. These processes include the size and demographics of remnant populations in fragmented landscapes, edge effects, and the more diffuse but larger scale impacts of invasive species or altered fire regimes. The present and future condition of our soils will be shaped by the management of agricultural and pastoral systems, and our capacity to match them to Australia’s climate variability.

Future land environments across Australia are likely to be (re)shaped by a different climate from that of Australia’s human history. As recent reviews have revealed, the potential impacts of climate change in addition to the other pressures on our land environment are truly profound. The impacts of global forces associated with a growing world population and associated growth in consumption of food and resources will also be felt in Australia. The United Nations Food and Agriculture Organization has predicted that an increase of 70% in global food production will be necessary to meet the world’s food needs in 2050, and the expansion of bioenergy production is already placing pressure on agricultural and forest land elsewhere in the world. Globally, these pressures are expected to intensify competition between land use for agriculture, bioenergy, wood and fibre production, and conservation. Australia will experience these pressures, although the ways in which they are likely to manifest in our landscape are not yet clear. For these reasons, and for others that are more domestic in origin, the outlook for Australia’s land environment is mixed.

On one hand, although information and understanding of many aspects of the land environment and its management remain imperfect, the knowledge and experience bases for land management are substantial. We generally know what needs to be done to manage our land environment well. Institutionally, we have taken important steps in empowering Indigenous Australians to manage their country, and private landowners to manage their properties for the broader public good, as well as for their own specific objectives. We have experimented with, but not yet committed decisively to, regional NRM arrangements that emphasise more locally driven priority setting within frameworks determined by national and state processes. Management of public lands in each jurisdiction increasingly emphasises integration and collaboration across tenures and between agencies,
and many private landowners are committed to delivering environmental benefits beyond those required by legislation. Landscape-scale connectivity initiatives link public and private land, and help build resilience to both current and future pressures. Each of these contributes to a positive outlook for the land environment.

On the other hand, the legacy impacts of previous land-management regimes, some current land-management practices, the lack of resources and capacity to manage some landscape-scale pressures, and the predicted impacts of climate change suggest the prospect of a different—and in many respects poorer—Australian land environment in the future.

The outlook for much of our land environment will remain poor, unless we are able to:

- mitigate the impacts of pressures such as climate change, invasive species, and uncontrolled grazing by livestock and feral animals
- better manage fire regimes
- restore ecological functionality in degraded landscapes and prevent degradation in others
- further improve the sustainability of our agricultural and forestry production systems
- address the emerging tensions between some forms of mining and other land uses and values
- better manage the expansion and impacts of urban settlements and the waste our cities generate
- invest more in NRM capacity and implementation.

Aerial view of agricultural land near Silvan Reservoir, Victoria
Photo by Andrew Griffiths
References


Acropora coral reef, Great Barrier Reef, Queensland
Photo by Gary Bell
The overall condition of the Australian marine environment is good.

Compared with the marine waters of other nations, Australia’s oceans are considered as being in good condition. This is a testament to the limited pressures of the past century, combined with relatively good management of high-priority and emerging issues in recent years.

Areas near the coast are suffering.

Despite the overall good condition, there is substantial degradation in the east, south-east and south-west. Ecosystems near the coast, bays and estuaries in these regions are in poor to very poor condition. Much of the impact occurred in the mid-19th and 20th centuries, and the recent impacts principally arise from unregulated human activities in river catchments, urban and coastal developments, and fishing. Aquaculture in coastal waters has resulted in major disease outbreaks that have affected the ecology of native species. Oyster reefs, which formerly occurred in many estuaries across the south-east region, were mined for lime in the 1800s and are now functionally extinct. There are also major new pressures developing for these coastal waters, including the impacts of the changing climate.

There are significant existing impacts on the oceans caused by human activities.

Fishing and offshore developments, particularly oil and gas extraction, all have local impacts on marine biodiversity. The pattern of impact is different between the north and the south, and between the east and the west—aligned with the distribution and intensity of the pressures.

An extended continental shelf has been granted.

Under the provisions of the United Nations Convention on the Law of the Sea, in 2008 Australia was granted a large (23%) increase in the seabed territory it controls. This is now 13.86 million square kilometres—the third largest national marine territory in the world’s oceans.
The ocean climate is changing and we need to prepare to adapt.

Changes in the world’s climate are affecting Australia’s oceans. There are likely to be major impacts in the coming decades from increasing sea level, increased severity and incidence of extreme weather events, altered ocean currents and associated changes in productivity, increasing acidity of the oceans (resulting from higher carbon dioxide levels), and changing patterns of biodiversity and productivity in nearshore waters. Although there are currently only limited signs of changes in ecosystems, these will develop further and have important consequences for our coastal communities, wildlife and fishing. Planning to cope with these incremental impacts will require considerable strategic investment and leadership from governments working with communities and the private sector.

Our understanding of major aspects of our unique biodiversity is limited.

Our knowledge of seabed geology and topography, oceanographic systems and physical processes has increased, but our knowledge of biodiversity and ecological processes remains limited. Ongoing research programs in marine biodiversity and ecological function are a high priority and, because our existing knowledge base is dominated by information about fished species, it is particularly important to increase our understanding of non-exploited species and their roles in maintaining healthy and resilient ocean ecosystems.

How inappropriate to call this planet Earth when it is quite clearly Ocean.
Arthur C Clarke, Nature, 8 July 1990

The lack of a nationally integrated approach inhibits effective marine management.

The cumulative pressures on our marine ecosystems are rapidly growing. Impacts from climate change are beginning to escalate, population pressures and coastal development continue to grow, globalisation of marine industries continues, the risks to tropical waters from oil and gas developments are increasing— but our understanding of how ocean ecosystems operate is still very limited. In addition, present-day management systems lack integration among the various federal, state and local government systems that provide for planning, regulation and management of the marine and estuarine waters. These weaknesses significantly impede the design and delivery of efficient and effective policies and programs to maintain healthy and productive marine ecosystems and oceans. Foremost among the many issues is the lack of an integrated national system for assessment and reporting of marine condition. Without an integrated and genuinely national system of multilevel governance for conservation and management, it will be difficult to properly maintain the natural wealth of our oceans in the face of the challenges ahead.
1 Introduction 377

1.1 The jurisdictions 377
1.2 The seabed 380
1.3 Structure of the oceans 381
1.4 Biodiversity and productivity 382
1.5 Uses and values 383
   1.5.1 Oil and gas 383
   1.5.2 Fisheries and aquaculture 383
   1.5.3 Recreational and subsistence fishing 386
1.6 In this chapter 387

2 State and trends of the marine environment 388

2.1 Marine biodiversity 389
   2.1.1 Quality of habitats for species 390
   Assessment summary 6.1—state and trends of quality of habitats for species 392
   2.1.2 Populations of species and groups of species 395
   Assessment summary 6.2—state and trends of species populations and groups 398
   2.1.3 Ecological processes 401
   Assessment summary 6.3—state and trends of ecological processes 402

2.2 Marine ecosystem health 404
   2.2.1 Physical and chemical processes 404
   Assessment summary 6.4—state and trends of physical and chemical processes 406
   2.2.2 Pests, introduced species, diseases and algal blooms 409
   Assessment summary 6.5—state and trends of pests, introduced species, diseases and algal blooms 412
   Assessment summary 6.6—state and trends of the national marine environment 413

3 Pressures affecting the marine environment 414

3.1 Pressures resulting from climate change 415
   3.1.1 Temperature 415
   3.1.2 Ocean acidification 416
3.2 Fishing 417
3.3 Oil and gas exploration and production 423
3.4 Shipping and associated infrastructure 425
3.5 Aquaculture facilities 425
   3.5.1 Sydney rock oyster 427
   3.5.2 Abalone 427
   3.5.3 Cage fish culture 428
   3.5.4 Longline culture 429
3.6 Catchment run-off and land-based sources of pollution 429
3.7 Additional pressures 430
   Assessment summary 6.7—pressures affecting the marine environment 432
Pouring forth its seas everywhere, then, the ocean envelops the earth and fills its deeper chasms.

Nicolaus Copernicus, *On the revolutions of the celestial spheres*, 1543
Introduction

Our coastal lands and waters, beaches, bays and inlets hold a special place in Australian culture—for many, the coast is a defining attribute of what it is to be an Australian. Australia’s vast ocean territory offers the opportunity to generate wealth, as well as the concomitant responsibility for conservation, management and sustainable use of the environment and living resources.

The majority of our cities and smaller coastal communities rely heavily on coastal waters for economic and recreational pursuits, coastal shipping, energy production and seafood products. Land near the coast—with ocean views and breezes, and easy access to waterways, walks, swimming and surfing beaches—commands a premium value everywhere. The ocean is the inspiration for contemporary music, film, books, stories and legends. The commercial opportunities in tourism, recreational fishing, water sports and the amenity of coastal waterfront lands drive the development patterns of our coastal cities and major towns.

Outside the towns and cities, our natural treasures—such as Fraser Island and the Great Barrier Reef in Queensland; Lord Howe Island and Jervis Bay in New South Wales; the Great Australian Bight in South Australia; Shark Bay, Ningaloo Reef and the Kimberley coast in Western Australia; and many more—stand as icons of Australia’s national identity.

1.1 The jurisdictions

Australia’s marine environment extends from the landward limit of marine waters (which, in many places, is the high tide level) along the coastline of the continent and islands to the deepwater outer limit of the continental shelf, as recognised by the United Nations Convention on the Law of the Sea (UNCLOS) in 2008. This includes parts of the Indian, Southern and Pacific oceans. The outer boundary of the Australian marine jurisdiction adjoins boundaries of other countries, mainly in the north and east, including France, Indonesia, New Zealand, Papua New Guinea, the Solomon Islands and Timor-Leste. In the west and south, Australia’s outer marine boundary mainly meets international waters—the high seas.

Management of Australian waters is divided into a number of complex administrative zones, reflecting the role of state and territory governments in the nearshore waters, and the terms of international agreements and conventions, principally UNCLOS, in the offshore waters (Figures 6.1 and 6.2). The two main zones of management are the three-mile zone and the 200-mile zone. The three-mile state waters zone (which is not a zone recognised by UNCLOS) extends from near the shoreline to approximately three nautical miles offshore. In 1983, title to the seabed, rights to the water column and some legislative powers in this zone were granted to the adjacent
state or territory under the Offshore Constitutional Settlement. Full responsibility for the marine seabed and the waters between the three-mile zone and the 200-mile zone—the territorial sea and the exclusive economic zone (EEZ)—remains with the Australian Government.

On 9 April 2008, the United Nations Commission on the Limits of the Continental Shelf confirmed Australia’s entitlement to an area of continental shelf that extends beyond the EEZ, known as the extended continental shelf (ECS). When this is proclaimed, it will increase the size of Australia’s marine jurisdiction by around 2.56 million square kilometres. Australia’s marine jurisdiction (including the ECS of the mainland and islands, but not the ECS of the Australian Antarctic Territory, the claim for which is disputed by several countries) will then cover around 13.86 million square kilometres—nearly twice the size of the Australian landmass and islands. As a result, Australia will have stewardship of approximately 3.8% of the world’s oceans, one of the top three in area in the world, along with the United States and France. The seabed and all the living and nonliving resources of the ECS, but not the water column and its resources, will be under the control of the Australian Government.

In December 1998 the Australian Government released a national Oceans Policy for implementation through regional marine plans, to provide a basis for integrated management of Australia’s oceans. This has been superseded by a series of bioregional marine plans being established under the Environment Protection and Biodiversity Conservation Act 1999 to provide an ocean planning system with a legislative base, although the plans themselves are not legislative instruments. These bioregional plans apply to the waters of the EEZ and the territorial sea, but not to the state and territory coastal waters as was envisaged by Australia’s Oceans Policy and the intended regional marine plans.2-4

![Figure 6.1 Jurisdiction zones for Australia’s marine environment](image-url)

1 nautical mile (M) = 1852 metres
Source: Adapted from Symonds et al.1
Territorial sea and internal waters

Australia’s exclusive economic zone as defined by the United Nations Convention on the Law of the Sea and certain treaties (not all in force)

Australia’s extended continental shelf (ECS) beyond 200 nautical miles as confirmed by the Commission on the Limits of the Continental Shelf and as defined by certain treaties (not all in force)

Australia’s ECS considered by the commission and yet to be resolved

Australia’s ECS off Antarctica as submitted on 15 November 2004 to the commission that Australia requested not be considered for the time being

Joint Petroleum Development Area as defined in the Timor Sea Treaty between Australia and Timor-Leste

Treaty boundary with opposite or adjacent state

AAT = Australian Antarctic Territory; FR = France; NOR = Norway; NZ = New Zealand; PNG = Papua New Guinea

Source: Symonds et al.¹

Figure 6.2 Zones and limits of Australia’s marine jurisdiction
1.2 The seabed

The seabed of Australia’s marine jurisdiction is diverse and complex, reflecting the large area it covers and its span from the tropics to the Antarctic, with many coastal and offshore islands and their fringing geomorphic structures. The continental mainland has a coastline of around 36,000 kilometres, and spans more than 5000 kilometres from the tropics (9°S) to temperate latitudes (47°S).

Recent mapping of nearly 50 million square kilometres of the seabed in our region has identified 21 types of geomorphic features. These include major features such as the continental shelf, slope, plateaus and abyssal plain (bottom of the deep ocean at a depth of more than 2000 metres); and smaller features such as basins, terraces, reefs and seamounts (Figure 6.3). The geomorphology at the margin of the continent is the most complex aspect of the region and includes marginal plateaus, trenches, troughs and submarine canyons. The plateaus along the Australian margin cover around 1.5 million square kilometres—20% of the total world area of marginal ocean plateaus. The great diversity of geomorphic structures provides an equivalent diversity of habitat types for animals and plants that live on, or are closely associated with, the seabed.

Broadscale mapping of seabed environments into a series of ‘seascapes’ has uncovered great diversity in Australia’s marine jurisdiction, including aspects of...
Australia is heavily influenced by four major ocean currents (Figure 6.4):

- The East Australian Current flows southward along the east coast of Australia from near Fraser Island in Queensland to Tasmania. It is an important feature of the Tasman Sea between Australia and New Zealand, and generates large eddies that peel off the main current as it moves south.
- The Leeuwin Current forms near the North West Shelf and breaks into a series of eddies as it travels south along Australia’s west coast, eventually dissipating in the Tasman Sea and Southern Ocean. It is the longest coastal current in the world and has a major influence on the weather in Western Australia and the distribution of marine life.

In coastal waters, recent studies have revealed the complex interplay between sediment types, local geomorphology and ocean conditions, producing a classification of sediment compartments that describe the structure of coastal seabed systems. The compartments broadly reflect the vulnerability of coastal seabed and beach systems to ocean-driven change, and therefore contribute to regional development planning and conservation activities.
• The Indonesian Throughflow is a system of currents that carries water westward from the Pacific Ocean to the Indian Ocean through the Indonesian Archipelago. Beyond Australia, the throughflow is a critical element in the global climate system because the heat it carries from the tropical Pacific Ocean into the Indian Ocean affects regional sea surface temperatures and rainfall, including the Asian and Australian monsoons.

• The 20 000-kilometre-long Antarctic Circumpolar Current is considered to be the powerhouse for global climate. It connects the Atlantic, Pacific and Indian oceans with an eastward flow equivalent to 150 times the combined flow of all the world’s rivers. The current comprises merging and separating jets between different masses of water—the subtropical front and the subantarctic front. This turbulent region, well south of Australia, is characterised by high ocean nutrient levels and primary production, and typically hosts large aggregations of krill, migratory fish, birds and marine mammals.

Together, these four major currents have a driving influence on the conditions and biodiversity in our oceans and coastal environments, and on Australia’s climate.

Along with the major ocean basin currents and the continental currents, there are a number of smaller and more complex current systems. All these ocean features can change from season to season, and may be more or less extensive and energetic, depending on climate factors that influence the oceans at the scale of the whole ocean basin.

1.4 Biodiversity and productivity

The coastal waters of Australia are generally low in nutrients all year round and are not highly productive (exceptions to this are the shallow waters of the tropics and the shallow shelf and gulf systems, such as Torres Strait). This means that the diverse species and ecosystems of these waters are very sensitive to the addition of even small amounts of land-derived or ocean-derived nutrients, and disturbances of the seabed that resuspend nutrients.

The low nutrient status of our waters is a result of the limited penetration of nutrient-rich deep ocean currents into shallow coastal waters where there is enough sunlight to drive primary production (where organisms such as phytoplankton use solar energy to convert carbon dioxide and nutrients into new organic materials). As a result, Australia’s oceans do not support a large biomass of fish or dependent predators, as occurs in waters off South Africa and South America. However, in the high density of canyons along the edge of the continental shelf, there are areas that experience periodic small intrusions of deep, cold ocean waters. These canyons and shelf-edge features are therefore small hot spots that are rich in diversity and biomass of invertebrates, fish, and their prey and predators. For example, the line of shelf-edge canyons on the west coast of Australia and their associated production systems are thought to support the ‘whale highway’—the annual migration pathway of humpback whales from the Antarctic to their calving grounds in the warm tropical waters of the Kimberley region. A cold-water upwelling system (where sea water rises from the depths to the surface, typically bringing nutrients to the surface) also regularly occurs along the west coast of Victoria and near South Australia’s Kangaroo Island, extending to the Eyre Peninsula.

Elsewhere, the remoteness, diversity of habitat types and low-nutrient waters have created highly diverse flora and fauna. Many areas have locally endemic (unique to the region) species, and assemblages of low species diversity that are unique and highly ecologically valued. For example, the tropical, subtropical and temperate reefs, shelves, bays and gulfs around the Australian coast are home to a rich diversity of species and ecosystems. At different times of the year, depending on river inputs and coastal run-off, these coastal features can be dominated by turbid and productive waters or, alternatively, by clear waters with low nutrient status. The flora and fauna of these areas are specialised and resilient to such variable coastal conditions. The Australian waters have a high number of endemic species, particularly in the southern regions that are most isolated from other land masses in the Pacific and Indian oceans.

While our knowledge of the distribution and taxonomy of Australia’s marine biodiversity (particularly the invertebrates) remains patchy, the recently conducted Census of Marine Life summarised our knowledge of animals from the major marine biodiversity databases. The census found approximately 33 000 marine species that were confirmed to occur in Australian waters; of these, 130 species are introduced, 58 are listed as threatened, and an unknown (but likely to be large) number of species are endemic. Levels of endemism are low in the tropics because many species also occur across the broader Indo–West Pacific region but, in the temperate waters of southern Australia, endemism is likely to be high (possibly up to 90%). Although the
taxonomy of marine plant species is reasonably well known, particularly for the 75 species of seagrasses and mangroves, they are not well represented in the national biodiversity database systems that describe their distributions.

The marine animal species confirmed to occur in Australian waters are dominated by molluscs (8525 species), crustaceans (6365) and fish (5184)—a pattern that is consistent across all the world’s oceans. A further estimated 17,000 species are likely (reported but not confirmed) to occur in our waters, including the many soft-bodied pelagic and benthic (sea-floor) invertebrate species (such as worms) that play important ecological roles. Crude estimates based on the rate of biological exploration and discovery suggest that the total number of marine species (those known to occur, likely to occur and yet to be discovered) in Australian waters is around 250,000 macroscopic species, and many more if microscopic species are included.

1.5 Uses and values

Australia’s oceans inspire many of our social and cultural values, and the marine sector contributes significantly to the national economy through energy and food production, recreation and tourism. A recent evaluation of Australia’s marine industries showed that the sector provides at least 4% of gross domestic product and is undergoing rapid growth, increasing by approximately 50% since 2000 and conservatively valued at $48 billion in 2007–08. This estimate did not include a number of emerging industries, such as seabed mining, carbon capture, desalination, tidal and wave power, or the use of marine organisms as the source of new materials or pharmaceuticals.

1.5.1 Oil and gas

The economic backbone of the marine sector is the oil and gas industry. More than 90% of Australia’s liquid hydrocarbon and 74% of the nation’s natural gas production is extracted from ocean areas. The annual value of this activity was estimated at around $22 billion in 2007–08. Increasing global demand for energy and fewer discoveries of new oil and gas fields are increasing the pressure for further exploration and extraction within Australia’s EEZ and ECS. Associated with this challenge is the need for novel extraction technologies to increase recovery rates and safety of extraction, capture and storage of carbon; more onshore and floating processing plants; new shipping facilities; and higher standards of environmental protection. Oil and gas production in Australia is concentrated in the north-western and southern regions (Figure 6.5).

1.5.2 Fisheries and aquaculture

Although considerably smaller in economic value than oil and gas, the coastal fisheries and aquaculture sector is the mainstay of Australia’s renewable marine resources. The gross value of production (GVP) in 2008–09 was $2.2 billion, from a production of 238,000 tonnes of seafood. The majority of the sector—86% of the value of commercial fisheries in 2008–09—is managed by state and territory agencies. These commercial fisheries focus on several hundred high-value, but low-yield, marine species and products. For example, the New South Wales commercial wild-catch sector in 2008–09 was valued at approximately $93 million, based on around 100 species of fish and invertebrates (mostly low-volume products considered to be currently fished to their maximum capacity). The highest value production is the Atlantic salmon aquaculture industry (GVP of $323 million; 15% of the total seafood value in 2008–09), and the largest wild-catch fishery is for Australian sardines (31,500 tonnes, 13% of the total wild catch in 2008–09), much of which is used as fish food in aquaculture.

Australia’s overall seafood production over the decade from 1999–2000 to 2008–09 increased steadily for the first six years, rising from 223,000 tonnes in 1999–2000 to peak at 279,000 tonnes in 2004–05. Production remained relatively stable for the period 2005–06 to 2008–09, at an average of 242,000 tonnes per year (Figure 6.6). Production from our wild-catch fisheries increased initially from 2001–02 until 2004–05, but then declined subsequently to 2008–09. Similarly, global catches have remained stable, but stocks in wild-catch fisheries have declined. The annual GVP of Australia’s fisheries declined by 30% from 1999–2000 to $2.2 billion in 2008–09 (Figure 6.7). Most of this decline in value was related to the decline in the GVP of the wild-catch sector from $2.5 billion in 1997–98 to $1.4 billion in 2008–09. The main reason for this trend was a fall in prices for the major wild-caught species (rock lobster, prawns, tuna), but overall wild-catch production also fell significantly, from 236,864 tonnes in 2004–05 to 173,142 tonnes in 2008–09.
Commonwealth-managed commercial fisheries are the responsibility of the Australian Fisheries Management Authority (AFMA), either directly, indirectly through joint management authority with a state or territory, or under international agreements on the high seas. The products of AFMA-managed fisheries include some of the better known species to be found in mainland fish shops, such as banana prawns from the Gulf of Carpentaria, flathead from the continental shelf waters off Victoria and scallops from Bass Strait. In 2008, there were 20 AFMA-managed fisheries targeting 98 stocks or species groups. Catch levels vary widely, depending on the area and target species (Figure 6.8). The AFMA fisheries are becoming better understood as a result of many years of significant investment in research and management. The condition of the Commonwealth-managed fisheries is assessed and reported annually by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES, an independent research agency of the Australian Government).

In 2008, AFMA applied a new harvest policy\(^3\) that seeks to manage each fishery so that fished stocks are generally maintained between two reference points—an upper-level ‘target’ biomass (population size to be achieved) that is considered to be a relatively safe level of biomass for the fished stock, and a low-level ‘limit’ biomass that represents a minimum permitted level. The setting of these

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**Figure 6.5 National distribution of oil and gas facilities**

The facilities shown within the Great Barrier Reef region are historical drilling sites on islands, and are not within the marine park.
target and limit reference points recognises that biomass is a central attribute of fish populations and an important metric to be tracked in management. While target and limit reference points are currently set mainly on the basis of economic yield, the stage is set for the future management of harvests so that both ecological and economic parameters can be considered simultaneously. The challenge for the wild-catch sector of all Australian jurisdictions is for ecosystem-based fisheries management to be developed and implemented in a way that protects the biodiversity values of the ocean ecosystems, as well as the harvests from fishable stocks. In particular, we need to avoid the pitfalls of ‘Ludwig’s ratchet’, in which fisheries overcapitalise in fishing technology and overexploit species to cover their debt, despite scientific evidence that stocks are declining. When the fishery is no longer economically viable, governments provide financial assistance to minimise economic hardship. When stocks increase, there is another rush to invest in yet newer technology, and the cycle repeats.

In 2009, the condition of 59 AFMA stocks was classified as not overfished, and 73 were classified as not suffering overfishing. Twelve further stocks were assessed as overfished (12%, reduced from 19% in 2004) and 10 as suffering ongoing overfishing (10%, reduced from 12% in 2004); there was too much...
make a major contribution to the Australian way of life. The recreational amenities of many regional cities, coastal towns and (increasingly) remote communities are dominated by marine attractions and recreational fishing. No data are available for subsistence fishing, but it is likely to be difficult to separate from recreational fishing, since a significant portion of the recreational catch is consumed by fishers. For many of the highly sought-after species, recreational fish catches are likely to be larger than the commercial catches of the same species. Marine tourism and recreation, including fishing, were estimated to contribute $18.7 billion to the Australian economy in 2007–08—about the same value as the oil and gas industry—and fishing is now considered to be the nation’s largest participatory recreational activity.

A recent study of recreational fishing in South Australian waters found that approximately 16% of the population (about 240 000 people) participated in recreational fishing during the survey year (2007). Over the year, with a total fishing effort of around 1 million fishing-days, these fishers caught almost

1.5.3 Recreational and subsistence fishing

Beyond commercial fishing and aquaculture, recreational and subsistence fisheries form an important part of Australia’s coast-focused culture and uncertainty to determine if the remaining 30 stocks were overfished or not. These figures show a steady improvement since 2004; however, some key stocks (such as school shark) remain in the overfished category and continue to require priority action.

The number and identity of the AFMA stocks reported by the ABARES system have changed substantially since this form of reporting began in 1992. This has been generally positive, with new stocks being added to increase resolution of the reporting system. Updating by dropping stocks that are no longer important (two stocks reported in 1992 are no longer reported) risks confounding the capacity to assess long-term trends in fish populations and fishing activity, and is generally avoided.

Figure 6.8 Relative catch levels of all Commonwealth-managed fisheries, 2009

Source: Wilson et al.
10 million fish, crustaceans and molluscs, from 98 species. However, they also released large numbers of these fish. Release rates varied from less than 10% to more than 70%. However, there is little information about the subsequent survival rates, which may not be very high for some species. The survey also revealed that there had been a substantial decline in catches of six of the eight key recreational species since a similar survey in 2000, together with a 5% decline in participation and a 42% decline in fishing effort. Such declines in participation and effort may reflect reduced expectations of the fishers about the experience.

1.6 In this chapter

This chapter reports on the state of our vast system of marine waters and seabed. The present-day condition and trends for marine ecosystems, biodiversity and ecological health over the period 2005 to 2010 are assessed and reported in a standardised report-card system (assessment summaries), based on the expert judgement provided by a selected group of experienced Australian marine scientists at a series of national condition assessment workshops. The design, methodology and outcomes of the assessment workshop process are available on the State of Environment (SoE) website. Supplementary materials for various sections of this chapter are also available on the website.

The chapter also examines the pressures for change that marine systems are experiencing and the risks they face in the near future. This information is used to project an outlook for the marine environment for the next 20–50 years. Some further important aspects of the marine environment are described and reported in Chapter 2: Drivers, Chapter 8: Biodiversity and Chapter 11: Coasts. The state of the waters of Australia’s Antarctic Territory is reported in Chapter 7: Antarctic environment.

a www.environment.gov.au/soe
State and trends of the marine environment

Australia’s marine environment encompasses the structures of the seabed, ocean and shoreline systems, marine and estuarine waters, and their species and biological structure and function, all of which interact in a complex and interdependent web. Biodiversity and ecological health is assessed and reported here for:

- **marine biodiversity**
  - quality of marine habitats for marine species
  - populations of the main types of marine species
  - ecological processes that support biodiversity and habitats
- **ecosystem health**
  - quality of the physical and chemical processes that maintain the health of marine ecosystems
  - extent of diseases, algal blooms, pests and introduced species.

For this SoE report, the condition and trends for the main aspects of marine biodiversity and ecosystem health have been assessed within each of the major Australian marine regions (Figure 6.9). These five regions include the Australian Government’s marine planning regions, the extended continental shelf, the offshore islands and territories (other than the subantarctic islands), and the state and internal waters, up to high tide level at the shoreline. The assessment of conditions reported here must be interpreted with caution, because studies and data directly relevant to the Australian marine environment are limited. The assessments reported here are derived from available data and information, and from the judgement of a limited number of experts who participated in the national marine condition assessment workshops that contributed to the analyses presented here.

Marine biodiversity overall is in good condition, but nationally there are a number of areas on the coast, continental shelf and upper slope where the condition of some elements of biodiversity is very poor, as a result of the effects of specific human activities. Condition remains poor to very poor for a number of iconic species that have failed to recover from earlier impacts of excessive hunting and fishing, and some species continue to decline. These include Australian sea lions, which are unique to temperate southern Australian waters and are showing no substantial signs of population recovery from the hunting of previous centuries; and migratory wading birds, which appear to be continuing to decline across many of their Australian habitats. Southern bluefin tuna, formerly a major predator of our regional seas, has been fished to the edge of population survival but is now listed as conservation dependent under the Environment Protection and Biodiversity Conservation Act 1999; its global catch has been reduced, and a management procedure has been proposed that is intended to rebuild the population.

In addition to national-scale biodiversity problems, there are many more habitat and species issues in smaller local areas. These judgements are based on a generally low level of certainty, with most of the available knowledge linked to fished species and threatened species. A much more detailed national assessment of marine biodiversity is required to properly clarify the nature, extent and significance of the condition of our marine biodiversity.

The overall health of our marine ecosystems is good, but this finding is influenced by the good condition of the offshore waters and the remote coastlines of regions where pressures are lowest. In inshore waters near the coast of the south-west, east and south-east regions, and near urban areas and industrial developments, the ecosystems are in poor health. Algal blooms occur regularly; natural levels of freshwater, sediment and nutrient inputs have been heavily altered; and worrying levels of pesticides are found in waters near areas of intensive agriculture. The ecosystem health of some nearshore marine waters and many estuaries is poor, particularly across the temperate areas and in many parts of the south-east region. In this report, the south-east region is assessed to be in the worst condition: most places are good, but the worst 10% of the region is poor—existing values are significantly impacted, and serious further degradation is expected within 50 years.
2.1 Marine biodiversity

The status of marine biodiversity has been assessed by examining marine habitat quality, the species and populations, and the ecological processes that support the species and populations. These assessments of marine biodiversity are summarised for each region (the criteria used and detailed results are available on the SoE website\(^b\)) and aggregated into a single national assessment and report card for biodiversity.

The overall assessment of biodiversity found that the north and north-west regions are in very good condition, the east and south-west regions are in good condition, and the south-east region is in poor condition, although bordering on good (Figure 6.10).

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2.1.1 Quality of habitats for species

Good-quality habitat is essential to support species populations and to allow natural ecological processes to operate. Habitat quality is defined using structural and functional intactness, relative to the conditions at the time of European settlement of Australia.

This section reports at the national level on our best understanding of the status and trends of marine habitat quality in 21 types of habitats that occur broadly and in more than one region, and 60 habitat types that occur principally in only one region.

South-west region

The habitats of the south-west region are overall in good condition. There are, however, a number of localised coastal areas of historical heavy impact where the effects remain—these include pollution and dredging of seagrass beds in Cockburn Sound, Perth; pollution-induced losses of seagrasses in Gulf St Vincent, Adelaide; and pollution of Albany harbours in Western Australia. Away from areas of coastal development or river run-off, many habitats remain in good condition. Water conditions overall are very good, particularly away from the shoreline. Conditions of habitats of the estuaries and lagoons of this region are considered overall to be very poor. Seagrass beds are a dominant habitat in the south-west of Australia, occurring in many intertidal and subtidal areas of coastal waters and estuaries, and in offshore locations down to 50 metres depth. Seagrasses provide important habitat for many fish and invertebrate species, and they host important parts of the lifecycle of a number of fished species. Although two species of seagrass (Posidonia sinuosa and P. australis) are considered threatened or near-threatened with extinction, in most places in this region seagrasses are in very good condition.

North-west region

The habitats of the north-west region are overall in very good condition. Much of this region is very remote (particularly the north) and, as a result, many habitats are considered to be very good and in nearly pristine condition. These include the large gulfs and bays, fringing coral reefs, and seagrass and algal bed systems of the Kimberley, and most of the offshore shoals and islands, canyons and shelf-break ecosystems of the region. Some of the world’s most extensive undisturbed tropical and subtropical habitats occur in the shallow waters of the Kimberley, Ningaloo Reef, Roebuck Bay and Shark Bay. Nonetheless, there are localised areas where the habitats are in very poor condition, such as near Dampier, Port Hedland and Onslow, where ports and shipping activities have heavily impacted coral and mangrove habitats. Offshore habitats are generally in good condition, although the deepwater corals and sponges of the North West Shelf are still considered to be heavily degraded and only slowly recovering from the extensive impacts of historical trawling, and some offshore islands have been heavily impacted by foreign fishing.

In the Kimberley, there are 343 islands with more than 20 hectares of land above mean high water, and many more smaller islands. Almost all the islands have fringing reef systems of complex hard coral and algal (rhodolith) habitats. Most of these are remote from human influences and in very good and near-pristine condition.

North region

Like the north-west, the habitats of the north region are also remote and pristine tropical habitats, and most are considered to be in very good condition. These include the nearshore shallow-water marine systems, the extensive shoreline wetlands, and the bays and gulfs of the region. However, the pressures of coastal development are evident in some areas, such as Darwin Harbour and Melville Bay (Nhulunbuy, Northern Territory), where a localised, biologically dead area has been created by mining wastes. Most of the rivers are substantially unmodified. Exceptions are the Ord River, which is heavily modified by the Ord River Dam, resulting in substantial impacts on the estuarine habitats of the delta in Cambridge Gulf; and the Macarthur River, which is modified by mining.

East region

The east region includes the Great Barrier Reef, Torres Strait, the Coral Sea plateau and islands, Fraser Island, Sydney Harbour, Jervis Bay, and the many smaller islands, bays and estuaries of the New South Wales coast. Habitats of the northern part of the region are considered to be in good condition overall, despite considerable pressure from land-based sources of pollution. The Great Barrier Reef region has been considered in detail, and a condition assessment is presented in the Great Barrier Reef outlook report 2009.

In the Kimberley, there are 343 islands with more than 20 hectares of land above mean high water, and many more smaller islands. Almost all the islands have fringing reef systems of complex hard coral and algal (rhodolith) habitats. Most of these are remote from human influences and in very good and near-pristine condition.
However, the habitats of the central and southern part of the region are more degraded, and many are considered to be poor. This is mainly the result of population pressures in coastal areas (such as in south-east Queensland and northern New South Wales), beach modifications, loss of major areas of seagrass and corals, historical effects of heavy trawling on the continental shelf, and major modification of rivers, some of which (such as the Tweed River) have significantly modified catchments for agriculture and altered freshwater flow regimes feeding to the estuaries and bays. Herbicides have been found in all water sampling sites in the inshore waters of the Great Barrier Reef and, in some places, are approaching levels that may have significant impacts on coral and other marine life.32 In New South Wales, the seagrass *Posidonia australis* is proposed to be declared as an endangered species in six areas where it formerly occurred widely, because of various impacts (such as dredging and pollution) over the past decades.33

![The world's largest fish—the filter-feeding whale shark (*Rhincodon typus*) with a diver, Ningaloo Marine Park, Western Australia](Photo by Tourism Western Australia)

**South-east region**

The overall quality of habitat in the south-east region is poor; the pressures of population, shipping, fishing and development in many places have degraded habitats of inshore waters, bays and estuaries. This is the only region where a habitat type has been made functionally extinct by human activities—the oyster reef beds that formerly dominated a number of the estuaries and small bays were exterminated by mining and fishing practices by the end of the 1800s. Seven of the 11 formerly existing oyster reefs assessed are functionally extinct, while the remaining 4 were assessed as having more than 90% of their area lost.34 This has had a significant impact on ecological systems, reducing habitat for many other species and probably greatly affecting the overall water filtering (purification) capacity of these affected areas and their capacity to assimilate nutrient inputs.
### State and trends of quality of habitats for species

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gulfs, bays, estuaries, lagoons</td>
<td>South-east, south-west and east regions heavily degraded in many places; north region in very good condition</td>
<td>Poor</td>
<td>In grade</td>
</tr>
<tr>
<td>Beaches</td>
<td>South-west and north regions in very good condition</td>
<td>Poor</td>
<td>In grade</td>
</tr>
<tr>
<td>Fringing reefs—corals, intertidal and subtidal, of coast and islands</td>
<td>East region in very poor condition</td>
<td>Poor</td>
<td>In grade</td>
</tr>
<tr>
<td>Seabed inner shelf (0–50 m)</td>
<td>South-east and east regions in poor condition</td>
<td>Poor</td>
<td>In grade</td>
</tr>
<tr>
<td>Seabed outer shelf (50–200 m)</td>
<td>South-east and south-west regions in poor condition</td>
<td>Poor</td>
<td>In grade</td>
</tr>
<tr>
<td>Seabed, shelf break and upper slope (200–700 m)</td>
<td>South-east region in very poor condition</td>
<td>Poor</td>
<td>In grade</td>
</tr>
<tr>
<td>Seabed lower slope (700–1500 m)</td>
<td>South-east region in poor condition</td>
<td>Poor</td>
<td>In grade</td>
</tr>
<tr>
<td>Seabed abyss (&gt;1500 m)</td>
<td>Abyss depths in very good condition in all regions</td>
<td>Good</td>
<td>In grade</td>
</tr>
<tr>
<td>Water column, shoreline (0–20 m), not estuaries</td>
<td>East region in poor condition</td>
<td>Poor</td>
<td>In grade</td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
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<tr>
<td>Water column, inner shelf (20–50 m)</td>
<td>East region in poor condition</td>
<td></td>
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</tr>
<tr>
<td>Water column, outer shelf (50–200 m)</td>
<td>All regions in good or very good condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water column offshore (&gt;200 m)</td>
<td>All regions in good or very good condition</td>
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<tr>
<td>Mangroves</td>
<td>East and south-east regions in poor condition</td>
<td></td>
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<tr>
<td>Seagrasses</td>
<td>East and south-east regions in poor condition</td>
<td></td>
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<tr>
<td>Algal beds</td>
<td>East and south-east regions in poor condition</td>
<td></td>
<td></td>
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<tr>
<td>Coral reefs (&lt;30 m)</td>
<td>North-west and north regions in very good condition</td>
<td></td>
<td></td>
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<tr>
<td>Deepwater corals and sponges (&gt;30 m)</td>
<td>North and east regions in very good condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bryozoan reefs</td>
<td>Only assessed in the south-east region</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canyons and shelf break</td>
<td>South-east region in poor condition</td>
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### State and trends of quality of habitats for species continued

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Seamounts (&gt;-1000 m rise from sea floor)</td>
<td>East region in poor condition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offshore banks, shoals, islands</td>
<td>Only assessed in north-west and east regions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regionally unique features</td>
<td>Assessed 60 individual habitat features that occur primarily in only one region</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Recent trends
- Improving
- Deteriorating
- Stable
- Unclear

#### Grades
- **Very good**: All major habitats are essentially structurally and functionally intact and able to support all dependent species
- **Good**: There is some habitat loss, degradation or alteration in some small areas, leading to minimal degradation but no persistent, substantial effects on populations of dependent species
- **Poor**: Habitat loss, degradation or alteration has occurred in a number of areas, leading to persistent, substantial effects on populations of some dependent species
- **Very poor**: There is widespread habitat loss, degradation or alteration, leading to persistent, substantial effects on many populations of dependent species

#### Confidence
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment
2.1.2 Populations of species and groups of species

This section reports on our best understanding at the national level of the status and trends of 31 major populations and groups of marine species, including threatened species. Condition of the populations of species and groups of species is defined by the extent to which populations have declined because of human activities, relative to their condition at the time of European settlement of Australia. There has been no previous national synthesis of species condition, and the assessments reported here are derived from the national marine condition assessment workshops. The criteria used in the workshops are available on the SoE website.c

Species are threatened mainly by direct exploitation and by loss of, or changes in, their habitats. Future assessments of the condition of marine species will also need to consider the impacts of climate change on both the inherent biological properties of individual species and their preferred habitats. To enable accurate reporting of population conditions and trends, these future assessments will need to be conducted using more holistic ecological approaches to population condition assessment, such as those outlined for the coral trout and the butterflyfish in Box 6.5.35

South-west region

The populations of 16 of the 29 species and species groups assessed were found to be in poor or very poor condition in the south-west region—these were mainly the large species for which there was enough knowledge to be able to make a judgement. Species and groups considered to be in poor condition include exploited sharks and rays, whale sharks, great white sharks, exploited tuna and billfish, southern bluefin tuna, exploited species of reef fish, seabed species of the inner shelf, migratory seabirds, dolphins and porpoises, seals and sea lions, and baleen and toothed whales (although humpback whale populations are considered to be in good condition and strongly recovering from historical hunting). Invertebrate species, seahorses and their relatives, small pelagic fish, and sharks and rays that are not targeted by commercial or recreational fisheries are considered to be in good condition.

Australian sea lions are endemic to this region. After intense hunting in the 1800s, their population still does not show any significant recovery. Increases have been documented only at Dangerous Reef in South Australia. Breeding colonies are substantially isolated from each other, and population recovery will continue to be a very slow process and subject to pressures of climate change and incidental mortality in fisheries.

North-west region

The populations of 15 of the 21 species and species groups assessed in the north-west region were found to be in good or very good condition. These include most of the shelf invertebrate species, the corals and shoreline species, dugongs, dolphins, humpback whales, crocodiles and sea snakes. Most of these groups that are in good or very good condition are considered to have stable populations. Nonetheless, the sea snakes at Ashmore Reef and the larger species of tuna and billfish across the region were considered to be in very poor condition. Also, across the region, large predatory reef fish (species targeted in commercial and recreational fisheries) were considered to be in poor condition overall.

Cod have been heavily fished in most of the southern parts of this region, including at Ningaloo Reef. Oral histories indicate that the populations that once existed are now largely gone, and the large, old fish no longer exist:

... cods were everywhere—there were hundreds of them there, and they were giving me trouble every day. One snuck up behind me and took a full bag of crayfish—and when I say a full bag I mean about eighty pounds of crayfish. When I looked around there was this big monster of a cod there and he had about a quarter of my bag in his mouth. Farinaccio36

North region

The species and their populations in the north region are considered to be overall in very good condition—14 of the 17 species and species groups were assessed as being in good or very good condition. The remoteness of the region and lack of major pressures indicate, with a high level of certainty, that many species and their populations have been only slightly changed from their likely condition at the time of European settlement. Nonetheless, a number of exploited populations could not be assessed, and their condition is likely to range

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from good to poor. Turtles and migratory seabird populations were considered to be in poor condition, mostly because of pressures on their populations outside the region, including internationally. Other species that occur in this region, such as the Indo-Pacific humpback dolphin and the Australian snubfin dolphin, are listed by the International Union for Conservation of Nature (IUCN) as near threatened.

**East region**

The species populations in the east region are overall in poor condition—20 of the 29 species and species groups assessed were in poor or very poor condition. The populations considered to be in the worst condition include the invertebrates and plant species of the dunes, shoreline and shallow inner-shelf waters; fish of the shallow-water reefs; migratory wading birds; sea snakes; dugongs; turtles; and whales. In some places, hard corals are considered to be in very poor condition. Within the Great Barrier Reef Marine Park, some of these populations are considered to be in good condition. The invertebrate species of the outer shelf and slope, the species of sharks and rays that are not targeted by fishing, and remote areas of the Coral Sea are considered to be in good condition across this region.

**South-east region**

The species populations of the south-east region are in poor condition overall—14 of the 24 species and species groups were assessed as being in poor or very poor condition. Populations considered to be in poor to very poor condition across the region include major predator species (such as great white sharks and southern bluefin tuna), species of the outer shelf and upper slope where intensive fishing was conducted in earlier years, inshore reef fish species, and species of seagrass and mangroves. The Oceania (south-west Pacific) subpopulation of humpback whales remains IUCN-listed as endangered.37

Schooling diagonal-banded sweetlips (*Plectorhinchus lineatus*),
Great Barrier Reef, Queensland
Photo by Gary Bell
## Assessment summary

### State and trends of species populations and groups

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharks and rays</td>
<td>East, south-east and south-west in poor condition for some species (e.g. east coast population of grey nurse sharks)</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Whale sharks</td>
<td>South-west in very poor condition</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Great white sharks</td>
<td>Condition continues to decline in the east</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Tuna and billfish</td>
<td>Condition very poor in the south-west and continuing to decline</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Southern bluefin tuna</td>
<td>Condition very poor and stable</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Outer shelf (&gt;50 m)—demersal and benthopelagic fish species</td>
<td>Condition improving in all regions except the north-west, where the condition is generally stable but the worst areas continue to decline</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Inner shelf—demersal fish species</td>
<td>South-east in good condition and improving</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Slope—demersal fish species</td>
<td>Only south-east was assessed</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Mesopelagic fish species</td>
<td>Only east and south-east were assessed</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Small pelagics—inner shelf</td>
<td>South-east and south-west were assessed, with condition improving in the south-west</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Inner-shelf reef fish species</td>
<td>South-west, east and south-east were assessed, and are all in poor condition</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Inner shelf—invertebrate species</td>
<td>East and south-east in poor condition</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
</tr>
<tr>
<td>-----------</td>
<td>---------</td>
<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td><strong>Outer shelf and inner slope—invertebrate species</strong></td>
<td>South-east in poor condition</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Shoreline and intertidal species</strong></td>
<td>East in poor condition and declining</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Seabirds—resident</strong></td>
<td>South-east in poor condition</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Seabirds—migratory</strong></td>
<td>South-west in very poor condition</td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Hard coral species</strong></td>
<td>East and south-east in poor condition</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Mangrove species</strong></td>
<td>East and south-east in poor condition</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Seagrass species</strong></td>
<td>East and south-east in poor condition</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Dune and saltmarsh plant species</strong></td>
<td>East in poor condition and declining</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Dugongs</strong></td>
<td>East in poor condition</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Turtles</strong></td>
<td>North and east in poor condition (greater understanding in east region)</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Sea snakes</strong></td>
<td>East in very poor condition and declining</td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Crocodiles</strong></td>
<td>Populations increasing</td>
<td>Poor</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Continued next page
State and trends of species populations and groups continued

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Dolphins and porpoises</strong></td>
<td>Populations generally stable, although some are declining in the east and south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Baleen whales (not including humpbacks)</strong></td>
<td>Condition and trends are poorly understood for some species, but recovery occurring generally</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Humpback whales</strong></td>
<td>Condition in the east and south-east remains very poor and stable</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Toothed whales</strong></td>
<td>Condition and trends are poorly understood</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fur seals</strong></td>
<td>Assessed only in the south-west and east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Australian sea lions</strong></td>
<td>Assessed in the south-west</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Seahorses and allies (families Syngnathidae, Solenostomidae)</strong></td>
<td>Assessed in the south-west and south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Regional features</strong></td>
<td>Assessed nine species or population features that principally occur in only one region</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Recent trends**
- Improving
- Stable
- Deteriorating
- Unclear

**Grades**
- Very good: Only a few, if any, species populations have declined as a result of human activities or declining environmental conditions
- Good: Populations of a number of significant species (but no species groups) have declined significantly as a result of human activities or declining environmental conditions
- Poor: Populations of many species or some species groups have declined significantly as a result of human activities or declining environmental conditions
- Very poor: Populations of a large number of species or species groups have declined significantly as a result of human activities or declining environmental conditions

**Confidence**
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment
2.1.3 Ecological processes

This section reports on our best understanding at the national level of the status and trends of the 15 major national-scale ecological processes that operate in the regions and the effects of human activities on them. The processes assessed here include aspects such as migration pathways (are human activities interrupting the normal migration routes of animals between their feeding and breeding grounds?), and trophic (food web) structures of the ecosystems (does the abundance and distribution of the species among primary producers, secondary producers and predators reflect the natural structure and rates of interaction?). Condition of the processes is defined by the extent to which they have declined because of human activities, relative to their condition at the time of European settlement of Australia (further details of the criteria are on the SoE website).

South-west region

The main ecological processes for the south-west region are in good condition, including unimpeded physical pathways for migration, maintenance of most feeding grounds, and maintenance of the main sources of water column productivity, reef building processes and symbiotic relationships across the region. However, coastal development has had major impacts on recruitment and settlement processes for fish and invertebrate coastal species across the region; and nesting, roosting and nursery sites for seabirds. Predation as a process has been severely affected by the removal of top predators from across the region. These impacts continue to increase.

North-west region

Like the south-west, the main ecological processes in the north-west region are in good condition overall. This is partly because the two regions are closely connected by the Leeuwin Current, and because some of the same threats apply to both regions. In parts of both regions that are remote from human influences, some of the ecological processes (such as offshore benthic productivity, symbiosis and reef building) are considered to be in very good condition. However, in other areas, removal of top predators has affected predation as a process, which is considered to be in poor condition and significantly affects ecosystem function in some areas of this region.

East region

The ecological processes of the east region are considered to be in good condition overall. These include processes such as the maintenance of migration pathways; availability of nesting, roosting and feeding grounds; reef building; activities of herbivores; and algal-derived calcification processes. However, the flooding cycles of the coastal wetlands are considered to be in very poor condition, with substantial changes across a wide area, resulting in serious effects on ecosystem functions. Hydrological regimes altered by land use, coastal engineering, water harvest and flood protection have substantially altered the seasonal habitat cycles in wetlands.

South-east region

The ecological processes of the south-east region are considered overall to be in very good condition. However, the reef-building process has been heavily reduced and is in poor condition. The loss of oyster reefs from shallow inshore waters is widespread (these reefs are considered to be functionally extinct), and trawling has removed much of the deepwater bryozoan reef in fishable depths.

d www.environment.gov.au/soe
## Assessment summary

### State and trends of ecological processes

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connectivity—spatial/physical disjunctions</td>
<td>South-east has been significantly affected</td>
<td>Poor</td>
<td>Very poor</td>
</tr>
<tr>
<td>Connectivity—biological, migration, flyways</td>
<td>South-east in poor condition and continues to decline</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Connectivity—recruitment, settlement</td>
<td>Variable across the regions, improving in some and declining in others</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Connectivity—genome structures, genetic adaptation</td>
<td>Knowledge base very limited and condition hard to assess</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Nesting, roosting and nursery sites</td>
<td>Knowledge base very limited and condition hard to assess</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Feeding grounds</td>
<td>Whale feeding grounds significantly affected by human activities in the south-west and north-west</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Trophic structures and relationships</td>
<td>South-west and north-west are in poor condition, substantially affected by historical and ongoing fishing</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Water column, pelagic productivity</td>
<td>Good to very good in all regions</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Benthic productivity</td>
<td>Good to very good in all regions</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Reef building</td>
<td>Condition poor in south-east</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>------------------</td>
<td>------------</td>
</tr>
<tr>
<td>Symbiosis—fish, corals, molluscs</td>
<td>Knowledge base very limited and condition hard to assess</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Predation</td>
<td>Condition of the worst areas very poor in the south-west and north</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herbivory processes</td>
<td>Declines observed in the east</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter feeding</td>
<td>Condition poor in the south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microbial processes</td>
<td>Knowledge base very limited and condition hard to assess</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional features</td>
<td>Assessed four ecological process features that principally occur in only one region</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Recent trends

- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**

### Grades

- **Very good**: There are no significant changes in ecological processes as a result of human activities.
- **Good**: There are some significant changes in ecological processes as a result of human activities in some areas, but these are not to the extent that they are significantly affecting ecosystem functions.
- **Poor**: There are substantial changes in ecological processes as a result of human activities, and these are significantly affecting ecosystem functions in some areas.
- **Very poor**: There are substantial changes in ecological processes across a wide area of the region as a result of human activities, and ecosystem functions are seriously affected in much of the region.

### Confidence

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

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*Australia State of the Environment 2011*
2.2 Marine ecosystem health

The health of marine ecosystems has been assessed by examining the status and trends of the major physical and chemical processes that maintain the quality of the biodiversity and habitats in each region. Outbreaks of diseases, non-natural algal blooms and infestations by pests have been assessed as symptoms of an unhealthy marine ecosystem. The assessments of marine ecosystem health (available on the SoE website) are summarised for each region, and aggregated into a single national assessment and summary.

The overall assessment of ecosystem health found that all the regions are in very good condition except for the south-east, which is in good condition (Figure 6.11).

2.2.1 Physical and chemical processes

This section reports on our best understanding at the national level of the status and trends of the 14 major national-scale physical and chemical processes that operate in the regions and their interaction with human activities.

South-west region

The physical and chemical processes in the south-west region are considered to be in very good condition, with little human-induced impact. Ocean currents have broadly maintained their natural structure and dynamics; nutrient cycling (the movement and exchange of organic and inorganic matter back into the production of living matter) has been maintained at natural levels and extent in ocean waters (although it has been severely affected in estuaries and some coastal waters); and salinity and oxygen conditions remain in natural condition. However, near to the shore, the light, sediment, freshwater and nutrient regimes have been severely altered in a number of the estuaries and bays in the region, and several estuaries have a significant number of recurrent dead-zone (low oxygen) episodes. These nearshore pressures are continuing to increase, most notably the land-based sources of nutrients, and increasing changes are noted for sea level rise, frequency of storms and changes to ocean current patterns, associated with gradually changing global climatic conditions.

North-west region

Like the south-west region, the physical and chemical processes across most of the north-west region are considered to be in very good condition, with little human-induced impact. Ocean currents have broadly maintained their natural structure and dynamics; and nutrient cycling has been maintained at natural levels and extent in ocean waters. The most important process in this region that has been affected by human activities is the coastal sediment supply regime, which is considered to be in poor condition in some places. The sediment supply and dynamics of the coastal region have been heavily affected by structural developments on beaches and dunes in the southern part of this region (particularly port development and shipping channels), and by broadscale agricultural practices and mining in the central parts of the region.
**North region**

The physical and chemical processes in the north region are also considered to be in very good condition, approaching pristine in most places. Although there have been extensive agricultural changes in a number of catchments, and mining has had a major impact in some localised areas, these are not regional-scale effects. The most affected process is the flow and hydrological regime, which has been affected by major modification to some of the significant rivers of the region (such as the Macarthur River).

**East region**

Physical and chemical processes overall are considered to be in very good condition in the east region. However, a number of processes have been degraded at a regionwide scale. These include the sediment input regime, and the freshwater inputs and hydrological cycles—these are considered to be good overall, but very poor in some areas; and the changes in sea temperatures, which are in poor condition across the region (because of increasing ocean temperature across the region). Other issues include the prevalence of pesticides in waters across the region, which may be affecting biodiversity.

**South-east region**

Physical and chemical processes overall are considered to be in good condition in the south-east region. However, there have been substantial changes to sediment input, the dynamics of freshwater inputs and hydrological cycles, the land-based nutrient inputs, the turbidity and light regime of inshore waters, and the dynamics of the East Australian Current that affect this region. In some areas in the region, these changes are extreme, and there have also been substantial inputs of toxicants, resulting in serious impacts on ecosystems. Taken together, this region has experienced changes in physical and chemical processes that are significantly affecting ecosystem functions. Examples include the Coorong, the Derwent River and estuary, and the Gippsland Lakes.

![Australia’s largest water storage, Lake Argyle, created by the Ord River Dam, the Kimberley, Western Australia](image)

Photo by John Baker and the Australian Government Department of Sustainability, Environment, Water, Population and Communities
## State and trends of physical and chemical processes

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ocean currents, structure and dynamics</strong></td>
<td>Significant changes in dynamics of currents in the south-east, and changes are increasing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Storms, cyclones, wind patterns</strong></td>
<td>Wind patterns are changing in the south-west and south-east, affecting ocean ecosystems</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sediment inputs</strong></td>
<td>Substantial changes to sediment input regimes in the south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inshore water turbidity, transparency and colour</strong></td>
<td>Substantial changes to inshore water conditions and processes in the south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sea temperature</strong></td>
<td>Significant changes in all regions, and changes are increasing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sea level</strong></td>
<td>Significant changes in the south-west and south-east, and changes are increasing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nutrient supply and cycling—land based</strong></td>
<td>Major changes in land-based nutrient inputs in the south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nutrient supply and cycling—ocean based</strong></td>
<td>Significant changes in ocean-based nutrients in the south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Freshwater inflow; surface and groundwater run-off</strong></td>
<td>Major changes in freshwater inflows in the south-west and south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Toxins, pesticides, herbicides</strong></td>
<td>Significant changes in the south-west and south-east</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Component Summary

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dumped wastes</strong></td>
<td>Significant issues with dumped wastes in the east and south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ocean acidity</strong></td>
<td>Acidification is a significant risk in all regions, although only limited evidence of change to date</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ocean salinity</strong></td>
<td>Significant changes evident in the south-east</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Low oxygen—dead zones</strong></td>
<td>Each region has one or more examples, and these have major or extreme local impacts, but limited regional consequences</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Regional features</strong></td>
<td>Assessed 13 regional features; impacts on river discharges in the east and changes to the East Australian Current were assessed as major changes with significant impacts on ecosystem functions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Recent trends

- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**

### Grades

- **Very good**: There are no significant changes in physical or chemical processes as a result of human activities.
- **Good**: There are some significant changes in physical or chemical processes as a result of human activities in some areas, but these are not to the extent that they are significantly affecting ecosystem functions.
- **Poor**: There are substantial changes in physical or chemical processes as a result of human activities, and these are significantly affecting ecosystem functions in some areas.
- **Very poor**: There are substantial changes in physical or chemical processes across a wide area of the region as a result of human activities, and ecosystem functions are seriously affected in much of the region.

### Confidence

- **Adequate high-quality evidence and high level of consensus**
- **Limited evidence or limited consensus**
- **Evidence and consensus too low to make an assessment**
2.2.2 Pests, introduced species, diseases and algal blooms

This section reports on our best understanding for each region of the status and trends of outbreaks of diseases, pests and introduced species (including pests listed in the National Introduced Marine Pest Information System—NIMPIS), and algal blooms in the region and their relationship with human activities. These are summarised at the national level in the assessment summary.

South-west region

The south-west region is overall in very good condition in relation to pests, introduced species, algal blooms and outbreaks of disease that can cause ecological imbalances. However, pest species have been documented from a number of the ports across the region, and have caused significant ecological impacts in their local areas. A large number of introduced species are recognised across the region whose ecological significance is unknown. The herpes-like virus that has seriously affected the region in past decades (see Box 6.8) appears to have now declined, and there are no obvious ongoing impacts on pilchard populations. However, there is only limited knowledge of the impact of the previous virus outbreaks on bird populations and other species that may be ecologically dependent on the pilchards. Blooms of toxic and nuisance algae continue to be a problem in a number of the estuaries and inshore waters across the region, creating substantial changes, fish kills (deaths of a large number of fish over a short period) and associated ecological impacts. When they occur, algal blooms in this region can cover large areas (see Box 6.1).

North region

The north region is also in very good condition overall in relation to pests, introduced species, algal blooms and outbreaks of disease. Only two pest species (striped mussel) have been recorded in the region, but is now thought to have been largely eliminated. Monitoring of the high-risk areas (Darwin Harbour) has not detected further pest incursions. The region is also likely to have many introduced species, as in other areas of Australia, and for the same reasons (including shipping activity, the aquarium trade, tourism and petroleum industry infrastructure). There are few ecological data on impacts.

East region

The east region overall is considered to be in good condition in relation to pests, introduced species, algal blooms and outbreaks of disease. Four species of pest have been recorded in the region, in and around the ports, shallow bays and estuaries. However, the region suffers from periodic outbreaks of crown-of-thorns starfish, and there are extensive algal bloom issues in Moreton Bay and other bays and shallow coastal northern waters, including outbreaks of Lyngbya. These shallow and inshore waters of the region are considered to be heavily impacted at times by algal blooms, and their condition is considered overall to be poor in this respect. When they occur, algal blooms in this region can cover large areas. The Pacific oyster (Crassostrea gigas, endemic to Japan) has been introduced to the region for oyster farming and has spread, with a significant ecological impact in the estuaries of the southern part of the region.

South-east region

Pests and outbreaks of disease have had major impacts in the south-east region and, overall, the regionwide condition is poor with respect to pests, diseases, introduced species and algal blooms. The pests noted
in the region (some of which are widespread and have major ecological impacts at times) include starfish (*Asterias*), sea urchins (*Centrostephanus rodgersii*), plankton (toxic dinoflagellates), algae (*Undaria*, *Caulerpa*), molluscs (*Maoriocolpus*), crustaceans (*Carcinus*) and worms (*Sabella*). Port Phillip Bay has been described as one of the most invaded marine ecosystems in the Southern Hemisphere, but there are others of equal note, including the Derwent estuary. Outbreaks of harmful native species are also pervasive, mainly toxic algal blooms. The zooplankton *Noctiluca* (a red form of ‘sea sparkle’, often responsible for ‘red tides’) has recently become very widespread and is dominant in many parts of the region, probably displacing other forms of native species. The drivers and consequences of this phenomenon are unknown, but are of ecological concern across the region. A severe outbreak of abalone viral ganglioneuritis has affected abalone in several parts of the region, with serious ecological consequences (Box 6.8, p. 428).

### Box 6.1 Surface phytoplankton blooms and phytoplankton biomass in coastal waters

Timeseries from satellite data at five coastal sites (monthly data from 2003 to 2010) have compared chlorophyll-a concentrations in the upper water column (a proxy for phytoplankton biomass) with the occurrence and extent of surface phytoplankton (or algal) blooms. The information retrieved from satellite ocean-colour remote sensing is based on the cloud-free portions of the images. Therefore some sites, such as Storm Bay or Broome, may have a more restricted spatial and temporal representation due to more frequent cloud cover.

**Site 1: Darwin**

The phytoplankton biomass peaks in January and then progressively declines through the rest of the year, before increasing again at the start of spring (September). The biomass level here is the highest of all the sites, and shows the greatest decline of all the sites over the period reported. There is a peak in surface phytoplankton blooms during September and October, covering a limited spatial extent (<8%) of the site.

**Site 2: Burdekin River, Townsville**

The Burdekin River catchment is located in the Great Barrier Reef region, and generates significant river plumes during wet-season flood events (see Box 6.10). The phytoplankton biomass peaks during the early wet season, between February and March. The biomass shows a general decline during the reporting period, although there was high phytoplankton biomass during the 2007 and 2008 wet seasons, following the large flood events in those years. Surface phytoplankton blooms, likely *Trichodesmium* spp., occur mainly between June and October, and may cover large areas (>30% of the site).

**Site 3: Storm Bay, Hobart**

The phytoplankton biomass data from this site were affected by cloudy conditions (annual cloud cover 70–80%). The phytoplankton biomass peaks annually in September–October, the ‘spring bloom’. However, the available satellite data and field studies confirm a decline in phytoplankton biomass during the reporting period. Surface phytoplankton blooms occur mainly in June and May and may cover up to 10% of the site.

**Site 4: Geographe Bay, Perth**

The phytoplankton biomass is localised close to the coast and is highest during winter. Nutrients supporting this biomass probably come from local river run-off and storm disturbance of sediments. Compared with the other sites, this is the only site with an apparent increasing (although not statistically significant) trend in phytoplankton biomass. Surface phytoplankton blooms were found to occur mainly in early autumn, sometimes covering large areas (>30% of the site).

**Site 5: Broome, south Kimberley**

There is a peak of phytoplankton biomass in May, with high variability in August. The biomass shows a significant decline over the reported period. Surface phytoplankton blooms occur mainly in March and September. They appear to be more limited in extent than those at the Geographe Bay site, covering <5% of the site.

A detailed description of the methodology and additional data can be found in Blondeau-Patissier et al.38
Box 6.1 continued

<table>
<thead>
<tr>
<th>Study area</th>
<th>Water depth &lt;100 metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Darwin</td>
<td>12 123 km²</td>
</tr>
<tr>
<td>2 Burdekin River</td>
<td>2923 km²</td>
</tr>
<tr>
<td>3 Storm Bay</td>
<td>4049 km²</td>
</tr>
<tr>
<td>4 Geographe Bay</td>
<td>5694 km²</td>
</tr>
<tr>
<td>5 Broome</td>
<td>11 800 km²</td>
</tr>
</tbody>
</table>

**Chlorophyll concentrations**

Chlorophyll seasonal cycles of monthly mean values and standard deviations

Chlorophyll timeseries from January 2003, showing the indicative linear trend

**Surface phytoplankton blooms**

Seasonal cycle of bloom events: median monthly number of blooms detected

Extent of detected blooms as percentage of the total area of the site

<table>
<thead>
<tr>
<th>Study area</th>
<th>Water depth &lt;100 metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Darwin</td>
<td>12 123 km²</td>
</tr>
<tr>
<td>2 Burdekin River</td>
<td>2923 km²</td>
</tr>
<tr>
<td>3 Storm Bay</td>
<td>4049 km²</td>
</tr>
<tr>
<td>4 Geographe Bay</td>
<td>5694 km²</td>
</tr>
<tr>
<td>5 Broome</td>
<td>11 800 km²</td>
</tr>
</tbody>
</table>

CHL = chlorophyll-a; km² = square kilometre; mg/m³ = milligrams per cubic metre

a 2003–06, incomplete satellite dataset
## State and trends of pests, introduced species, diseases and algal blooms

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number and abundance of NIMPIS-listed pests</strong></td>
<td>Condition in the south-east region is poor and declining</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number and abundance of introduced species</strong></td>
<td>Number of introduced species is high, possibly increasing, but their impacts and trends are unknown</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Viral diseases, parasitic infestations, fish kills</strong></td>
<td>A major disease outbreak has occurred, and condition in the south-east region is poor</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Algal blooms, jellyfish blooms</strong></td>
<td>Blooms of algae and other species occur regularly, and condition in the south-east region is poor</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Crown-of-thorns starfish abundance and distribution</strong></td>
<td>Occurs regularly across the east region, and condition there is poor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Recent trends
- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

### Grades
- **Very good**
- **Good**
- **Poor**
- **Very poor**

### Confidence
- **Adequate high-quality evidence and high level of consensus**
- **Limited evidence or limited consensus**
- **Evidence and consensus too low to make an assessment**

---

**NIMPIS = National Introduced Marine Pest Information System**
### State and trends of the national marine environment

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Habitats for species</strong></td>
<td>Overall, the 22 types of habitats assessed are in very good condition. However, nationally, two seabed habitats of the outer continental shelf and slope are in poor condition, and the condition of the water column of the inner shelf and shoreline (&lt;50 m depth) is declining. Habitats in the east and south-east are in the poorest condition</td>
<td>Poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Species populations and species groups</strong></td>
<td>Overall, the 32 species groups assessed are in good condition, but 13 groups are in poor or very poor condition, and only 5 groups are considered to be in very good condition. Nationally, 4 species groups are in decline, and 7 are recovering from extensive hunting and fishing of earlier times. The species of the east are in the poorest condition</td>
<td>Poor</td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td><strong>Ecological processes</strong></td>
<td>Overall, the 16 types of ecological processes are in very good condition. Nationally, predation is poor, reflecting the extensive impacts of historical and present-day fishing, and connectivity in the south-east continues to decline</td>
<td>Poor</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
<tr>
<td><strong>Physical and chemical processes</strong></td>
<td>Overall, the 27 physical and chemical processes assessed are in excellent condition, with most indicating no significant changes caused by humans that would affect ecosystem structure or functions. However, the worst places show substantial changes, with significant ecological impacts—the south-east region is the worst affected, with major changes to freshwater, sediment and nutrient input to estuaries and bays</td>
<td>Excellent</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Pests, introduced species, diseases and algal blooms</strong></td>
<td>Overall, there are no regionally or nationally significant changes to ecosystems caused by these factors, although in the worst places there are effects that are significant. The east, south-east and south-west regions are the worst affected, and impacts are major in some areas</td>
<td>Excellent</td>
<td>Limited evidence or limited consensus</td>
</tr>
</tbody>
</table>

#### Recent trends
- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

#### Grades
- **Very good**
- **Good**
- **Poor**
- **Very poor**
Pressures affecting the marine environment

Australia’s oceans are highly dynamic—they vary daily, monthly and annually, driven by winds and tides, the seasons, the influence of the world’s major ocean currents and the global climate. Near the shore, marine ecosystems are heavily influenced by land-based factors such as river run-off, non-point sources of pollution and the effects of human activities. Most of these impacts have historically been focused in the coastal lands (such as mangrove wetlands, shallow reefs and beaches) and the shallow inshore waters down to a depth of approximately 100 metres, which are usually found close to shore and are readily accessible by small boat.

However, technological advances have enabled our marine activities to become more intensive in nearshore waters and progressively expand into deeper waters. For example, in the past three decades, high-quality position-finding and underwater acoustic systems have become affordable and widely available. As a result, oil and gas exploration and fishing have now moved into waters more than 1 kilometre in depth. This has increased the potential for impacts in the oceans in remote places and at greater depths. The exploitation of places that were once beyond the reach of fishing, or could not be repeatedly targeted, has contributed to the problems of overexploitation in many fisheries—the refuges that once existed for many species in places remote from the coast, or where the seabed was formerly too rugged to be fished, have been reduced or removed. Equally, onshore development is reducing the size of coastal wetlands that are valued as breeding and nursery areas for marine species.

The primary broad drivers of environmental change in Australia’s marine ecosystems are outlined in Chapter 2: Drivers. These drivers are expressed in various places and times as specific pressures on the marine environment, many of which cause obvious and measurable ecosystem impacts. However, not all the impacts are measurable, because of their type, extent or complexity; and many ecosystem changes result from the cumulative effect of two or more pressures. As a result, it is rarely possible to identify a single cause for changes that may be considered detrimental.

![At a glance]

The Australian marine environment is experiencing a broad range of pressures that affect the quality of habitats, species and environmental health. The main pressures are in coastal areas, particularly in sheltered enclosed bays, estuaries and lagoons, where removal of land-based sources of pollution and wastes by flushing is most limited. These pressures and their impacts primarily affect the east, south-east and south-west regions; many parts of the north and north-west regions remain in near-pristine condition, although development pressures are rapidly increasing. This pattern reflects both the existing distribution of Australia’s population and the distribution of the industries and activities that rely on coastal resources.

Exploitation has overtaken waste disposal as the major source of impacts in Australia’s oceans. Although the overall set of pressures is much more limited than in many other nations, the worst areas in Australia are equivalent to, and in some cases actually are, the world’s worst. The juxtaposition of the persistent Macquarie Harbour anoxic (low or no oxygen) dead zones and the nearby pristine Tasmanian marine and forest wildernesses stands as a stark reminder of the issues. Such localised but severe cases serve as early warning that Australia is not immune to the pressures and impacts that are widespread in some other countries.

The present-day pressures are interacting with the effects of past activities (legacy impacts). In the case of fishing and coastal development, although today’s management practices are much improved, a number of ecosystems, habitats and species were heavily impacted in previous centuries and will continue in their degraded condition under current management policies and practices. The resilience of the environment in the face of the emerging pressures of climate change, oil and gas production, aquaculture, energy generation and desalination is highly uncertain.
The pressures and their impacts primarily affect the east, south-east and south-west regions; many parts of the north and north-west regions remain in near-pristine condition, although development pressures there are rapidly increasing, particularly from mining. Pressures in parts of the temperate regions are very high; they include the impacts of climate change, urban areas, ports, catchment run-off, fishing, aquaculture, tourism and mining. This pattern reflects both the existing distribution of our population and the distribution of the industries and activities that rely on coastal resources.

Australia is also following the global pattern for coastal zone areas, which are under much greater pressure than the offshore areas. Despite our investments in management systems, many of the same impacts that occur overseas are apparent in areas of Australia’s oceans and coasts. For example, the impacts of fishing—such as the large and broadscale reductions in biomass that persist even when fishing ceases—have been observed in many large species that are fished, across all the global oceans and in Australian waters. It is possible for biodiversity to recover when pressures are reduced, as has been observed in the case of humpback whales in Australia’s waters. However, the recovery is usually much slower than the rate of decline and often more uncertain.

This section summarises the known and likely extent of impacts from the drivers and pressures on the environment, considering the interactions between the highly complex and natural dynamics of the ocean ecosystems and the effects from human sources.

### 3.1 Pressures resulting from climate change

Australia’s oceans and marine ecosystems are changing in response to changes in the global climate systems. A recent review of the Australian marine impacts of climate change found that significant changes were under way in 15 of the 17 environmental aspects considered, and that these changes could be linked to climate change factors with varying degrees of confidence. The review concluded that:

- Australian ocean temperatures have warmed, with south-western and south-eastern waters warming fastest
- the flow of the East Australian Current has strengthened, and is likely to strengthen by a further 20% by 2100
- marine biodiversity is changing in south-east Australia in response to increasing temperatures and a stronger East Australian Current
- observed declines of more than 10% in growth rates of massive corals on the Great Barrier Reef are likely to be due to ocean acidification and thermal stress.

The most important changes deriving from climate change that will affect marine ecosystems are gradually increasing water and air temperatures, sea level rises and acidification. Nearshore, the increased frequency of storms and associated run-off of fresh water, nutrients and suspended sediments will also be very important.

#### 3.1.1 Temperature

Sea surface temperatures (SSTs) around Australia have significantly increased since the early 20th century (by 0.7 °C, comparing 1910–29 with 1989–2008). This rate of warming is similar to that for global average land and sea temperatures. All global and regional temperatures have accelerated their rate of warming since the middle of the 20th century (Figure 6.12)—for Australian SSTs, the rate of warming was 0.08 °C per decade from 1910 to 2008, and 0.11 °C per decade from 1950 to 2008. The warmest year for Australian average SSTs was 1998, and 6 of the 10 warmest years for SST have occurred in the last 10 years (based on data since 1910). The rate of warming of the ocean, although interrupted by volcanic eruptions and hence variable, has been steady since 1950, and is observable at all depths in the ocean. Although there are seasonal and spatial variations in the magnitude of SST increase around Australia, the greatest rates of warming have been observed off the south-west and south-east coasts.

By the 2030s, SSTs are projected to be around 1 °C higher (relative to 1980–99) around Australia, with slightly less warming to the south of the continent. By the 2070s, SSTs are projected to be 1.5–3.0 °C higher, with slightly less warming to the south of the continent and the greatest warming to the east and north-east of Tasmania.
This changing ocean temperature directly affects the distribution and abundance of many species and habitats, including seagrasses, macroalgae, phytoplankton, coral reefs, tropical and temperate fish, pelagic fish, marine reptiles and seabirds. The general trend is that species habitats and distributions are forced southward, consistent with the prevailing temperature regime. In the future, we are likely to see further declines in nearshore seagrass meadows and algal beds due to storms, turbidity and warmer water, and a loss of diversity in coral-dependent fish and other coral-dependent organisms.

For species that require shallow and cool coastal waters, such as for breeding or nursery grounds, this southward shift in temperatures will eventually result in major population reductions as the availability of habitat decreases and finally disappears south of the mainland and Tasmania. Temperature alone is likely to create the greatest set of ecological changes in shallow-water marine ecosystems in the coming decades. Increasing ocean temperatures play an important role in coral bleaching, and probably pose the most severe threat to Australia’s coral reef systems (see Box 6.2).

3.1.2 Ocean acidification

The natural physical and biological processes of the ocean’s carbon cycle absorb carbon dioxide gas from the atmosphere. Human-derived carbon dioxide emissions have increased, mainly as a result of fossil-fuel combustion, land-use practices and concrete production during and since the industrial revolution. The end result is more carbon dioxide dissolved in the world’s oceans.

The ocean is a weakly alkaline solution (with a pH of around 8.1), but the extra carbon dioxide changes the carbon chemistry of the surface waters of the ocean. The carbon dioxide forms a weak acid (carbonic acid) in water, making the ocean more acidic (lowering the ocean’s pH). This process is referred to as ‘ocean acidification’.

The process of ocean acidification is already under way and has lowered the pH of the global oceans by about 0.1 pH units from their pre-industrial state. The concentration of atmospheric carbon dioxide is now higher than at any time in at least the past 650,000 years, and probably the past 20 million years. By the end of this century, the ocean’s pH is likely to drop to 0.2–0.3 units below pre-industrial levels.

Carbon dioxide–driven acidification shifts the proportion of dissolved carbon dioxide away from carbonate ions and towards bicarbonate ions. Organisms that make their shells from calcium carbonate need carbonate ions for the biological calcification processes that create their shell. Ocean acidification poses a risk to marine food chains, potentially affecting fisheries and highly valued species by also affecting the primary production systems in the ocean. Observational data have now begun to detect changes in calcification in Southern Ocean zooplankton and Great Barrier Reef corals, indicating that acidification has already started to have detectable impacts on biological processes in our oceans.
3.2 Fishing

Fishing has provided an important commercial, recreational and subsistence resource for Australians for many decades. As fishing effort has expanded, so have the environmental impacts that inevitably accompany such exploitation. These impacts include the direct effects of fishing on the species being caught (related to the intensity and extent of fishing effort); the effects on other species that may depend on the targeted species as predators or prey; the direct effects of fishing gear on habitats; and the catch of unwanted species (bycatch). Fishing in all its forms is now recognised as a major factor affecting marine ecosystems through these various impacts. Jointly, exploitation and habitat loss are considered to be the primary threats to fish stocks, with major potential impacts on the ecology of ocean ecosystems. Almost all the species that are large enough and abundant enough to be fished are targeted, and they comprise important ecological components of the ecosystems.
Despite this, there is no nationally integrated analysis of the cumulative impacts of fishing or fisheries on ecosystem structure or function, and no national-level initiatives to assess and report on ecological sustainability of commercial or recreational fishing sectors. This major gap limits the extent to which the pressures on marine ecosystems can be assessed.

With increasing population and rapidly improving technology, virtually all of Australia’s marine areas that are less than 1 kilometre in depth are, or have been, fished to some extent. In the sanctuary zones of marine protected areas and other small areas protected from fishing as nursery grounds (less than 5% of our marine environment), all forms of fishing are permanently banned to protect biodiversity, and there are some areas where fishing gear is too difficult to use. These highly protected areas and topographic refuges are mainly found offshore and in deep waters; the biodiversity of these deeper regions is poorly understood, with more than half of species in some surveys previously undescribed. Some regions have areas with high levels of permanent restrictions on fishing (for example, within more than a third of the Great Barrier Reef Marine Park). Numerous smaller fishery closures have been implemented in recent years to protect sensitive habitats and species.

The historical patterns of catches over the period of post-European exploitation of Australia’s fish stocks reveal that there have been major changes in many of the stocks and probably also in their associated ocean ecosystems. In many cases, fishing has shifted from one species to another as a target species becomes difficult to catch. This is known as serial depletion—the systematic ‘fishdown’ of target species to levels that become uneconomic to exploit. In Australian waters, there are a number of examples of such depletion and, although it has not resulted in the extinction of any fished species, many stocks have been left at such low levels that they may take many years (and possibly centuries) to recover. Most stocks are managed to avoid such extremely low biomass, and a number have been restored by strong management actions after very low stock sizes were detected. Possibly the worst contemporary example of fishdown is the eastern gemfish population in south-eastern Australian waters, which has been intensively fished down over the past 50 years (Figure 6.13).

AFMA-managed fisheries are using the newly developed harvest strategy (see Section 1.5.2), to move towards a more secure and sustainable level of production for the various species within the Commonwealth jurisdiction. The need for this strategy is illustrated by the history of the Western Deepwater Trawl Fishery (Box 6.3).

![Figure 6.13](source: Little & Rowling)
Box 6.3 Western Deepwater Trawl Fishery

The Western Deepwater Trawl Fishery (WDTF), managed by the Australian Fisheries Management Authority, operates off Western Australia between the western boundary of the Great Australian Bight Trawl Sector in the south and the western boundary of the North West Slope Trawl Fishery in the north. The WDTF targets more than 50 species in waters exceeding 200 metres in depth, in habitats ranging from temperate–subtropical in the southern region to tropical in the north.23

The history of the WDTF follows the trajectory of many of Australia’s offshore fisheries—a boom period of exploitation, followed by a long, sometimes slow, decline, and now either a continuing low level of productivity or, in extreme cases, closure of the fishery.

The WDTF was initially discovered in the early 1980s. Eight fishing licences were awarded, eventually increasing to more than 100 licences. By the mid-1990s, fishing permits had been reduced to 11, the dominant species in the initial exploratory catches (boarfish) were no longer caught, and the fishery had moved to other nearby areas and a different primary species (ruby snapper). Boarfish were assessed as ‘underfished’ in the 1992–95 stock status reports from the Bureau of Rural Sciences, but in 2009 reported catches of this fish were so low that it was effectively dropped from the reporting system. The fishery has also previously targeted three species of shark that are now considered too low in abundance to permit ongoing harvest.23

The species mix in the present-day catches is very different from that in the early days of the fishery. As well as a change in targeted species, this probably reflects a local reduction in populations and a consequent ecological impact of the fishery on the structure and function of the ecosystem. Recovery of the affected species is possible, although the timescale is uncertain and likely to be long.

Both offshore and coastal fisheries have suffered substantial declines over the past century. A recent study of the coastal fish of Tasmanian waters suggests that both climate change and fishing have had severe impacts on approximately 20% of the island’s coastal fish species, beginning with the arrival of Europeans and their fishing practices in the early 1800s, and made worse more recently by accelerating climate change. The reduction in a number of popular fishing species has been offset by the appearance of several alternative species that are expanding their range southwards from the mainland. These substantial changes in species composition demonstrate that the drivers of long-term shifts in coastal diversity may have a variety of sources, and their ecological impacts may extend beyond a reduction in fishing resources to include direct impacts on coastal ecosystems by affecting interactions within the food chain.47

In other states, the coastal fisheries are also suffering declines—many species are considered to be fully fished, while others are recognised to be depleted and suffering population declines. In coastal waters and the continental shelf, the species that can be fished are mostly fished to their limits and, for some, overfishing has resulted in population collapse.48 So, while modern-day fishing practices are generally much improved over practices used as recently as 30 years ago, the legacy effects from the intense fishdown phase of virgin stocks (such as in the South-east Tiger Flathead Fishery—see Box 6.4) are a dominant feature of the population structure of most fishable species. The relative risks from other impacts are now increasing, requiring intense vigilance from fishery managers to avoid catastrophic and long-term impacts on populations of these (mostly large) marine species that were once considered to be abundant and widespread in our oceans and estuaries.

There is a high risk that, after heavy fishdown or other forms of overfishing, depleted stocks may not be resilient or recover quickly (such as the eastern gemfish example in Figure 6.13). While they are in such poor condition, they may be subject to other environmental pressures, including climate change impacts. The flow-on effects on the ecological functions of the oceans are largely unknown. It is likely, however, that fishdowns of most of the fished species have left Australia’s oceans much less resilient by reducing diversity, modularity and feedback within ecosystems (see Section 5 of this chapter). This probably has important consequences for the capacity of marine ecosystems to adapt to the combined effects of the present-day pressures of climate change, habitat loss and fishing pressure.45

Declining stocks may lead fishers to fish harder to catch the remaining fish. In fish catch data, this pattern can be detected as a progressive reduction in the size of catches, reduction in the size of fish being caught, or a change in the type of fish being caught. It can also bring about a shift in the trophic level of the fish in the catch. Where this occurs, fish catches shift from
According to Klaer, tiger flathead have been commercially fished since the development of the steam trawl fishery in 1915. Steam trawlers were used until about 1960. Danish-seine gear, a fishing method that is still being used today, was developed in the 1930s. Diesel trawlers began landing tiger flathead in the 1970s, and currently diesel trawlers and Danish-seine methods take the total catch. A total allowable catch was introduced in the fishery for this species in 1992.

With increasing catches, population biomass declined until about 1950. In the 1980s, the population began to increase again, until it stabilised at the present-day level of around 45% of pristine levels. The fishery is now managed to maintain the spawning stock biomass (an approximate index for the size of the total population biomass) at around the 40–50% level, which is considered to be near-optimal to maintain ongoing economic production from this fishery (Figure A).

Catches from the fishery have repeatedly spiked and declined over the years (Figure B), and catches in the past few years have been trending downwards.

---

**Figure A** Spawning stock biomass levels in the South-east Tiger Flathead Fishery

This is the base-case analysis of the 2006 full assessment. The horizontal lines represent the 20%, 40% and 48% limit and target reference points.
species higher in the food chain (at a high trophic level), including large carnivores such as sharks, to successively lower trophic levels of smaller and less valuable fish. This is measured by the marine trophic index (MTI)—an international marine indicator.49

For most Australian stocks, there are insufficient data to calculate a shift in trophic structure of the fisheries, such as that estimated by the MTI.50 However, there is evidence in places that fishing may have altered species composition. Although the MTI is a gross index, it is the only indicator that is widely used to detect and report on gross changes in the trophic structure of fished ecosystems over time. The MTI has not been adopted in Australia, and there is no requirement for fisheries to report on such matters. Most of the impacts of fisheries in Australia are now historical, and present-day management practices are (generally) much improved. However, most of today’s fisheries have harvest strategies that manage the stock biomass at an agreed level that is significantly lower than pristine levels (typically 40%), with management arrangements to reduce pressure if stocks drop below this level. The pressure of present-day fishing (both commercial and recreational) acts to maintain low abundances and biomass (relative to pristine levels) and probably to reduce the resilience of the populations being fished and their ocean ecosystems.

However, not all fished stocks have failed to recover from overfishing, and there are a number of documented recoveries and management success stories, most notably the South-east Tiger Flathead Fishery (Box 6.4). After extensive management intervention, this species has been found to be remarkably resilient and has shown significant population recovery.

Recovery of fish stocks is a common objective of modern fisheries management, and Australia has a number of success stories. It has long been known that the key to success is to ensure that populations are fished at rates that are below the level at which optimum yield could be taken, allowing stocks to gradually rebuild while continuing to provide for sustainable fishing.52 By extracting slightly less each year than the maximum sustainable yield, a fishery can gradually increase both the overall stock size and the annual yield, providing for substantial long-term gains at the cost of minor short-term losses (in terms of catch). Such approaches are now in wide use, together with the careful application of no-take marine protected areas and reserves (see Box 6.5), to begin the long process of rebuilding stocks and recovering degraded ecosystem functions. However, the effectiveness of these management interventions to achieve long-term stock rebuilding remains to be assessed in most Australian fisheries.

Source: Klaer, CSIRO, pers. comm.; Klaer; Melville-Smith

Figure B Total retained catches of tiger flathead, 1915–2010 calendar years (catch is estimated for 2010)
Box 6.5 Assessing the condition of fish populations using ecological criteria

More than 5000 species of fish are known from Australian marine waters, but assessments of population condition have been conducted for only a few of these species. Available assessments have been mainly for fisheries management purposes, and do not take account of a range of environmental and ecological issues that are known to influence the vulnerability, status and resilience of fish populations.

Three ecological indicators— inherent vulnerability to extinction, current population status and population resilience—and 10 associated criteria have been used to demonstrate how existing data and knowledge can be applied to assess the ecological condition of marine fish populations. The populations of two fish species with contrasting ecology and life history (the redfin butterflyfish, Chaetodon lunulatus, and the leopard coral trout, Plectropomus leopardus) were assessed to demonstrate the usefulness of this approach. Population condition was graded on a scale of very good, good, poor or very poor.

The inherent vulnerability to extinction for both species was considered low, given their reasonably large geographic ranges and ability to use a wide range of different reef habitats. The current population status of both species was considered good, with no evidence of long-term, reef-wide declines in abundance. However, both species are facing distinct threats, due to habitat degradation (especially coral loss for butterflyfish) and direct fisheries exploitation (for coral trout). Current fisheries for the coral trout on the Great Barrier Reef appear to be sustainable, and the populations exhibit considerable resilience. With the recent expansion of no-take marine reserves to cover more than 30% of the Great Barrier Reef Marine Park, the populations of coral trout on reefs closed to fishing have recovered very quickly from earlier intensive fishing, and population resilience is assessed as good. In contrast, the butterflyfish appears to have poor population resilience, with no recovery observed more than five years after severe coral bleaching in the central Great Barrier Reef.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Criterion</th>
<th>Leopard coral trout condition</th>
<th>Redfin butterflyfish condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inherent vulnerability to extinction</td>
<td>Geographic range</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td></td>
<td>Population size</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Ecological versatility</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>Resource vulnerability</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Current population status</td>
<td>Population trends</td>
<td>Good</td>
<td>Very good</td>
</tr>
<tr>
<td></td>
<td>Extent of known threats</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>Population structure</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Population resilience</td>
<td>Observed recovery</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td></td>
<td>Reproductive mode and recruitment</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Population connectivity</td>
<td>Good</td>
<td>Poor</td>
</tr>
</tbody>
</table>

Source: Pratchett
3.3 Oil and gas exploration and production

Exploration in the oil and gas industry involves geophysical surveys (using acoustic arrays and other specialist survey tools), exploratory drilling of seabed cores and test wells. Production involves a range of fixed and moveable facilities, such as fixed production platforms and floating platforms that are used as the base for drilling of wells and, with an appropriate array of seabed pipelines, as collection points for oil and gas. Every stage of development and production of these facilities involves substantial risks. The world’s worst oil and gas industry impacts have arisen from all stages of the industry’s activity: shipping, production and exploration. In Australia, the activities of the oil and gas industry are now concentrated in Bass Strait and on the north and north-west regions (Figure 6.5).

In Australia, as well as complying with national environment law, industry must comply with several national industry laws, including the Offshore Petroleum and Greenhouse Gas Storage Act 2006, which is administered by the Australian Government Department of Resources, Energy and Tourism. Under this legislation, companies must prepare legally binding environmental plans, including oil spill contingency plans (see Box 6.7).

In Western Australia, the Gorgon gas production project is the largest ever approved. It is building an industrial base on Barrow Island, approximately 30 kilometres off the coast west of Dampier. Barrow Island has been recognised as an outstanding island for nature conservation. A large proportion of Australia’s flatback turtle population uses the beaches of Barrow Island for nesting, and the Gorgon project has been predicted to significantly affect the access and use of nesting beaches by these turtles. Although the Western Australian Environmental Protection Authority initially recommended against the island’s use for this project, the decision was subsequently revised to permit the industry to build on the island, subject to a number of environmental management conditions and commitments to offset impacts by improving protection of turtles elsewhere in the region.

The Gorgon project is funding the North West Shelf Flatback Turtle Conservation Program, contributing around $1 million per year for 60 years to increase protection of flatback and other turtles. It is also funding the monitoring and auditing of marine activities during the project’s dredging and marine construction phase.a

The environmental management and research activities developed and applied as conditions to the development project are not likely to substantively mitigate the impacts of the industry’s activity on the nesting of flatback turtles at Barrow Island itself. The research projects aim to increase survival of flatbacks (and other turtles) at other locations, and to gather more detail about the impacts of the reduction of Barrow Island nesting beaches on the flatback population. The program is supervised and assessed by a Marine Turtle Expert Panel of company and government experts appointed by, and accountable to, the Western Australian Minister for the Environment. This, and similar mining environmental offset arrangements in Western Australia, has been heavily criticised for a lack of transparency and public accountability.b

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The oil and gas industry in north-western Australia is rapidly expanding. Although individual wells or a coastal processing plant may have limited and local impacts, the widespread development of the industry is bringing new challenges to regional planning systems. Among other issues, the cumulative effects of dispersed production water, drilling fluids and wastes, and the increasing risk of ship strike and acoustic impacts on cetaceans are becoming significant management issues for fisheries and wildlife management. At present, there are:

- no regional strategic environmental assessments to guide planning and impact management systems, and limited baseline studies of existing conditions
- no systematic or structured interfaces with regional conservation and environmental management; each development is considered on its own merits, with very little consideration of cumulative impacts across a region
- no regionally integrated transportation management systems that recognise the specific requirements of the sensitive species and habitats of the region; there is no upper limit on vessel size, shipping lane use, frequency of transits or seasonal constraints on oil-industry vessels transiting the north-west in the path of the ‘whale highway’—a feature of north-western Australia (see Section 1.4).
3.4 Shipping and associated infrastructure

The shipping industry, with its associated substantial infrastructure (ports, harbours, shipping lanes, coastal support), is the major transportation link between Australia and other nations, and provides important linkages between regional Australia and the cities. Ports and shipping are a key component of the economic activity of Australia, with 99% by weight and 74% by value of our international trade carried by sea. Seventy commercial ports around the Australian coast deal with international shipping, and there are hundreds more smaller facilities providing critical infrastructure for a range of activities. In 2008–09, approximately 800 million tonnes of cargo were moved through Australian wharves by 4200 vessels that made 26 700 port calls.\(^5\) In 2002, more than 3000 foreign commercial ships made more than 18 000 separate calls at Australian ports.\(^4\) In Dampier (Western Australia) alone, in 2006, there were more than 3000 vessel visits, mostly from overseas ports, and these vessels discharged 42 million tonnes of water.\(^6\)

The continuing development of regional Australia is resulting in many new ports and expanding and upgrading of existing ports. To service these developments, there is always a backdrop of coastal infrastructure, some of which is new, creating further demand on coastal land and recreational facilities in marine systems. Many of these new and upgraded facilities are developing to support the growing mining industry in Queensland, the Northern Territory and Western Australia.

Shipping lanes traverse some of the most ecologically sensitive marine areas, and regular groundings and accidents at sea place additional pressure on the marine environment. Also of increasing concern is the frequency of ship strikes on marine mammals, many of which occur in open waters and pass unreported.

The increase in shipping traffic is also increasing the risk of introductions of foreign marine species, and there is a risk that some of these will turn into serious pests in our waters. Many hundreds of introduced marine plants and animals have already hitchhiked to Australian waters on vessels of all types, from yachts to commercial ships, carried on their hulls and in ballast waters (water carried in tanks to maintain stability when a ship is lightly loaded). Some of these species have taken over habitats from our native species, changing our coastal areas and damaging our fishing, aquaculture and tourism industries.

Once marine pests are established, eliminating them is virtually impossible. Where conditions suit, they may multiply quickly and force out native species. Some (such as toxic algae) can pose a threat to human health as well as ecological health. The Australian, state and territory governments, along with marine industries and marine scientists, are implementing a National System for the Prevention and Management of Marine Pest Incursions to identify and respond to marine pests. This system aims to prevent new pests arriving, respond if a new pest does arrive, and minimise the spread and impact of pests that are already established in Australia. The system accepts that, where they have become established, marine pests will not be able to be eradicated, so ongoing management and control of introduced marine pests will be required.\(^7\)

3.5 Aquaculture facilities

Australia’s sheltered coastal waters are increasingly being considered as providing important opportunities for aquaculture. The main species being farmed are Atlantic salmon, southern bluefin tuna, rock oysters, pearl oysters, mussels, prawns and abalone. These species are farmed in land-based and sea-based facilities, both of which have a range of environmental risks. There are four main areas of environmental concern: the potential for spread of diseases and parasites, the impacts of the facilities and supporting infrastructure, the interaction with wildlife, and the source and sustainability of wild stocks (if required) and feed. Key issues of environmental concern are diseases that can be harboured in, and spread from, both types of facilities; treatment and impacts of wastes, particularly feed and faeces; intensification of infrastructure in sensitive habitats; and effects on species that may become dependent on the structures or waste discharges.

In Australian waters, evidence indicates that both land-based and sea-based aquaculture has been the source of a number of major outbreaks of diseases in wild populations. The resulting impacts have been ecologically significant and will leave a lasting imprint on some of the affected ecosystems. In addition to disease outbreaks, there have been issues associated with use of chemicals, and impacts on threatened species such as sharks and seals. This is consistent with overseas experience of aquaculture impacts.\(^6\)

However, given appropriate levels of management and verification, the impacts of aquaculture facilities can be constrained to a minimal and acceptable level, bringing
the aquaculture industry in Australia into line with other modern farming practices to produce wealth from the ocean with minimal environmental degradation.

3.5.1 Sydney rock oyster

Australia has a long history of aquaculture in the estuaries of the east coast. The Sydney rock oyster (shell) was harvested for use as lime in cement production in Sydney in the 1800s, but this quickly depleted the local oyster beds. The earliest marine farming operations of oysters were subsequently established by Thomas Holt in Gwawley Bay (Georges River) in 1872, in response to the depletion of wild oysters. The industry was heavily focused on the Hawkesbury River in its early years, but declining water conditions and high levels of diseases have now almost eliminated production from this estuary. Oyster farming in New South Wales has now diversified to include the Pacific and flat oyster, on selected sites held under some 3200 aquaculture leases, with a total current area of approximately 4300 hectares. The main oyster-producing areas are located away from urban areas. Commercial production in New South Wales occurs in 41 estuaries between Eden in the south and the Tweed River in the north, although Wallis Lake (on the north coast) is now the main Sydney rock oyster–producing area.

In the first 75 years of the New South Wales oyster industry, production of the endemic Sydney rock oyster grew to about 60 million oysters per year. In the subsequent 25 years, production increased to about 175 million oysters per year, peaking in 1977, and then trended downwards to the current 70 million oysters per year—less than half the production of the industry at its peak. Disease and environmental issues remain significant problems for this industry.

The statewide reduction in production is related to the impact of land-based sources of pollution (from urbanised areas and agriculture), and to an extensive and diverse set of waterborne diseases in farmed oysters, including viral and bacterial infections, protozoa and flatworms. These accelerating issues have resulted in a much greater emphasis on the development of land management in river catchments that recognises the need for high water quality in oyster-growing areas.

Disease issues in the oyster industry are also concerns for wild oyster populations. They include the potential transmission of diseases between the estuaries, related to industry practices, and possible maintenance of diseases in the wild population that might otherwise naturally dissipate to background levels. Oysters (wild and farmed) have an important role in estuaries, filtering water and feeding on plankton and other fine debris to clarify the water. Although the role of the intensive aquaculture system in transporting and spreading disease among the wild population or to other molluscs is unclear, these are important ecological impact issues for these estuaries and coastal waters. Also of concern is the spread of the Pacific oyster—this species is endemic to Japan and farmed in several states, and has developed many naturalised populations along the east coast. The ecological impact of this introduced species is uncertain, but is likely to be significant. Where its populations have become established, it is likely to compete with native species (including the Sydney rock oyster) for space and food, and possibly has impacts on a range of other sedentary species that also inhabit the estuaries of New South Wales.

3.5.2 Abalone

Abalone aquaculture is a recent initiative, mainly undertaken in Tasmania, Victoria and South Australia, where the most substantial natural populations of abalone also occur. In 2008–09, around 640 tonnes of abalone were produced from the aquaculture facilities in these states.

Two species are farmed—greenlip abalone (Haliotis laevigata) and blacklip abalone (H. rubra)—as well as a hybrid of these species, in land-based and sea-based farming systems. The two systems have very different siting and infrastructure requirements, and a different range of associated environmental risks. For example, in land-based tank systems, the growing abalone are fed on an artificial diet, require large volumes of fresh sea water and produce a large volume of wastewater. In sea-based systems, the growing abalone are fed on natural macroalgae (which may be harvested locally by hand), require only modest current flows of high-quality sea water and produce little waste. However, in both cases, high densities of individuals can lead to the risk of outbreaks of diseases that can very quickly (within days) become difficult to treat and control (Box 6.8).
Box 6.8 Abalone viral ganglioneuritis

In 2010, wild abalone populations in Victoria suffered from an outbreak of the lethal abalone virus known as abalone viral ganglioneuritis (AVG). AVG is a herpes-like virus that causes inflammation of the nervous tissues in the abalone, interfering with its ability to properly adhere to surfaces or feed. An AVG outbreak has also recently been identified in Tasmanian farmed abalone, although it is suspected to be of a different origin from the strain in Victoria.63-64

AVG was first reported in Australia in December 2005, when several abalone aquaculture farms near Portland and Port Fairy in western Victoria experienced unusually high levels of abalone deaths. It is suspected that a discharge from one of these farms where AVG was first detected permitted the virus to escape and infect wild abalone nearby. Since then, the virus has caused substantial deaths in wild abalone populations and continues to spread eastwards along the coastal waters of Victoria to Cape Otway. The persistence of AVG in wild abalone populations now threatens the vigour of these populations in Victorian waters, and may also affect the fishery for wild abalone. The broader ecological impacts of this disease outbreak are as yet unknown, but are likely to be regionally significant, given the important role that abalone play in the benthic ecology of reef systems across the southern Australian shores, from New South Wales to Western Australia.

3.5.3 Cage fish culture

At-sea cages for salmon culture are the fastest growing Australian aquaculture industry. The salmon farming industry is now Australia’s single most valuable seafood production sector, overtaking the wild-catch fishery for western rock lobster, which has been in decline for a number of years. Australia’s total production of caged salmonids—around 30 000 tonnes of salmon and trout, mainly Atlantic salmon from Tasmanian waters—was valued at $323 million in 2008–09, while the Western Rock Lobster Fishery production was valued at less than $200 million. However, salmon farming is not without environmental impact, and there are many areas of major uncertainty, particularly surrounding the use of chemicals to treat disease outbreaks.65 Disease outbreaks destroy the farmed stock, can easily escape into wild populations66 and are the subject of intense management in marine fish-farming systems (see Box 6.9). Entrainment of wild species on cage facilities is also a major global issue, attracting fish to the locality of the cages for access to uneaten feed pellets and other waste materials from the cages.67

Despite these and other issues, the careful siting and management of caged fish facilities can result in acceptably low impacts and risks. For example, the Australian Conservation Foundation has accepted the barramundi sea cage farm at Cone Bay, Kimberley, for recommendation within its sustainable seafood program, after an independent ecological assessment found that the impacts of these key factors were acceptably low.68

Box 6.9 Pilchard kills

Perhaps the worst fish kill in a wild population recorded from human causes is the massive series of pilchard kills that repeatedly occurred across temperate Australian waters (New South Wales to Western Australia) in 1995 and 1998–99. After a single event in 1999, at three Western Australian locations, 28 000 tonnes of pilchards were estimated to have been killed.66,69 The fish kill episodes were observed across more than 4000 kilometres of temperate Australian coastline. Although there has been no attempt to estimate the total mortality of pilchards, mass fish mortalities of this scale are of national and probably global importance. The most likely source of the virus thought to be responsible is the frozen, but otherwise unprocessed, food used for tuna aquaculture sea cages on the Eyre Peninsula in South Australia.66 Food for aquaculture purposes is now more systematically managed to reduce the risk of such disease importations. However, the virus that affected the pilchards is probably now well established in Australian marine ecosystems and likely to have low-level but ongoing impacts on the pilchard population and species that depend on this fish, including seabirds such as terns and penguins.70
3.5.4 Longline culture

The main aquaculture system based on lines is Australia’s tropical pearl farming industry. This is a lucrative business that harvests natural tropical pearl oysters, seeds them with ‘nuclei’ of carbonate material, and then grows the oysters attached to long lines or dropper lines in at-sea facilities. A similar system is used to culture mussels in various bays and gulfs of temperate Australia. Such line systems, provided they are well designed and managed, are thought to have only limited environmental impacts on surrounding waters and seabeds; however, their extensive spatial scale can have other impacts, depending on the location of the facilities. The leases for pearl culture, for example, can spread across large areas, restricting access for other marine users (such as recreational fishers and boaters, and Indigenous people wishing to access their sea country71); dolphins and their calves, which avoid transit through the facilities; and whales, which are at risk of entanglement.72

3.6 Catchment run-off and land-based sources of pollution

Coastal habitats are susceptible to many impacts that arise from the adjacent lands, and from rivers that discharge into the gulfs, coastal lakes and lagoons directly to inshore waters. The species and habitats that occupy these marine areas are often well adapted to the dynamics of variable levels of salinity and contaminants such as suspended sediments and nutrients, although their capacity to withstand these pressures is limited. Extensive and frequent extreme weather events, or persistent low-level pollution from rivers, may exceed the capacity of many species to resist such pressures. If these impacts occur broadly across a region, or persist locally for a long time, they will lead to irreversible change in habitats and species distributions. Examples from New South Wales and Western Australia illustrate these problems.

More than half the estuaries in New South Wales are subject to double the natural levels of sediment and nutrient inputs, and around one-third of catchments are more than 50% cleared of natural vegetation.18 These and other pressures are directly linked to the poor water quality found in a high proportion of New South Wales estuaries—only 11% of the estuaries were found to comply more than 90% of the time with guidance levels for chlorophyll-a—and to losses of coastal vegetation, including seagrasses, which are estimated to have been reduced by more than 30% from their natural (pre-European colonisation) extent.18

The Northern Rivers region of New South Wales has 46 estuaries (25% of the total in the state) that cover 350 square kilometres (20% of the total state estuarine area) and drain an estuary catchment area of 49 600 square kilometres (39% of the total in the state). The 46 estuaries comprise 20 barrier rivers and lakes that are generally open, 23 creeks and lagoons with intermittently open entrances, and 3 brackish water bodies. Measured against benchmarks in recent history and using comparisons with the existing conditions in other New South Wales estuaries (which may also be degraded), a number of indicators are rated as very poor, including seagrasses, saltmarsh and chlorophyll in the water column. Many of the estuaries are under pressure from excessive inputs of sediments and nutrients, and altered freshwater inputs and hydrological regimes.18,73

Tuggerah Lakes in New South Wales is a barrier estuary with a long history of urbanisation of the catchment, including reclamation of foreshore wetlands and structural realignment of water passages between the individual lakes and the opening to the ocean. About half of the wetlands (the upstream ‘biological filter’ system) are already lost, including 85% of the saltmarsh, and urban development is directing surges of stormwater into the lakes. These changes contribute to problems such as ‘black ooze’ (monosulfidic black ooze causes rapid oxygen depletion of lake and drainage waters when the ooze is mixed with oxygenated waters during disturbance) and serious degradation of water quality in the lakes.74 The lakes system has been subjected to a long series of structural solutions (such as dredging of the lake bed) over many years, and is currently funded for major ongoing restoration and environmental management works under the Australian Government’s Caring for our Country program.

As with most such estuaries, coastal lakes and lagoon systems, many issues and many authorities are involved in management attempts to reduce environmental impacts and restore more desirable natural conditions. The New South Wales Government ‘owns’ the Tuggerah Lakes, while Wyong Shire Council is the main manager of the catchment that flows into and affects the environmental health of the...
Tuggerah Lakes estuary. A number of state and federal authorities have a role in management. Private and community sector organisations also have a direct interest in the management of the lakes, including community groups, the real estate industry, various recreational groups and commercial fishers.

The most recent assessment of Tuggerah Lakes indicates that, although turbidity is ranked as fair, important ecological aspects are in good or very good condition, including fish, seagrasses and saltmarshes, suggesting that restoration efforts have been at least partially successful.73,75

In Mandurah (Western Australia), major nutrient and algal bloom problems have a long history in the Peel–Harvey Estuary, caused principally by nutrient pollution from upstream agricultural lands.76 The $57 million Dawesville Channel was opened in 1994 to create an artificial opening from the Peel–Harvey Estuary to the ocean, to increase flushing in the estuary and reduce the frequent and extensive algal blooms and nutrient pollution problems. Subsequently, local residents observed a temporary improvement in conditions, but deteriorating water quality and adverse biological conditions returned within five years of the channel opening. These included further major algal blooms and deterioration of some indicator species to levels equivalent to those documented before the channel.77 Thus, despite a large investment of public funds, restoration efforts may not have been able to persistently improve environmental conditions in this estuary.

In addition to impacts in enclosed coastal waters, such as the examples above, land-based sources of pollution can have serious impacts in open coastal waters. On the Queensland coast adjacent to the Great Barrier Reef, there are 38 major river catchments, including some of Australia’s largest rivers (such as the Burdekin and Fitzroy rivers), and these combined sources deliver substantial amounts of sediments and nutrients into the shallow coastal waters of the nearshore lagoon system. The catchments now deliver 2–10 times more nutrients and sediments to the lagoon waters than they did before European settlement.79 They also deliver significant amounts of pesticides to the reef and lagoon waters, although the impact of these chemicals on habitats and species are as yet unclear.80 Nonetheless, the combined impacts of the sediments, nutrients and agricultural chemicals reaching the coral reef systems of the Great Barrier Reef are considered to be highly significant. Models have estimated that minimising agricultural run-off could reduce macroalgal cover, which threatens the viability of corals on reefs across the Great Barrier Reef, by 39% on average, and increase the richness of hard corals and phototrophic octocorals on average by 16% and 33%, respectively.78

The evidence indicates that, although we can point to many small-scale successes, the problems of land-based pollutant sources, coastal development and catchment run-off are likely to be much more effectively resolved by systems that deliver prevention rather than cure. Both prevention and cure can be complex and expensive, and take a long time to implement and produce results. Whereas the pathway to effective prevention is moderately clear, achieving a successful cure for impacts of coastal development once they have occurred is not only difficult and costly, but also uncertain. Unfortunately, management systems around Australia appear to have difficulty learning from past failures, and this impedes the application of more effective planning for prevention rather than applying a cure.

3.7 Additional pressures

A large range of additional pressures not discussed here also operate across the regions. These include other pollutants, such as marine debris; and the activities of a range of industries and groups, such as tourism, mining, energy generation, desalination, defence, recreational boating and the traditional use of marine resources.

Generally, these apply less acute pressure, or data on their impacts are more difficult to acquire. For example, marine debris (particularly derelict fishing nets) is a well-known issue in Australian and global tropical waters. Available information indicates that at least 77 species of marine wildlife found in Australian waters, including turtles, cetaceans and seabirds, have been affected by entanglement in, or ingestion of, plastic debris during the past three and a half decades (1974–2008). Most records of impacts of plastic debris on wildlife relate to entanglement, rather than ingestion.80 The extent of impact from marine debris on marine populations overall is unclear.
Box 6.10 River flood plumes from the dry tropics into the Great Barrier Reef lagoon

Source: Based on or contains data provided by the Commonwealth Scientific and Industrial Research Organisation, NASA (source data) and Geoscience Australia. These organisations give no warranty in relation to the data and accept no liability for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for direct marketing or be used in breach of the privacy laws. Also includes data from the Great Barrier Reef Marine Park Authority.

Satellite image of the Burdekin River flood plume on 22 February 2008

From 2000 to 2006, the Burdekin and Fitzroy river catchments received relatively small amounts of rainfall (around 670 millimetres annually), leading to only limited river plumes flowing into the Great Barrier Reef lagoon. From 2007 to the 2011 wet season, this changed significantly. Monsoonal or cyclonic rainfall sometimes reached the annual average for the catchment in a few weeks, causing small, medium and large river flood plumes along the entire east Queensland coast that extended well into the lagoon.

The flood plume shown by the true-colour satellite image above extended more than 40 kilometres into the Great Barrier Reef lagoon and was caused by significant rainfall from several low pressure systems. This flood plume merged with the wide band of flood-affected waters following the coast in a south-to-north direction, originating mainly from the Fitzroy, Pioneer and Proserpine rivers. The clear, beige colour shows water masses that are strongly dominated by freshwater suspended sediment, such as clays, whereas the water with a darker brown colour is a mix of fresh and marine water, with more dissolved and particulate organic material. The mid-shelf broad green band south of the plume is likely to be a phytoplankton bloom that resulted from the increase in nutrient availability provided by the river flood plume waters. The satellite image shows that the coarse material of suspended sediments is deposited near the coast, while the finer particulate and dissolved fractions merge into a 30–40-kilometre-wide band that gradually disperses towards the Reef. In some cases, these floodwaters may disperse through the inner, mid and outer reef into the Coral Sea, and occasionally curve back towards the outer reefs tens to hundreds of kilometres north of their source rivers. There is evidence that an increase in frequency, intensity or duration of these flood plumes causes increased primary production during the wet season through phytoplankton growth, and this may contribute to decreased resilience of the coral systems of the Reef.

The long Great Barrier Reef coastline (2000 kilometres) and the short-term duration of floods make monitoring the flood plumes difficult. However, several institutes (Commonwealth Scientific and Industrial Research Organisation, James Cook University, Australian Institute of Marine Science, Great Barrier Reef Marine Park Authority) regularly combine their field sampling efforts and expertise to monitor such events and assess the impact of floods on the water quality of this world-renowned ecosystem.

Source: Blondeau-Patissier
### Pressures affecting the marine environment

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pressures resulting from climate change</strong></td>
<td>Sea level rise, increasing ocean temperatures and acidity are beginning to have significant impacts in all regions, and these effects are expected to increase. The worst affected areas are in the south-east and south-west, and are irreversibly and very seriously impacted. Changes in ocean current dynamics driven by climate change are also affecting these two regions</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Coastal urban development</strong></td>
<td>The worst affected areas are in the east, south-east and south-west, and are irreversibly and very seriously impacted</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Port facilities</strong></td>
<td>Pressures are widespread and serious in all regions except the north</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Oil and gas exploration and production</strong></td>
<td>Most pressures are localised. The worst areas are in the south-east and north-west, but impacts remain minor overall. Pressures are expected to increase in the north-west</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Fishing</strong></td>
<td>Pressures are decreasing overall, although in the worst areas of the south-east, east and south-west, pressures are widespread and causing serious degradation, and the east continues to degrade</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Shipping</strong></td>
<td>Pressures are increasing in all regions, resulting in declining conditions</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Aquaculture</strong></td>
<td>Pressures continue to increase in the south-east, where the worst areas are already suffering serious degradation</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Catchment run-off</strong></td>
<td>Most areas in the south-east and east are suffering serious degradation</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Marine debris</strong></td>
<td>There are widespread pressures in all regions</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
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</tr>
<tr>
<td><strong>Tourism facilities</strong></td>
<td>The worst areas, in the south-west, have suffered serious degradation</td>
<td>Very poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Mining and industry</strong></td>
<td>The worst areas, in the south-east and south-west, have suffered serious degradation</td>
<td>Very poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Energy generation</strong></td>
<td>These pressures are localised and stable</td>
<td>Very poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Desalination</strong></td>
<td>Only local impacts have been observed</td>
<td>Very poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Recreational boating</strong></td>
<td>There are widespread pressures that are increasing</td>
<td>Very poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Defence</strong></td>
<td>These pressures are localised and stable</td>
<td>Very poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Traditional use of marine resources</strong></td>
<td>These pressures are localised and stable</td>
<td>Very poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
</tbody>
</table>

**Recent trends**
- Improving
- Stable
- Deteriorating
- Unclear

**Grades**
- **Very low**: There are few or negligible impacts from this pressure, and accepted predictions indicate that future impacts on the environmental values of the region are likely to be negligible
- **Low**: There are minor impacts in some areas, and accepted predictions indicate that future impacts from this pressure on the environmental values of the region are likely to occur but will be localised
- **High**: The current and predicted environmental impacts of this pressure are significantly affecting the values of the region, and predictions indicate serious environmental degradation within 50 years
- **Very high**: The current and predicted environmental impacts of this pressure are widespread, irreversibly affecting the values of the region, and predictions indicate widespread and serious environmental degradation across the region within 10 years

**Confidence**
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment
Effectiveness of marine management

Assessing management effectiveness addresses the question of how well the management responses that are applied to an environmental problem identify, avoid, react to or resolve the issue. Each government entity—national, state or territory, local—has a range of different policies, laws, regulations and established practices at their disposal to deal with environmental issues. These cover the full gamut of strategic planning, implementation of management activities, and compliance assessment and reporting. Increasingly, larger private-sector entities (such as major companies) have a range of similar tools available to them to plan for and manage environmental problems that may arise within their areas of control, usually to ensure compliance with government requirements. Indeed, in some jurisdictions, some specific government responsibilities are devolved to private-sector entities to implement under the broad strategic guidance of government. Common tools applied to environmental issues in the private sector include strategic planning systems (such as risk assessment), operational management systems (such as best-practice guidelines), and whole-of-operation reporting systems. These may be developed on an industry-wide basis or, more commonly, on a company-wide or operation-wide basis.

Assessing private-sector and public-sector management of any specific marine environmental issue in Australia requires a comprehensive analysis of the hierarchical relationships between the various entities with jurisdiction and responsibility, and the extent of achievement of the explicit and implicit intended environmental outcomes. The ultimate measure of effectiveness is the extent to which the environment is protected. This can best be demonstrated through performance reporting on habitats, species and ecological health against established standards (as summarised in Section 2 of this chapter). The situation and issues in some selected jurisdictions are discussed below.

4.1 Environment protection systems

All jurisdictions in Australia have core environmental management and conservation functions, expressed through their respective legislation, policies and programs. This section considers a small sample of relevant activities.

4.1.1 Australian Government

The Australian Government’s principal regulatory tool for managing marine environmental issues is the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The Act provides a framework for the management of matters of national environmental significance in the entire Australian marine environment. The primary activities of the EPBC Act in marine matters relate to marine bioregional planning, protected and listed species, world heritage and, in the Commonwealth marine area, marine reserves and mitigation of marine impacts. The Act also provides for activities in relation to threatened ecological communities, but no marine communities have yet been approved for EPBC Act listing.
In Australia, Commonwealth-managed fisheries and all fisheries intending to export products (irrespective of jurisdictional control) are assessed within the terms of the EPBC Act, principally using the Guidelines for the ecologically sustainable management of fisheries (second edition) (GESMF), established under the Act. These guidelines explicitly endorse and aim to facilitate ecosystem-based fisheries management, in addition to the management of specific target and protected species. The GESMF provides a basis for evaluating the environmental performance of fisheries, including:

- the strategic assessment of fisheries (under Part 10 of the Act)
- assessments relating to impacts on protected marine species (under Part 13 of the Act)
- assessments for the purpose of export approval (under Part 13A of the Act).

The areas of the Act that relate to exploited marine species are dominated by matters involving fishing systems, particularly aspects of fishing that relate to two key issues:

- the condition of the species being exploited (through assessments using the GESMF)
- the impacts of fishing systems on protected and listed species, and more generally on marine ecosystems.

The primary tools used to assess the condition of exploited species are the GESMF and the strategic assessment of exploited species for export purposes. Both assessments are conducted by the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC), based on information provided by individual proponents specifically for the assessment process, and public comment. The proponents are usually state fishing agencies, AFMA or individual fishing entities (such as fishing companies and industry associations); submissions often include scientific research and assessments commissioned by these entities. More than 120 fisheries around Australia have been assessed under the EPBC Act and the GESMF. Most of the assessment process is devoted to the condition of the exploited stocks, and the extent and nature of the direct impacts of fishing activities on listed and protected species under the Act (through assessing byproduct and bycatch). There is typically less information to support the consideration of broader marine conservation issues at the ecosystem level, including trophic and cumulative impacts.

Strategic assessment under the EPBC Act assesses fishing activity at the level of management plans or policy, rather than each individual action or permit. The benefit of this approach is that it enables the collective impacts of a fishery to be considered and provides certainty for the proponent about the activities that are permitted. When the assessment is complete, the Australian minister for the environment may then ‘accredit’ the management plan or policy and make a declaration under the Act that activities conducted under the accredited plan or policy do not require further impact assessment approval under the EPBC Act.

Although a number of marine species are listed under the provisions of the EPBC Act (mainly marine mammals, seabirds, reptiles and some fish species, including seahorses and their relatives), their conservation is assisted by few recovery plans or threat abatement plans. Threat abatement plans address key threatening processes rather than individual species, but only two threat abatement plans have been approved for action to protect marine species (relating to the impacts of marine debris and the bycatch of seabirds in longline fishing). No listed marine species have yet recovered to population levels that have removed them from protected status under the Act. The recent independent review of the Act recommended significant changes. In particular, the review noted that any change should improve, not downgrade, the standards of protection afforded to marine ecosystems in fishery assessment systems under the Act, and provide for much greater levels of integration in the vertical and horizontal directions (between national, state, industry and community organisations; and between the organisations themselves). This is a call for change that has been widely recognised in the marine science community for many years. The Resources Assessment Commission Coastal Zone Inquiry (1993), the preparatory phase for Australia’s Oceans Policy (1998) and many more reviews over recent decades have called for a systematic and nationally integrated approach to management of the oceans and coasts. The independent review of the EPBC Act reinforced the principle of subsidiarity (that decisions should be made by a central authority where they cannot be made effectively by a lower level of government), and that a coordinated and integrated national approach to environmental management is the most appropriate way to ensure credible and lasting national outcomes.

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Important achievements of the EPBC Act have been the setting of approaches and standards for listed marine species—those considered to be rare, endangered, or vulnerable to excessive impacts or exploitation; to be related to matters of national environmental significance; or to have special international significance (such as migratory wading birds). In this matter, the Act has provided a system that propagates from Australian Government policy-level decisions down to state-level policy and operational management systems, and gives significant effect to the principle of subsidiarity. However, the Act is silent, or gives only weak guidance, on many other important aspects of the marine environment.

Although there have been important achievements under the EPBC Act, the lack of effective outcomes in marine environments is clear, and the independent review draws attention to the structural, process and content issues with the Act that need attention to enable an integrated approach to environmental protection and management. The review identifies the need to establish a new Act (notionally, the Australian Environment Act) with improved structure and objects, designed to give primacy to the protection of the Australian environment ‘through the conservation of ecological integrity and nationally important biological diversity and heritage’.

Beyond the EPBC Act, the Australian Government also has a range of responsibilities to provide broad policy guidance on many land-based environmental issues that affect marine ecosystems, and particularly coastal and estuarine systems. These include catchment management systems, various aspects of urban and agricultural land use, natural resource management, and specific issues in rainforests and coastal ecosystems.

To improve knowledge about the oceans, the Australian Government has funded a series of major new programs. These include ocean observing systems to build a better understanding of the current flows and their variability (such as the Integrated Marine Observing System), and research to better understand how climate changes may affect the ocean systems (such as programs conducted by the Commonwealth Scientific and Industrial Research Organisation, the Bureau of Meteorology and the Australian Institute of Marine Science). The Australian Government (through DSEWPaC) has also recently established the National Environmental Research Program, which is providing public-good funding for marine (and terrestrial) biodiversity research.

These and a number of other measurement and monitoring systems are greatly improving our knowledge of the physical aspects of the oceans, but a considerable amount of uncertainty remains on biological and ecological issues. There is also a major lack of capacity to translate our modern understanding of the science issues into information that is used in management and policy decision systems. These combined weaknesses significantly hinder, for example, our understanding of the interaction of climate change with the marine and coastal values and resources, and hence the extent of environmental impacts, and the level and extent of changes that may be required in management programs.

4.1.2 State and territory governments

State governments have initiated a number of state-level programs aimed at mitigating recognised issues in their waters. These include area-specific programs such as the Derwent Estuary Program in Tasmania, the Healthy Waterways Program in southern Queensland, and the Cockburn Sound Management Strategy in Western Australia. Many of these have achieved significant success. For example, the Reef Water Quality Protection Plan brings together people and projects to help improve the quality of water entering the Great Barrier Reef lagoon. Launched in 2003 as a joint initiative of the Australian and Queensland governments, the plan was revised and updated in 2009. The plan has two primary goals: to halt and reverse the decline in water quality entering the Great Barrier Reef by 2013, and to ensure that, by 2020, the quality of water entering the Reef from adjacent catchments has no detrimental impact on the reef’s health and resilience. These are all important initiatives, incrementally contributing to reducing pressures on the ecosystems by addressing local factors that are considered to be important stresses on ecosystems.

The states and territories also have a highly complex set of Acts, regulations, policies and strategies affecting the marine environment. These jurisdictions have direct control over their internal waters and most aspects of their nearshore waters (the three-mile zone). They also have various levels of control over many of the Australian Government’s renewable, and some nonrenewable, resources in the exclusive economic
zone. Responsibility for these resources was provided to the respective states and territories under the Offshore Constitutional Settlement and formalised in the Coastal Waters Acts in 1980, which give the states and the Northern Territory powers over three nautical miles of the territorial sea. A number of major fisheries are managed under this arrangement—as a result, a fishery may be managed either by a state, by the Australian Government, by a joint authority, or by both a state government and the Australian Government. Similarly, the Australian Government delegates the assessment of various environmental impacts to state agencies under a system of joint arrangements. The states and territories also directly control the land-based activities that result in pressures and impacts in the highly valued nearshore waters of coastal marine ecosystems. Overall, it could be argued that the state jurisdictions may have greater influence on the status and values of Australia’s marine biodiversity than does the Australian Government. An overarching framework for nationally integrated management would therefore make a major contribution to improving management of the marine environment.

State-level arrangements for managing issues in marine and coastal ecosystems are complex. For example, in Western Australia, a number of agencies and their respective Acts have responsibility for various marine and coastal issues, and there are only weak arrangements for horizontal integration to ensure that the full range of values of marine ecosystems are maintained within the state jurisdiction. The agencies with such responsibilities include:

- Department of Environment and Conservation (marine mammals, seabirds, reptiles, marine water pollution and quality, environmental impacts, terrestrial and marine parks and reserves)
- Department of Water (estuaries and rivers, water quality, environmental health, aquatic and fringing vegetation)
- Department of Fisheries (fisheries for exploited species, aquaculture)
- Department of Planning (regional and local coastal planning)
- Department of Transport (coastal beaches, dunes, commercial and recreational boating, marinas, jetties, shipping channels)
- Department of Mines and Petroleum (mining and exploration).

The state agencies have established coordination mechanisms that might best be described as ‘systems to avoid treading on each other’s toes’, but there is no formal or informal system that has the responsibility of maintaining the environmental values of the marine and coastal ecosystems of Western Australia or providing for systematic reporting on their condition. The Marine Parks and Reserves Authority has established a systematic process for auditing and reporting on the environmental conditions in marine parks and reserves, and the Cockburn Sound Management Council has a system of auditing and reporting for Cockburn Sound. However, together these cover only a very limited area of Western Australia’s marine environment, and issues remain about lack of capacity and resourcing for auditing and reporting.

Like all Australian SoE reports at either state or national level, the compilation of the Western Australian SoE report has been hampered by a major lack of data and information about the condition of the Western Australian marine environment. A significant amount of marine monitoring data has been collected to inform and report on the success of management initiatives in Cockburn Sound, but marine management and reporting programs elsewhere are fragmented and only weakly coordinated. Where monitoring data are available and recent investigations have been conducted, such as in the Peel–Harvey Estuary, further environmental degradation has been observed, contrary to model predictions made as recently as 20 years ago, reinforcing the need for a comprehensive system of monitoring and reporting to ensure that public expenditure on environmental reforms achieves its intended outcomes.

All states and territories have equivalent agencies and responsibilities, although they vary greatly in the way they are structured and how they work together.

In New South Wales, the State Plan 2006 was established to stem decline in water quality conditions and biodiversity across the state’s marine, coastal lake and estuarine ecosystems, with an explicit commitment that, by 2015, there will be no decline in the condition of ecosystems. The plan identifies the need for a mix of natural resource management and conservation measures to meet the goal. The principal legislative instruments applied in New South Wales waters to protect and manage these ecosystems and associated biodiversity are the Environmental Planning and Assessment Act 1979, the Coastal Protection Act 1979,
the NSW Coastal Policy 1997, the Fisheries Management Act 1994 and the Marine Parks Act 1997. These are supported by legislation to control point sources and shipping sources of pollution and the establishment of an IMOS (Integrated Marine Observing System) monitoring system near Sydney. This set of legislation is typical of the diverse and complex policies that apply at state and territory level to the protection of coastal and marine ecosystems across Australia.

Fisheries legislation in all jurisdictions is tasked with maintaining sustainable fisheries, but most (e.g. New South Wales, Victoria, South Australia, Western Australia) also have a requirement to manage ecosystem impacts and a commitment to ecosystem-based approaches to fisheries management. The latter is intended to provide broader and more precautionary levels of protection for targeted marine populations and their supporting ecological communities. Ecologically sustainable development in fisheries is interpreted and applied in Australia to ensure that the maximum sustainable economic yield can be extracted from target populations. Additional restrictions or closure of fisheries most often occur when the target stocks drop to a level where the economic and ecological viability of a fishery can no longer be assured. A recent international evaluation of ecosystem-based management in fisheries found that the Australian system rated as ‘adequate’ (behind six other countries), while the New South Wales system failed.86

Best-practice fishery management approaches applied to both nontarget and target species dictate that populations of nontarget species affected by fishing (either directly, such as through bycatch, or indirectly, such as through trophic dependencies) need to be considered. For instance, Sainsbury87 suggested that, to ensure that natural trophic dependencies are maintained and natural ecosystem functions can continue, nontarget species in fisheries may need to be maintained at or above 75% of their natural population levels. However, there are few documented examples where such standards are applied (or achieved) in Australian fisheries, and most fisheries do not report on such matters. Most of the fisheries that do report in this manner are Commonwealth-managed fisheries, but they comprise only 14% of Australia’s fisheries by value (30% by weight of catch). Using fishery legislation only to protect and manage marine environments gives primacy to use rather than conservation and, worldwide, this has resulted in significant problems in maintaining the biodiversity and trophic structures of marine ecosystems where intensive fishing is conducted.

4.2 Marine protected areas

All jurisdictions other than the Northern Territory have legislation dedicated to the design, declaration and management of marine protected areas (MPAs) in their waters. Australia has a national program to coordinate the jurisdictions in their approach to design, declaration and reporting of MPAs (the National Representative System of Marine Protected Areas—NRSMPA),88 and all jurisdictions support the NRSMPA. However, although the program has been in operation for 20 years, it has been unable to achieve a significant level of standardisation in planning, design or reporting on MPAs in Australian waters.

In 2004, the NRSMPA covered just 7% of Australia’s marine jurisdiction. It has now expanded to nearly 10% of Australia’s marine waters, mainly as a result of the declaration of large areas of MPAs in the south-east region.89 It is clear that Australia has been proactive in declaring MPAs to assist with biodiversity conservation, probably as a result of the highly valued marine biodiversity in our waters.

However, Australia’s focus has been on declaring MPAs for high protection in the offshore deep waters and on the Great Barrier Reef, not the continental shelf and shoreline elsewhere, where biodiversity values are most under pressure.89 Although there have been some attempts at interjurisdictional cooperation, the cross-shelf and interjurisdictional MPA planning to protect mutual biodiversity values and ecological processes has been lacking or heavily constrained. Although several states (such as South Australia) have active programs of MPAs that are well advanced, it is unclear what contributions these will make to the national system of MPAs. Many of the MPA designations have resulted from piecemeal or ad hoc decision-making and do not reflect the ecosystem-based or regionwide needs for conservation. In addition, a consistent approach among jurisdictions to the use of MPA designations is lacking—for example, a ‘marine park’ in Western Australia permits fishing, while in Victoria it does not.

Schooling green puller (Chromis virdis) and orange fairy basslets (Pseudanthias squamipinnis) above Acropora coral, Great Barrier Reef, Queensland

Photo by Gary Bell
In Victorian waters, there are 24 MPAs of category I or II (highly protected) under the classification system of the International Union for Conservation of Nature (IUCN). However, a recent audit of performance found that only weak arrangements were in place to enable a clear definition of roles, responsibilities and accountabilities between stakeholders, and this prevented effective planning and management of the Victorian MPAs. The audit also found that there was little interaction between the various Victorian agencies that have marine interests or activities. This resulted in a lack of effective or efficient mechanisms for integrated management across all the environment issues in the state’s marine waters.90

In the face of the many environmental pressures, some of which are accelerating, this situation would generally be considered to pose an unacceptably high risk that significant biodiversity loss may be happening and passing unnoticed.

While the NRSMPA is intended to be underpinned by the ‘CAR’ principles of comprehensiveness, adequacy and representativeness, interpretation and implementation of these principles vary across jurisdictions, and there is considerable concern about a lack of attention to CAR principles in the NRSMPA.91 Clear and nationally consistent guidelines are lacking for applying CAR principles to inform the prioritisation and selection of areas; and complementary, ecosystem-based, cross-shelf planning is not widely conducted to coordinate national and state efforts. The lack of a cooperative and integrated approach to the planning and management of MPAs in Australian waters (particularly coastal shelf waters) has become a critical impediment to achieving an adequate level of conservation and effective management of representative elements of Australia’s marine environment and biodiversity.

As of 2008, Australia had declared 4.3% of its waters as highly protected (IUCN categories I and II) MPAs, including MPAs in Australian waters and state and territory waters (Table 6.1).

In addition to the NRSMPA system, a wide range of jurisdictional measures provide other forms of area protection for marine ecosystems. Each of these contributes to some elements of marine biodiversity protection, although not in any planned or systematic manner, nor with specific objectives for nature conservation. They include subsidiary marine protected areas that may be designated as no-fishing zones for the management of fish stocks, recreational zones designed for non-extractive tourism ventures, and Indigenous protected areas (IPAs). These subsidiary protected areas typically allow various forms of resource extraction, provide limited protection for species, and do not afford comprehensive area protection.

In northern Australia, there is rapidly increasing momentum to establish marine IPAs (on waters adjacent to Indigenous lands), but this is on an ad hoc

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Table 6.1 Area (square kilometres) of Australia’s marine parks and reserves in high-protection categories (IUCN categories I and II)

<table>
<thead>
<tr>
<th></th>
<th>C’wlth</th>
<th>NSW</th>
<th>NT</th>
<th>Qld</th>
<th>SA</th>
<th>Tas</th>
<th>Vic</th>
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<td>IUCN I</td>
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<td>0</td>
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<td>–a</td>
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<td>477</td>
<td>535</td>
<td>2974</td>
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</tr>
<tr>
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<td>357597</td>
<td>665</td>
<td>0</td>
<td>16609</td>
<td>1636</td>
<td>1215</td>
<td>535</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Total waters: 8528214 | 8802 | 71839 | 121994 | 60032 | 22357 | 10213 | 115740 | 8939191

% in IUCN I and II: 4.19 7.56 0.00 13.61 2.72 5.43 5.24 2.57 4.26

Australia = total for all jurisdictions; C’wlth = Commonwealth (managed by the Australian Government); IUCN = International Union for Conservation of Nature; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a IUCN II data from Western Australia and the Northern Territory have been removed, because in these jurisdictions fishing is permitted, which is inconsistent with IUCN II zoning.

Source: 2008 Collaborative Australian Protected Area Database data (excludes the extended continental shelf and the Australian Antarctic Territory)
basis without any consistent regional approach, and without any national or state and territory policy frameworks. The lack of these latter arrangements inhibits integration with broader management frameworks to ensure that protected area planning contributes to biodiversity protection through systematic planning underpinned by CAR principles. Terrestrial IPAs (see, for example, the Dhimurru IPA plan of management\textsuperscript{92}) currently make a significant contribution to the regional terrestrial CAR principles, and it seems likely that well-planned marine IPAs could ultimately make an important contribution to regional marine conservation objectives.

At present, these various types of subsidiary areas are not considered to make a formal contribution to marine biodiversity protection because they usually do not have secure tenure—their uses can be reversed or altered without recourse to open public scrutiny and transparency. Generally, when MPAs are declared under parks and reserves legislation, formal public parliamentary processes—including a public debate—are required before their use can be altered or rescinded. Collectively, the lesser forms of protection cover large areas of Australia’s marine environment, but their contribution to the protection and conservation of marine biodiversity and environments cannot be easily assessed or compared with areas that are determined with a higher level of certainty, such as MPAs managed for high protection (IUCN categories I and II).

4.3 Managing for the externalities

Australia’s formal environment protection system is broadly charged with the responsibility to deliver protection of the environment while providing for the ongoing development of the wealth and wellbeing of our human communities. This objective means that governments and their environmental protection and management systems need to provide a balanced view of the extent of environmental degradation that can be accepted in achieving acceptable environmental, social and economic outcomes. That is, the environment is protected to the extent that it can be while still providing for advancing economic and social development. This approach can result in, for example, a government authority rejecting an industry proposal on the grounds of unacceptable levels of environment impact, but the government of the day overturning this decision, seeking to provide the balance described above. In this way, setting policy objectives and processes to achieve balance can trade away environmental quality through the tyranny of many small decisions (‘death by a thousand cuts’).

The balance in the Australian environment has become heavily contingent on globalisation of the markets for Australia’s raw resources, commodity goods and services. The price that can be achieved for an exportable resource or product governs the extent to which Australia can achieve increased economic and social development. This typically moves the balance and can allow economic drivers from overseas to increase local environmental impacts by greatly increasing the attractiveness and economic feasibility of (for example) an individual resource exploitation project.

‘Creeping degradation’ can be effectively prevented by the establishment of absolute standards for the environment. Important calls have been made for environmental benchmarks to be set for use in environmental accounts,\textsuperscript{93} but a set of standards based on equivalent metrics is equally important. The lack of a set of standards for the Australian marine environment that are based on measurable and ecologically sound metrics means that acceptability on social and economic grounds can, and often does, result in greater pressures being applied to the Australian environment.

In marine systems, there are very few defendable metrics that can be used within management frameworks for this purpose. Probably the best developed standards are those within the Australian Government’s fisheries management systems, although these are primarily directed at production systems, not environmental protection. Not only are there few marine standards, but there are no national monitoring systems that could be used to determine if a relevant standard is being achieved and maintained.

In the absence of a system of national marine standards for ecosystems and biodiversity, or an integrated framework of national marine management that could be used to apply such standards, the marine environment is destined to be continually rebalanced in a downward direction. Although there are many examples of improving local conditions, there are very few examples of improvements in ecosystems at the regional scale. For this report, 13 of the 31 major species or groups assessed (40%) were rated as being in poor or very poor condition, and only four...
of these were considered to be improving. These four groups were considered to be recovering because of the removal of excessive fishing pressure, reflecting the legacy of overfishing and the improvements in contemporary AFMA fisheries management practices. It is therefore clear that sector-by-sector changes can be (and have been) made to reduce impacts. However, such changes are slow and costly unless an integrated system of management is established that sets targets based on environmental standards.

4.4 Integrated management

Integrated marine management involves establishing objectives for managing all activities pertaining to assets and values of the environment. In this sense, the values and assets of the marine environment, and the processes that support them, become the endpoints for management. Maintaining these values and assets involves responsibilities across many spheres of government, the private sector and local communities. Each of these has to know what is expected of their activities in relation to the quality of the values and assets, so that each knows what types of activities will be acceptable and compatible with the marine values and assets. An integrated approach to management involves establishing and maintaining a set of standards that reflect the desired condition of the values and assets; controlling activities to ensure that the standards are met; and establishing appropriate information, consultation and transparency systems to ensure that the public knows that the standards are appropriate and maintained. This is particularly important for the marine environment, because many aspects of marine management, and marine values and assets, involve the expenditure of large amounts of public funds, for which accountability is required.

Many attempts have been made to develop and implement various forms of integrated marine management in Australian waters, but none have persisted. In 1998, the Australian Government released Australia’s Oceans Policy, a far-reaching initiative that was intended to provide, for the first time, a nationally integrated approach to the management of Australia’s maritime jurisdiction outside the three-mile zone. Unfortunately, the Oceans Policy has failed to achieve its primary objective—it has not embedded integrated approaches, but has merely become an additional tool for marine environmental protection.2-4

There are a number of small-scale integrated marine management initiatives (such as at Rottnest Island near Perth). The most successful example is the Great Barrier Reef Marine Park (GBRMP), which operates under its own Act of Parliament, the Great Barrier Reef Marine Park Act 1975. The Act provides a framework for the Great Barrier Reef Marine Park Authority to address pressures on the values of the GBRMP from activities within the GBRMP. Pressures on the values of the GBRMP that occur from activities outside the GBRMP are addressed through the EPBC Act. The Great Barrier Reef Marine Park Authority has recently completed a pioneering analysis of management systems and effectiveness in the GBRMP, culminating in an outlook report that identifies the full range of issues, anticipates the future and highlights the key pressures that will influence the future condition of the GBRMP.31 The report identifies issues that span many sectors of activity, including activities that do not occur within the GBRMP but have an important bearing on the future condition of the park and its conservation status. It reflects an integrated approach to management, focused on achieving specific objectives for the natural ecosystems of the GBRMP (including resource exploitation).

4.5 Evaluation of management effectiveness

Evaluation of management effectiveness involves assessing each of the core elements of an effective and efficient management framework (understanding, planning, inputs, processes, outputs and outcomes—see Chapter 1: Approach).

No national evaluation of marine management effectiveness has been conducted. Applying the principle of subsidiarity (as proposed by the independent review of the EPBC Act81) implies that an analysis of the Australian Government’s marine management system would be a suitable point to start an initial national evaluation. Although the independent review of the EPBC Act mainly considered future arrangements, with past performance inferred rather than reported, the depth and breadth of the recommended improvements in relation to all marine matters suggest a high level of inadequacy in existing arrangements.81 Notwithstanding progressive improvements and many important recent achievements from both the states and the Australian Government management systems, the review’s summary of an expected
role for the Australian Government in such matters encapsulates the broad extent of the system’s weaknesses and needs:

The Commonwealth’s role in a national system should be one of leadership, as a champion of the national interest, and a standard setter in environmental management.

In assessing the effectiveness of current management of the marine environment, it is valuable to examine the effectiveness of the management system—particularly the six elements of management listed above—in dealing with the main pressures on the environment (as identified in Section 3 of this chapter), to maintain the assets, values and resilience of the marine environment.

Smaller scale assessments of management effectiveness have been conducted in marine areas across Australia—for example, in the Great Barrier Reef and in Western Australia.

The GBRMP evaluation found that many of these elements were being achieved. Importantly, objectives relating to community understanding of issues and development of effective partnerships were found to be achieved. However, arguably the most substantive element (achievement of desired outcomes) was ranked as poor for GBRMP management effectiveness as a whole. Achievement of desired outcomes (values protected, threats reduced, long-term environmental and economic sustainability) was found to be very variable across issues. Overall, the greatest concern in relation to achieving desired outcomes related to the management of impacts of climate change. Poor outcomes were also found for management of coastal development, extractive use (fishing) and water quality.94

At a state level, in Western Australia, 18 actions were identified by the Western Australian Government for the ‘Marine’ theme in response to the 1998 Western Australian SoE report. By 2007, 14 of these actions remained incomplete, 2 were completed but not evaluated, and only 2 had been completed and evaluated. The large number of incomplete actions reflects the lack of attention to the marine environment and the sheer size of the state’s marine environment, its remoteness from major settlements and the high costs of research and monitoring in such circumstances.48
### Effectiveness of marine management

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<td>Partially effective</td>
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#### Climate change impacts

**Understanding:** Strong institutional partnerships are being formed to develop a comprehensive and agreed knowledge base about drivers—which includes knowledge of physical processes; knowledge of biological process is lagging. Cross-discipline synthesis programs are developing, as yet embryonic.

**Planning:** Limited preparedness or anticipation in most affected assets and systems.

**Inputs:** Few resources are devoted to identifying the issues, or to strategies for responses or mitigation of impacts.

**Processes:** Very limited development of management tools or approaches to adapt in an integrated manner to climate impacts.

**Outputs:** ‘Business as usual’ strategies prevail, except in coastal flood-prone lands; few strategic responses to provide for maintenance of biodiversity values.

**Outcomes:** Habitat and species declines are beginning to become evident, with limited preparedness to adapt.

#### Coastal urban development

**Understanding:** Good understanding of types and sources of pollution, impacts of habitat alienation, and broad dependencies of coastal ecosystems and valued assets. Information base lagging on impacts of endocrine disruptors from sewage, stormwater, groundwater and agricultural systems on nearshore species and habitats.

**Planning:** Strong regulatory measures are being developed and applied. Asset amenity and economics of coastal lands continue to preclude assessment of environmental issues that reflect ecological processes and biodiversity values.

**Inputs:** Major resources are devoted to planning and management at all levels of government.

**Processes:** No national synthesis of coastal impacts or development issues recognising the natural values of coastal systems. No integration of effective management approaches or frameworks. Incremental development prevails, focusing on technological advancement rather than avoidance of impacts.

**Outputs:** Impacts are decreasing, but no agreed management system for identifying capacity limits, or low-impact development solutions that maintain biodiversity and ecological aspects of shoreline ecosystems.

**Outcomes:** Coastal lands continue to be developed, with pollution and impacts on habitats in adjacent waters, and extensive growth in all regions.
### Port facilities

**Understanding:** Management issues and impacts of port developments are well known

**Planning:** Planning and approval systems are advanced, and continue to provide high-quality assessment systems to minimise impacts

**Inputs:** Commitment of resources to avoiding impacts is limited by cost factors and operational requirements

**Processes:** Issues are managed on a local and individual issue scale; little management of cumulative impacts or impacts outside local precincts

**Outputs:** Ports are managed loosely as a system, often privatised and outside direct government control, typically implementing generic rule-based systems that do not always recognise impacts on local values

**Outcomes:** Port developments continue to be driven by operational requirements at the expense of local species and habitats, with substantial ongoing levels of cumulative impact

### Oil and gas exploration and production

**Understanding:** Impacts of the exploration, production and transport phases of the industry are well understood, although specific issues about dispersants and medium-term effects are yet to be resolved

**Planning:** Major lack of a regional environmental planning and assessment framework with relevant constraints on development

**Inputs:** Substantial resources are applied to the impact issues

**Processes:** Individual sites are approved based on production and economic requirements rather than environmental constraints; there appears to be only limited cumulative impact assessment. Site-based processes are good, although human error continues to have major consequences and needs much better supervision of compliance

**Outputs:** Strong regulatory regime at the site level, although lacking in onsite compliance systems; few effective outputs at the region level

**Outcomes:** Increasing rate of disturbance of marine mammals, and risk of accidents and oil spills due to large number of seabed and land-based structures; increasing exploration, construction activity and ship movements; and remoteness from regulatory control centres
### Effectiveness of marine management continued

#### Summary

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<td>Effective</td>
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<tr>
<td>Very effective</td>
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#### Fishing

**Understanding:** Limited context is applied, mainly focused on resource use; limited recognition of trophic or cumulative impacts

**Planning:** EPBC Act assessments cover more than 120 fisheries. Marine bioregional planning for Commonwealth waters is committed to considering pressures, including fishing. State-based fisheries legislation is generally committed to ecological outcomes, as well as economic ones. However, there is no comprehensive national assessment or reporting system for fisheries sustainability or environmental impacts; no national mechanism for assessing environmental outcomes; no national system for information capture across environmental aspects

**Inputs:** Limited mainly to resource management systems, not environmental impacts

**Processes:** Strong systems are in place for management of commercial fishing impacts on habitat and EPBC Act–listed species, but limited management of trophic impacts. Limited management of recreational fishing. Many jurisdictions, including the Commonwealth, are moving to improve ecosystem-based fisheries management approaches

**Outputs:** Good achievement of commercial fisheries programs; limited achievement in recreational fishing management; strong growth of resource certification systems in the private sector

**Outcomes:** Fisheries management achieves limited environmental outcomes: all species that can be fished are held at population sizes significantly below pristine levels under current management systems. Trophic structures in the oceans are heavily impacted—ecosystem resilience to trophic impacts, cumulative impacts and potential time to recovery are uncertain

#### Shipping

**Understanding:** Good understanding of impacts, other than acoustic impacts and behavioural disturbance

**Planning:** Good level of national and international coordination to manage shipping impacts

**Inputs:** Strong management systems are in place, although issues remain regarding monitoring and compliance

**Processes:** Shipping management systems are well developed and moderately effective. Groundings, shipping lanes and pest species are generally well managed nationally and internationally, but species introductions continue to occur at a high rate

**Outputs:** Further management is needed to ensure that best-practice procedures are maintained

**Outcomes:** Intensification of shipping remains a significant risk for pests, groundings and marine mammals
## Aquaculture

**Understanding:** Impacts and risks of land-based and sea-based aquaculture are reasonably well understood

**Planning:** Management systems are dominated by resource and commercial issues, not environmental impacts; limited regional planning systems have been developed

**Inputs:** Very limited external inputs are deployed; management systems are mainly confidential and commercial property; inputs to management of diseases, chemical use and wildlife interaction are generally very limited

**Processes:** Limited management systems control and report on impacts of aquaculture. All industries are managed with some attention to major environmental issues, but with little public scrutiny or government accountability. Site-level management is held to best industry practice, but there is limited compliance monitoring

**Outputs:** Repeated episodes of serious disease outbreaks sourced from farms, both within farms and in wild species. Rapid growth of sea cages resulted in increasing fishing pressure on wild populations of small pelagic fish for feed. Wild-caught sardines for use as aquaculture food are now Australia’s largest fishery by weight

**Outcomes:** Widespread ecological impacts from multiple disease outbreaks; local impacts on ecosystems; increasing trophic impacts from small pelagic fishing; very limited control of cumulative impacts

## Catchment run-off

**Understanding:** Issues and context are reasonably well defined, including nutrients, sediments, agricultural pollutants, dams, soil management practices; linkages to marine impacts are not well known

**Planning:** A strong catchment management ethos and natural resource management system are developing to better manage catchments and land run-off

**Inputs:** Commercial pressures are high, and restoring catchments is expensive; dealing with catchment health as it impacts marine ecosystems has had a limited focus

**Processes:** Catchment management systems and natural resource management organisations are becoming well developed; effectiveness across Australia is variable, particularly for the estuaries and nearshore marine ecosystems

Continued next page
### Effectiveness of marine management continued

<table>
<thead>
<tr>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
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<tbody>
<tr>
<td>Catchment run-off continued</td>
<td></td>
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<tr>
<td>Outputs: Historical degradation of soils, deforestation and salinisation of lands. Estuaries remote from urban areas are affected, some severely, by nutrients and sediments from poor agricultural practices. More urban rivers are affected by poor sewage and stormwater practices</td>
<td>Ineffective</td>
<td>Partially effective</td>
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<td>Outcomes: Legacy of heavily impacted estuaries and nearshore ecosystems, including wetland habitats reclaimed; rivers with highly altered flood regimes; and coastal rivers, lakes and lagoons with altered mouth dynamics</td>
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<td>In trend</td>
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<td>Tourism facilities</td>
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<tr>
<td>Understanding: Good understanding of the issues and management requirements</td>
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<td>Planning: Planning systems are comprehensive, and many respect the environmental assets that are also the attractions, although cumulative impacts remain a weak area of knowledge</td>
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<td>Inputs: Considerable private and public input of resources and activities to manage and maintain environments; management of unstructured tourism and cumulative impacts is limited</td>
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<tr>
<td>Processes: Strong management of commercial tourism facilities. Effective measures ensure impacts are acceptably small. Unstructured tourism is largely unmanaged</td>
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<td>Outputs: Industry best-practice systems are in place; some certification systems operate; structured tourism conducts self-assessment and monitoring</td>
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<td>Outcomes: Structured tourism has few significant impacts. Unstructured tourism is reliant on site, asset and values management, which has limited effectiveness in marine ecosystems</td>
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<td>Mining and industry</td>
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<tr>
<td>Understanding: Impact issues are clear, although cumulative effects are poorly understood</td>
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<tr>
<td>Planning: In relation to marine issues, this is mainly ad hoc, driven by commercial constraints; resource projects are not denied on environmental impact grounds; there is little consideration of regional cumulative impacts</td>
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<tr>
<td>Inputs: Site-based inputs are substantial, and there is substantial monitoring of site impacts</td>
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<td>Processes: Shoreline and marine-based structures are heavily regulated and subjected to site-based assessments to minimise local impacts</td>
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</table>
### Mining and industry continued

**Outputs**: Increasing management programs for water, air and land pollution; limited management of cumulative impacts, alienation of coastal habitats for infrastructure requirements, or alterations to water and sediment regimes in adjacent areas

**Outcomes**: Modern industry and mining have limited local area impacts, except where the resource itself is mined, such as marine sands. However, cumulative impacts of infrastructure are significant, and risks (such as pollution) are increased by intensification, with demonstrated impacts on local habitats and species

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### Marine debris

**Understanding**: Management systems are poorly informed about the extent and risks of debris, or the relationships to trade globalisation and container shipping systems

**Planning**: Much of the issue is global, and global shipping systems (International Convention for the Prevention of Pollution from Ships [MARPOL]) are in place, but there are few practical arrangements in place to combat either gross or microparticle debris

**Inputs**: Domestic and global waste management programs have been developed

**Processes**: Management of marine debris issues is weak; domestic and foreign-sourced materials management is limited to industry arrangements and codes of conduct on shipping traffic and fishing vessels; limited processes to reduce losses from container vessels or manage waste from accidents

**Outputs**: Limited compliance monitoring of vessel-based waste management arrangements

**Outcomes**: Debris heavily impacts tropical waters; whales, birds and turtles are impacted (entanglement and ingestion) and probably a range of invertebrates. Plastic microparticles are globally widespread and increasing in all ocean waters, with an increasing but unknown level of ecological impact

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Resilience of the marine environment

The resilience of marine systems is a function of the structure of the ecosystems (such as the types and numbers of species they contain), the components and functions of the habitats that support those species, and the interaction of this ecological system with physical attributes such as the dynamics of the ocean currents.

Assessing the resilience of marine systems is based on the concept that resilient systems do not remain unchanged, but that change occurs within limits. Resilience of ecosystems can be assessed by asking:

- What has been the past resilience of the system? What evidence is there of past resilience?
- What are the known pressures that will have to be dealt with? Is the management system prepared to deal with, or respond to, these anticipated pressures?
- Are the attributes of the ecosystems in good shape to permit a favourable response to unpredicted pressures or changes that may arise? Are the factors that affect the capacity to deal with surprises intact?

Keeping ecosystems resilient is an important attribute of ecosystems and a common generic goal of management, but rarely can resilience itself be quantified or measured. There are no national-scale reporting systems or datastreams that can provide useful surrogates to measure or report on the resilience of marine ecosystems, habitats or species. This section considers some of the important attributes of resilient systems in relation to the management of marine issues.

5.1 Resilience of marine systems

Marine populations wax and wane over time. This natural variation is caused by the natural environmental drivers of change, such as differences in conditions between seasons and years. However, sudden environmental shocks (such as major storms or flood events) can create major changes in populations and ecosystems related to the size of the disturbance. Few ecosystems affected in such major ways will ‘bounce back’ to the same state they were in before the serious shock. However, humans tend to focus on rapid change and are slow to appreciate less obvious, but not necessarily less relevant, change. This is sometimes caused by the phenomenon known as the ‘shifting baseline’, when managers base decisions on conditions they have personally experienced, with each successive manager relating to sequentially degraded conditions. With fishing, scientists, managers and even the general public are quick to identify and attempt to curb obvious overfishing or damage due to irresponsible fishing practices, but they have been slow to respond to less obvious signals, such as those due to climate change and fishing-induced genetic impacts. Both the fast (major shock) and the slow (incremental temperature shifts or genetic restructure) drivers of impacts affect resilience, and they can be equally significant.
Considering fishing as an example, species that are fished are ecologically important—they are often large, long lived and abundant, so are important in marine ecosystem functions. However, while fishing mortality plays a part in influencing resilience, other forces act on the population and its ecosystem that determine the population’s ability to recover from fishing (and other) pressures. Events that accompany overfishing often include pollution, eutrophication (a large increase in nutrients in the water, often leading to algal blooms), physical destruction of habitats and introduction of pest species. These impacts are often further complicated by social and economic responses of governments and communities that try to maintain stability in ways that have outcomes that are counter to their objectives. Systems that are compromised by the effects of overfishing are made more vulnerable to these additional disturbances, potentially opening the way to population collapse.

Recovery of ecosystems can be hindered by complex and often indirect species interactions. One of the factors that helps to make ecosystems more resilient to change is high ecological redundancy (i.e. there are many species that perform similar functions), because this allows other species to potentially replace one or more key species in the ecosystem to maintain ecosystem services. Species-rich systems are more likely to have greater functional redundancy and flexibility, and this can provide them with a degree of ecological insurance against uncertainty, although this is not always the case. Populations in highly diverse ecosystems may therefore be more likely to be resilient to change—in diverse ecosystems, compared with systems that are naturally low in species numbers, a smaller fraction of commercially fished species have collapsed, and there has been a higher rate of recovery of collapsed species.

The natural dynamics of marine species are related to the recovery potential of healthy marine populations. Those that have high levels of spawning biomass, a natural range of ages in populations and are widely distributed across their habitat range can be considered to be naturally resilient. When a diversity of secure areas protected from environmental and human pressures is available, populations can capitalise on good environmental conditions with strong reproductive outputs, often creating a strong year-class (all individuals spawned in a single year) that will survive and maintain the population’s recovery potential through subsequent poor years until the next environmentally favourable year occurs.

This feature can also provide fisheries with increased security of catch and a greater buffer against environmentally driven fluctuations that would otherwise reduce stability in the industry.

A recent international workshop that reviewed human impacts in the global oceans concluded that the extent and importance of the cumulative impacts of the various types of pressures (exploitation, climate change, pollution, habitat loss) have been significantly underestimated. In particular, the extinction threat to species is rapidly accelerating, and there is an unparalleled global rate of regional extinction of marine habitat types. The review concluded that a number of high-priority actions are required, including the proper and universal application of the precautionary principle to reverse the burden of proof (new activities that may damage the oceans should only be approved when they can show minimal and acceptable levels of impact both singly and cumulatively with other stressors). The review has also proposed that a United Nations Global Ocean Compliance Commission be established to oversee the charter of ocean protection.

5.2 Management for resilience

Management of marine systems to support and build resilience has been considered to require four key attributes:

1. Embracing uncertainty and change: management systems need to accept that external change, such as climate effects, evolving market demands, or changes to economic subsidies and government policies, are inherently a part of resilient systems.

2. Building knowledge and understanding of resource and ecosystem dynamics: supporting resilience requires an understanding of ecosystem processes and functions; the scale of issues and the functional roles of biodiversity are crucial components of marine resilience.

3. Developing management practices that measure, interpret and respond to ecological feedback: successful management must continuously test, learn from and modify its activities and understanding for coping with change and uncertainty in complex systems. Knowledge of ecosystems should evolve with the institutional and organisational aspects of management.
4 Supporting flexible institutions and social networks in multilevel governance systems: an adaptive governance framework relies on the collaboration of a diverse set of stakeholders operating at different social and ecological scales. The sharing of management power and responsibility can involve multiple institutional linkages among user groups or communities, government agencies and nongovernmental organisations, from local to international levels.

Considering fishing, developing management systems that are consistent with multiscale ecological drivers to support resilience is a major challenge. Institutions that manage fisheries at a very broad scale are likely to ignore local heterogeneity (e.g. small-scale spawning aggregations that are readily fished to extinction) and thereby reduce population-level diversity and resilience. Conversely, institutions that are narrowly concerned with a particular locality or a particular species are susceptible to external processes (such as recruitment failure, climate change and market demands) that operate predominantly at larger scales.

Similarly, institutions that are concerned mainly with resource management are susceptible to ignoring the environmental changes brought about by resource extraction but expressed at scales that are inconsistent with the resource management system or the natural scales at which the ecological system operates.

Considering coral reef ecotourism, resilience has been linked to the type and level of stakeholder engagement. Higher lifestyle values in tourist operators (more experience, more active choice of tourism venture) are also associated with a higher level of support for reef conservation in tourists, a greater level of participation in reef conservation activities and a greater level of resilience of the tourism venture itself. It is perhaps unsurprising that coral condition relates to the resilience of tourism ventures (although the relationship is far from clear), but perhaps of greater relevance is the role that such tourists play in supporting reef conservation values, and hence indirectly promoting reef resilience. This support role played by tourists appears to depend on the type of operator—operators with higher lifestyle values are likely to promote greater resilience of the social–ecological enterprise that is ecotourism, including natural values. In this sense, maintaining a tourism industry that comprises both operators and tourists with higher lifestyle values should be an important objective of resource management, since there are indirect connections to the resilience of the resource.
Risks to the marine environment

This section summarises the main risks to the marine environment and ranks their potential for impact in 20-year and 50-year timeframes, presented in the form of a simplified risk assessment matrix. These risks have been assessed as remaining risks, taking into account current management arrangements that apply in the relevant jurisdictions. The risk assessment approach and grading statements are described in Chapter 1: Approach.

The main risks to the future of the marine environment are from the impacts of climate change—mainly increased temperature, ocean acidification and sea level changes. The interaction of these with the legacy effects of past poor management practices, and with the existing pressures of fishing, catchment-derived pollutants, and coastal urban, industry and port development, pose a major threat to the values of marine ecosystems as we currently know them.

The changes are likely to affect the natural diversity and ecology of inshore waters, bays, estuaries and intertidal zones, and the fishing, recreation and tourism industries, with unpredictable results. For example, as ocean temperatures rise, the survival of cold-water species that are fished may be gradually reduced, but these species might be temporarily replaced by warmer water species. In the east, the impacts of rising ocean temperatures will also affect coral species diversity, distribution and, ultimately, survival.

Each region has a specific set of pressures that will almost certainly increase in risk ranking over the coming 20–50 years, given current management arrangements. For example, in the north-west, while many habitats and species populations are in near-pristine condition, more impacts will occur with the escalation of the oil and gas industry. The lack of a regionally integrated framework for management of the marine environment is currently a major risk, and this will increase as the pressures and complexities grow, with unpredictable consequences for marine ecosystems.
### 6.9 Assessment summary

#### Current and emerging risks to the marine environment

<table>
<thead>
<tr>
<th>Catastrophic</th>
<th>Major</th>
<th>Moderate</th>
<th>Minor</th>
<th>Insignificant</th>
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<tbody>
<tr>
<td>Ocean temperature increases, with impacts on corals, fish and plankton</td>
<td>Port development or coastal urban development, leading to destruction or disturbance of the environment</td>
<td>Fishing (commercial), leading to change or loss of species or impacts on ecosystems</td>
<td>Fishing (commercial), leading to change or loss of species</td>
<td>Fishing (commercial), leading to change or loss of species</td>
</tr>
<tr>
<td>Ocean acidification, with impacts on plankton and production, corals, and shell calcification processes</td>
<td>Fishing (recreational and illegal), leading to change or loss of species or impacts on ecosystems</td>
<td>Shipping, leading to the wider introduction of pests</td>
<td>Vessel strikes on cetaceans</td>
<td>Vessel strikes on cetaceans</td>
</tr>
<tr>
<td>Marine debris, which may poison or entangle species</td>
<td>Marine debris, which may poison or entangle species</td>
<td>Beach or shoreline modifications, leading to change or loss of habitat</td>
<td>Ghost fishing—lost nets that may entangle species</td>
<td>Ghost fishing—lost nets that may entangle species</td>
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<tr>
<td>Sea level rise and impacts of coastal erosion and inundation</td>
<td>Extreme or severe event (storm, tidal, rainfall, flooding), which may increase run-off and sediment/nutrient levels</td>
<td>Oil and gas extraction, leading to increased shipping and onshore development, and consequent impacts on ecosystems</td>
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<td></td>
<td>Increase in catchment-sourced nutrients, sediments and toxins</td>
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<td>Algal blooms in estuaries, which can be toxic or may result in hypoxic water</td>
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<td>Ocean current changes, leading to shifts in production</td>
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<tr>
<td>Catastrophic</td>
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<tr>
<td>Aquaculture disease escapes, with impacts on native species</td>
<td>Oil and gas accidents, or oil spills, with impacts on species populations, ecosystems and habitat</td>
<td>Aquaculture sea cages and related risks of waste disposal, dependence of wild species, impacts on feed stock</td>
<td>Oil and gas exploration and related risks of seabed disturbance</td>
<td>Oil and gas exploration and related risks of seabed disturbance</td>
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<tr>
<td>Shipping accidents, with impacts on species populations and habitats</td>
<td>Desalination discharges, with impacts on water quality and habitats</td>
<td>Coastal and island tourism facilities, leading to disturbance or destruction of the environment</td>
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<tr>
<td>Mining of sand, shorelines and islands, leading to destruction or disturbance to species populations and habitats</td>
<td>River damming or flood mitigation that changes local habitats and freshwater flows into the ocean</td>
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<td>Pest species introductions and outbreaks, leading to increased competition or other impacts for native species</td>
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<td>Lack of integrated management, affecting the conservation of ecosystems</td>
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<td>Possible</td>
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<tr>
<td>Major volcanic/tectonic event in Indonesian plate; leading to tsunami and atmospheric deposition</td>
<td>Introduced species outbreaks</td>
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<td>Shipping noise, with impacts on marine mammals</td>
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<td>Unlikely</td>
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Outlook for the marine environment

Our ocean and coastal ecosystems are used by everybody but are the primary responsibility of nobody. They are consequently suffering from ‘death by a thousand cuts’. The often-identified need for the integration of marine management is now critical and urgent. The most significant and urgent challenge for policy makers is to establish an effective set of national arrangements to connect national and international policies with state and local management activities, and to involve communities and the private sector.

Marine ecosystems and the environment are naturally dynamic—change is their byline. We have linked our communities to many of the assets and resources offered by coastal waters and estuaries, and we have built our communities on their shores. Now that they are recognisably changing, and we can detect the early signs of accelerating change, we must prepare ourselves to adapt to these changes.

Nearshore development proceeds apace, replacing vegetated landscapes with hard surfaces and converting marine habitats into new land. Land-based sources of pollution and expanding pressure on coastal lands continue to be significant concerns, despite strong improvements in land-use planning and the management of many pollution point sources. Fishing has reduced most populations of sought-after species to low levels, mainly in previous decades, and these persistent low population levels probably have significant flow-on consequences for the resilience and persistence of marine biodiversity in the inshore waters. The major looming threat for our oceans and coastal waterways is the changing global climate, which is creating significant changes in ecosystems and biodiversity, shorelines and coastal lands, and our wealth generation from the oceans.

Climate change is also threatening the existence of our coral reefs at their present-day scale and grandeur (particularly in the east region). A proliferation of oil and gas exploration and extraction, together with mining, wave energy and desalination systems, and other shoreline industries, will not only generate wealth but also bring a new set of major risks to our waters that will need intensive strategic and regional management.

This is particularly true for the north-west region, which is under intense development pressures from the resource extraction sectors (oil and gas, mining, fishing, shipping). The national demand for port capacity is forecast by the Australian Bureau of Agricultural and Resource Economics and Sciences to double each coming decade to service growth in cities and the mining sector. Only the marine values and assets of the north region remain relatively pristine; however, even there, mining and the damming of rivers are beginning to become more substantial regional pressures. The south-east region remains under the greatest stress, with a legacy of impacts from a wide variety of sources, and is suffering the greatest impacts from climate change—the East Australian Current is changing its pattern of extension into Tasmanian waters, with an intensification of gyres (circular currents), and is becoming warmer and saltier. There has been substantial coastal retreat (loss of coastal land due to higher sea levels) in areas such as Corner Inlet; urchin barrens (where unchecked urchin populations are so dense that they consume
all vegetation) have expanded; and there have been major changes in cold-water algal beds caused by the changes in water temperature. The recent blooms of the zooplankton *Noctiluca*, extending its range from the east region, raises the spectre of regime shift (the rapid and complete reorganisation of an ecosystem from one relatively stable state to another)—this species has rapidly become the dominant grazer in Tasmanian marine waters in recent years, with uncertain ecological consequences.

The interaction of accelerating changes in atmospheric and ocean climate with existing land uses, fishing systems, shoreline industries and new risks has raised the management stakes to an unprecedented level. There is a plethora of responses to this situation, many of which are achieving good outcomes; some are even reducing pressures and holding aspects of the ecosystems and biodiversity in good condition. These are a necessary but insufficient response. The evidence is that the fractured, weakly coordinated and poorly integrated management systems that we have currently deployed will inevitably result in accelerating degradation of the unique values of our oceans and coastal ecosystems, spreading outwards from the current centres of local environment degradation where system complexity is highest. The early signals of such decline are now evident across a number of areas of our coastal waters. The experience of the Oceans Policy of 1998 demonstrates the major challenge of achieving a truly national approach to address the drivers of decline in Australia’s marine ecosystems.

The overall outlook for Australia’s marine environment is uncertain—most aspects are currently not in decline, and those that are declining have moderately well understood underlying pressures and drivers. Of those assets and values that are already in poor condition, very few are recovering. But perhaps most critical of all, there are several important uncertainties that are yet to be addressed, most notably our own ability to design and deliver good, effective and efficient multilevel governance (including information and reporting systems) to address the known threats and accelerating risks to our unique marine environment.
References


Farinaccio N, as told to Peter Mack. It was quite amazing really: stories from the Ningaloo coast. Drummond Cove, Western Australia: Peter Mack, 2003.


58 McDonald JI. A likelihood analysis of non-indigenous marine species introduction to fifteen ports in Western Australia. Fisheries research report no. 182. Perth: Western Australian Department of Fisheries, 2008.


A lone Adélie penguin (*Pygoscelis adeliae*) in front of a spectacular iceberg, Antarctica

Photo by Doug Thost
Antarctic environment
Key findings

The ozone hole has largely protected East Antarctica from global warming.
Over the past half-century, western Antarctic surface temperatures have shown general warming trends with significant regional patterns. The Antarctic Peninsula is warming faster than anywhere else on Earth. In East Antarctica, the lower stratosphere has cooled and changed the atmospheric circulation through the loss of stratospheric ozone. A recovery of the ozone hole will reverse these processes and significantly increase the warming trend in East Antarctica.

The East Antarctic Ice Sheet is losing ice at its coastal fringes.
Although the mass of the whole Antarctic ice sheet has remained roughly the same over recent decades, the coastal fringes of the East Antarctic Ice Sheet have lost about 60 billion tonnes of ice each year since 2006. The annual loss is occurring at an increasing rate and may contribute significantly to sea level rise in the future.

Major regional changes are occurring in Antarctic sea ice coverage.
Over the past 30 years, there has been a small increase in the areal extent of sea ice around Antarctica, but with strong regional differences. Most notable are contrasting regional changes in sea ice seasonality (i.e. timing of annual ice advance and retreat and resultant coverage duration) attributed to changing patterns of large-scale atmospheric circulation. In the Western Antarctic Peninsula region, there is mounting evidence that a shortening of the ice season has affected multiple levels of the marine food web, whereas there is a trend towards lengthening of the annual sea ice season in the Western Ross Sea sector. The signal in the East Antarctic sea ice zone is mixed and complex, and is currently under investigation.

The Southern Ocean is getting warmer.
In the region from 35°S to 65°S, the upper Southern Ocean has warmed by 0.2 °C since the 1950s. This rate of warming is faster than elsewhere in the global ocean. Warmer waters enable alien species to extend their range southwards. These immigrating species are less specialised for the cold environment than Antarctic species, and are likely to outcompete, and perhaps replace, the native species. This could have a significant impact particularly on benthic (ocean floor) communities and ecosystem functioning.

Increased acidification of the Southern Ocean can affect the base of Antarctic food webs.
Dissolved carbon dioxide acidifies the ocean and reduces the availability of carbonate ions that calcium carbonate shell-making organisms require for calcification, diminishing the ability of these organisms to form shells. Change in acidity of the ocean is already affecting calcifying organisms—the shells of planktonic organisms known as foraminifera, which are food for many other organisms, are now about one-third lighter compared with pre-industrial times. These types of changes, which affect the base of the food web, can potentially change the dynamics of the Southern Ocean ecosystem significantly.
Antarctic vertebrates are highly specialised to survive in the Antarctic. Whether they can adapt to new conditions due to climate change is currently unknown.

Antarctic vertebrates encompass a variety of flying seabirds and penguins, several seal and whale species, and numerous fish. In the Antarctic Peninsula region, an apparent decrease in the abundance of Antarctic krill has been attributed to the observed reduction in winter sea ice coverage. This in turn has caused a decrease in Adélie and chinstrap penguin populations. Environmental changes cascade through ecosystems. As the rate of environmental change increases, it may exceed the rate at which vertebrates can adapt. Hence, it is likely that some species will not survive the coming decades.

The pressure of human activities on Antarctica and the Southern Ocean is increasing.

The Protocol on Environmental Protection to the Antarctic Treaty commits signatories to comprehensive protection of the Antarctic environment. Australia has ratified the protocol by establishing legislation to enforce procedures for reducing the impacts of Australians visiting Antarctica and has taken practical steps to reduce the impacts of past activities, such as the clean-up of abandoned waste disposal sites. However, the human footprint in the region is gradually increasing. New stations are still built; tourism to the continent continues to grow, particularly to the Antarctic Peninsula near South America; and, with a growing world population, commercial fishing activities are likely to increase. Adequate resources are needed to monitor the intensity and frequency of all human activities.

The terrestrial ecosystems are changing, especially where snow fall is replaced by rain.

Retreating glaciers, particularly in the subantarctic, higher ambient temperatures and precipitation as rain rather than snow make the terrestrial environment more accessible to plant and microbial communities. A warmer climate and increased availability of liquid water enables their populations to expand and non-native species to become established.

The natural heritage of Macquarie Island has suffered under the impact of introduced species, but a large-scale eradication program is under way.

Introduced vertebrates, such as rats, mice and rabbits, have caused a major deterioration of the natural heritage values of Macquarie Island. Overgrazing by these species in particular has increased landslides, many of which have damaged seabird colonies. A large-scale eradication program is currently under way to rid the island of these alien species.
5 Resilience of the Antarctic environment 548

6 Risks to the Antarctic environment 550
   - Assessment summary 7.15—current and emerging risks to the Antarctic environment 552

7 Outlook for the Antarctic environment 555

References 557
The Antarctic increasingly will serve as a barometer of change and an indicator of human impact elsewhere in the globe.

Introduction

Antarctica is the southernmost continent and, including all islands and ice shelves, covers an area of about 13.8 million square kilometres (km²). It is nearly twice the size of Australia. The sea ice that surrounds it adds approximately another 19 million km² at its maximum extent in September–October, diminishing to 2–3 million km² in February. The annual growth and retreat of the Antarctic sea ice is one of nature’s most significant large-scale annual changes. Antarctica is Earth’s coldest, highest, windiest and driest continent, and its largest cold desert. Only about 44 900 km² or 0.4% of the total Antarctic land mass is ice free. Antarctica also has the deepest continental shelf and is surrounded by the largest wind-driven currents, which circulate the Southern Ocean. It is the only continent that has never had a native human population.

1.1 Global importance of Antarctica

Although isolated from other continents, Antarctica is connected to the rest of the world through oceanic and atmospheric circulations. Antarctica and the surrounding Southern Ocean are key drivers of Earth’s oceanic and atmospheric systems. A critically important feature is that about 90% of Earth’s ice (around 25.2 million gigatonnes) is found here, and 70% of all available fresh water is locked up in the Antarctic ice sheet—if melted, this would raise sea levels by nearly 60 metres.

Equally important, between the coastline of the Antarctic continent and the Antarctic Polar Frontal Zone (the boundary between subtropical and subantarctic waters) lies the Southern Ocean, which extends over some 38 million km² and encompasses about 20% of the world’s ocean waters. The Southern Ocean connects the three main ocean basins (Atlantic, Pacific and Indian) and creates a global circulation system that is largely driven by the eastward flowing Antarctic Circumpolar Current—the world’s largest current. The current generates an overturning circulation (movement of water masses of different densities caused by variations in salinity and temperature) that transports vast amounts of heat and also takes up a significant amount of carbon dioxide from the atmosphere. Atmospheric pressure, humidity, air temperatures and wind patterns for our entire planet are interconnected and greatly influenced by processes in the Southern Ocean. As well as playing an important role in influencing weather patterns, the Antarctic environment provides a valuable benchmark for climate change. The Antarctic continental ice holds one of the oldest and most detailed climate records. Moreover, the Antarctic environment and biosphere comprise highly sensitive indicators of present-day environmental change. Predictions made in the 1980s and 1990s about climate change and its effects in the polar regions in the 21st century have largely been confirmed. The major difference between previous predictions and recent observations is that the forecast change appears to be occurring at a faster rate than originally expected; for example, changes in ice sheets and glaciers are accelerating. The western Antarctic Peninsula region has been warming two to three times faster than the global average and has become one of the fastest warming...
regions on Earth. Over this period, 3 of the 12 ice shelves in the peninsula region have retreated significantly and 4 have collapsed, amounting to a loss of about 18% of the floating ice. However, in East Antarctica, which has been shielded from the effects of global warming by the ozone hole, the warming is less than the global average. The regional differences in the responses to climate warming and variability highlight the complexity of the processes currently affecting Earth’s environment.

1.2 The natural environment

The Antarctic environment comprises diverse habitats and ecosystems that include ice-covered areas; ice-free vegetated areas; ice-free rocks; saltwater and freshwater lakes and streams; and the intertidal areas, mid-water, deepwater and benthic regions (the benthic zone is the ecological region at the lowest level of an ocean or lake, including the sediment surface and some subsurface layers) of the Southern Ocean. In the terrestrial environment on the continent, species diversity is low compared with mid-latitudinal or tropical ecosystems; however, many species are very abundant. Species that have made the Antarctic continent their home have evolved over very long timescales so that they are now highly specialised and able to survive in the extreme conditions of the southern continent and the frigid ocean surrounding the continent. Only a few species of terrestrial invertebrates occur and flowering plants are limited in their distribution to small areas at the Antarctic Peninsula. There are no flowering plants in East Antarctica, and lower plants such as mosses, lichens and bryophytes live in the few ice-free areas; algae prosper not only in the marine environment but also in snow fields.

The species composition on the subantarctic islands is quite different from that found on or near the continent. The vegetation of Heard Island, for example, covers ice-free areas of the island and includes a variety of vascular plants (12 species), mosses (44 species), lichens (34 species) and liverworts (17 species). Macquarie Island supports 45 species of vascular plants and 91 species of moss, as well as a large number of lichens and liverworts.

Land-breeding vertebrates are represented by only a few species. However, they tend to occur in large numbers on both the continent and on the subantarctic islands. The most diverse vertebrate groups comprise flying seabirds (seven species) and penguins (two species on the continent and five on subantarctic islands); four species of ice-breeding seals, fur seals and elephant seals are also part of the Antarctic fauna.

The abundance of terrestrial invertebrates varies regionally and depends upon the conditions of the local microhabitats and particularly the topography and vegetation. Many invertebrates live under rocks or in the relatively moist moss beds, Antarctica’s ‘forests’, where moisture is available. The species diversity is low; the most abundant phyla are rotifers (wheel animals), nematodes (worms) and tardigrades (water bears) but mites and springtails are also found. The terrestrial species diversity of the region pales in comparison with the marine species. Invertebrate taxa living at the continental shelf (0–1000 metres) and in the deep ocean (>1000 metres) encompass more than 3500 species. Creatures such as seaspiders, sea urchins, marine worms, molluscs and sponges are highly diverse with a large percentage of endemic species (i.e. species unique to the region). The list of species is expected to grow with the publication of a large-scale, international survey of the Southern Ocean—the Census of Antarctic Marine Life of 2007–08. Antarctic fish are also often endemic and are dominated by notothenioids (icefish), which make up more than half of the 320 fish species known to exist in the Southern Ocean.

Marine microbes are highly abundant and constitute most of the biomass in the Southern Ocean; they play a crucial role in the turnover of nutrient cycles.

1.3 Antarctic governance

The Antarctic Treaty and a set of related international agreements, known collectively as the Antarctic Treaty System, provide the framework for governance of the Antarctic region.

1.3.1 Antarctic Treaty

The Antarctic Treaty and related instruments of the Antarctic Treaty System provide the international
framework for management of the Antarctic region. From the 12 original signatories (including Australia) in 1959, membership of the treaty has now grown to 48 countries. The Antarctic Treaty area—the area south of 60°S—comprises 10% of our planet’s total surface area. Australia is one of seven countries that claim territory in Antarctica. While the Antarctic Treaty is in place, territorial claims are effectively set to one side and the Antarctic is available to be used by any nation for peaceful purposes. Russia and China have maintained stations in the region administered by Australia (Figure 7.1) for many years and India is currently building a station.

Australia was instrumental in the negotiations leading to the treaty and, together with France, instigated the negotiations that resulted in the 1991 Protocol on Environmental Protection to the Antarctic Treaty. The Madrid Protocol, as it is known, establishes an internationally agreed framework for comprehensive protection of the Antarctic environment. It designates Antarctica as a ‘natural reserve, devoted to peace and science’. Activities subject to the protocol must undergo an assessment of environmental impacts and then be conducted in a manner that limits adverse impacts on the Antarctic environment and dependent and associated ecosystems. Each signatory state is required to create enabling legislation to give effect to the environmental protection measures of the protocol on the activities of their national programs and citizens while in Antarctica. The Antarctic Treaty does not apply to Australia’s subantarctic Islands.

1.3.2 Convention on the Conservation of Antarctic Marine Living Resources

Conservation of Antarctic marine living resources is subject to the regulations imposed under the Convention on the Conservation of Antarctic Marine Living Resources. This convention came into force in 1982 as part of the Antarctic Treaty System. Article 1 of the convention defines its area of operation as “the area south of 60° South latitude and ... the area between that latitude and the Antarctic Convergence which form part of the Antarctic marine ecosystem”. The Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR) was established because of a general concern among the treaty parties that an increase in krill catches in the Southern Ocean could have a serious effect on populations of krill and other marine life; particularly on birds, seals and fish, which mainly depend on krill for food. Antarctic krill (Euphausia superba) was first fished in the 1960s at low levels (4 tonnes in 1961–62 and 306 tonnes in 1964–65) as an exploratory fishery. Commercial exploitation began only in the late 1970s and early 1980s when around 500 000 tonnes of Antarctic krill were caught each year. CCAMLR was initiated in response to this rapid expansion of the krill fishery.

The philosophy underlying this convention aims to ensure not just a sustainable fishery but a sustainable ecosystem. This sets CCAMLR apart from regional fisheries management organisations, which focus solely on the management and production of harvested species. CCAMLR considered the needs of krill-dependent predators and set catch limits to ensure their needs were met. A number of krill-dependent predators were selected as indicators of the health of the Southern Ocean ecosystem and the CCAMLR Ecosystem Monitoring Program was developed. Its aim is ‘to detect and record significant changes in critical components of the ecosystem to serve as a basis for the conservation of Antarctic marine living resources’. Indicator species include Adélie penguins (Pygoscelis adeliae) and crabeater seals (Lobodon carcinophagus).

CCAMLR now considers and adopts a range of conservation measures, including those that protect the general marine environment, species and communities, and those that manage commercial fishing activities. The precautionary approach adopted by CCAMLR requires that conservation and management measures are established so that populations of harvested species do not decrease in size below levels that ensure stable recruitment. CCAMLR also encourages national programs operating in Antarctica to undertake fisheries-related research aimed at maintaining stocks of harvest species at levels that allow the greatest possible recruitment into populations of target species.

The Convention on the Conservation of Antarctic Marine Living Resources was the first international convention whose fisheries management strategy was based on the ecosystem approach. It has successfully implemented this tactic in new, as well as established, fisheries. Until recently, fishing for Antarctic krill in the Southern Ocean has remained well below set catch limits. How well the current management strategy will function when the fishery expands remains to be seen.
1.4 Australian Antarctic Territory

Australia’s interest in the southern continent began in 1911 when Sir Douglas Mawson led an expedition to Commonwealth Bay to conduct a variety of scientific studies that included discovering the magnetic South Pole. From 1929–31, Mawson returned to East Antarctica on the British, Australian and New Zealand Antarctic Research Expedition, during which he claimed 42% of the continent as Australian territory. Today, the Australian Antarctic Territory (AAT; Figure 7.1) comprises all land and islands south of 60°S and extends from 45°E to 160°E, with the exception of the French Territory of Adélie Land (136–142°E). The AAT covers some 5.95 million km², with ice shelves and ice tongues comprising another 0.14 million km².
The AAT coastline extends over 11,200 kilometres (excluding offshore islands). Only 1,110 kilometres or 10% of the coastline is exposed rock. Some parts of the rock coastline are very steep, such as the Scullin Monolith, and only few areas offer the opportunity for establishing scientific research stations on ice-free rock. Thus, while the total area of the AAT is vast, the region of operation is comparatively small and human activities are concentrated on small areas where the impacts can be significant.

Australia works actively within the international forums of the Antarctic Treaty System to pursue its Antarctic interests. The Australian Government has retained a keen interest in Antarctica and has declared four goals for the Australian Antarctic Program: b

1. To maintain the Antarctic Treaty System and enhance Australia’s influence in it.
2. To protect the Antarctic environment.
3. To understand the role of Antarctica in the global climate system.
4. To undertake scientific work of practical, economic and national significance.

The AAT is administered by the Australian Antarctic Division of the Australian Government Department of Sustainability, Environment, Water, Population and Communities. Australia maintains a permanent presence in Antarctica through three continuously occupied continental stations, a station at Macquarie Island, and temporary field stations (Figure 7.2). Priority scientific research is conducted in diverse areas of Antarctic science on land and at sea. The goals and priorities of the scientific work are set out in the Australian Antarctic Science Strategic Plan 2011–2021. c

1.5 In this chapter

This chapter presents information on matters that affect the Antarctic environment and that describe the current state of the environment. The focus is on the AAT, because this is where Australia’s activities are centred—although certain trends in the environment may relate to East Antarctica in general, or Antarctica as a whole. Also discussed are Australia’s subantarctic island groups—Macquarie Island, and Heard Island and McDonald Islands—and the Southern Ocean.

Discussing every aspect of the Antarctic environment comprehensively is beyond the scope of this chapter. Instead, it reports on a number of selected indicators, some of which have long-term (more than one decade) data, and offer the best representation of current change in high-priority areas. The discussion identifies and considers environmental variables that are currently subject to pressures that are likely to become influential in the foreseeable future. This chapter aims to set a benchmark for future monitoring of environmental change and the outcomes of management actions by summarising indicators discussed in recently published scientific literature, as well as offering information on operational indicators that are relevant to running Australia’s Antarctic program. Although only a limited number of sites are monitored regularly in the AAT, some results are representative of other areas in East Antarctica with similar ecological characteristics. Where appropriate, comparisons are made with events occurring in West Antarctica, where environmental change is proceeding at a faster rate than in the eastern part of the continent.

Sources: Map provided by the Australian Antarctic Data Centre; additional data from Intergovernmental Oceanographic Commission et al., Antarctic Digital Database version 5, © Scientific Committee on Antarctic Research 1993–2006

Figure 7.2 Operational area of the Australian Antarctic Division


australian-antarctic-science-strategic-plan-201112-202021
State and trends of the Antarctic environment

In a rapidly changing world, environmental assessment requires long-term data to enable a comparison of the different states a natural ecosystem can achieve, and to determine trends of various parameters or indicators sensitive to possible change. For example, many vertebrate populations need to be monitored for two or three generations to establish the extent of natural fluctuations. Moreover, because of the local differences in environmental conditions, it is important to monitor comparable indicators at more than one site to study the abilities of systems or organisms to adapt to changing conditions. It is also important to establish the processes that regulate and sustain a system. However, long-term data are often lacking; when they are available, they may be limited in their spatial scales and quality. The following section provides information on a number of key indicators important to the Antarctic environment, based on the available data.

2.1 The physical environment

The physical environment includes both the nonliving factors that characterise an ecosystem (e.g. weather patterns, ice coverage, atmosphere), and the processes that drive them (e.g. weathering of rocks, ozone depletion of the atmosphere).

2.1.1 The atmosphere—climate and weather patterns

The climate of our polar regions and their dominant weather patterns are due to the shape of the planet. As Earth is spherical, the angle of incidence of solar radiation is shallower at the poles than at the equator. Thus, the same amount of sunlight is distributed over a larger area in the polar regions than at lower latitudes. The interior of Antarctica, where the ice sheet is 2–4 kilometres thick and hence high above sea level, remains very cold as it is generally well shielded from the warmer air masses found at the mid-latitudes.

At a glance

The physical and chemical components of the Antarctic environment are changing on a region-specific basis. Recent studies suggest that rate of change is increasing, and East Antarctica, so long thought of as safe from climate change, is undergoing measurable change and may contribute significantly to sea level rise in the future. The complex Antarctic food web is based on vast numbers of marine microorganisms, including bacteria, phytoplankton and zooplankton. Changes to the marine environment, including ocean acidification, will have a significant impact on these organisms, and since they are at the base of the food web, these changes will have profound effects throughout the Antarctic ecosystems.

Climate change and warming conditions are also supporting the movement of alien species into the region, where they may outcompete endemic species. For example, there is already evidence that king crabs are expanding their range and are moving south, where they will be a new predator for the local soft-shelled and no-shelled invertebrates. Many subantarctic islands already harbour alien plant species, which often thrive and outcompete endemic species. Many also carry the legacy of introduced vertebrates, such as rabbits or pigs that were released onto the islands during the sealing years as food sources. Rats and mice also abound and can cause havoc among seabird colonies.

Some populations of seals and penguins that were slaughtered in huge numbers in the late 19th and early 20th centuries have recovered while others, especially the seabirds, still suffer great losses in commercial fishing operations. The greatest threat, however, may well be the bycatch in illegal, unregulated and unreported fisheries. Most whale species that visit the Southern Ocean are still on the Red List of Threatened Species of the International Union for Conservation of Nature.
State and trends | Antarctic

(Figure 7.3). In contrast, the equatorial regions, where seasonal change is barely apparent, remain warm all year round. This latitudinal pressure difference causes circulation patterns in the atmosphere that create cyclonic systems between 40°S and 70°S. The clockwise movement of the cyclones transports heat from the equator towards the Antarctic continent. With the high elevation of the Antarctic ice sheet (average about 2200 metres), the air above the continent cools significantly, becoming much denser than the air at the coast, and results in gravity-driven, strong katabatic winds (caused by local downward motion of cool air) in the coastal regions, where they are particularly prevalent during winter.

Although the atmosphere above Antarctica has been studied since the early 20th century, it is only in the past 30 years that increasingly detailed measurements have been available—albeit sparsely spaced. The Australian Bureau of Meteorology gathers year-round detailed weather information at all of Australia’s Antarctic and subantarctic stations. Similar data are collected by other countries. In addition, weather data are gathered by automatic weather stations at more than 20 remote locations in East Antarctica, as well as by drifting buoys, balloons, and various satellite and ground-based remote sensing techniques. While there is significant inter-annual variability in Antarctic weather due to various large-scale processes associated with the global movement of heat, trends are apparent in the historical and palaeoclimate records. In 2009, the Scientific Committee for Antarctic Research published a detailed assessment of the impact of climate change on the Antarctic environment, and a summary of the outlook for the continent and the Southern Ocean over the next century.

Over the past half-century, the western and northern parts of the Antarctic Peninsula have warmed faster and to a greater extent than anywhere else on Earth; at the Vernadsky Station a statistically significant annual trend of +0.53 °C per decade occurred from 1951 to 2006. Winter temperatures at this site have an even stronger trend of +1.03 °C per decade. West Antarctica has warmed by approximately +0.1 °C per decade, particularly during winter and spring. On the high plateau at the South Pole, a statistically significant cooling trend has been observed, which may be due to reduced penetration of weather systems to the pole. Coastal East Antarctica is warming less than West Antarctica.

Figure 7.3  Mean time-weighted air temperature record 1 metre above ground level at Automatic Weather Station LGB35 (76°2′34″S, 65°0′0″E, elevation 2342 metres above sea level), January 1994 – July 2008
Balloon and satellite measurements indicate that the Antarctic lower troposphere (surface to 10-kilometre height) has warmed over the past 50 years,\textsuperscript{37} while the lower stratosphere (10–30 kilometres) has cooled.\textsuperscript{39} These temperature changes are very likely due to the effects of increased greenhouse gas concentrations in the atmosphere and, particularly in the case of the stratosphere, to decreases in ozone concentrations.\textsuperscript{40}

The main variability of the atmosphere at southern mid and high latitudes is associated with the southern annular mode (SAM). This is a see-sawing of pressure levels between mid and high latitudes that operates on seasonal and inter-annual timescales around the entire Southern Hemisphere. Since the 1960s, the surface air pressure has decreased around the Antarctic coast but increased at southern mid-latitudes, producing a long-term trend in SAM. The trend has deepened the meteorological feature known as the Amundsen Sea Low, which resulted in the warming of the Antarctic Peninsula and to a lesser extent West Antarctica, and to a reduction of sea ice in these regions. Additionally, changes in SAM have led to fewer but more intense cyclonic weather systems in the Antarctic coastal region (60°S–70°S), except in the region of the Amundsen and Bellingshausen seas.\textsuperscript{37}

Recent findings\textsuperscript{37,40-41} show that the trend in SAM is largely due to atmospheric circulation changes that have been brought about by the 'ozone hole'—the anomalous reduction of the amount of ozone in the lower stratosphere (12–20 kilometres in altitude) above Antarctica that has occurred each spring since around 1980 (Figure 7.4). The destruction of ozone is caused by chemical processes involving human-made halon gases, particularly chlorofluorocarbons (CFCs), which are promoted by the extreme cold and special circulation conditions in the Antarctic stratosphere during winter. The ozone hole led to an increase in the damaging ultraviolet radiation received by Earth and also a cooling of the stratosphere. Each year, ozone levels are depleted in late winter to early spring, reducing temperatures of the Antarctic stratosphere during spring. The consequences of the cooling are changes in the lower atmosphere leading to a polewards shift of about 300 kilometres of the jet stream (strong winds 7–12 kilometres above Earth’s surface), which in turn influences the route of storms in the high to mid-latitudes. The wind changes have been linked to regional changes in precipitation,\textsuperscript{42} increases in sea ice around Antarctica,\textsuperscript{37} warming of the Southern Ocean,\textsuperscript{37} a local decrease in the ocean sink of carbon dioxide\textsuperscript{40} and influences on the circulation in the mesosphere.\textsuperscript{43}

Restrictions on the use of CFCs and other ozone depleting substances were negotiated internationally when the Montreal Protocol was signed in 1987. This treaty has since been ratified by 196 states and has led to a gradual reduction in equivalent effective stratospheric chlorine, which is an estimate of the effective quantity of halogens in the atmosphere. This estimate is used to quantify the depletion of ozone in the stratosphere. The levels of CFCs peaked in the mid-1990s; since then, the use of

![Figure 7.4 Average total column ozone in Dobson units (DU) for 63°S–90°S latitude in October for the Northern Hemisphere and Southern Hemisphere](image-url)
these chemicals has been greatly reduced and Antarctic ozone levels appear to have increased by approximately 15\%.\(^{44}\) Since about 2000, the ozone hole has not increased in size. Although ozone levels are expected to fluctuate from year to year,\(^{44}\) they are expected to recover in the middle of this century,\(^{40}\) and over the remainder of the 21st century the surface changes brought about by ozone loss are expected to gradually relax.\(^{44}\)

However, two recent studies report that the effects of the reversal of the ozone hole may be countered by increases in the concentrations of greenhouse gases, at least during the southern summer.\(^{45-46}\) While the jet stream should return to the same latitude where it occurred before the ozone depletion, increasing greenhouse gas concentrations may cancel out the effects of the ozone recovery and the jet stream may stay at its current latitude. The interactions of these two competing events are not yet fully understood and much will depend upon the speed of the ozone recovery and the rate of increase of greenhouse gases.\(^{45-46}\)

The El Niño Southern Oscillation (ENSO) is a large-scale mode of atmospheric and oceanic variability that is mainly situated in the low latitude Pacific Ocean region. It is associated with pooling of warm water alternately on the western and eastern Pacific Ocean every few years. ENSO does provide a contribution to climate variability in coastal Antarctica, but there is currently no evidence that this influence is changing in the long term.\(^{37}\)

![An iceberg and new sea ice, Antarctica](Photo by Doug Thost)
# Assessment summary

## State and trends of the Antarctic atmosphere

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence in grade</th>
<th>Confidence in trend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Surface temperature</strong></td>
<td>Long-term measurements exist only at a limited number of sites (primarily since 1957), and large-scale analyses have used satellite thermal infrared data. The temperature increase in the West Antarctic Ice Sheet has been 0.1 °C per decade.</td>
<td>Very poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Tropospheric temperature</strong></td>
<td>Satellite and radiosonde measurements are available; most extensive and reliable data have been available since the late 1970s. The general warming trend, linked to human factors, is taking place in the lower troposphere; the trend decreases towards the tropopause.</td>
<td>Very poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Stratospheric temperature</strong></td>
<td>Satellite and radiosonde measurements are available; most extensive and reliable data have been available since the late 1970s. The general cooling trend is most significant over the Antarctic continent in spring and summer due to annual formation of the ozone hole.</td>
<td>Very poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Mesospheric temperature</strong></td>
<td>Limited satellite and ground-based remote sensing data are available; however, there is some evidence of decreasing temperatures, but modes of variability make the interpretation complex.</td>
<td>Very poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Greenhouse gas concentrations</strong></td>
<td>There are few tropospheric measurement sites in Antarctica and the subantarctic, but increases in carbon dioxide and methane linked to human factors are apparent.</td>
<td>Very poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
<td></td>
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<td>----------------------------------------</td>
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<tr>
<td>Stratospheric ozone concentration</td>
<td>There are possible signs of recovery (increased concentration of ozone) in spring and summer over Antarctica, but there is also significant inter-annual variability due to meteorological factors. Stronger signs of ozone recovery are expected over the next decade or two.</td>
<td>Very poor</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Effective equivalent stratospheric chlorine</td>
<td>Improvement (decrease) in ODSs is expected in the troposphere. Estimates of EESC in the stratosphere are based on the level of tropospheric ODSs combined with transport modelling; however, few measurements of EESC are available.</td>
<td>Very poor</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

**Recent trends**

- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**

**Confidence**

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Grades**

- **Very good** Component unaffected by pressures
- **Good** Component affected by pressures and likely to recover in future
- **Poor** Component affected by pressures and trends likely to continue
- **Very poor** Component affected by pressures and unlikely to recover in future

EESC = effective equivalent stratospheric chlorine; km = kilometre; ODS = ozone depleting substance
2.1.2 The cryosphere—Antarctic ice sheet and glaciers

The Antarctic ice sheet consists of three topographically different regions: the Antarctic Peninsula, which reaches further north than any other area in Antarctica; the West Antarctic Ice Sheet (WAIS); and the East Antarctic Ice Sheet (EAIS), which is by far the largest component, extending from about 30°W to about 165°E.

The ice mass budget of the Antarctic continental ice sheet is the balance between mass gained from snow fall and mass lost by melt and discharge as icebergs at the coast. The net mass balance is complex to assess because changes in snow fall and iceberg discharge vary by region and are not uniform across the continent. In some coastal regions abrupt changes have been observed, including the rapid disintegration of floating ice shelves, and this has raised questions about the potential for rapid ice discharge from Antarctica into the sea. The major environmental consequences of changes in the Antarctic ice sheet are to global sea level and to the freshwater input to the Southern Ocean, with possible flow-on effects to global ocean circulation and marine ecosystems.

Based on measurements from the Gravity Recovery and Climate Experiment (GRACE) satellites, which determine the weight of the ice sheet from space, Rignot et al.\textsuperscript{47} report that the entire Antarctic ice sheet may have a net loss of 150 ± 75 billion tonnes per year (this is equivalent to a sea level rise of 0.4 millimetres each year), and that this rate is accelerating (by 14.5 ± 2 billion tonnes each year) (Figure 7.5). They claim that the loss estimate is supported by separate estimates of snow fall and ice discharge—the input–output method. However, the timespan of these observations is short, and there are considerable uncertainties in the observations. It is important to note that the observed net loss in ice mass is despite an overall thickening of the interior of East Antarctica by 1.8 ± 0.3 centimetres per year, measured by satellite radar altimetry from 1992 to 2003, which has been attributed to increased snow fall.\textsuperscript{48} This increase in snow fall is consistent with a warmer atmosphere, which leads to more evaporation from the ocean.\textsuperscript{48-49} Hence, increased snow fall on the interior of the ice sheet is consistent with the predicted responses to global warming.

In West Antarctica, GRACE satellite observations indicate that 132 ± 26 billion tonnes of ice per year are lost.\textsuperscript{51} The WAIS is predominantly resting on bedrock that is far below sea level, and which is widely expected to make it vulnerable to global warming. The WAIS has been thinning during the most recent decades; however, this was due to the increased discharge of ice by a number of glaciers rather than surface melt.\textsuperscript{52} For example, the flow rate of the Pine Island Glacier in West Antarctica has recently accelerated. The glacier ice is thinning and its grounding line (where the continental ice begins to float) is retreating southward. This is attributed to warmer ocean waters that increase melting from the base of the floating ice. As the bedrock beneath the glacier becomes deeper south of the grounding line, it is argued that the melt could continue to accelerate, due to the effect of pressure further lowering the freezing point, and therefore further contribute to sea level rise.\textsuperscript{53}
In contrast, the EAIS is believed to be relatively stable; it is larger and higher than the WAIS and there are currently not such clear signs of warming in East Antarctica as there are in the west. However, recent results from field measurements show that much of the EAIS is also below sea level, and that the ice in some coastal regions is thinning and losing mass. Measurements by the GRACE satellites indicate the coastal fringes of the EAIS have lost about 60 billion tonnes of ice each year since 2006 (again with considerable uncertainty: 57 ± 52 billion tonnes of ice per year) and that the annual loss has increased over the short measurement period. Satellite measurements of the elevation of the ice sheet surface also show that the ice sheet is thinning near the coastal margins in a few locations in East Antarctica, particularly in the Totten Glacier and Cook Ice Shelf regions, indicating ice discharge is exceeding input. This is in general agreement with the regions of East Antarctic loss indicated by GRACE. The bedrock topography beneath East Antarctica is only recently being revealed from airborne surveys, with recent studies showing that the bedrock in the Totten Glacier catchment is largely below sea level. Further inland, as much as 21% of the Aurora Basin, Wilkes Land region, is more than 1000 metres below sea level. Further investigations of the depth and the bedrock slopes will determine the response of thinning at the margins to the ice mass balance of the region.

The influences of climate change on Antarctica are also illustrated by events in the Antarctic Peninsula region. The Antarctic Peninsula has experienced one of the highest regional temperature increases on the planet (2.8 °C in 50 years). Several floating ice shelves in that region have recently collapsed abruptly; for example, the Larsen B Ice Shelf collapsed in March 2002, and the Wilkins Ice Shelf started to disintegrate in March 2008. By 2009, the Antarctic Peninsula had lost about 28 100 km² from the 152 200 km² of ice shelves present in the 1950s. With the buttressing effect of grounded ice sheets gone, glaciers adjacent to the collapsing ice shelves now flow around three to four times faster into the ocean since the shelves disintegrated. This increase in the discharge of grounded ice from the ice sheet to the ocean is contributing to sea level rise.

Glaciers at subantarctic Heard Island are also retreating. For example, the areal extent of Brown Glacier decreased from approximately 6.2 million square metres in 1947 to 4.4 million square metres in 2004, a 29% loss of its original area. Measurements in 2000 and 2003 reveal the recent rate of ice loss of this glacier is more than double the 57-year average from 1947–2004.

### 2.1.3 The cryosphere—sea ice

Sea ice plays a key role in ocean–atmosphere interactions, global ocean circulation and the global climate system by forming an insulative, high-albedo cover (reflective of solar radiation) over a vast, although seasonally variable, area of the Southern Ocean (of around 3–19 million km²). It strongly influences the ocean and ecosystems through the injection of brine during its formation and fresh water when it melts. Being closely associated with patterns of atmospheric and oceanic temperature and circulation, sea ice responds sensitively to climate change and variability, and is also a key modulator of change and variability. It also dominates the seasonal physical and chemical dynamics of the high-latitude Southern Ocean and plays a major role in structuring high-latitude marine ecosystems. It follows that any substantial change in sea ice coverage will have potentially complex and wide-ranging impacts (Box 7.1), although the task of tracking environmental and biological consequences is immense and complex.

There has been a small increase in the net areal extent of sea ice around Antarctica over the past 30 years (based on satellite data analysis), although this result has recently been called into question. However, undisputed regional changes are occurring in the Antarctic sea ice cover in response to changing patterns of large-scale atmospheric circulation. Most notable are the strong reductions in the sea ice extent west of the Antarctic Peninsula in the Bellingshausen Sea, and the strong increases in sea ice extent in the Ross Sea. In the western Antarctic Peninsula region there is mounting evidence that a decreasing ice season duration has affected multiple levels of the marine food web. The sea ice signal in the East Antarctic sea ice zone is mixed and complex, but has shown only minor changes over the satellite record, consistent with natural variability.
Box 7.1 Recent Antarctic sea ice change and variability, and their implications

Antarctic sea ice forms a highly reflective insulating ‘skin’ over much of the Southern Ocean. It expands from 3–4 million square kilometres each summer to about 19 million square kilometres each September–October. Sea ice and its accumulated snow cover are very important for both climatic and biological systems. Sea ice formation is a driver of global ocean circulation and is also a habitat for algae, which forms the base of the Antarctic food web. Consequently, significant changes in the amount of sea ice formed each year will impact the climate, biology and ecology of Antarctica and the Southern Ocean, with potentially significant global consequences.

Over the era for which satellite imagery of sea ice is available (1979 to present), the areal extent of sea ice has increased at a small but statistically significant rate of approximately 1% per decade. However, of much greater significance are the regional changes observed. Increases in the Weddell Sea sector have been around 1% per decade, 0.9% per decade in the West Pacific Ocean sector, 2.1% per decade in the Indian Ocean sector, and the largest increase has been in the Ross Sea with 5% per decade. In contrast, the Amundsen–Bellingshausen seas have lost sea ice at 7% per decade. Moreover, proxy records derived from analysis of ice sheet core and historical whaling records suggest that sea ice coverage may have declined substantially in certain regions since the late 1950s and early 1960s.

The seasonality of the sea ice coverage (formation and retreat) has also changed, but again with large differences between regions, especially in West Antarctica (Figure A). In the north-east and west Antarctic Peninsula and in the Bellingshausen Sea, the sea ice season has shortened by about 85 days from 1979–80 to 2004–05. These changes are probably due to changes in large-scale modes of atmosphere circulation affecting regional winds and temperatures, although other factors, such as the recent incursion of relatively warm waters onto the continental shelf, may also have been a factor in the weakening of ice shelves.

In contrast, sea ice in the western Ross Sea now persists for about 60 days longer than in 1979. In East Antarctica, the sea ice zone is narrower than in West Antarctica. The large sea ice area and the longer season are linked to lower surface temperatures and an increase in the occurrence of more southerly winds. Complex patterns of change have been observed in both the timing and extent of the seasonality of sea ice across the region from 1979 to 2009, with sea ice persisting for one to two days more per year (R Massom, University of Tasmania, pers. comm., May 2011). In the Prydz Bay region, sea ice persists for two to three days more per year.

While observations show sea ice extent is increasing slightly over time, current models predict that Antarctic sea ice will decrease in extent by 24% and 34% by volume, by 2100, highlighting the need to understand the current conditions and how sea ice impacts the biological components of the Southern Ocean ecosystem. For example, fast ice is an important habitat for sea ice algae and microorganisms, and a breeding platform for Weddell seals and emperor penguins. Increased fast ice extent or duration can negatively affect breeding success. Pack ice, the area where many top predators forage, is influenced by snow fall and surface flooding. Changes in sea ice and wind regimes, light availability and mixed-layer depth of oceanic waters affect phytoplankton communities, which in turn affect food availability for these predators.

Fieldwork within the Australian Antarctic Program provides crucial and essential information on sea ice, biological and biogeochemical processes and properties, and is an important means of validating key satellite data products, including sea ice thickness, which remains difficult to measure accurately around Antarctica (photo © Tony Worby, courtesy Australian Antarctic Division).
Box 7.1 continued

Figure A Trend map of Antarctic annual sea ice duration (in days/year) derived from satellite passive microwave data for the period 1979–80 to 2004–05

The black/white contours delimit 0.01–0.10 significance levels, while grey shading within the sea ice zone signifies a near-zero trend.
## 7.2 Assessment summary

### State and trends of the Antarctic cryosphere

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sea ice extent</strong></td>
<td>Antarctica-wide since 1960 (the start of the modern satellite era): 1.2 ± 0.2% increase per decade with regionally opposite trends; 7.1 ± 0.9% decrease per decade in Amundsen–Bellingshausen seas, 4.9 ± 0.6% increase per decade in Ross Sea. There is more certainty about the observations than about the environmental consequences; however, proxy information from ice core and historical whaling records suggests that a major decline in sea ice coverage occurred in the decades before the late 1950s to early 1960s</td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Sea ice seasonality</strong></td>
<td>There are major and opposing trends in different areas. In the West Antarctic Peninsula and north-west Weddell Sea, later annual advancing of sea ice edge and earlier retreat means the sea ice season is shortening, with deleterious effects on ecosystems; sea ice advance appears more sensitive to climate variability than sea ice retreat. Conversely, there is a longer season in the western Ross Sea. There is no clear trend in seasonality for East Antarctica, where the pattern of change is complex</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pack ice (ice floes of varying sizes and density) characteristics</strong></td>
<td>Changes to the characteristics of pack ice are likely to have a cascading impact through the ecosystem. At present, there is great uncertainty in large-scale estimates of the thickness distributions of sea ice and its snow cover. Research is under way to derive these key quantities from satellite data</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fast ice (sea ice adjacent to land)</strong></td>
<td>There is insufficient information about the seasonality of fast ice (current satellite-derived timeseries is too short and limited to East Antarctica for 2000–08). From 2000–08, there were different responses in the Indian Ocean and West Pacific sectors</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
East Antarctic Ice Sheet (EAIS)

There is mounting evidence that the EAIS is losing mass, although by how much is uncertain. Continent-wide, there are also signs of acceleration in the loss rates, although the timespan of comprehensive observations is short. Lack of in situ data on glacial isostatic adjustment (uplift) limits interpretation of observations of ice sheet mass and elevation change. Net mass loss contributes to global sea level, and changes the freshwater budget of the Southern Ocean.

Heard Island and other subantarctic glaciers

Most Heard Island glaciers have retreated since 1947: total glacier area decreased (from 288 km$^2$ in 1947 to 231 km$^2$ in 1988); for 2000–03, ice loss of Brown Glacier is estimated at around 8.0 × 10$^6$ m$^3$/year, more than double the average of the last 57 years. Rising temperatures and newly exposed terrain led to changes in distribution of flora.

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Recent trends

<table>
<thead>
<tr>
<th>Grade</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving</td>
<td>Stable</td>
</tr>
<tr>
<td>Deteriorating</td>
<td>Unclear</td>
</tr>
</tbody>
</table>

Confidence

<table>
<thead>
<tr>
<th>Confidence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate high-quality evidence and high level of consensus</td>
<td></td>
</tr>
<tr>
<td>Limited evidence or limited consensus</td>
<td></td>
</tr>
<tr>
<td>Evidence and consensus too low to make an assessment</td>
<td></td>
</tr>
</tbody>
</table>

Grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>There are no significant changes in physical or chemical processes</td>
</tr>
<tr>
<td>Good</td>
<td>There are some significant changes in physical or chemical processes in some areas, but these are not to the extent that they are significantly affecting ecosystem functions</td>
</tr>
<tr>
<td>Poor</td>
<td>There are substantial changes in physical or chemical processes and these are significantly affecting ecosystem functions in some areas</td>
</tr>
<tr>
<td>Very poor</td>
<td>There are substantial changes in physical or chemical processes across a wide area of the region as a result of human activities, and ecosystem functions are seriously affected in much of the region</td>
</tr>
</tbody>
</table>

km$^2$ = square kilometre; m$^3$ = cubic metre
2.2 The Southern Ocean

The Southern Ocean is the only ocean that encircles the globe uninhibited by land masses. It flows around Antarctica, connecting the world’s major southern ocean basins, and also links the surface of the ocean with the deepwater layer. The Southern Ocean covers an area of approximately 20.3 million square kilometres. Much of its area is 4000–5000 metres deep and its temperatures are below 0 °C. Various currents form the Southern Ocean. The major current in the Southern Ocean is the Antarctic Circumpolar Current, which flows mainly eastwards, although important north–south movements also occur in various water masses. The structure of the water current system is still being investigated. Recently, measurements of a deep current system 3 kilometres below the surface and flowing along the Kerguelen Plateau in the southern Indian Ocean found that more than 12 million cubic metres of cold water are transported here each second. This system—the Kerguelen Deep Western Boundary Current—makes a significant contribution to global ocean circulation as these deep currents transport Antarctic waters into deep layers of the major ocean basins.

Emperor penguin (Aptenodytes forsteri) colony, near Mawson Station, Antarctica
Photo by Graham Robertson
In winter, the surface of the ocean bordering the Antarctic continent freezes. The exceptions are a few areas, called polynyas, where persistent katabatic winds, formed by cold air draining from the interior of the continent, blow from the land to the sea and keep the sea surface clear of ice. When sea ice forms, salt is forced out of the forming ice (brine rejection) making the water below this ice denser and more saline. The densest water mass of the Southern Ocean is the Antarctic bottom water, which forms in only a few locations near the Antarctic continent. Antarctic bottom water is derived from shelf waters that are dense, cold and oxygen rich. The bottom water spills over the edge of the continental shelf and reaches deep oceanic waters that move northwards along the ocean bottom. The warmer waters in the north flow south and fill the gap, and as they reach higher latitudes they cool and sink. Through this cycle of water movement and the connection of all major ocean basins, heat and other components are redistributed and make the bottom water a key driver in the world’s ‘conveyer belt’ of ocean currents. These processes influence weather, rainfall patterns and temperatures around the world.

Although generally nutrient rich, the productivity of the Southern Ocean is not as high as may be expected due to low levels of iron (an important micronutrient) and low light levels (because of persistent cloud cover), particularly during the southern winter.

The Southern Ocean is the least well understood ocean due to its vast size and the difficulties in obtaining measurements in winter, because large areas are covered by ice. Nonetheless, some measurements have been possible: in the region of the Weddell Sea from 35°S to 65°S, the Southern Ocean has warmed by 0.17 °C in the upper 1000 metres since the 1950s. This rate of warming is faster than anywhere else in the world. Ocean acidification is likely to affect the efficiency of the Southern Ocean as a sink for atmospheric carbon dioxide and will also have profound impacts on species and ecosystems (see Sections 2.3.1 and 3.1.1).

2.2.1 Ocean acidification

The Southern Ocean is one of the world’s largest sinks for atmospheric carbon dioxide. Approximately 25–30% of the anthropogenic (caused by human activity) carbon dioxide released to the atmosphere has been taken up by the world’s oceans—some 40% of which has been taken up by cold Southern Ocean waters that lie south of 40°S. While reducing the accumulation of carbon dioxide in the atmosphere, ocean uptake is making sea water more acidic. Current atmospheric carbon dioxide levels of approximately 391 parts per million are higher than they have been for at least the past 25 million years and models predict it could rise to >1000 parts per million by 2100. Compared with pre-industrial times (pre-1700s) when carbon dioxide levels were around 280 parts per million, the pH (measure of acidity) of the ocean has dropped from pH 8.2 to pH 8.1, indicating increased acidity. Thus, although the ocean is still alkaline, its level of acidity is increasing. This drop in pH is linked to the dramatic rate of increase of carbon dioxide in the atmosphere—the rate is one hundred times greater than that during any other time in the past 650 000 years. In the period from 2000 to 2004, the rate of global carbon dioxide emissions grew by 3.3% per year compared with 1% per year in 1990–99 (Figure 7.6).

![Figure 7.6 Recent global monthly mean carbon dioxide (CO₂) concentration, 2007–11](image)

In April 2011, the global average carbon dioxide concentration was 391.55 parts per million. The red line shows the mean monthly values centred around the middle of each month; the black line is the corrected version based on a seven-month running average.

Ocean acidification is likely to affect the efficiency of the Southern Ocean as a sink for atmospheric carbon dioxide and will also have profound impacts on species and ecosystems (see Sections 2.3.1 and 3.1.1).
### State and trends of the Southern Ocean

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sea surface temperature</strong></td>
<td>Since 1950, the upper kilometre of the water column and densest part of Antarctic bottom water in the Weddell Sea warmed by 0.2 °C at 700–1000 metres between 35°S and 65°S</td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Ocean acidity</strong></td>
<td>Polar pH levels are changing twice as fast as tropical ones; pre-industrial pH 8.2 dropped to pH 8.1, indicating increased acidity</td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Ocean salinity</strong></td>
<td>The coastal waters between the Ross Sea and the southern Indian Ocean are fresher now than 50 years ago, making the Antarctic bottom water that forms here less saline</td>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td><strong>Southern Ocean circulation and structure</strong></td>
<td>Increase in wind strength is expected to affect the ACC and upwelling of circumpolar deep water, formation of different water masses and gyre activity</td>
<td>Unchanged</td>
<td>Stable</td>
</tr>
<tr>
<td><strong>Sea level</strong></td>
<td>In December 2009, data were obtained from about 135 locations from 250 tide gauges, but large gaps still exist in datasets. Sea level changes are not expected to be uniform across Earth. Sea level rise in the Southern Ocean south of the ACC is predicted to be less than in the Arctic</td>
<td>Unchanged</td>
<td>Stable</td>
</tr>
</tbody>
</table>

**Recent trends**

- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**

**Grades**

- **Very good**
- **Good**
- **Poor**
- **Very poor**

**Confidence**

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**ACC** = Antarctic Circumpolar Current

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492
2.3 The living environment

Given its extreme conditions, the Antarctic comprises a perhaps surprising diversity of ecosystems. Antarctica is the coldest, windiest, driest and highest continent. Only about 0.4% of the continent is ice-free. Since plants and the invertebrates associated with them and most seabirds require bare rock as growth or breeding habitats, the ice-free areas are important for their survival; consequently, many species are often found breeding close to each other. Antarctica and the Southern Ocean, distinct in their physical properties from other parts of the world, have a large number of endemic species. For example, 100% of the nematodes, 50% of the lichens and more than 30% of the terrestrial invertebrates on the Antarctic continent are found nowhere else, and the dominant fish species in the Southern Ocean are endemic to the region.

2.3.1 Marine environments

One of the likely results of climate change is an alteration in the distribution of species, as those adapted to warmer climes expand their ranges south. For example, crabs are not found in the ocean around Antarctica—they became extinct there some 15 million years ago. Many invertebrate organisms, such as brittle-stars and molluscs, evolved to have only soft shells in the absence of predators. Others, such as some marine snails, have lost their shells altogether. These creatures are no match for shell-crushing invaders, such as king crabs. There is already evidence that king crabs are expanding their range and moving south. In 2004, four specimens of a king crab that is abundant in the coastal waters of New Zealand were found in the northern Ross Sea and near the Balleny Islands (approximately 67°S). More recently, thousands of these creatures have been found on the shelf slope of the western Antarctic Peninsula. Their presence alone has the potential to extensively modify species diversity in the region.

The pelagic environment

Marine microorganisms form the basis of Antarctic food webs. They include vast numbers of bacteria, phytoplankton (single-celled plants) and zooplankton (single-celled animals). Bacterial communities occur throughout the water column of the Southern Ocean, as well as in the sea ice. These tiny, single-celled organisms provide food for zooplankton, krill, fish and other vertebrates. They are exceptionally numerous and comprise around 90% of the living matter produced in Antarctic waters. The biomass of phytoplankton is estimated to be 5000 million tonnes; there are also about 1200 million tonnes of bacteria and some 600 million tonnes of protozoa. The number of species for many groups of organisms is still unknown. The Census of Antarctic Marine Life found many new species that are still being identified; this is particularly true for bacteria. The phytoplankton (diatoms, dinoflagellates, ciliates and other protists) in the Southern Ocean comprises 560 known species, but only a few are widely dominant; their community structure is not constant throughout the Southern Ocean. One group, the diatoms, is responsible for most of the primary production (fixing of inorganic carbon into organic molecules). Their level of productivity varies greatly with season, being highest in spring and early summer. Most of their production is consumed or recycled by bacteria and protozoa.

Intense phytoplankton blooms occur in Antarctic waters during spring and summer when increasing sunlight melts the sea ice and warms the ocean. The high light conditions and high nutrient content in the surface waters are ideal conditions for the growth of phytoplankton cells. During photosynthesis, phytoplankton take up carbon dioxide that dissolves in the ocean from the atmosphere. They also produce dimethyl sulfide, a natural aerosol, which is released into the atmosphere. Here it helps cloud formation as it acts as a cloud condensation nucleus and increases the reflectance of the sun’s heat from Earth. Thus, these single-celled organisms not only support the food web, they also influence the biochemistry of the ocean and play a vital role in affecting global climate by reducing carbon dioxide in the atmosphere and altering global heat balance. In turn, they are affected by anthropogenic changes to the atmosphere. Ozone depletion has increased the damage they experience due to increased ultraviolet B radiation (Box 7.2). Anthropogenic environmental changes are likely to have far-reaching impacts on the Antarctic marine ecosystem.
Box 7.2 Phaeocystis antarctica and climate change

Phaeocystis antarctica is among the most abundant phytoplankton species in Antarctic waters. It is one of the first species to reproduce in spring, when its blooms can dominate the phytoplankton community at the ice edge, as well as in deeper offshore waters. This alga has a complex life history involving solitary cells and a colonial life stage. Individual cells give off much of their photo-assimilated carbon to form a colony matrix containing thousands of cells. These colonies offer protection from grazing, mediate trace metal dynamics, and are a repository of carbon that can be metabolised in the dark. With some exceptions, Phaeocystis spp. blooms are commonly remineralised in near-surface waters and contribute little to the vertical carbon export (movement of carbon from surface to deeper ocean waters). Phaeocystis antarctica also releases ultraviolet (UV)-screening compounds (Figure A), an antibiotic and large amounts of dimethyl sulfide (DMS).

This alga has a significant effect on a number of ecosystem and physical processes because of its abundance and physiology. The peculiar physiology of this alga causes its blooms to strongly influence the structure and function of the plankton community. It also plays a disproportionately large role in mediating global climate by affecting vertical carbon flux and enhancing cloud formation and solar reflectance (global albedo) via the release of DMS. Climate change is predicted to increase stratification of surface waters, especially at high latitudes, trapping phytoplankton in shallow water where they are exposed to high UVB radiances (280–320 nanometre wavelength). Competition experiments show that Phaeocystis antarctica can outcompete other phytoplankton species, such as diatoms, in high UVB radiances. Further research is required to determine Phaeocystis antarctica’s tolerance of other predicted changes including temperature, salinity, nutrients and pH, and how changes may affect its role in the ecosystem.

**Figure A** Changes in species-specific biomass of phytoplankton grown in mixed culture under different ambient Antarctic light conditions
Zooplankton includes creatures like krill—small shrimp-like crustaceans that rank highly on the menu of many top predators, such as fish, whales, seals, penguins and flying seabirds. Krill in turn feed on phytoplankton and sometimes small zooplankton. Copepods (minute crustaceans) are another grazer on phytoplankton, making up most of the biomass in many pelagic zooplankton communities, and are an alternative food source for higher predators. Krill distribution and abundance were examined in 2006 during a major marine science voyage known as BROKE-West (Baseline Research on Oceanography, Krill and the Environment–West) in the western sector of East Antarctica. Transects were sampled from 30°E to 80°E and krill abundance in this region was estimated to be more than 2.6 million tonnes.114

Both phytoplankton and zooplankton comprise species that build shells made of aragonite or calcite. An increase in the acidity of the Southern Ocean is likely to first affect these planktonic species that form the base of the food web. Carbon dioxide–driven acidification reduces the availability of the carbonate ion that calcium carbonate shell-making organisms require for calcification, reducing the ability of these organisms to form shells. The rapid change in the acidity of the ocean is already affecting calcifying organisms—the shells of planktonic organisms known as foraminifera are now about one-third lighter compared with pre-industrial times.115 However, the Australian Antarctic Division–led Southern Ocean Continuous Plankton Survey has observed very large blooms of foraminiferans, especially in the southern summer of 2004–05 when they dominated the surface plankton (up to 80% of abundance) through much of the Southern Ocean south of Africa to Australia.116

It is important to note that different species respond differently to environmental changes. While some are likely to be affected adversely, others might benefit from the changes.117 However, changes at the base of the food web, such as to phytoplankton and zooplankton, can potentially radically change the dynamics of the Southern Ocean ecosystem, but it is still unclear whether (or how) higher order organisms are affected.

**The benthic environment**

The bottom of the Southern Ocean offers rich habitats on hard and soft substrata to a great number of species, many of which grow much slower than their temperate counterparts. Both fixed and mobile species including sponges, molluscs, sea stars and worms are highly diverse and abundant. Bryozoans are particularly diverse and have a high level of endemism.118 Based on the outcomes of the Census of Antarctic Marine Life, the CCAMLR proclaimed two ‘vulnerable marine ecosystems’ to protect species assemblages and aid the conservation of biodiversity.118

At depth, environmental conditions are stable and species communities and assemblages appear not to change much. A threat to the biodiversity of the benthos is iceberg grounding. Icebergs break off glacier snouts and ice shelves and often get caught in currents that transport them away from their calving sites. In shallow water, icebergs can become grounded, which stirs up the sediment and crushes benthic fauna in the way. The damage caused by grounding icebergs tends to be local. So far, these grounding events appear to have contributed to the species diversity in the benthic communities by creating a patchwork of areas that are in different stages of recovery. However, an increased rate of iceberg calving may cause more frequent disturbances to benthic areas and not leave sufficient time for populations to recover. Fast-growing organisms are likely to have a better chance to resettle than slow-growing ones. In the long term, while the benthos may not remain scarred and unpopulated, its communities may change in their species composition and some organisms are likely to be lost, at least locally.

### 2.3.2 Terrestrial environments

#### Antarctic continent

Antarctica is almost entirely covered in permanent ice. Ice-free areas of exposed rock are rare and account for only about 0.4% of the total area. Most of the exposed rock is in remote mountain ranges; less than 6000 square kilometres is found in small, isolated patches adjacent to the coast but this provides habitat for most of the terrestrial biodiversity of Antarctica. Exposed, ice-free mountain tops exist inland, and about 40–50 species of mosses and lichens survive at elevations of 2000+ metres above sea level. Temperatures range from –30 °C in summer to about –70 °C in winter and the moisture content of the air...
is typically very low (less than 0.5 kilograms per cubic metre). Adélie penguins, and seabirds such as Antarctic petrels (*Thalassoica antarctica*) and snow petrels (*Pagodroma nivea*), use ice-free habitats for nesting, and some seals use coastal Antarctic beaches as haul-out areas and fast ice (sea ice adjacent to land) for breeding.

The coastal areas and offshore islands are largely south of the Antarctic circle (66°33’S), which marks the most southerly latitude at which the sun is above the horizon at the winter solstice. The climate here is defined as cold maritime. Milder than the interior, average temperatures can rise above 0 °C in summer but drop to less than −30 °C in winter. The region between 60°S and 70°S is the cloudiest on our planet, with a cloud cover of 85–90% throughout the year. Winds generated in the interior of the continent drive cold, dense air towards the coast. Smooth ice surfaces on the ice plateau and steep slopes at the coast reduce friction and intensify katabatic winds, which are strongest at the edge of the continent (often 180 kilometres per hour or more). Terrestrial ecosystems are isolated from each other and their floral and faunal communities are less complex than those at lower latitudes or the Arctic region. For example, there are 900 species of vascular plants in the Arctic compared with 2 species in the Antarctic, where lichens and mosses dominate the visible flora.

The microbiotic communities (bacteria and fungi) are species-rich in comparison to other communities and exist in lakes, moss cushions and the soil. Many microorganisms, such as diatoms and cyanobacteria, are endemic to Antarctica.

Lakes and drainage systems are also part of the ice-free areas of Antarctica. Many of these systems exist close to the freezing point of water and their water levels and salinity react quickly to changes in the moisture content of the environment. Changes in the water chemistry affect life in the lakes, which include bacteria, algae, viruses and some invertebrates, such as copepods and rotifers.

In researching the terrestrial environment, a number of important questions remain unanswered. These concern the species diversity and distribution of soil organisms, such as invertebrates, microbes and algae. New genetic techniques reveal an increasing complexity of species, for example among crustaceans, such as amphipods and bacteria. How these organisms participate in the cycling of nutrients and the flux of carbon through the terrestrial systems is poorly understood. There is also insufficient knowledge about their contribution to the hydrology of terrestrial systems or feedback loops that link them to climate changes. Box 7.3 discusses changes in Antarctic vegetation communities.

### Subantarctic islands—Heard Island and McDonald Islands, and Macquarie Island

High-latitude islands and island groups are part of the Antarctic terrestrial environment. Terrestrial ecosystems of the subantarctic islands are very different from those of continental Antarctica. Surrounded by the Southern Ocean and located south of 50° latitude, they are mostly free of permanent ice, although Heard Island, situated south of the Antarctic Polar Frontal Zone has a permanent ice cover. Macquarie Island lies to the north of this zone. The seasonal temperature fluctuations are modest, with mean temperatures of around −2 °C in winter and about 8 °C in summer. Species diversity increases with decreasing latitude but is still lower in the subantarctic zone than in subtropical and tropical regions; however, species are often highly abundant. Compared with the terrestrial flora of Antarctica, vascular plants are diverse, with several flowering plants, including megaherbs and grasses; only two flowering plants are found on the Antarctic Peninsula. Mosses and liverworts are a significant component of the landscape. Trees and shrubs are absent from the Australian subantarctic islands, but do occur on other subantarctic islands.

The faunal diversity is dominated by invertebrates and includes microarthropods, such as springtails, and insects including beetles and flies. Many vertebrates, such as flying seabirds, penguins and seals, rely on the ocean for food but depend on the islands for breeding and moulting sites.
The vegetation of East Antarctica is limited to the small areas that are ice-free for some of the year and comprises only cryptogamic organisms: lichens, bryophytes, algae and cyanobacteria. These plants are mainly influenced by three factors: the availability of water, nutrients and ultraviolet B (UVB) radiation. While lichens can obtain moisture and nutrients from the air and snow fall, bryophytes are restricted to areas of reliable water supply and occur therefore largely in the vicinity of summer melt streams (Figure A).

Antarctic soils are typically not well developed and are low in carbon and nutrients. Nutrient sources include windblown inputs from nearby penguin rookeries and past guano deposits from abandoned rookeries. The growing season is restricted to the summer months when there is adequate light and water. For example, the growing season for mosses is only 1–3 months and growth rates are therefore very slow at around 1 millimetre per year. The subantarctic and Antarctic Peninsula regions, which support some vascular species, have undergone considerable warming in recent decades and plant communities have changed in response to this environmental shift. Until recently, the situation for continental Antarctica, and particularly East Antarctica, was unclear. However, recent studies provide evidence of significant warming. Plants also have to cope with increased UVB radiation because of ozone depletion and increased disturbance where they occur near human habitation. There is also evidence of increased drying of plants, possibly due to increased wind speeds.

Photo by Sharon Robinson, University of Wollongong  
Photo by Jane Wasley, Australian Antarctic Division

**Figure A** Antarctic bryophytes

Well-developed community (left). Moribund bryophytes on an undulating substrate encrusted with lichens, dominated by *Xanthoria mawsonii* (orange), *Candelariella flava* and/or *Caloplaca citrina* (yellow) and *Pseudephebe minuscula* (black) (right).

**How do different species respond?**

The different plants respond in varying ways to environmental stressors. Different plants form communities along a moisture gradient (Figure B). Bryophytes will be the vegetation component most at risk from changes in the water regime. The endemic species *Schistidium antarctici* (also known as *Grimmia antarctici*) is more sensitive to UVB than other species, because it lacks UVB screening pigments. The widely distributed species *Bryum pseudotriquetrum* and *Ceratodon purpureus* both have more of these pigments and are more resilient to UVB radiation than *S. antarctici*. *C. purpureus* is the most resilient, probably because it has cell wall–bound screening pigments that offer good protection. *C. purpureus* and *B. pseudotriquetrum* also are more resilient to desiccation, while *S. antarctici* is probably most tolerant of freezing conditions.

**What are the potential long-term consequences of pressures on communities?**

The long-term consequence of a drying trend is that *S. antarctici* may be at risk, along with the invertebrate and microbial communities that it supports. Potentially, the existence of all mosses is at risk because of an increased frequency of freeze–thaw cycles and a drying environment, due to depletion of permanent snow and ice reserves, with more frequent cycles of dehydration–rehydration and a shorter growing season.

Low genetic diversity and lack of sexual reproduction mean that these organisms are probably not equipped to quickly adapt to change. With UV levels predicted to remain high until mid-century, plus the predicted warming of the atmosphere in Antarctica, the habitat of the vegetation communities is expected to be severely compromised.
Changing environmental conditions may increase the likelihood of alien species establishing themselves in new niches in areas that are, at the moment, too extreme for them to survive. Such changes could become a threat to important areas of biological, scientific, historic, aesthetic and wilderness values.

In the Australian research program, detailed studies of the subantarctic terrestrial environment and environmental change are largely limited to ongoing work at Macquarie Island. A number of vertebrate species have become established on the island. European starlings (*Sturnus vulgaris*), for example, are self-introduced via New Zealand, while European rabbits, rats and mice arrived with the sealers in the 19th century. Some of these populations, such as the rabbits, have reached vast numbers, which have significantly affected the island’s terrestrial environment (Box 7.4). For example, excessive grazing by introduced rabbits destabilised the underlying rock and soil and—in conjunction with high rainfall—led to massive landslides near penguin colonies, killing large numbers of birds. Since similar introductions did not occur on Heard Island or the Antarctic continent, the findings at Macquarie Island are unique to its ecosystem and cannot be extended to other areas.
Since 2002, rabbit numbers have dramatically escalated on Macquarie Island, causing widespread vegetation damage and destruction from grazing. Many coastal slopes were transformed from lush, waist-high vegetation to grazing lawns or bare ground increasingly prone to landslips from high rainfall events and seismic activity. Seabird colonies have been affected through loss of protection afforded by vegetation, and loss of habitat and breeding grounds. Some vegetation types, such as *Polystichum vestitum* fernbrakes, are under threat and remaining patches have been fenced to maintain existing populations. Populations of rats and mice have also been increasing since the cats that were introduced to the island in the early 1800s were eradicated in 2001. The current Macquarie Island Pest Eradication Project aims to eradicate rabbits, rats and mice simultaneously. In 2010, the rabbit calicivirus was released on the island as part of the eradication program and has reduced rabbit numbers dramatically. In some areas, the vegetation is showing promising signs of regenerating only five months after the release of the virus. Eradication efforts are continuing.
## 7.4 Assessment summary

### State and trends of the terrestrial environment of Macquarie Island

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coastal vegetation</strong></td>
<td>Degraded through rabbit grazing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Upland vegetation</strong></td>
<td>Degraded through rapid dieback, probably climate induced</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Terrestrial invertebrate populations</strong></td>
<td>Variable responses but major degradation and change from rabbit grazing</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Stream invertebrate populations</strong></td>
<td>Degraded through rabbit grazing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recent trends</th>
<th>Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving</td>
<td>Very good</td>
</tr>
<tr>
<td>Deteriorating</td>
<td>Good</td>
</tr>
<tr>
<td>Stable</td>
<td>Poor</td>
</tr>
<tr>
<td>Unclear</td>
<td>Very poor</td>
</tr>
</tbody>
</table>

**Confidence**
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Assessment grade**
- Very poor
- Poor
- Good
- Very good

**In grade**
- Improving
- Deteriorating
- Stable
- Unclear

**In trend**
- Stable
- Improving
- Deteriorating
- Unclear

Communities are not affected by changes and operate at maximal reproductive capacity.
Few communities are affected and operate below maximal reproductive capacity; structure and function of system/community not impaired.
Some communities are affected and operate well below maximal reproductive capacity; structure and function of system/community impaired.
Affected systems/communities barely functional.
2.3.3 Vertebrate populations

Antarctic vertebrates encompass a variety of flying seabirds and penguin species, several seal and whale species and numerous fish species. The species diversity, especially on the Antarctic continent, is greatly reduced compared with the temperate and tropical regions and even the Arctic. However, the abundance of many species is very high. All are highly dependent upon the Southern Ocean for food, while their breeding areas include terrestrial, fast ice and marine regions. Many of the large, air-breathing vertebrates are also highly migratory and explore areas far outside the Antarctic and the Southern Ocean.

Status and trend data are available for only a few species, notably the two penguin species on the continent, some albatross and giant petrel populations, and fur and elephant seals at Macquarie Island. Long-term population data do not exist for the ice-breeding seals and whales, most of the flying birds and some of the penguins at Macquarie Island. Hence, trends and status are difficult to establish. Heard Island and McDonald Islands are visited infrequently and data are largely lacking.

Fish

The fish fauna of Antarctica is unique. Their species composition and to a large extent their distribution in the Southern Ocean have been well documented. There are some 322 recognised species in Antarctic waters but only about half (161 species) live in the high Antarctic (i.e. south of the Antarctic Polar Frontal Zone). Of those, most (77%) are notothenioids—the most diverse group, with 129 species belonging to five families. Their biomass makes up 91% of the Antarctic fish fauna. Notothenioids have lived in the Antarctic environment for millions of years and are well adapted to life in a polar ocean. Key to their survival in the freezing temperatures is that these fish evolved to produce glycoproteins that act as antifreeze agents in their blood.

In terms of their populations, there is virtually no information on the status and trends of Antarctic fish. This is partly due to the vast area covered by the Southern Ocean that renders population surveys near impossible, especially those frequent enough to estimate abundance and trends. Therefore, formal stock assessments are only available for some of the exploited fish populations.

Historically, vessels from the Soviet Union and other Eastern Bloc countries conducted large-scale fishing operations in the Southern Ocean off the AAT in the mid-1960s. Marbled rock cod (*Nototthenia rossii*) was caught in such quantities that the stock had noticeably reduced by the 1970s and was depleted by the end of the 1980s to a point at which commercial operations were no longer profitable. Off South Georgia, stocks had all but disappeared after only two years of fishing. Currently, only two species of finfish are harvested in the Australian exclusive economic zone at Heard Island and McDonald Islands, and Macquarie Island: the Patagonian toothfish (*Dissostichus eleginoides*) and the mackerel icefish (*Champsocephalus gunnari*). The latter is being targeted only at Heard Island and McDonald Islands.

CCAMLR regulates all legal commercial catches, but illegal, unregulated and unreported fishing still occurs in the high seas of the CCAMLR area, albeit at probably lower levels than in the 1980s and 1990s. It is worth noting that in 2010, no illegal, unregulated and unreported fishing was reported in Australia’s exclusive economic zone at Heard Island and McDonald Islands, or at Macquarie Island.

Whales

Both toothed and baleen whales are found in Antarctic waters, at least during the southern summer. The former comprise several species, some of them rare, and include killer whales or orcas (*Orcinus orca*) and sperm whales (*Physeter macrocephalus*). Baleen whales include the blue (*Balaenoptera musculus*), Antarctic minke (*B. bonaerensis*), fin (*B. physalus*), sei (*B. borealis*), humpback (*Megaptera novaeangliae*) and southern right (*Eubalaena australis*) whales. Most Antarctic baleen whale species spend the summer in the open waters of the Southern Ocean, where they feed extensively as the sea ice recedes. In autumn, they migrate north to warmer waters where they give birth to their young.

By the mid-1900s, a number of great whale species (e.g. blue, humpback and sei whales) living in the Southern Ocean had nearly become extinct after decades of intensive hunting. Today, despite efforts to protect them by banning commercial whaling and declaring the Southern Ocean an international whale sanctuary, rates of recovery vary among species and regions, and some populations are still showing no sign of recovery. The reasons for this are largely
unknown. Blue, fin and sei whales are listed by the International Union for Conservation of Nature as endangered species, while sperm whales are classified as vulnerable to extinction. Blue whales have not been hunted for 65 years, but so far there are only very limited indications of a possible population recovery. On the other hand, humpback and southern right whales are comparatively abundant again and are listed as being of least concern. However, the vast abundance of whales from pre-industrial times will, in all likelihood, remain a thing of the past.

Seals

Four species of seal (crabeater, leopard \[Hydrurga leptonyx\], Ross \[Ommatophoca rossii\] and Weddell \[Leptonychotes weddellii\]) inhabit the sea ice zone that surrounds Antarctica and are reliant on the sea ice at critical stages of their lives, particularly in the reproductive and moulting periods. Their populations are difficult to study because these seals are highly mobile, are dispersed over very large and inaccessible regions, spend long periods of time foraging in the ocean where they are difficult to survey, and do not appear to occupy set territories. Sightings are usually of individuals or very small groups. Surveys to estimate their population sizes are infrequent because they are expensive and labour intensive. Consequently, population trends are largely unavailable.

In the past, estimates of the global population of crabeater seals ranged from 2–5 million individuals in the mid-1950s to about 75 million in the early 1970s and 11–12 million in the 1990s. In 1972–73, Laws estimated 772,000 crabeater seals in the Wilkes Land region, East Antarctica, and postulated that these seals should increase in numbers because of all the ‘excess’ krill available after many krill-eating whales had been removed from the Southern Ocean. A detailed aerial survey of 1.5 million square kilometres from 64°E to 150°E, roughly coinciding with the area where Laws operated, was conducted in 1999–2000. If Laws’ krill surplus hypothesis had been correct, several million crabeater seals could have been expected. However, the survey estimate for crabeater seals yielded fewer than 1 million individuals in the survey area with a range of 0.7–1.4 million. Thus, it appears that crabeater seals are abundant but that earlier estimates were too high. Leopard and Ross seals are probably also abundant, but less so than crabeater seals, with numbers in the tens of thousands.

Crabeater, leopard and Ross seals inhabit the northern region of the sea ice that consists of ice floes of varying sizes and density—known as pack ice. Weddell seals are found on the fast ice—the sea ice that is attached to the continent. How the pack ice seals respond to environmental stressors may vary among species. However, changes in the structure and size of ice floes could lead to the loss of pupping platforms. A reduction in sea ice persistence may decrease the availability of Antarctic krill, an important food source for all pack ice seals—although, if coastal polynyas (ice-free areas) increase in size, crystal krill may become more abundant and may partially offset the loss of Antarctic krill. Leopard seals have the most diverse diet among the ice seals and are likely to be least immediately affected by changes in food availability. However, depending on the rate, kind and magnitude of change, they are likely to be affected eventually.

Antarctic fur seals (Arctocephalus gazella) and southern elephant seals (Mirounga leonina) inhabit the subantarctic islands, but can be encountered as far south as the Antarctic continent. While fur seal populations appear still to be increasing, the numbers of southern elephant seals at Macquarie Island are still in decline (Figure 7.7). The reasons for this are unknown and difficult to investigate, because this species performs long-distance migrations for 8–10 months each year; however, elephant seals are probably subjected to a number of different pressures throughout the year, as well as at various stages of their lifecycle.

![Figure 7.7](image-url)
**Flying seabirds**

Seabirds are typically long lived. They mature late and only lay one or two eggs per year, which are not usually replaced if lost. Also, some albatross species breed only every second or sometimes third year. Although adult survival is usually very high (around 95% of adults return the following year to their colonies), their low reproductive output does not enable seabirds to withstand even small increases above their natural mortality rates.

Most seabird populations in the Antarctic are only infrequently surveyed, because it is difficult to access their colonies. Consequently, few seabird populations have been assessed in a reliable way. Populations comprising fewer than 100 breeding pairs are extremely vulnerable. About one-third of global albatross populations are in this category, including most breeding populations at Australia’s subantarctic islands.

The threats that seabirds encounter at sea include competition with commercial fishers for their prey species, death or injury as bycatch in longline and trawl fisheries, intentional shooting, increased dependence on fisheries’ discards, and injury from marine pollution. The consequences of global warming and ocean acidification are also likely to threaten many seabirds by affecting the abundance and spatial distribution of their food supply.

On land, seabirds may experience disturbance by humans, loss of breeding habitat, and—because of increased competition for nest sites—exposure to parasites and pathogens. On subantarctic islands, their breeding success can be reduced directly by alien predators, such as cats, rats and mice, as happened on Macquarie Island. Heard Island has so far remained free of introduced vertebrates. Alien species can also have an indirect effect where overgrazing leads to destabilisation of the substratum, which in turn can lead to an increase in landslides.

One of the most serious threats to seabirds, particularly those breeding at lower latitudes on the subantarctic islands, is commercial fishing operations. Within the Australian jurisdiction, incidental seabird mortality is strictly controlled and regulated. However, seabirds fly enormous distances and often forage in the high seas in international waters where they interact with the pelagic longline fisheries. The seabirds become hooked when they scavenge for food behind the vessels; as the line sinks, they drown. Significant research has been undertaken and mitigation methods adopted by CCAMLR as a result have seen the seabird mortality reduced to near zero in the legal fishery. The approach taken is to collaborate with industry members to develop gear that is seabird-safe but does not impact on catch rates of fish (see Box 7.8). CCAMLR continues to monitor fishery interactions with seabirds and has been adjusting the mitigation methods accordingly.

**Penguins**

In terms of biomass, most Antarctic seabirds are penguins—they make up about 90% of the total avian biomass. Like all seabirds, penguins are long lived and only produce one or two eggs per year. Penguins often live in large colonies in the coastal areas of subantarctic and Antarctic islands. During the breeding season, the foraging areas of the breeding population are limited, because they need to return regularly to their colonies to feed their offspring. Of the 18 species in the penguin family, 7 live and breed in the AAT at Macquarie Island, but only emperor penguins (*Aptenodytes forsteri*) and Adélie penguins inhabit colonies in the high Antarctic. Adélie penguins spend the winter months at sea, returning to their breeding colonies during the southern summer, while emperor penguins breed during the winter months and fledge their young in summer. Consequently, these two species are subject to marine and terrestrial processes at different times of the year.

Penguins moult once a year. To prepare for the moult, they feed extensively to lay down sufficient reserves of body fat; during the moult, they cannot fish as their plumage is no longer waterproof. Thus, for several weeks they survive on stored body reserves. With the exception of gentoo penguins (*Pygoscelis papua*), they forage offshore and are migratory outside the breeding season.

The greatest threats for penguins in East Antarctica are likely to be loss of breeding habitat (in the case of emperor penguins) and a reduction in food availability due to global warming and ocean acidification. Changes in sea ice conditions have varied consequences (Box 7.5). For example, a reduction in the sea ice extent potentially shortens foraging distances, but less sea ice also means a reduced production of krill. It is difficult to predict to what extent penguins may be able to adapt to environmental change, particularly as the rate of change is likely to increase once the ozone loss is reversed, making adaptation difficult for these long-lived species.
Adélie penguins breed in colonies that are distributed all around the Antarctic continent. They breed in summer and usually lay two eggs. A number of studies investigated the complex link between the breeding success of Adélie penguins and the extent of sea ice, as well as the length of time it persists (e.g. Emmerson & Southwell168). Sea ice exists in two main forms:

- the continuous sheet of land-fast ice that largely excludes the penguins from potential foraging areas
- the pack ice north of the fast ice that, because it is subject to wind and wave action, consists of mobile ice floes that allow penguins to access the sea.

The breeding success of Adélie penguins depends upon the food available to them during winter, and their body condition at the beginning of the season (they have to have sufficient body reserves to start breeding). It may also depend on the distance they have to travel across the fast ice to their colonies (Figure A).

A 17-year study at Béchervaise Island, off Mawson Station, showed Adélie penguins bred most successfully in years when the winter sea ice was extensive (producing a lot of food and enabling the penguins to build up their body reserves), and when the nearshore fast ice was reduced during the breeding season, allowing the penguins quick access to foraging areas and ensuring a good food supply for chicks. In addition, during successful years, the offshore sea ice was still extensive and provided reliable food production, access and a platform for resting and predator avoidance for the penguins.168

Thus, the timing, quality and extent of both fast and pack ice contribute to the breeding success of Adélie penguins. To predict how Adélie penguin and other top predator populations are affected by changing environmental conditions, it is necessary to determine which factors ultimately influence their reproductive success and long-term survival. The extent of the fast ice is certainly an important factor.168 In years when the fast ice persists throughout the summer, Adélie penguins suffer a significant reduction in breeding success, and even complete breeding failure.168

![Figure A](https://example.com/image.png)

Figure A Satellite image of the Mawson region in East Antarctica taken on 2 January 1995

The area of ice cover was calculated between 60.8°E and 65.8°E for nearshore fast ice (solid blue line), extending from the coastline out to 66.8°S; offshore pack ice (dashed yellow line), extending northward of 66.8°S; and total ice cover (sum of nearshore and offshore) from the coastline northward. The coastline is in red, and the boundaries of ice tongues and shelves are in pink.
## 7.5 Assessment summary

### State and trends of Antarctic and subantarctic vertebrates

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fish</strong></td>
<td>Geographic distribution and species composition of Antarctic fish reasonably well understood; however, abundance estimates or population size estimates are not available</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td><strong>Toothed whales</strong></td>
<td>Whales found in Antarctic waters include sperm whale and orcas; many species are data-deficient and their populations and trends cannot be estimated</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td><strong>Baleen whales</strong></td>
<td>Includes the Antarctic blue, sei, fin, minke and humpback whales; all but minke whale species are listed by the IUCN on the Red List of Threatened Species</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td><strong>Ice-breeding seals</strong></td>
<td>Populations apparently abundant and unaffected by human activities; however, much is still unknown and population trend data are not available</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td><strong>Fur seals</strong></td>
<td>Populations still recovering from sealing exploitation, but are increasing</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td><strong>Elephant seals</strong></td>
<td>Population at Macquarie Island still decreasing; reasons are unknown</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td><strong>Wandering albatrosses</strong></td>
<td>Listed as vulnerable; only about 10 breeding pairs at Macquarie Island; commercial fishing operations are a threat</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td><strong>Small albatrosses</strong></td>
<td>All species are listed by the IUCN because of conservation concerns; many are caught as bycatch in commercial fisheries</td>
<td>Poor</td>
<td></td>
</tr>
</tbody>
</table>
### Antarctic petrels

Long-term population data for these birds not available; however, they still appear to be abundant

<table>
<thead>
<tr>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

### Subantarctic petrels

Long-term population data not available for most species; however, some populations are known to have decreased (e.g. at Macquarie Island)

<table>
<thead>
<tr>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

### Antarctic penguins

Overall, penguin populations appear to be stable in the Australian Antarctic Territory; however, long-term monitoring studies are limited to a small number of sites.

Populations breeding in other areas of Antarctica are showing rapid declines coinciding with decreases in sea ice

<table>
<thead>
<tr>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>Only a few, if any, species or species groups have declined as a result of human activities or declining environmental condition</td>
</tr>
<tr>
<td>Good</td>
<td>Populations of a number of species or species groups have declined significantly as a result of human activities or declining environmental condition</td>
</tr>
<tr>
<td>Poor</td>
<td>Populations of many species or species groups have declined significantly as a result of human activities or declining environmental condition</td>
</tr>
<tr>
<td>Very poor</td>
<td>Populations of large numbers of species or species groups have declined significantly as a result of human activities or declining environmental condition</td>
</tr>
</tbody>
</table>

### Subantarctic penguins

Many species appear to suffer population declines, but long-term population data are available only for a few colonies.

King penguins appear to be the only species with a growing population

<table>
<thead>
<tr>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very poor</td>
<td>Poor</td>
</tr>
<tr>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

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**IUCN = International Union for Conservation of Nature**
2.4 The station environment

Human activities in Antarctica are very limited in comparison to other continents. There are no permanent populations living in Antarctica and neither industrial nor agricultural activities occur there. However, although the human presence is quite small compared with the overall size of the continent, human activities are concentrated on small ice-free areas adjacent to the coast, because they are easy to access by ship and they provide a stable surface for building. These ice-free areas are also home for most of the land-living plants and animals of Antarctica. The environmental impacts of human activities are concentrated in these areas, and impacts include disturbance to the landscape and contamination with pollutants.

Australia operates three permanently occupied research stations on the Antarctic continent (Casey, Davis and Mawson), as well as a station at Macquarie Island, and uses various ships and aircraft to transport people and goods to and from the stations.

Figure 7.8 Number of person-days by month for all Australian Antarctic stations, 1986–2009
2.4.1 Operational indicators

Under Article 17 of the Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol), all parties are required to provide an annual report on steps taken to implement the protocol. To help monitor and manage the ways in which the Australian Antarctic program interacts with the Antarctic environment, the Australian Antarctic Division established a set of operational indicators. A number of these are discussed below. Annex III to the protocol outlines minimum requirements for waste disposal and waste management practices in the Antarctic, and this forms the basis of the division’s waste management practices.

The operational indicators provide information about the actual or potential impacts of Australian Antarctic program operations on the Antarctic environment. The number of people present at or near the stations and on the ships is recorded monthly and reported annually (Figures 7.8 and 7.9). This provides a measure of the human pressure on the natural environment. Population sizes vary among the stations, between seasons (summer versus winter) and with year, depending on the research and building and maintenance requirements.

In the most recent decade, the winter populations on stations ranged from 14 at Macquarie Island to 25 at Davis Station. Since the rodent and rabbit eradication program began in 2010, the winter population has more than doubled at Macquarie Island. In 2011, there are 40 personnel on the island. Davis Station, where a variety of research, maintenance and building programs occur, has had the largest population over summer for many years, of up to 100 personnel.

The Australian Antarctic Division operates ships only from mid-October until April the following year.
year. Winter travel by ship is impossible because of the extensive sea ice. Voyages have different purposes, such as deployment and retrieval of personnel, resupply of stations and marine science research. The ice breaker RSV Aurora Australis caters for all these purposes. However, supplying four stations in a timely manner with one vessel has proven to be a challenge. Hence, personnel may be deployed, for example, via tourist vessels that visit Macquarie Island. Occasionally, vessels larger than the Aurora Australis are chartered for a particular task, such as removal of waste (Box 7.7, p. 520).

**Waste treatment and disposal**

Waste treatment and disposal are a measure of human impact. The stations produce liquid waste comprising human waste, waste from kitchens and bathrooms, and limited volumes from workshops. Contamination of the latter is usually minimal as it is cleaned of oil before discharge into the sewage system. Wastewater effluent is discharged directly to the sea adjacent to the stations.

At Davis Station and Macquarie Island, sewage is macerated and released. Maceration is the minimum

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**Figure 7.10** Amount of suspended solids in the effluent of Australia’s three Antarctic stations, 2003–11
level of sewage treatment required under the Madrid Protocol. At Macquarie Island, sewage is discharged into a high-energy environment where the macerated particles are quickly diluted and dispersed. The wastewater treatment plant at Davis ceased to function and was removed in 2005. In the summers of 2009–10 and 2010–11, the Australian Antarctic Division investigated the potential impacts of sewage on the marine flora and fauna. Once available, the results of this research will inform decisions about future waste treatment options.

At Casey and Mawson stations, treatment plants process the sewage before it is released into the ocean. One of the measures used to assess waste treatment is the ‘biological oxygen demand’, which indicates how efficiently the stations’ waste treatment plants remove organic matter from the sewage and how much organic matter is being released into the ocean. The quantities of suspended solids are also measured. Suspended solids indicate how efficiently the waste treatment plants break down organic matter, as well as the amount of organic matter that is released into the ocean as a result of human occupation (Figure 7.10).

In 1991, the parties to the Antarctic Treaty introduced the Madrid Protocol. Waste is minimised wherever possible; for example, by reducing packaging—goods delivered to Antarctica are contained in minimal packing, and substances such as washing powders and dishwashing liquids are biodegradable. Most rubbish and material no longer required are collected and returned to Australia (Figure 7.11) where they are reused, recycled or disposed of. Waste typically includes battery acid, laboratory chemicals, sewage sludge, paint, oil, paper, glass, aluminium, plastic (PET and HDPE), steel, copper, brass and building materials. Some waste, such as kitchen scraps and soiled food wrappers, is incinerated, resulting in exhaust emissions to the environment. For example, burns containing plastics generate hydrogen chloride; toxic gases, such as toluene, sulfur dioxide and chlorobenzene can also be generated. The ash may contain heavy metals. Australia aims to reduce the amount of materials incinerated on the stations, either by reducing the amounts of certain materials sent to the stations, or by diverting materials from incineration to reuse or recycling. Ash from the incinerators is returned to Australia. Data collected on waste levels enable the evaluation of the environmental impacts of operational and scientific activities, and the extent of community adoption and the economics of recycling.

Waste is returned by ship usually during the stations’ resupply. How much waste is returned to Australia each year is highly variable and dependent upon the availability of cargo space on the ship. When necessary, vessels are hired especially for the purpose of returning waste; for example, in 2010–11 for the clean-up of the tip site in the Thala Valley (Box 7.7, p. 520).

**Figure 7.11** Amount of total waste returned from the three Antarctic stations, and Macquarie Island, 2000–10

**Fuel usage**

The quantity of fuel used by generator sets and boilers at all stations is recorded because the environmental impact of the emissions released from power generation and heating is proportional to the amount of fuel used in Antarctica. Special Antarctic blend (SAB), a light diesel fuel blended especially for cold climates, is used at the stations to power the stations’ generator sets, to provide heat through boilers, and to run plant and equipment including the station incinerators and vehicles.
The quantity of fuel used to generate heat and electricity is a reflection of the efficiency of various electrical and heating systems and is also affected by energy saving strategies, the number of people on the station and the amount of heat and lighting required, which varies with ambient temperature and daylight hours. The need for electricity increases from summer to winter, although fewer people occupy the stations (Figure 7.12), because current station designs mean that buildings are unable to be closed down during winter, even though some may be little used. A range of initiatives have been introduced to reduce fuel consumption wherever possible. The living areas are kept at 19 °C during the day and 16 °C at night. Those buildings that are connected to the general site services are kept warm using heat created by the generators in the powerhouse and only a few small buildings have their own electrical heating systems. Fuel-efficient ‘cold pump’ technology is being used for the long-term storage of perishable food. At Davis Station, air-to-air heat exchangers are used to pre-warm fresh air brought into buildings without introducing cold. At Mawson Station, two wind turbines were installed in 2003 to generate electricity (Box 7.6) and a ‘smart grid’ is being installed to regulate power use.

Figure 7.12 Monthly electricity use at Australian Antarctic stations, 1986–2010

kWh = kilowatt hour
Source: Bonnice et al.24
Box 7.6 Renewable energy production at Mawson Station

Australia’s stations provide a safe and comfortable environment for the personnel living and working there. However, it costs a lot of fuel to run these stations. Electricity is required for heating and power is needed for water production, light and other necessary domestic activities. Mawson Station burns 2.1 megalitres of diesel each year, producing about 5500 tonnes of carbon dioxide.

To address this environmental impact, the Australian Antarctic Division installed two wind turbines in the summer of 2002–03. With an average wind speed of about 40 kilometres per hour, Mawson Station is Australia’s windiest Antarctic station and an ideal location for the use of wind turbines. The turbines could be purchased off the shelf and required only minimal modifications to operate in the Antarctic environment. The turbines generate electricity in wind speeds ranging from 9–100 kilometres per hour and together can produce 600 kilowatts of energy.

Three years after the installation, an annual fuel saving of 29% was achieved, significantly reducing the overall quantity of fuel required by the station, as well as the amount of carbon dioxide emitted. Improvements to the software through which the turbines are operated have further increased the savings. In May 2011, the turbines produced 111 495 kilowatt hours; this is equivalent to a fuel saving of 13 379 litres of diesel and 35 tonnes of carbon dioxide.

Smaller wind generators have been used successfully at field stations. The advantages of using renewable energy sources include a significant reduction in environmental and operating costs, as well as more efficient running of station operations as certain processes are now automated.

Mawson Station with wind turbine (photo by Glenn Jacobson, Australian Antarctic Division, © Commonwealth of Australia)
Fuel use by vehicles is also measured and reported. There are differences in vehicle use in summer and winter (Figure 7.13). During winter, vehicle use tends to be less than in summer—populations at the stations decrease to about 20 people or fewer and vehicles are generally not used in inclement weather. In summer, the station populations increase dramatically and with it maintenance, building and scientific activities. Since the introduction of the airlink, the fuel use at Casey Station has soared in summer and far exceeds fuel consumption at the other stations. Vehicles are required to prepare the ice runway and also to transport people between Wilkins runway (on the plateau behind Casey Station) and Casey Station. During winter, the fuel use at Casey Station is similar to that at the other continental stations. At Macquarie Island, vehicle use is largely limited to the station surroundings on the isthmus.

The quantity of fuel used by ships travelling to Australian Antarctic stations and on marine science voyages differs with variation in shipping demands between years. Marine gas oil (MGO) is a marine version of normal diesel and is used on the vessels to power the main engines and generator sets, to provide propulsion and general services to the

Figure 7.13 Fuel consumption by vehicles on Australia’s Antarctic stations, 2000–11
vessels, such as power and heating. IFO 40 (RMC 10) is a light-grade fuel oil used by some of the Australian Antarctic Division vessels. This fuel is used for the main engines, and in some cases the generators.

**Aircraft operations**

In September 2005, the Australian Antarctic Airlink between Hobart and Casey Station was launched. The maintenance of the Wilkins Aerodrome requires about 10 000 litres of SAB per week (Figure 7.14). The Australian Antarctic Division uses an Airbus A319-115LR for transport between Australia and Antarctica. This airbus was selected in part because it has sufficient range for a return trip from Hobart to Antarctica without refueling in Antarctica. This avoids a range of potential environmental risks associated with the transport, handling and storage of large volumes of jet fuel. Two smaller, ski-equipped CASA 212-400s are used for intracontinental activities in summer. Each summer, there are also two to three single-engine Eurocopter AS-350 helicopters. When required, long-range helicopters (e.g. the Sikorsky S-76) join the fleet to support a variety of biological, glaciological, geological and operational programs. The helicopters also link Davis Station and the Davis Plateau ice airstrip some 20 nautical miles from the station, where the fixed-wing aircraft land when the sea ice runway no longer exists, and provide helicopter services from the icebreaker *Aurora Australis*.

![Australia’s icebreaker RSV *Aurora Australis* cuts through sea ice, Antarctica](Image)

Photo by Doug Thost

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**Figure 7.14** Fuel consumption of fixed-wing aircraft and helicopters operating in the Australian Antarctic program, 2005–06 to 2010–11

Data do not include ground-support fuel consumption.
## State and trends of the station environment

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Person-days on ships and stations</strong></td>
<td>Person-days are a proxy measure for wide-ranging human activities that can interfere with physical, chemical and biological systems. Person-days vary annually depending on the number of scientific and operational projects that are approved</td>
<td>![Assessment grade icon]</td>
<td>![Confidence grade icon]</td>
</tr>
<tr>
<td><strong>Biological oxygen demand</strong></td>
<td>Estimate of the biological oxygen demand of effluent discharged into the ocean from the waste treatment plants at each continental station. Impact of sewage on environment at Davis Station currently under investigation</td>
<td>![Assessment grade icon]</td>
<td>![Confidence grade icon]</td>
</tr>
<tr>
<td><strong>Suspended solids</strong></td>
<td>Amount of organic matter in effluent discharged into the ocean from the waste-treatment plants at each continental station</td>
<td>![Assessment grade icon]</td>
<td>![Confidence grade icon]</td>
</tr>
<tr>
<td><strong>Waste returned to Australia</strong></td>
<td>Composition and weight of waste returned to Australia from Macquarie Island and the continental stations. The amount of waste returned to Australia is dependent upon the cargo limit of the ship and varies between years</td>
<td>![Assessment grade icon]</td>
<td>![Confidence grade icon]</td>
</tr>
<tr>
<td><strong>Incinerated waste</strong></td>
<td>Total weight of material incinerated, and the weights of the major components at all stations, is decreasing as importation of packing materials, for example, is being reduced</td>
<td>![Assessment grade icon]</td>
<td>![Confidence grade icon]</td>
</tr>
<tr>
<td><strong>Fuel use by generators and boilers</strong></td>
<td>Quantity of fuel used by generator sets and boilers at all stations</td>
<td>![Assessment grade icon]</td>
<td>![Confidence grade icon]</td>
</tr>
<tr>
<td><strong>Fuel use by vehicles</strong></td>
<td>Quantity of fuel used for vehicles at all stations is highly variable and depends on the use of vehicles; however, the total quantity of fuel across all stations is increasing</td>
<td>![Assessment grade icon]</td>
<td>![Confidence grade icon]</td>
</tr>
</tbody>
</table>
## Component Summary Assessment grade Confidence

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electricity</strong></td>
<td>Quantity of electricity used; also indicates fuel use</td>
<td>Very poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td></td>
<td>At Mawson Station and Macquarie Island, great savings are being achieved through the use of renewable energy sources</td>
<td></td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Poor</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Good</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very good</td>
<td>Limited evidence or limited consensus</td>
</tr>
</tbody>
</table>

### Fuel use by ships

- **Fuel use of all vessels engaged in transport of goods and people, as well as marine science voyages, varies with year because of differing demands and also variations in sea ice conditions. More fuel is required in years of heavy sea ice.**

### Fuel use by aircraft

- **Although fuel use by fixed-wing aircraft has been highly variable in the past, it has been fairly stable for the past 3–4 years, and has been less than expected due to minimal intrastation flights.**
- **Fuel use by helicopters is reasonably stable.**
- **Fuel use does not include aviation ground-support elements.**

### Recent trends

- Improving
- Deteriorating
- Stable
- Unclear

### Grades

- **Very good:** No risk of pollution and contamination of environment
- **Good:** Low risk of pollution and contamination of environment
- **Poor:** Medium risk of pollution and contamination of environment
- **Very poor:** High risk of pollution and contamination of environment
2.4.2 Contaminated sites and pollution

In the AAT, contaminated sites are largely a relic of the past (before the Madrid Protocol in 1991) when nonburnable rubbish was dumped at various locations near the stations, or was disposed of by leaving it on the sea ice until it broke out. The old rubbish sites contain a variety of materials, including wood, assorted metals and batteries, and hydrocarbons such as fuel oils and lubricants. Because of past practices of dumping on the sea ice, this waste material is in both the terrestrial and nearshore marine environment. Some contaminants are known to be present in quantities that are hazardous to the environment and although they might be frozen in place for much of the year, they can be dispersed and transported away from the dump site into the surrounding environment; for example, by the flush of melt water that occurs each summer as the winter snows retreat. Studies have shown that hydrocarbons have accumulated in the sediment of bays near Casey Station.176-177

The largest potential source of new pollution is the very large quantities of fuel that provide power for stations and vehicles. There is always the risk of oil spill when transporting or storing fuel and this is particularly so in Antarctica, where the climate makes all operations more difficult. Land-based fuel spills, some as large as 90,000 litres, have occurred either through mechanical failures or human error during refuelling or transfer from ship to shore (J Stark, Australian Antarctic Division, pers. comm., April 2011). Occasionally, fuel storage tanks have leaked during winter and the leaks have gone unnoticed until the summer melt reveals that they have drained their contents. Today, all tanks are bunded; that is, the tanks are surrounded by a secondary containment that restricts dispersion of fuel should a leak occur. Hence, the environmental damage is reduced or avoided altogether.

Before a site can be cleaned, it needs to be assessed to determine whether clean-up can be achieved without creating more environmental harm from the disturbance of the site. Chemicals present are identified and their concentrations determined. Currently, a number of tip sites and old fuel spill sites are at various stages of assessment and several fuel spills are being remediated (T Spedding, Australian Antarctic Division, pers. comm., April 2011). Research is also being carried out to determine the maximum possible concentrations of chemicals that will have no measurable impact on the environment—this type of information is commonly used elsewhere in the world as targets for remediation works but, until now, site-specific, risk-based remediation end points have not been available for the Antarctic environment.

Despite the large distances that separate Antarctica from the rest of the world, pollution generated elsewhere on Earth can also travel to Antarctica by air or water. Some persistent organic pollutants, such as the insecticide DDT, can be selectively transported to the polar regions through the process known as global distillation. This process occurs when volatile chemicals evaporate in the warmer places in which they are used and condense in colder places.

The persistent organic pollutants that reach Antarctica by long-distance transport are not yet known to be present in the region in sufficient quantities to cause environmental damage; however, these chemicals do not occur naturally and have toxic properties that can be hazardous to organisms. Antarctica provides an important site for monitoring global background levels of known contaminants that are controlled by the Stockholm Convention on Persistent Organic Pollutants, and also serves as an early warning of the global environmental build-up of new and emerging contaminants.
The Thala Valley tip was used for disposal of waste from ‘Old’ Casey Station. The site is near the current Casey Station and contained waste that accumulated before Australia started returning all waste to Australia in the mid-1980s. The Protocol on Environmental Protection to the Antarctic Treaty 1991 (Annex III, Article I) established an international obligation for past and present waste-disposal sites to be cleaned up by the generators of such waste. The management measures of the protocol are enacted into Australian law through the Antarctic Treaty (Environment Protection) Act 1980, and its associated Regulations.

In the early 1990s, Australia undertook a preliminary assessment of contaminated sites at each of its stations in Antarctica and on Macquarie Island. The Thala Valley tip was identified as a priority because it contained high levels of several pollutants, including heavy metals, hydrocarbons (mostly fuel and lubricants) and some asbestos, and because it was hydrologically active, being in the path of a major melt stream that formed each summer and drained into the adjacent Brown Bay.

Studies were undertaken to identify the contaminants and to find technologies to remove the waste safely (e.g. Snape et al., 178 Townsend et al.179). For example, sediment cores were collected in Brown Bay and analysed for introduced contaminants—70–80% of lead isotopes found in the sediments had leached into the bay from discarded batteries.179 In 2000, suitable remediation technologies were identified for both the onsite environmental management of any remediation works and post-removal treatment of the contaminated waste. This included a custom-designed water-treatment plant capable of separating particulate and dissolved contaminants.178

In October 2003, the Australian Antarctic Division began removing waste and contaminated soil from the site. Approximately 834 tonnes of the most highly contaminated material was returned to Tasmania for treatment and disposal. Approximately 530 tonnes of less contaminated material was excavated and stockpiled for removal in subsequent years.

Final removal of the remaining Thala Valley material was completed in 2010–11 with the assistance of the Chinese Antarctic research expeditions, whose resupply vessel was used to transport the remaining material168—purpose-built containers were filled with the waste and shipped to Fremantle in March 2011. Permission had been obtained from the Western Australian Department for Conservation and Land Management and the Eastern Metropolitan Regional Council to deep-bury the 1005 tonnes of waste returned from Antarctica in 2011 in a Class 4 landfill site. The last burial took place on 7 April 2011.

All works were carried out in accordance with the requirements of Australian quarantine and environmental protection, as well as those of the protocol. The remediated Thala Valley area will be monitored for several years to ensure that remediation goals have been achieved, that site restoration is complete, and to determine whether the previously degraded marine environment of Brown Bay has recovered after removal of the tip.

This project required the Australian Antarctic Division to develop new techniques for remediation of contaminated soils in Antarctica, as well as new ways to monitor the environmental impact. Australia has shared the lessons learned with other nations at a number of international meetings, including the Antarctic Treaty Consultative Meetings, with the hope that this knowledge will assist other Antarctic countries to clean up their contaminated sites.
## Assessment summary

### State and trends of contaminated Antarctic sites

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thala Valley</td>
<td>Terrestrial section of Thala Valley clean-up finalised; some material still left in nearshore and marine environment</td>
<td>Very poor</td>
<td>adequate</td>
</tr>
<tr>
<td>Old Casey Station</td>
<td>Historical fuel spill (1980s)</td>
<td>poor</td>
<td>limited</td>
</tr>
<tr>
<td>Casey Station main powerhouse</td>
<td>Fuel spill at main powerhouse (1999); contaminants reached the melt lake from which fresh water is obtained for the station</td>
<td>poor</td>
<td>limited</td>
</tr>
<tr>
<td>Wilkes Station</td>
<td>Abandoned station (built in 1957); old tip site and fuel cache still present and contain a large volume of contaminated material</td>
<td>poor</td>
<td>limited</td>
</tr>
<tr>
<td>Davis Station tip site</td>
<td>Old tip site</td>
<td>poor</td>
<td>limited</td>
</tr>
<tr>
<td>Mawson Station tip site</td>
<td>Old tip site, large land-based debris removed; some material still left in nearshore marine environment</td>
<td>poor</td>
<td>limited</td>
</tr>
<tr>
<td>Macquarie Island fuel farm</td>
<td>Historical fuel spill (1980s)</td>
<td>good</td>
<td>adequate</td>
</tr>
<tr>
<td>Macquarie Island main powerhouse</td>
<td>Historical fuel spills (1980s–2000)</td>
<td>very good</td>
<td>adequate</td>
</tr>
</tbody>
</table>

### Recent trends

- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

### Grades

- **Very good**: Remediation activities completed; remediation monitoring continues
- **Good**: Remediation in progress and/or containment of contaminants achieved
- **Poor**: Preliminary impact assessment under way including identification of contaminants
- **Very poor**: No action yet

### Confidence

- **Adequate high-quality evidence and high level of consensus**
- **Limited evidence or limited consensus**
- **Evidence and consensus too low to make an assessment**
2.5 Heritage values

Antarctica’s unique environment is internationally recognised, and a wide range of its heritage values are protected under the Madrid Protocol. In addition to the general, continent-wide protection provided by the protocol, extra levels of protection can be applied to areas of outstanding environmental, scientific, historic, aesthetic or wilderness values by a range of frameworks (Table 7.1); for example, by designating them as Antarctic Specially Protected Areas. Sites of particular significance to Australia have also been added to the national heritage lists. Australia’s subantarctic islands, which do not come under the Antarctic Treaty, are on the World Heritage List.

2.5.1 Natural heritage

Australia’s two subantarctic islands or island groups, Heard Island and McDonald Islands in the Southern Ocean and Macquarie Island in the southwest Pacific, were listed on the World Heritage List and the National Heritage List in 1997 and 2007, respectively, because of their ‘outstanding natural universal values’. The inclusion of these areas on the World Heritage List underlines not only the physical and natural values these islands represent, but also their international importance. Moreover, these islands are significant for Australia’s Antarctic history, as both contain sites of cultural heritage value. Heard Island and McDonald Islands are Australian territory and are managed through the Australian Antarctic Division. Macquarie Island is part of Tasmania and in the care of the Tasmanian Parks and Wildlife Services. However, the division coordinates and manages the maintenance of the station and field huts, as well as logistic operations.

Australia also manages 11 Antarctic Specially Protected Areas, including one at Commonwealth Bay (see Section 2.5.2), as well as two Antarctic Specially Managed Areas (ASMAs): Commonwealth Bay (ASMA 03) and the Larsemann Hills (ASMA 06).

| Table 7.1 Status of listings of Australia’s natural and historic heritage in Antarctica |
|----------------------------------|--------------------------------------------|---------------------------------|---------------------------------|
| Site                            | Register of the National Estate | National Heritage List | Commonwealth Heritage List | World Heritage List |
| Natural and historic             |                                  |                               |                               |                      |
| Heard Island and McDonald Islands | Registered 1983                  | Listed 2007                  | Indicative property; formal nomination not made | Declared 1997         |
| Historic                         |                                  |                               |                               |                      |
| Mawson’s Huts and Mawson’s Huts Historic Site | Registered 2002 | Listed 2005 | Listed 2004 |                      |
| Wilkes Station                  | Indicative property; formal nomination not made | | | |
| Davis Station                   | Registered 1999                  |                               | Indicative property; formal nomination not made |                      |
| Mawson Station                  | Registered 2001                  |                               | Listed 2004                   |                      |
2.5.2 Historic heritage

Significant sites associated with cultural heritage can be found in the AAT, on Heard Island and Macquarie Island in the Southern Ocean. There are four key types of cultural heritage sites in the region,\(^{182}\) associated with:

- early scientific endeavour and exploration (1911–14)
- the sealing industry on Heard Island and Macquarie Island
- the British, Australian and New Zealand Antarctic Research Expedition (1929–31)
- Australian National Antarctic Research Expeditions and agencies of other nations that established research stations in the AAT after World War 2.

Any conservation work on the historic sites is assessed for its impact under the Antarctic Treaty Environment Protection Act 1980. The Environment Protection and Biodiversity Conservation Act 1999 also has application, because wildlife occurs within the protected areas. Rather than being managed onsite, some artefacts are recovered from Antarctica for conservation treatment or protection. These artefacts include books, clothing, scientific and mechanical devices, field equipment and many others that, if left in situ, would deteriorate and be lost. These items are catalogued in the Antarctic Heritage Register housed in the data centre of the Australian Antarctic Division.\(^{5}\)

One of Australia’s most important historic sites of international significance is Mawson’s Huts, which were erected at Cape Denison, Commonwealth Bay, in 1911 by the men of the Australasian Antarctic Expedition under the leadership of Sir Douglas Mawson. The expedition was the first major and, as it turned out, most dramatic, scientific program of the young nation and, at the time, was important for the application of new technologies, such as the use of wireless transmissions between Antarctica and the outside world via a relay post at Macquarie Island. The expedition collected a wealth of biological, magnetic, geological and meteorological data.

The base that Mawson and his team established at Cape Denison in 1912 was never intended to be a long-term establishment. While the huts were solidly built and survived the Antarctic conditions for many decades, wind ablation and snow intrusion have taken their toll and the structural elements of the site have been deteriorating since their construction. The main hut and the magnetograph house are in sound condition, and the integrity of their interiors is high. In 1998, the magnetograph house was altered by timber cladding on the roof. The transit hut and absolute magnetic hut are in poor condition; both huts have been stabilised to preserve them as standing ruins. The Memorial Cross is in good condition.\(^{183}\) Most of the portable artefacts outside the huts are still in the same locations they were in when Mawson left the site in 1914.\(^{182,184}\)

In 2005, the Australian Government registered the four huts on Australia’s National Heritage List as Mawson’s Huts and Mawson’s Huts Historic Site and launched a conservation management plan to protect the site. The management plan was also a requirement under the Madrid Protocol, as the site had been proposed to be nominated as a Historic Site and an Antarctic Specially Managed Area (ASMA 03). Furthermore, the site was declared an Antarctic Specially Protected Area (ASPA 162) embedded within the ASMA, to afford further protection. All access and activities within the ASPA are regulated by a permit system.

In addition to Mawson’s Huts, several sites within the AAT are formally protected under the Antarctic Treaty System through their designation as historic sites and monuments (Table 7.1). These include buildings at Mawson and Davis stations, and rock cairns erected by Sir Douglas Mawson at Proclamation Island, Enderby Land and Cape Bruce. Another cairn erected by Sir Hubert Wilkins in 1939 is located in the Vestfold Hills, Ingrid Christensen Coast. A further nine historic sites and monuments have been declared under Antarctic Treaty provisions to protect sites of significance to the United States and Russia.

Most sealing industry sites are on the coast and at risk from the effects of the extreme weather, climate change and a dynamic coastline, as well as human interference and encroachment by vegetation. At Heard Island, a significant amount of cultural heritage material has been lost or has had to be relocated since recording of the cultural heritage began in the mid-1980s. Many of the portable artefacts are slowly deteriorating and only have a limited lifespan.\(^{185}\) Many sites on Macquarie Island are now partially buried. Shipwreck material, structural elements and portable artefacts are slowly deteriorating.\(^{182,186-187}\) Ruins of the masts and huts on Wireless Hill survive but are deteriorating.\(^{182,187-188}\) One of the remaining masts was removed in 2011.

Most Australian National Antarctic Research Expedition buildings at Buckles Bay are intact and in good condition.

\(\text{d data.aad.gov.au/aadc/artefacts}\)
## State and trends of listed or specially protected sites in Antarctica

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heard Island and McDonald Islands</td>
<td>Retreating glaciers open potentially new habitat for flora and fauna; visits to the island are infrequent, making monitoring difficult</td>
<td>Poor</td>
<td>?</td>
</tr>
<tr>
<td>Macquarie Island</td>
<td>Rodent and rabbit eradication program began in 2010 is ongoing; if successful, the island is largely expected to be able to restore itself</td>
<td>Poor</td>
<td>🟢 🟢</td>
</tr>
<tr>
<td>Taylor Rookery (ASPA 101)</td>
<td>Contains one of only three known emperor penguin colonies located on land. The population of penguins has been monitored annually since 1988 and some historical information is also available</td>
<td>Poor</td>
<td>🟢 🟢</td>
</tr>
<tr>
<td>Rookery Islands (ASPA 102)</td>
<td>Six different seabird species are breeding on the islands. A very small colony of southern giant petrels is one of only four known colonies in East Antarctica</td>
<td>Poor</td>
<td>🟢 🟢</td>
</tr>
<tr>
<td>Ardery Island and Odbert Island (ASPA 103)</td>
<td>These islands provide breeding habitat for several species of petrel and are examples of their habitat. Visits to the islands are infrequent and no regular census work is done</td>
<td>Poor</td>
<td>🟢 🟢</td>
</tr>
<tr>
<td>North-East Bailey Peninsula (ASPA 135)</td>
<td>Scientific reference site for vegetation typical of the area. A number of flora studies were conducted in the 1980s. Changes to snow availability appear to put local vegetation under water stress</td>
<td>Poor</td>
<td>🟢 🟢</td>
</tr>
<tr>
<td>Clark Peninsula (ASPA 136)</td>
<td>Designated to protect the largely undisturbed terrestrial ecosystem that includes associations of macrolichens and bryophytes. There is also a colony of Adélie penguins. Possibly similar issues with regard to water resources as ASPA 135, but so far there is insufficient evidence</td>
<td>Poor</td>
<td>🟢 🟢</td>
</tr>
<tr>
<td>Marine Plain (ASPA 143)</td>
<td>The area is representative of an important ice-free terrestrial ecosystem. The area contains important sites for studying the palaeoecology and palaeoclimate</td>
<td>Poor</td>
<td>🟢 🟢</td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
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<tr>
<td>-----------</td>
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</tr>
<tr>
<td><strong>Frazier Islands</strong> &lt;br&gt;(ASPA 160)</td>
<td>A group of three small islands, all of which are occupied by a variety of seabirds, including small colonies of southern giant petrels. Trends are difficult to estimate because of a lack of data; a significant change in the population size cannot be demonstrated.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Scullin and Murray Monoliths</strong> &lt;br&gt;(ASPA 164)</td>
<td>The greatest concentrations of breeding seabirds in East Antarctica are found here; bird numbers range from tens to hundreds of thousands. Their remote location makes regular visits impossible.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hawker Island</strong> &lt;br&gt;(ASPA 167)</td>
<td>The declaration of this area as an ASPA meant that all colonies of southern giant petrels in the Australian Antarctic Territory are now protected.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amanda Bay</strong> &lt;br&gt;(ASPA 169)</td>
<td>The only large emperor penguin colony in Prydz Bay is located here. In the past, few visits were made to this area and insufficient information is available to predict a trend.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Larsemann Hills</strong> &lt;br&gt;(ASMA 06)</td>
<td>Two major peninsulas represent a significant part of the ice-free fraction of East Antarctica. Two permanently occupied non-Australian stations exist there and a third is under construction.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Recent trends**<br>Improving  | Deteriorating  | Stable  | Unclear  | Confidence  |
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate high-quality evidence and high level of consensus</td>
<td>Limited evidence or limited consensus</td>
<td>Evidence and consensus too low to make an assessment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Grades**<br>Very good  | Good  | Poor  | Very poor  | Component in excellent state and management plan in place  | Component is undergoing conservation work if needed and/or management plan in place  | Component in poor condition but can be rescued; no management plan in place  | Heritage component is damaged beyond repair  |

**ASMA** = Antarctic Specially Managed Area; **ASPA** = Antarctic Specially Protected Area.
### Assessment summary

**State and trends of the historic heritage in Antarctica**

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mawson’s Huts (ASPA 162), Commonwealth Bay (ASMA 03)</td>
<td>Site undergoing extensive conservation work in accordance with the management plan</td>
<td>Poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td>Old Mawson Station</td>
<td>Management plan is being prepared; Biscoe hut restoration nearly completed</td>
<td>Good</td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td>Old Davis Station</td>
<td>Donga line removed; a number of buildings currently under repair; Ongoing routine maintenance</td>
<td>Poor</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
<tr>
<td>Heard Island and McDonald Islands</td>
<td>Oil barrels and sealers graves deteriorating; visits are infrequent, making monitoring activities challenging; A management plan is in place</td>
<td>Very poor</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
<tr>
<td>Macquarie Island</td>
<td>A number of old structures removed, but the remains of oiling and sealing tryworks are still on the island</td>
<td>Very poor</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
</tbody>
</table>

**Recent trends**

- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

**Confidence**

- **Adequate high-quality evidence and high level of consensus**
- **Limited evidence or limited consensus**
- **Evidence and consensus too low to make an assessment**

**Grades**

- **Very good** Component in excellent state; management plan in place
- **Good** Component is undergoing conservation work; management plan in place
- **Poor** Component in poor condition but can be rescued; management plan in place
- **Very poor** Heritage component is damaged beyond repair

ASMA = Antarctic Specially Managed Area; ASPA = Antarctic Specially Protected Area
Pressures affecting the Antarctic environment

As detailed in Chapter 2: Drivers, the key drivers on the environment are population and economic growth, and climate change. Antarctica, as the only continent without a native human population, has been subjected to less pressure from human activities than other continents. However, the southern continent and its surrounding seas and islands have not escaped the effects of these activities. For example, the atmosphere above Antarctica experienced a major change due to the release of chlorofluorocarbons in the 20th century, which resulted in the development of the ozone hole. The establishment of permanent stations impacts on the local environment, and pollution elsewhere on our planet finds its way even to Antarctica: traces of DDT and its derivatives were discovered in the shells of Adélie penguin eggs in the mid-1960s. A number of vertebrate populations were hunted to near extinction, and economic activities such as fishing and tourism have all had an impact.

What is most likely to have the most lasting impact is the increasing amount of carbon dioxide produced by human activities. The Southern Ocean is absorbing vast quantities of carbon dioxide, leading to a change in the ocean’s chemistry that has the potential to affect organisms and their lifecycles in a variety of ways. Increased atmospheric carbon dioxide is also producing climate change. We have seen a warming of surface temperatures initially restricted to the Antarctic Peninsula, where surface temperatures increased by 0.56 °C per decade over the past 50 years, while the global temperature increase averaged 0.13 °C per decade. This warming has led to the collapse of most of the ice shelves in the peninsula region, retreating glaciers and a decrease in the extent of sea ice in the Bellingshausen Sea.

Until recently, East and West Antarctica appear to have responded differently to the influences of climate change (see Section 2.1.2). While only West Antarctica experienced warming conditions for several decades, changes in near-surface temperatures across the entire continent have now been estimated at 0.12 ± 0.10 °C per decade. Increasing air and ocean temperatures cause changes in snow-fall patterns, which in turn affect the quality of sea ice, as well as its extent and durability. For example, near Davis Station, a long-term monitoring study of sea ice detected a delay in the time when the maximum thickness is reached by the fast ice, and attributed this trend to the warmer winters in recent years.

Assessing the overall impact that climate change will have on Antarctic systems is difficult, however, because there is a lack of data for large parts of the continent; timeseries tend to be too short or available only for a small number of locations. The processes driving weather patterns and underlying climate change are complex, because they can operate on different time and spatial scales, and may lead to positive or negative feedback loops as they either increase or counteract each other.
Connections between, for example, atmospheric and oceanographic phenomena are also still poorly understood.

Similarly, while it is highly likely that climate change will alter ecosystems, the processes involved are complex and not fully understood. Currently available biological models are even less sophisticated than physical ones; models of the Southern Ocean’s food webs fall short in linking dynamics at the base of the food web to physical models of the oceans. Predicting how organisms will respond individually or collectively to climate change and other human-induced pressures is a major challenge of research today. We do not know which species may be able to adapt to the evolving environment through genetic responses. Some organisms may benefit from the effects of climate change—at least in the short term. For example, more ice-free areas offer a potential habitat for plants and animals. However, the long-term consequences are hard to predict.

The restoration of ozone levels will also have a profound effect on the region. The ozone hole is expected to vanish in the next three decades. This will reduce ultraviolet levels, to the advantage of many species (see Section 2.3.1). Ultraviolet radiation was 55–85% higher at the South Pole during 1991–2006 compared with 1963–80.40 However, the ozone hole has largely protected East Antarctica from global warming. The loss of stratospheric ozone cooled and changed the atmospheric circulation. A recovery of the ozone hole will reverse these processes and significantly increase the warming trend in East Antarctica.

### 3.1 Pressures on the marine environment

The water chemistry of the Southern Ocean appears to be changing at a faster rate than previously estimated, particularly in the deep ocean layers. In the cold Southern Ocean, carbon dioxide is being sequestered at a higher rate than in subtropical waters. Increases in carbon dioxide cause an acidification of ocean waters that make it difficult for shell-building organisms to extract the calcium they need from the ocean (see Section 2.3.1).

Changes in the physical ocean environment are likely to affect the ocean’s productivity, which influences the survival of higher order predators. However, the degree and nature of the effects of global warming on various levels of productivity, as well as on ocean circulation and chemistry, are still unclear. These uncertainties limit the degree to which we can predict the effects of changes in the physical environment and biological production, the rate and direction of change, or the relative importance of various pressures.

#### 3.1.1 Marine species

Wildlife populations have been exposed to change in their environment throughout the history of our planet. Some extreme events led to mass extinctions. However, other changes (for example, changes in atmospheric carbon dioxide) took place slowly over centuries or longer, and often enabled vertebrate species to evolve certain adaptive traits. By contrast, the current climate change is occurring at an unprecedented and increasing rate, leaving many species vulnerable because their capacity to adapt operates much more slowly. Also, the changes are not constant but often vary with region and may differ in their timing and scale. Species differ significantly in their ability to adapt, their generation time and longevity, reproductive output and success, and more. A particular problem occurs where the lifecycle of a prey species loses its synchronicity with dependent predators and food becomes less available at key times (e.g. onset of breeding, weaning or fledging of young). The inherent differences of species, plus a lack of understanding of how various environmental factors may interact, make it almost impossible to predict the fate of particular species and populations.

Organisms can react to their changing environments in three main ways:

1. Species shift to areas where the conditions are still similar to those they encountered previously and where adaptations are not required. Movement of species at the Antarctic Peninsula is possible: as the northern parts become warmer, affected species may move further south. However, the size of the Antarctic continent and access to food limit how far they can go. In the southern Indian Ocean, wildlife populations breeding on the subantarctic islands have far fewer options to move south, because there is no intermediate location between the islands and the Antarctic continent. Thus, if they were to shift their distribution, they may have to endure colder conditions than they have so far experienced.
Species adapt to live under warmer and perhaps more marginal conditions at their current breeding locations. This might require a shift in their behaviour and physiology to allow them to adjust, for example, the timing of their breeding season, the growth rate of their offspring or even the age of first breeding. In all likelihood, these changes would require a change in their genetic make-up. Which strategy species ultimately choose depends on their degree of adaptability, as well as the rates of change of the various parameters.

If species fail to move or to adapt to their altering environment, they will become extinct. Some species are clearly more threatened by the environmental changes than others.

The effects of ocean acidification are likely to have severe biological impacts within decades and could dramatically affect the structure and function of marine ecosystems. Such changes would have profound effects on ecosystem services, including the productivity of fisheries. These changes are most pronounced in the polar regions where the acidity of the water is changing twice as fast as in warmer, tropical and subtropical regions.

Antarctic invertebrate communities form a significant part of the marine food web. The responses by invertebrates to ocean acidification are expected to vary with species. Experimental work on temperate marine organisms has demonstrated a wide variety of responses ranging from potentially positive effects, such as increased metabolic rates in autotrophs (organisms that produce their own food from inorganic sources) to negative effects, such as decreased growth rates in sea urchins (see Hendriks et al. for review). Ocean acidification affects the life stages of organisms in different ways. For example, fertilisation of the Antarctic nemertean (ribbon) worm (Parborlasia corrugatus) may not be affected by a lowering of the pH, and experimental work showed that even egg development appeared resilient when seawater pH was reduced to neutral. However, abnormalities occurred at a later stage (blastula stage) of the embryos’ development. While the pH changes that produced the abnormalities are not predicted to occur in the near future (by 2100) they are expected if the oceans continue to acidify in the long term (by 2300).

The benthic invertebrate communities of Antarctica, especially those living outside the intertidal zone, exist in a very stable environment where temperatures fluctuate—for example, in the high Antarctic—as little as 1.5 °C throughout the year. These stenothermal (narrow temperature) environments came into existence about 4–5 million years ago as the waters surrounding Antarctica cooled. How a warming of the ocean may affect organisms adapted to live in a very narrow temperature range is difficult to predict. Many invertebrates die or cannot perform crucial biological activities when temperatures are raised 5–10 °C. However, these results are based on experiments during which temperatures are increased rather quickly. The more gradual the environmental change, the better are the chances of at least some species adapting to the modifying conditions.
### Assessment summary

**Pressures affecting Antarctic marine species**

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increases in ocean carbon dioxide</strong></td>
<td>Primary production by some species may increase up to 19%, but overall increase is likely to be small</td>
<td>High impact</td>
<td></td>
</tr>
<tr>
<td><strong>Ocean acidification</strong></td>
<td>Concentrations of nutrients and rates of calcification will decrease, causing changes in microbial composition, production and nutritional value</td>
<td>High impact</td>
<td></td>
</tr>
<tr>
<td><strong>Ultraviolet B radiation</strong></td>
<td>Interspecific differences in response but can reduce production, slow growth, limit survival and change species composition</td>
<td>High impact</td>
<td></td>
</tr>
<tr>
<td><strong>Sea surface temperature</strong></td>
<td>Surface warming may increase stratification, increase exposure to ultraviolet B radiation, reduce surface nutrient supply and change interactions among key species, causing changes in microbial composition and production. A latitudinal shift in productivity is predicted. There is also increased potential for invasion of alien species</td>
<td>High impact</td>
<td></td>
</tr>
<tr>
<td><strong>Sea ice extent</strong></td>
<td>Regional differences exist. Decreases in sea ice may reduce microbial food available to grazers (e.g. krill) and carbon dioxide draw-down; altered light climate will favour earlier, weaker blooms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Summary</td>
<td>Assessment grade</td>
<td>Confidence</td>
</tr>
<tr>
<td>----------------------</td>
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<td>------------</td>
</tr>
<tr>
<td>Sea ice thickness</td>
<td>Thinning alters the light regime; higher light intensities may reduce productivity of light-sensitive species</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marine pollution</td>
<td>Persistent organic pollutants and inorganic pollutants from local and exogenous sources exist; some are expected to increase and may have direct and indirect toxicological effects on Antarctic organisms Near the stations, the impact is localised and comes mainly from old tip sites</td>
<td></td>
<td><img src="confidence.png" alt="Confidence" /></td>
</tr>
</tbody>
</table>

**Recent trends**
- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

**Confidence**
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Grades**
- **Very low impact** Communities are not affected by changes; operate at maximal reproductive capacity
- **Low impact** Few communities are affected and operate below maximal reproductive capacity; structure and function of system/community not impaired
- **High impact** Some communities are affected and operate well below maximal reproductive capacity; structure and function of system/community impaired
- **Very high impact** Affected communities barely functional
3.1.2 Commercial fisheries

The largest commercial fishery in the Southern Ocean is for Antarctic krill. This fishery is currently concentrated in the South Atlantic Ocean and there is currently no krill fishery in East Antarctica—although there was one from 1974 to 1995. CCAMLR has recently received expressions of interest from fishing companies to fish for krill off the AAT. In 1996 and 2006, the Australian Antarctic Division conducted two major marine science voyages (BROKE in 1996, BROKE-West in 2005–06) to examine the distribution and abundance of krill in East Antarctic waters, and found quantities that could sustain commercial activities. The results of these surveys were used by CCAMLR to set precautionary catch limits on the krill fishery off most of the AAT (80°E to 150°E).

Australian fishing efforts for Patagonian toothfish and, to a lesser extent, mackerel icefish are concentrated around subantarctic Heard Island and McDonald Islands, and Macquarie Island. Commercial fishers operate throughout the year on Heard Island and McDonald Islands, and fishing activities are regulated by the Australian Fisheries Management Authority through CCAMLR. The fishery around Macquarie Island is also managed by the authority because the island falls outside the jurisdiction of CCAMLR, although CCAMLR-like procedures are adopted. Licensed vessels in the subantarctic fisheries show a very high degree of compliance to licence conditions. Australia undertakes regular fish stock assessments for the Heard Island and McDonald Islands region and catch limits, based on the best scientific information available, are adopted through the CCAMLR process.

In the Indian Ocean, illegal, unregulated and unreported (IUU) fishing is currently a significant problem in the high seas off Antarctica and outside the Australian exclusive economic zone at Heard Island and McDonald Islands. Bottom longliners and gillnetters exploit toothfish on the continental slope and submarine banks. In the absence of actual catch rates, it is difficult to determine how much fish is caught by illegal vessels. Based on the best available information, the estimated weight of IUU catches in the entire CCAMLR area was 1615 tonnes in the 2009–10 fishing season (1 December 2009 – 30 November 2010). Of this, about 1340 tonnes were caught in the region that includes the waters off the AAT and Australia’s subantarctic islands. This was four times as much as had been estimated in the previous season.

While fishing and the legal or illegal extraction of resources is itself a pressure on the Antarctic environment and its species, a number of pressures also affect the fisheries. These include the results of climate change as discussed above, particularly ocean acidification, and other anthropogenic factors, such as pollution.
# Assessment summary

## Pressures affecting Antarctic fisheries

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extraction of biotic resources</td>
<td>Rapidly increasing catches of krill and new fishing technologies threaten to outstrip the ability to sustainably manage fisheries</td>
<td>Very high impact</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td>Illegal, unregulated and unreported fishing</td>
<td>Remains a serious problem in the Southern Ocean; impact is difficult to ascertain with accuracy, but it threatens the sustainability of harvested and dependent species</td>
<td>Very high impact</td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td>Ocean acidification</td>
<td>Some marine organisms already affected by ocean acidification, including reduced calcification of shells and exoskeletons; current impact is probably low but expected to lead to measurable changes in the Southern Ocean ecosystem and change in species composition</td>
<td>Very high impact</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
</tbody>
</table>

### Recent trends

- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

### Grades

- **Very low impact**: There are few short-term, reversible impacts from this factor
- **Low impact**: There are transitory impacts from this factor but locally restricted
- **High impact**: There are significant impacts from this factor that may become irreversible in future and become effective regionally
- **Very high impact**: There are predicted significant impacts from this factor that are irreversible and impact is regional
3.2 Pressures on the terrestrial environment

As for the marine environment, pressures on the terrestrial environment operating on a global scale include anthropogenic climate change (e.g. atmospheric warming and changes to water regimes), while local pressures include the introduction of alien species and impact from human activities.

Climate change impacts in Antarctica and the subantarctic include changes in trends in climate parameters (such as air temperature, precipitation and wind speed), as well as increased frequency and impact of extreme or pulse events. Both are regionally specific. In Antarctica, flooding from an extreme summer warming event in 2002 altered species abundances in nematode communities in the Dry Valleys, and an extreme warming event in the winter of 2009 negatively impacted moss communities in the Windmill Islands (M Ball, Australian National University, pers. comm., April 2011).

The introduction of alien species has significantly altered the landscape, composition of ecosystems, and species interactions on many subantarctic islands not under Australian jurisdiction. Studies of the flora at the French subantarctic Kerguelen Island date back to 1874 when three introduced plants were collected. Large-scale surveys mainly in the 1970s and 1980s discovered a total of 168 introduced plant species on Possession, Kerguelen and Amsterdam islands. During a survey in 2000, 118 of these were still present. On some islands, the alien species are well established and outnumber the native species. For example, at Kerguelen Island, 68 introduced plant species were present in 2000 compared with only 14 native species. In addition, there are 30 known invertebrate alien species.

On Australia’s Macquarie Island, there are only 3 alien plant species but 28 alien invertebrate species. Recent research has suggested that the presence of some alien invertebrates has a negative impact on native invertebrate species richness and density. Australia’s McDonald Island appears to be the only island in the subantarctic that is free of introduced species. Nearby Heard Island has one known alien plant, the grass *Poa annua*, and three invertebrate species: the earthworm *Dendrodrilus rubidus*, the mite *Tyrophagus putrescentiae* and the small thrips *Apterothrips apteris*, but no introduced vertebrates.

Climate change and the intrusion of invasive species may combine as pressures. As global warming progresses and ambient temperatures rise, non-native species formerly unable to survive in the region may now be capable of establishing themselves and outcompeting the native organisms. New species that become established in a warming environment tend to be more competitive than native species because of better dispersal mechanisms or lack of predators, or may occupy niches that previously did not exist. Under such circumstances, food webs and ecosystem functioning could be altered dramatically (e.g. *Convoy & Lebouvier*).

Decaying iceberg and Antarctic petrels, Southern Ocean
Photo by Doug Thost
## Pressures affecting the Antarctic terrestrial environment

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Changes in ambient temperature</strong></td>
<td>At the Antarctic Peninsula, populations of two native flowering plants are expanding rapidly; similar observations have been made on subantarctic islands where ice-free areas are increasing; composition of plant assemblages may change</td>
<td><img src="Image" alt="Assessment Grade" /></td>
<td><img src="Image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>Changes in water availability</strong></td>
<td>In East Antarctica, mosses are drying out rapidly due to ice melt and channel run-off away from existing moss beds</td>
<td><img src="Image" alt="Assessment Grade" /></td>
<td><img src="Image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>Introduction of alien species and pathogens</strong></td>
<td>Invasive species can have a devastating effect on endemic species and communities. The eradication program currently under way at Macquarie Island will have a positive effect on seabird populations. Further warming of the atmosphere may help pathogens to become established</td>
<td><img src="Image" alt="Assessment Grade" /></td>
<td><img src="Image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>Erosion</strong></td>
<td>More ice-free areas are likely to suffer from erosion, especially on subantarctic islands</td>
<td><img src="Image" alt="Assessment Grade" /></td>
<td><img src="Image" alt="Confidence" /></td>
</tr>
<tr>
<td><strong>Pollution</strong></td>
<td>Deposition of solid and liquid wastes can impact both terrestrial and marine communities. Impacts tend to be localised, but pollutants are also received from nonlocal sources and are likely to contaminate much larger regions</td>
<td><img src="Image" alt="Assessment Grade" /></td>
<td><img src="Image" alt="Confidence" /></td>
</tr>
</tbody>
</table>
### Wildlife disturbance

**Summary**: Increased visitation puts pressure on wildlife populations; with increasing demands to see wildlife, more areas may be visited more frequently and in greater numbers.

**Assessment grade**

- **Very high impact**: Increased visitation puts pressure on wildlife populations.
- **High impact**: With increasing demands to see wildlife, more areas may be visited more frequently.
- **Low impact**: More areas may be visited more frequently and in greater numbers.
- **Very low impact**: In grade.

**Confidence**

- **Adequate high-quality evidence and high level of consensus**
- **Limited evidence or limited consensus**
- **Evidence and consensus too low to make an assessment**

**Recent trends**

- **Improving**
- **Deteriorating**
- **Stable**
- **Unclear**

**Grades**

- **Very low impact**: There are few short-term, reversible impacts from this factor.
- **Low impact**: There are transitory impacts from this factor but locally restricted.
- **High impact**: There are significant impacts from this factor (may be cumulative); impacts are regional and may become irreversible in future.
- **Very high impact**: There are predicted significant impacts from this factor that are irreversible; impact is regional.
3.3 Pressures on Antarctic historic heritage

The buildings and structures that make up Australia’s historic heritage were built up to 100 years ago. At the time of their construction, they were built to last only a few years (e.g. Mawson’s Huts at Commonwealth Bay). It was never anticipated that they would still be standing a century later and considered a valuable part of Australia’s Antarctic heritage.

The building materials are vulnerable to deterioration and the greatest threat to the integrity of the buildings and structures lies in the natural elements. Wind, weather, frost, ice and melt water all contribute to the deterioration of buildings. Corrosion, fungal growth, wind and snow loads, exposure to ultraviolet radiation, the freeze–thaw cycle and high relative humidity inside the main hut affect the conservation of structures and artefacts. An artefacts conservation program was instigated in 2008.

The illegal removal of artefacts is also a concern. All visitors require permits if they intend to visit the island; however, the region’s remoteness—which has protected its natural values—also makes it extremely difficult to control unauthorised access. For example, fishers on illegal fishing vessels operating in the area may visit and remove artefacts.

On the subantarctic islands, the maritime climate promotes corrosion of metal artefacts. Wooden items are abraded by windborne sand and salt particles. Disturbance by wildlife, land erosion and slippage is also a potential problem, as is erosion and exposure of artefacts. Cultural heritage on the islands may also be damaged by volcanic and seismic activities. Seismic activity has been identified as a specific threat to structures on Macquarie Island, although most of the research expedition buildings have been built to withstand tremors.

Heard Island is a long way from Australia and caring for the components of historic heritage on the island is an enormous challenge. The cultural heritage of Heard Island is conserved through a process of managed decay. This is a pragmatic management option, which acknowledges the practical impossibility of conserving all elements of the cultural environment in a remote area where access is extremely limited. Permitted visits are highly infrequent and tend to be restricted to the short summer. The management plan states that heritage values, such as buildings, are and have been in a greatly deteriorated state for a long time and are permitted to disintegrate under the influences of weather and climate.

There are several sealers’ graves in the south-eastern part of the island, not far from a large king penguin colony. The vegetation cover is dense and continues to engulf and cover the old graves.

A specific risk to Heard Island is the changing coastline. For example, wooden oil barrels that were left by sealers at Oil Barrel Point have disappeared steadily over the past few decades as the barrels have eroded out of the beach cliff. Fewer than a quarter of those recorded in the 1980s are still in place.
### 7.13 Assessment summary

#### Pressures affecting Antarctic historic heritage

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt water</td>
<td>Fine snow particles penetrate the buildings and fill the buildings; causes structural damage and damage to artefacts</td>
<td>Very high impact</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td>Wind</td>
<td>Can limit conservation work and destroy weakened structures</td>
<td>High impact</td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td>Climate change</td>
<td>Increased wind strength and frequency of storms puts pressure on huts</td>
<td>Low impact</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
<tr>
<td>Coastal erosion</td>
<td>Dynamic coastline at Heard Island changes and threatens some artefacts</td>
<td>Very low impact</td>
<td>Exiting</td>
</tr>
<tr>
<td>Fauna and flora</td>
<td>Wildlife such as elephant seals can exert considerable impact when they move across sites</td>
<td>Very high impact</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
<tr>
<td></td>
<td>Overgrowth by plants on subantarctic islands can lead to obscuring of items, such as the headstones of graves at Heard Island</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unauthorised</td>
<td>Could occur at Heard Island; unauthorised visits possibly occur</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Recent trends</th>
<th>Improving</th>
<th>Deteriorating</th>
<th>Stable</th>
<th>Unclear</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grades</td>
<td>Very low impact</td>
<td>Low impact</td>
<td>High impact</td>
<td>Very high impact</td>
<td></td>
</tr>
</tbody>
</table>

- **Very low impact**: Component is hardly impacted by factor and requires no further conservation efforts
- **Low impact**: Factor impacts on part of the component and may require further conservation efforts
- **High impact**: Factor impacts component moderately and requires further conservation efforts
- **Very high impact**: Factor impacts component significantly and limits further conservation efforts
Effectiveness of Antarctic management

Continually improving the environmental management of Australia’s activities and encouraging other states active in Antarctica and the Southern Ocean to do likewise is one of Australia’s key Antarctic management priorities.

There are four main types of human activities in the Antarctic region: fisheries, national Antarctic programs, commercial tourism and other nongovernmental activities, such as private expeditions. The Australian Antarctic Division administers Australia’s national Antarctic program, which focuses mainly on the East Antarctic region of the continent but also Australia’s subantarctic islands and the Southern Ocean. Other countries, for example China, India, Japan, Norway and Russia, also operate in East Antarctica, including within the AAT. Tourism, including by Australian tour operators, occurs mostly in the Antarctic Peninsula region away from the Australian national Antarctic program’s main areas of interest.

The Antarctic region and the Southern Ocean are remote from the Australian administrative head office so that management is effectively by ‘remote control’. This poses some unique challenges for Antarctic management and emphasises the importance of an effective environmental management regime.

4.1 Governance

As detailed in Section 1.3, the Antarctic Treaty System is the primary international governance framework for the Antarctic region. Australia’s engagement within the international forums of the Antarctic Treaty System supports Australia’s objectives for protection and management of the Antarctic region, including the AAT, as do a number of pieces of legislation within Australia. Other legislation and organisations are specifically responsible for managing the marine environment.

4.1.1 International engagement

Internationally, Australia has taken a leading role in promoting environmental protection within the Antarctic Treaty System since its inception. Australia actively participates and leads discussions in key Antarctic international forums that include the Antarctic Treaty Consultative Meeting, the Committee for Environmental Protection, CCAMLR, the Council of Managers of National Antarctic Programs, and the Agreement on the Conservation of Albatrosses and Petrels.

4.1.2 Australian legislation

The obligations contained within Australia’s international agreements are incorporated into Australian domestic law. The legal regime for the AAT is established in the Australian Antarctic Territory Act 1954. The Antarctic Treaty Act 1960 gives effect
to the Antarctic Treaty. Other Australian legislation implements parts of the Antarctic Treaty System into Australian law, including the Antarctic Treaty (Environment Protection) Act 1980, which gives effect to the Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol) and sets out environmental protection obligations for all activities in the Antarctic Treaty area. The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) applies to activities undertaken on Australian land (such as the AAT), including those that may have significant impact on matters of national environmental significance. The Convention on the Conservation of Antarctic Marine Living Resources is implemented in domestic law through the Antarctic Marine Living Resources Conservation Act 1981.

The legal regime for Heard Island and McDonald Islands is established in the Heard Island and McDonald Islands Act 1953. Under that Act, the Environment Protection and Management Ordinance 1987 provides for the protection of the environment and controls access to the territory. The territory is also a proclaimed Commonwealth Reserve under the EPBC Act and all activities in the territory must be in accordance with the Heard Island and McDonald Islands Marine Reserve Management Plan.

The Macquarie Island Commonwealth Marine Reserve is adjacent to the Macquarie Island Nature Reserve, which is managed by the Tasmanian Government. The marine reserve is subject to the EPBC Act with activities in the reserve governed by the Macquarie Island Commonwealth Marine Reserve Management Plan. This plan is currently under review and interim management arrangements under the EPBC Act apply until a new management plan is in place.

4.1.3 Marine environment

(This section relates to international agreements of relevance to the Antarctic marine environment other than the Convention on the Conservation of Antarctic Marine Living Resources and the Antarctic Treaty/Madrid Protocol, which are the primary instruments).

The International Whaling Commission was established in December 1946 when the International Convention for the Regulation of Whaling was signed by 15 nations, including Australia. The commission operates independently from the Antarctic Treaty System. Currently, there are 89 member nations, and annual meetings are held in the various member countries. A committee of about 200 whale biologists offers scientific advice to the commission.

Seals living in Antarctic waters are protected and managed under agreements separate from the Convention on the Conservation of Antarctic Marine Living Resources. The Convention for the Conservation of Antarctic Seals is part of the Antarctic Treaty and was entered into force generally in 1978 and for Australia in 1987. This convention applies to all earless seals, as well as all southern fur seals (Arctocephalus spp.) Currently, there is no commercial sealing.

The International Maritime Organization (IMO) is a United Nations agency that provides international standards for the operation and regulation of shipping and has been active since 1948. The Marine Environment Protection Committee (MEPC) is the main technical committee of the IMO that deals with the prevention and control of pollution from ships. In Australia, the Australian Maritime Safety Authority engages in the work of the MEPC. The International Convention for the Prevention of Pollution from Ships (MARPOL) is the most important tool of the MEPC in their regulation and prevention of pollution of the oceans. In recent years, a number of vessels operating in the Antarctic Peninsula region reported incidents that highlighted the risk of pollution by heavy fuel oils. Heavy fuel oils are hazardous to the environment because they break down more slowly than other fuels. In 2005, the parties to the Antarctic Treaty initiated discussions with the IMO to limit the use of heavy fuel oils in ships sailing to Antarctica. An amendment to MARPOL 73/78 Annex I that bans the use of heavy fuels in the Antarctic area entered into force on 1 August 2011.

4.2 Management processes

Several processes contribute to the overall management of the Antarctic region, including the framework provided by protected areas, as well as activities on the stations and in the field.

4.2.1 Protected areas

Under the Madrid Protocol, certain areas receive a higher level of protection if they have outstanding environmental, scientific, historic, aesthetic or wilderness values. The parties to the Antarctic Treaty have developed guidelines for assessing
areas suitable as Antarctic Specially Protected Areas (ASPAs), and for preparing the required management plans, which are submitted by the proposing party to the Committee for Environment Protection and approved at an Antarctic Treaty Consultative Meeting. The management plans contain information on the reasons for designating an area as an ASPA. They also identify restricted zones, the conditions under which permits may be granted, as well as the conditions under which an area may be accessed and what kind of activities may be conducted. Regular reviews—every five years—help to determine whether the management objectives are achieved and the values are preserved. Entry into an ASPA is prohibited unless a permit has been issued either by the Australian Antarctic Division or the equivalent government department of other countries.

Australia administers management plans for 11 ASPAs in Antarctica, and is also responsible for implementing the Heard Island and McDonald Islands Marine Reserve Management Plan, and the Mawson’s Huts Historic Site Management Plan.

4.2.2 Australian Antarctic Division environmental management system

In 2002, the Australian Antarctic Division became the first national Antarctic program to implement an environmental management system certified to the international standard ISO 14001. The environmental management system continues to provide a framework for the systematic management of the ways in which the Australian Antarctic program interacts with the environment.

Each station has a nominated environmental officer who is responsible for reporting issues as they occur and suggesting improvements in the way activities are carried out. However, there is recognition that environmental protection is everybody’s responsibility. A web-based reporting system allows any expedition member to submit information or suggestions on environmental issues.

4.2.3 Training and awareness

The Australian Antarctic Division, as lead agency for Australia’s Antarctic program, ensures that everyone involved in the program is aware of their personal responsibility to care for the environment. At appointment, all expeditioners must agree to abide by a code of personal behaviour, which includes a practical commitment to Australia’s environmental management responsibilities. Induction and training of new employees includes an introduction to the relevant Australian laws and the division’s approach to environmental matters. At Australia’s Antarctic and subantarctic stations, the station leader is responsible for environmental management and is assisted by the station environment committee, a station environmental officer and a station waste-management officer.

4.3 Management achievements

Australian officials actively participate in the international forums of the Antarctic Treaty System to promote improved environmental protection and conservation outcomes for the Antarctic region.

Examples of management achievements in recent years include:

- Australia co-convened a Committee for Environmental Protection workshop in 2006 on Antarctica’s Future Environmental Challenges, which led to the development of a strategic work plan for the committee. Highest priorities currently include removing non-native species and preventing new introductions, climate change, tourism and area protection.
- In 2007, parties to the Antarctic Treaty approved an Australian-led proposal to establish an Antarctic Specially Managed Area (ASMA) in the Larsemann Hills region of East Antarctica, with the objective of promoting cooperation and collaboration between the parties that are active in the region (Australia, China, India, Romania and the Russian Federation).
- In 2008, Australia led an international review of the environmental aspects of China’s proposal to establish a new research station at Dome A, within the AAT. Australia led a similar review in 2011 of the Republic of Korea’s proposal to establish a new station in the Ross Sea region of Antarctica.
In recent years, there has been near zero seabird bycatch by legal fishers operating in commission-managed fisheries. However, bycatch of seabirds, including endangered albatrosses and petrels, remains unsustainable in the Southern Hemisphere. All 22 species of albatross protected under the Agreement on the Conservation of Albatrosses and Petrels are now listed by the International Union for Conservation of Nature as threatened. It is estimated that worldwide up to 300,000 seabirds are killed each year during interactions with coastal and high seas fisheries. Coastal fisheries are subject to state legislations and fisheries regulations; in contrast, high seas fisheries are open access operations. Although the high seas have been divided into management areas of various regional fisheries management organisations, the incentives to avoid overexploitation and to operate sustainably are weak. Many of the high seas tuna fisheries, including in the Pacific, Atlantic and Indian oceans, have failed to adopt and effectively implement the known effective bycatch mitigation measures. Bycatch from IUU fishing is difficult to estimate but known to occur at a higher rate than from legal fisheries due to the likely absence of bycatch mitigation measures. Australia, through its active engagement with the Agreement on the Conservation of Albatrosses and Petrels and other international forums (including CCAMLR and regional fisheries management organisations) is actively pursuing the adoption of sustainable fishing practices that minimise seabird bycatch (Box 7.8).

- The 2010 Antarctic Treaty Meeting of Experts on Climate Change and Implications for Antarctic Management and Governance and the subsequent Antarctic Treaty Consultative Meeting endorsed Australia’s assessment of climate change implications for current and future Antarctic infrastructure, logistics and environmental values, and agreed that other parties to the Antarctic Treaty should undertake and report on similar assessments.

- In 2010 and 2011, Australia conducted official inspections of several Antarctic facilities operated by other parties, including assessing compliance with the provisions of the Antarctic Treaty and Madrid Protocol.

- Australia held the Chair of the Committee for Environmental Protection from 2003 to 2006, and since 2008 has held the position of committee Vice-Chair. Since 2008, Australia has also led an official subsidiary body of the committee, established following an Australian proposal, with the objective of improving the effectiveness of management plans for ASMAs and ASPAs.

- In CCAMLR, Australia has played a leading role in discussions about how to improve the conservation of Antarctic marine living resources. For example, in 2006, CCAMLR prohibited the use of bottom trawling gear in areas shallower than 550 metres in the high seas areas of the convention area. CCAMLR also now requires an assessment of impacts on bottom environments before any fishing activities occur. Following an Australian proposal in 2006, CCAMLR prohibited the use of deep-sea gillnets in the convention area. Directed fishing for sharks has also been prohibited by CCAMLR. Australia’s patrol presence in the Heard Island and McDonald Islands region has resulted in no reported IUU fishing activity in the Heard Island and McDonald Islands exclusive economic zone since 2004–05.

- A CCAMLR Conservation Measure was adopted to increase cooperation between CCAMLR and noncontracting parties to undertake more coordinated capacity building, including in port and flag states. Australia co-sponsored a successful proposal to CCAMLR that resulted in a productive workshop in Africa in 2010 to build capacity among African states that have engaged in IUU fishing or IUU-related activities.
Seabirds have long suffered high mortality rates in interactions with commercial fishing operations throughout the Southern Hemisphere. This is primarily due to longlines, where birds are attracted by the baited lines, become hooked and drown. For example, since 2002, about 40,000 white-chinned petrels (Procellaria aequinoctialis) alone were killed mainly on longlines set in the southern Indian Ocean near Crozet and Kerguelen islands. Many thousands of seabirds were also killed in fishing areas managed by the Commission for the Conservation of Antarctic Marine Living Resources. However, during their annual meeting in 2009, the commission announced that only two seabirds had been killed by legally operating demersal toothfish longliners in commission-managed waters (seabird deaths were reduced in the subantarctic but remained high). This was truly remarkable given that some 32 million hooks had been set to catch toothfish.

This achievement was due to the collaboration of scientists, policy makers and industry members wanting to reduce the bycatch of seabirds. Key to the collaboration was a long-term study into the effectiveness of various mitigation measures, and particularly the development of the integrated weight longline. This new line contains 50 grams of lead at its core, which makes it much heavier than standard longlines. The result is that this line sinks faster when set and arrives much quicker than standard lines at depths that are beyond the reach of most seabirds, especially albatrosses (Figure A). The commission adopted the sink rate of 0.3 metres per second as one of its conservation measures. That means this sink rate is part of the licence conditions that commercial fishers must adhere to in their operations.

Integrated weight longlines were readily adopted by owners of fishing vessels because these lines are part of the fishing gear and do not require extra effort to operate. They are now used widely in the world’s longline fisheries and have reduced the mortality of white-chinned petrels by 95%.

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**Figure A** Longlines with integrated weight sink much faster than normal (unweighted) gear and greatly reduce seabird mortality.

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White-chinned petrels are the most common seabird species killed in longline fisheries in the Southern Hemisphere; every year, tens of thousands are caught in commercial longline operations (photo by Simon Bennet, Australian Government Department of Sustainability, Environment, Water, Population and Communities).
However, the problem remains for small petrels, like grey petrels, in some fisheries. These small seabirds can dive to depths of about 70 metres, making it very difficult to deter them, because they can quickly follow even a fast-sinking longline. Hence, another project was launched to develop an underwater-setting device that deploys baited hooks well below the ocean’s surface where the petrels can neither see nor smell the bait. The bait setter uses a capsule that carries baited hooks 8–10 metres below the ocean’s surface and is designed for tuna and swordfish in longline fisheries. Trials of a prototype of the device are currently under way.

The underwater bait setter delivers hooks 8–10 metres underwater, which are unseen by seabirds, and has the potential to eliminate the mortality of albatrosses and greatly reduce the mortality of deep-diving species, such as white-chinned petrels and shearwaters (photo by Graham Robertson, Australian Antarctic Division).
## Assessment summary

### Effectiveness of Antarctic environmental management

<table>
<thead>
<tr>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Heritage and protected areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Understanding:</strong> The nomination of World Heritage and protected areas is based on their recognised natural and cultural values</td>
<td>Partially effective</td>
<td></td>
</tr>
<tr>
<td><strong>Planning:</strong> Management plans are in place and are reviewed regularly</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inputs:</strong> Financial, human and information resources are available to implement the management plans</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Processes:</strong> For Heard Island and McDonald Islands, there is stakeholder consultation and all management plans are open to public consultation</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Outputs and outcomes:</strong> Identified natural and cultural heritage values are being preserved</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land use and management</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Understanding:</strong> There is a good understanding of the impacts of human activities in our operational environment</td>
<td>Partially effective</td>
<td></td>
</tr>
<tr>
<td><strong>Planning:</strong> The AAD’s environmental management policy provides an overarching policy framework for all activities in the Australian Antarctic Territory and subantarctic islands. This policy is consistent with Australia’s obligations under the Antarctic Treaty</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inputs:</strong> The AAD administers an environmental management system supported by a program of scientific research</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Processes:</strong> The environmental management system is certified to the internationally recognised standard (AS/NZS ISO 14001:2004). The AAD’s environmental policy was last reviewed in 2009</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Outputs and outcomes:</strong> Relevant management information collected through the environmental management system is used to guide management decisions</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Adaptation to climate variability and change

**Understanding:** There are several significant uncertainties about the impacts of climate change; however, scientific programs are in place to further our understanding of processes and future implications.

**Planning:** The forecast infrastructure plan takes into account energy efficiencies and carbon emissions.

**Inputs:** Adaptive management is resourced within the current operational framework.

**Processes:** Scientific studies are examining potential effects of climate change.

**Outputs and outcomes:** As scientific results become available, policies will be formulated.

Pests and invasive species management

**Understanding:** There is a good understanding of threats and impacts of alien species, both on the Antarctic continent and subantarctic islands.

**Planning:** Policies are in place to minimise the risk and impact of alien introductions.

**Inputs:** Human resources are allocated to implement policies that minimise the risk of alien introductions (participation in the Committee for Environmental Protection’s Aliens in Antarctica science program, environmental officers on all stations, ships and at the AAD).

**Processes:** Environmental training and information are provided to all personnel and to the public.

**Outputs and outcomes:** There is a legacy of alien introductions into Antarctic and subantarctic environments (e.g. rabbits and rodents on Macquarie Island); however, in recent years, programs have been effective in mitigating the risks.

---

**Recent trends**
- Improving
- Deteriorating
- Stable
- Unclear

**Confidence**
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Grades**
- Very effective
- Effective
- Partially effective
- Ineffective

AAD = Australian Antarctic Division
Resilience of the Antarctic environment

To date, the question of the level of resilience inherent in Antarctic ecosystems has not received much attention because it is a complex concept and many parameters required to assess resilience are still unknown. The Scientific Committee on Antarctic Research produced a comprehensive review of the impact of climate change on the Antarctic environment in 2009, highlighting areas where knowledge is still lacking. Although marine and terrestrial ecosystems are now better understood than in the past, baseline data on biogeography and biodiversity are still scarce, as are fundamentally important long-term monitoring data. Researchers have only just started to investigate how organisms adapt to current climate change, and how resistant and resilient organisms and systems are.

For many, if not most, vertebrate species, important aspects of the dynamics of populations are either largely unknown or have been studied only at a few sites. Without comprehensive insights into variables, such as age of first reproduction, survival of different age classes, fecundity and the extent of emigration and immigration into and out of populations, as well as the drivers that influence these variables, we are unable to make long-term predictions about the viability of species in a changing environment. A thorough understanding of the ecological framework in which organisms live is also important when considering their resilience. For example, a number of Antarctic organisms live at South Georgia where the summers are up to 3 °C warmer than on the Antarctic Peninsula. Thus, the vulnerability of species needs to be determined on the basis of their ecological circumstances.

Natural disturbances are part of life in Antarctic ecosystems and the endemic species are generally capable of surviving shock events because they have evolved strategies that allow their populations to rebuild after mass mortalities. Longevity among seabirds, and the ability of plant seeds to survive for long periods and to disperse, are among those strategies.

Shock events that test the level of resilience of a system occur in Antarctica just as they do in other parts of the world, ranging from intense storms affecting large areas to more localized incidents, such as scouring of the benthic environment by drifting icebergs (see Section 2.3.1). As long as these shock events are rare, communities can recover. However, increases in the magnitude and frequency of such events, as well as the duration of serious disturbances, are likely to become major challenges to the resilience of benthic communities. The slowest growing species may never recover if the interval between disturbance events is too short to develop and grow into mature organisms, whereas populations of fast-growing species may benefit if the competition for space, for example, is reduced.

We know that populations of some species of whales, seals and penguins have suffered human-induced mortality rates that pushed these species to the brink of extinction. Once hunting ceased, a number of species recovered; some, like king penguins, in a spectacular manner. However, these recoveries took place in a world where environmental conditions were not exposed to the rapid change that is currently under way. Today, a number of environmental components are changing rapidly (increasing sea temperatures, ocean acidification, higher intensities of ultraviolet radiation, etc.). The changes are complex and not always unidirectional, and there is currently little evidence on how the various factors are going to interact. There is no doubt that some organisms will benefit from these changes in the short term,
but it is difficult to predict the effect of rapid climate variations on ecosystems. Many species may be vulnerable because their capacity to adapt operates at a much slower rate than the changes currently observed (see Section 3.1.1).

In the physical sciences, researchers are only just beginning to understand feedback loops and processes in the physical environment. Long-term monitoring data are also lacking in fields such as glaciology—particularly with regard to understanding changes in the active layer of the Antarctic ice sheet, as well as permafrost. The Scientific Committee on Antarctic Research recommends studies to further the understanding of the hydrological cycle and emphasises the need for improved estimates of the freshwater budget. Atmospheric sciences also need to address changes in the atmosphere’s chemistry to improve the ability of models to predict the consequences of changes in ozone concentrations.
Risks to the Antarctic environment

It is clear that Earth’s polar regions are likely to be affected severely by changing climate conditions. These changes represent the highest risk to the region, since they are unlikely to be mitigated by any management measures. The impacts of climate change on the Antarctic environment are detailed in Sections 2 and 3 of this chapter.

Population and economic growth are leading to other risks. Remaining fish stocks around the world are highly depleted and appear largely unable to recover. With a growing human population demanding a new source of protein, the pressure on the industry to catch krill is likely to increase. A rapidly expanding krill fishery will have a considerable environmental impact and is a risk, particularly if the fishery expands at a rate that outstrips the ability of CCAMLR to manage it. In the past, the fishing nations that are active in the Southern Ocean had never reached the catch limits set by CCAMLR. However, in the 2009–10 season, the fishery reached the ‘trigger level’ in one of the subareas in the South Atlantic and the fishery was closed for the first time. Newly developed technology has allowed the vessels to catch about 800 tonnes per day compared with about 400 tonnes landed by ‘old style’ vessels. This advanced fishing technology has contributed to the rise in the krill catch to 210 000 tonnes in 2009–10 and high catch rates may force the krill fleet to expand into new areas to avoid exceeding the existing catch limits.

The consequences of krill fishing continuously operating at the catch levels set by CCAMLR are as yet unknown. The impact of environmental changes on the krill population, such as ocean acidification, will also have to be taken into account in the process for calculating precautionary catch limits for Southern Ocean fisheries.

Acidification of the world’s oceans is occurring due to several concurrent processes but there is still much uncertainty about how, for example, climate change affects these processes, such as the ‘biological pump’. However, it is well established that levels of anthropogenic carbon dioxide are increasing in the atmosphere, transferring 1 million tons of carbon dioxide to the world’s ocean per hour. For the Southern Ocean, the process of overturning circulation (where deep water upwells and releases carbon dioxide to the atmosphere; see Section 1.1) is particularly important. As the atmosphere warms, the warming of surface waters increases stratification and limits gas exchange of this upwelled water with the atmosphere. This in turn causes greater retention of carbon dioxide, allowing more time for respiration of organic matter by marine bacteria. All these processes increase acidification. An increasing number of studies are highlighting diverse and sometimes unexpected consequences on marine ecosystems:

• The effects of ocean acidification on the availability of nutrients and the ability of organisms to deposit and maintain exoskeletons of calcium carbonate is compromised. With less calcium in their shells they are lighter and less likely to sink into deeper waters. This reduces the flux of organic material to the deep ocean (the ‘biological pump’) and increases the amount of carbon dioxide that is respired in the upper water column. The overall effect of climate change on the biological pump is influenced by many competing pathways (e.g. photosynthesis, grazing, sinking and respiration); the outcome is currently uncertain but is likely to have severe biological impacts within decades and could dramatically affect the structure and function of marine ecosystems. Such changes would have profound effects on ecosystem
services, including the productivity of fisheries and the efficiency of the Southern Ocean sink for atmospheric carbon dioxide. These changes are most pronounced in the polar regions where the acidity of the water is changing twice as fast as in warmer, tropical and subtropical regions.

• Growth and survival of fish populations could become impaired in an acidifying ocean. Tropical fish larvae that were exposed to increased levels of carbon dioxide changed their behaviour in a manner that made them five to nine times more prone to predation. Such an increase in mortality can be detrimental to the long-term survival of fish populations.231

• A decrease in the ocean’s pH may affect the absorption of sound in the ocean, making the oceans noisier.229,232 Whether this will impact marine mammals—for example, in their ability to communicate—is currently unclear.

Human activities are increasing on the Antarctic continent. The human footprint on Antarctica is small compared with the total size of the continent; however, the impacts are not evenly spread. Human activity and associated impacts are concentrated around stations, and stations tend to be built on ice-free land close to the sea. This land is also important habitat for the plants and animals of Antarctica. In East Antarctica, most of the sites suitable for building stations are already occupied and one new station is under construction. Currently, 53 research stations house up to 4000 individuals during summer and 1000 during winter.233

Through the Madrid Protocol’s indefinite ban on mining activities in the Antarctic Treaty area, the Antarctic region is presently largely immune to the growing global demand for mineral resources. The Madrid Protocol and the Convention on the Conservation of Antarctic Marine Living Resources have so far been quite successful in managing human activities and reducing the impact of the human presence in the Antarctic region. However, as Tin et al.233 concluded when reviewing human impact on Antarctica, ‘in the coming decades, the effectiveness of these regimes [the Madrid Protocol and the Convention on the Conservation of Antarctic Marine Living Resources] will be put to the test in the face of the continuing increase in intensity and diversity of human activities in Antarctica’.
### Assessment summary

#### Current and emerging risks to the Antarctic environment

<table>
<thead>
<tr>
<th>Risk</th>
<th>Catastrophic</th>
<th>Major</th>
<th>Moderate</th>
<th>Minor</th>
<th>Insignificant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea level rise through melt and ocean warming</td>
<td>Reversal of ozone hole, reducing ultraviolet B radiation but increasing warming</td>
<td>Stronger winds and shift in oceanic fronts bringing warm water toward the ice shelf, leading to increased destabilisation of the ice</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Increased warming of atmosphere, leading to loss of ice cover and changes in sea ice seasonality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Changes in ecosystem structure</td>
<td>Increased pollution (water and air)</td>
<td></td>
<td>More continental stations, intensifying pressures on local environments</td>
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<tr>
<td>Increased illegal fishing, leading to impacts both on targeted and dependent species, as well as bycatch</td>
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<tr>
<td>Breakdown in food web productivity</td>
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<tr>
<td>Lack of knowledge of interactions of processes, leading to poor management decisions</td>
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<tr>
<td>Increases in numbers of alien species with subsequent effects on native species and communities</td>
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<tr>
<td>Improved survival of pathogens with subsequent effects on native species and communities</td>
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<tr>
<td>Risk Category</td>
<td>Catastrophic</td>
<td>Major</td>
<td>Moderate</td>
<td>Minor</td>
<td>Insignificant</td>
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<td>------------------------------------------------------------------------</td>
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<td>--------------------------------------------------------------------------------</td>
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<tr>
<td>Loss of biodiversity</td>
<td></td>
<td>▪ More extreme weather events due to climate change</td>
<td>▪ Growth of tourism and the consequent increase in environmental impact (highly dependent on oil prices)</td>
<td></td>
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<tr>
<td>Loss of keystone species as their physiological limits are exceeded</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Collapse of the Antarctic Treaty System (in the foreseeable future)</td>
<td></td>
<td>▪ Mineral exploitation, leading to disturbance or destruction of the environment</td>
<td>▪ Oil and gas exploration, potentially leading to disturbance or destruction of the environment</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>▪ Increased noise levels in ocean due to acidification, potentially impacting the communications of marine mammals</td>
<td></td>
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<tr>
<td></td>
<td>Unlikely</td>
<td></td>
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<tr>
<td></td>
<td>Rare</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- Not considered
Outlook for the Antarctic environment

To assess the future of Antarctica and the Southern Ocean, a global perspective is required. Despite Antarctica’s remoteness from centres of human population, the pressures generated in the rest of the world impact on Antarctic and Southern Ocean ecosystems through the linkages provided by atmospheric and oceanic circulations. Although the rate has slightly decelerated, the human population is still increasing and is expected to reach 9.3 billion in 2050. Increasing demands for raw materials and protein sources can only increase the possibility that, at some stage, people will look to Antarctica and the Southern Ocean, especially when resources reach their limits in other parts of the world.

The Scientific Committee on Antarctic Research has reviewed all available information on the impacts of climate change on Antarctica and the Southern Ocean, and provides a comprehensive synthesis of the future of the southern continent in its report, Antarctic climate change and the environment. The report highlights that changes have been observed in the Antarctic environment and continued changes are expected in the climate and weather patterns of Antarctica, as well as in the physical and chemical properties of the Southern Ocean. While many of the underlying processes driving the changes are still not well understood, the processes that are changing the Antarctic environment appear to be well under way and are unlikely to be stopped in the immediate future.

While important regional differences of a number of indicators vary markedly in their expression and intensity, the overall trend away from the status quo in the Antarctic system is similar throughout the region. Change in East Antarctica is currently occurring at a slower rate than in West Antarctica, but the trends are similar. However, there are indications that this will change in the future. The fourth report of the Intergovernmental Panel on Climate Change predicts that changes expected in Antarctica will include a warming of the Southern Ocean, a freshening of at least its upper water masses, and a strengthening of the southern annular mode (SAM), which influences wind patterns. SAM is expected to strengthen and its storm tracks are likely to move south. The result is strengthening westerly winds and increasing insulation of Antarctica. This would limit the heat exchange between Antarctica and the tropics, and cool the southern continent. At the same time, the ozone hole (which currently has a relatively stable size and depth) may recover. Presently, the ozone hole buffers Antarctica from warming through a layer of clouds and may have led to an increase in sea ice extent over the past 30 years. Its recovery, which is expected in
the middle of the 21st century, is likely to increase
the warming of Antarctica, especially in the east.
This makes it highly likely that the extent of sea ice
will shrink: a reduction of 2.6 million square kilometres
(or 33%) in the annual sea ice area is forecast (although
models are currently unable to predict changes on a
regional scale).

Over the next decades, ocean acidification will
become more pronounced in the cold Southern Ocean
than in warmer regions, particularly if the production
of anthropogenic carbon dioxide continues at its
present rate. There is a limit to how much carbon
dioxide can be absorbed by the Southern Ocean
and, if carbon dioxide production is not reduced,
the Southern Ocean may no longer act as a carbon
dioxide sink. A similar effect will be achieved as
the ocean warms, because warmer waters have a
reduced capacity to act as a carbon dioxide sink
than cold waters. Over the past two centuries, the
hydrogen ion concentration of surface water has
increased by 30% in the world’s oceans, lowering the
pH by 0.1 units. This rate is about 100 times higher
than it has been in the past. Given the amount of
carbon dioxide already in the atmosphere, a reversal
of ocean acidification is unlikely in our lifetime.

In all likelihood, the distribution of species will
change as those adapted to warmer climes expand
their ranges south. Those organisms already existing
in the high Antarctic will have to adapt or they will
disappear. The most likely candidates to vanish in
the long term are those that have adapted to live in
very narrow environmental limits. Their extended
life histories mean that, with the increasing rate
of change in their environment, fewer and fewer
generations will be able to acclimatise and adapt to
the new conditions. Range expansions have already
been reported from the Antarctic Peninsula region.
Some animal, plant and microorganism populations
are expected to expand in areas where more liquid
water will become available and temperatures
will increase.

We cannot yet predict the extent to which
biodiversity will be impacted by the expected future
changes. However, ocean acidification in particular
is likely to have a profound effect on the Antarctic
ecosystem because it affects organisms at the base
of the food web. Whatever changes may occur in the
biodiversity of Antarctica, the effects are expected
to cascade through the entire ecosystem.
References


References


de la Mare WK. Changes in Antarctic sea ice extent from direct historical observations and whaling records. Climate Change 2009;92:461–93.


References


151 Hutchinson A. Baleen out the IWC: is international litigation an effective strategy for halting the Japanese scientific whaling program? Macquarie Journal of International and Comparative Environmental Law 2006;3:1–33.


202 Ericson JA, Lamare MD, Morley SA, Barker MF. The response of two ecologically important Antarctic invertebrates (Stechinichthys menehuy and Parbolaria corrugatus) to reduced seawater pH: effects on fertilization and embryonic development. Marine Biology 2010;157:2689–702.


Biodiversity has declined since European settlement. Although we can reliably establish recent trends in distribution or abundance for only a small proportion of species, data on these suggest that population size, geographic range and genetic diversity are decreasing in a wide range of species across all groups of plants, animals and other forms of life. Unexpected declines in numbers of birds and mammals in northern Australia in particular suggest that trends might be worse than previously expected.

Most pressures on biodiversity that arise directly or indirectly from human activities appear to still be strong. Those pressures that have decreased, such as land clearing, continue to have legacy effects that will continue for some years or decades. However, other pressures, such as those from invasive species, are generally increasing.

Despite promising investment by all jurisdictions in addressing the main pressures on biodiversity, pressures are not being substantially reduced, nor is the decline in biodiversity being arrested or reversed. While all jurisdictions have appropriate goals in high-level plans, these are often not matched with implementation plans or levels of resourcing that are capable of achieving the goals. State of the environment reports from around the nation do not suggest any great improvement in biodiversity or reduction in pressures.

The major future drivers of change—climate change, population growth, economic development and associated consumption of natural resources—must be managed carefully if a sustainable relationship between biodiversity and human societies is to be achieved. Human activities have the potential to further reduce genetic, species and ecosystem biodiversity, which will seriously affect the delivery of environmental benefits to Australians and reduce our quality of life.
... biodiversity is much more than beauty and wonder, important though that is. It also underpins ecosystem services that—although not counted in conventional GDP—humanity is dependent upon.


Data on long-term trends in biodiversity are limited, making it difficult to interpret the state or trends of major animal and plant groups in most jurisdictions.

The development of a new national approach to environmental information is intended to address this serious deficiency, which has now been identified by four national State of the Environment reports. The ability of all jurisdictions in Australia to develop and enact evidence-based biodiversity policy is severely constrained by the lack of such data.

Australia can improve its biodiversity management significantly.

Australian governments and nongovernment organisations have debated and trialled a range of new approaches to managing our environment, including better stakeholder engagement. Australia is poised to build on these ‘experiments’ and, if wise decisions are made, could make major advances in biodiversity management. However, the legacies of past pressures like land clearing, ongoing pressures like invasive species, and emerging challenges like climate change, will take decades to address fully. Even the most optimistic scenarios envisage gradual, rather than immediate, progress.

Australians cannot afford to see themselves as separate from biodiversity.

Biodiversity depends on us for survival and we depend on it for our survival and wellbeing. Our ecosystems and the biodiversity that they support provide services fundamental to human life, such as regulation of the atmosphere, maintenance of soil fertility, food production, regulation of water flows, filtration of water, pest control and waste disposal. As Australia’s population grows, the Australian community will need to decide how best to protect both biodiversity and human wellbeing.
## Contents

### Introduction

1.1 The importance of biodiversity
   1.1.1 Global importance
   1.1.2 National importance

1.2 Assessing and interpreting changes in biodiversity

1.3 In this chapter

### State and trends of biodiversity

2.1 Availability of information

2.2 Genetic and species diversity

2.3 Terrestrial ecosystems and communities
   2.3.1 Reporting by jurisdictions
   2.3.2 Extent of vegetation communities
   2.3.3 Quality of habitat
   2.3.4 Capacity to meet human needs or resource demands

2.4 Plant and animal species
   2.4.1 Threatened species lists
   2.4.2 Plant species
   2.4.3 Fungi and other nonplant, nonanimal species
   2.4.4 Animal species overall
   2.4.5 Mammals
   2.4.6 Birds
   2.4.7 Freshwater fish
   2.4.8 Reptiles and amphibians
   2.4.9 Invertebrates

2.5 Aquatic species and ecosystems

2.6 Marine species and ecosystems

2.7 Assessing the state and trends of biodiversity
   Assessment summary 8.1—state and trends of biodiversity

### Pressures affecting biodiversity

3.1 Drivers versus pressures

3.2 Availability of information

3.3 Spatial distribution of pressures

3.4 Local climate

3.5 Pollution

3.6 Consumption and extraction of natural resources
   3.6.1 Harvesting of species
   3.6.2 Pressures related to population size and lifestyles
   3.6.3 Consumption of water

3.7 Clearing and fragmentation of native ecosystems
   3.7.1 Land clearing
   3.7.2 Urban development
   3.7.3 Extractive industries

3.8 Pressures from livestock production
3.9 Invasive species and pathogens 633
  3.9.1 Weeds 633
  3.9.2 Invasive fungi 633
  3.9.3 Invasive animals 634
  3.9.4 Invasive species affecting inland aquatic environments 634
  3.9.5 Marine invasive species 634
  3.9.6 Jurisdictional reporting on invasive species and pathogens 634
3.10 Altered fire regimes 638
3.11 Changed hydrology 638
3.12 Pressures on marine ecosystems 638
3.13 Interactions among pressures 638
  Assessment summary 8.2—pressures affecting biodiversity 640

4. Effectiveness of biodiversity management 642
4.1 Management context 643
  4.1.1 Adequacy of information and understanding 643
  4.1.2 Planning 645
4.2 Management capacity 647
4.3 Management achievements 649
4.4 Examples of key responses 649
  4.4.1 The National Reserve System 650
  4.4.2 Conservation outside reserves 655
  4.4.3 Invasive species and pathogens 656
4.5 Assessing the effectiveness of biodiversity management 660
  Assessment summary 8.3—effectiveness of biodiversity management 662

5. Resilience of biodiversity 668
  5.1 Evidence of past resilience 668
  5.2 Preparedness for known or anticipated future pressures 670
  5.3 Factors affecting potential capacity to deal with surprises 672

6. Risks to biodiversity 674
  6.1 Escalation of existing pressures 674
  6.2 Escalating interactions among existing pressures 675
  6.3 Emerging risks 675
  Assessment summary 8.4—current and emerging risks to biodiversity 676

7. Outlook for biodiversity 679
  7.1 A pessimistic outlook 680
  7.2 An optimistic outlook 680

References 682
If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering.

Aldo Leopold, *Round river*, 1953
Introduction

Biodiversity is the variety of life. It includes not only the diversity of species of plants, animals, fungi, bacteria and viruses that inhabit our planet, but also the genetic material within those species, the diversity of ecosystems, habitats and communities within which they live, and the diversity of processes that are performed by genes and species and the interactions among them.

1.1 The importance of biodiversity

Australia’s biodiversity is important both globally and nationally. It is important to the world because of its uniqueness and its global significance, and it is important to Australians for both moral and utilitarian reasons.

1.1.1 Global importance

The global importance of Australia’s biodiversity is due to both its richness and its uniqueness, as Steffen et al. describe:

Between 7 and 10% of all species on earth occur in Australia. More than 4500 species of marine fishes—and the greatest number of species of red and brown algae, crustaceans, sea squirts, and bryozoans in the world—live in Australian inshore waters. Fifty-seven per cent of all mangrove species are found in Australian intercoastal zones. There are more than twice as many species of reptiles in Australia as there are in the United States, and Australian deserts support more lizard species than any other comparable environment.

The uniqueness of Australia’s biodiversity is largely due to this continent being separated from other land masses for millions of years. In addition, the range and diversity of environmental conditions in Australia is different from most other countries due to characteristics such as nutrient-poor soils, high fire frequencies and a generally flat topography. Many of Australia’s species, and even whole groups of species that comprise taxonomic families, are endemic (unique) to this continent (Table 8.1). As a result, Australia is identified as one of the world’s ‘megadiverse’ countries (Figure 8.1).

Australia’s biodiversity is globally significant in both the terrestrial and marine environments. Chapter 6: Marine environment points out areas of Australia’s marine environment that are particularly biodiverse. South-western Australia has been identified as one of 34 global ‘biodiversity hot spots’. These are estimated to include 50% of the world’s endemic plant species and 42% of all endemic terrestrial vertebrate species.

This use of ‘hot spots’ is a global definition that refers to places in which not only levels of biodiversity, but also previous loss of habitat and ongoing pressures, are exceptionally high. Overall, these hot spots once covered 15.7% of the world’s surface, but 86% of that area has been destroyed. The latest analyses are an update of the published analysis by Myers et al.

The distribution and abundance of biodiversity are uneven across Australia. Australian biodiversity hot spots, defined by the Australian Government as areas in which the numbers and diversity of species are higher than elsewhere, are distributed in the north, south, east, west and centre of the continent (see Section 2.3). Efforts to conserve remaining biodiversity are likely to be most effective in these areas.
Table 8.1 Australian contribution to the global status of major animal, fungus and plant groups

<table>
<thead>
<tr>
<th>Species</th>
<th>Australian diversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine fish</td>
<td>One of the most diverse fish faunas in the world, with more than 4500 species</td>
</tr>
<tr>
<td>Sharks and rays</td>
<td>54% of the entire chondrichthyan fauna is endemic to Australia</td>
</tr>
<tr>
<td>Ectomycorrhizal fungi</td>
<td>95% endemic (22 genera and 3 endemic families)</td>
</tr>
<tr>
<td>Terrestrial vertebrates</td>
<td>1350 endemic terrestrial vertebrates, far more than the next highest country (Indonesia, with 850 species)</td>
</tr>
<tr>
<td>Terrestrial mammals</td>
<td>305 species, of which 258 (85%) are endemic; more than 50% of the world’s marsupial taxa occur only in Australia</td>
</tr>
<tr>
<td>Birds</td>
<td>17% of the world’s parrots occur in Australia—more than 50 species (second highest level of endemism after Brazil and the same as Colombia)</td>
</tr>
<tr>
<td>Reptiles</td>
<td>89% endemic; some groups such as front-fanged snakes (family Elapidae), pythons and goannas are more diverse than elsewhere in the world; Australian deserts have the world’s highest diversity of lizard species</td>
</tr>
<tr>
<td>Frogs</td>
<td>94% endemic; around 230 total species of amphibians in Australia (highest level of endemism of any vertebrate group in Australia)</td>
</tr>
<tr>
<td>Marine invertebrates</td>
<td>17.8% of the world’s crustaceans, 22% of bryozoans and 29.4% of sea squirts occur in Australian waters</td>
</tr>
<tr>
<td>Vascular plants</td>
<td>91% of flowering plants are endemic; 17 580 species of flowering plants, 16 endemic plant families (the highest in the world) and 57% of the world’s mangrove species</td>
</tr>
<tr>
<td>Butterflies and moths</td>
<td>Many groups are unique to Australia</td>
</tr>
</tbody>
</table>

Source: Steffen et al.1 with some modifications for frogs from Chapman3
1.1.2 National importance

Australia is party to many international treaties and other agreements designed to protect biodiversity globally. National and state governments in Australia have also enacted policies and strategies to protect biodiversity within our borders.

There is increasing recognition that protecting other species is a smart strategy for the long-term benefit of humans. For example, the genes that are the basis for all life on Earth, and that determine what metabolic processes occur within a species and their products and byproducts, are a vital source of life-supporting resources for humans. Many of our crops, domestic animals, pharmaceuticals and other chemicals, building materials, fuels and many other products that have allowed humans to thrive in a range of environments, and respond successfully to many challenges, come from other species. The variety of genetic material in other species gave humans choices and options for dealing with challenges and opportunities. In addition, interactions of other species with the nonliving environment produce benefits for humans, such as water filtration; protection from floods; pest control; regulation of the atmosphere; formation of soil and maintenance of its fertility; and a range of physical, mental health and cultural benefits (Figure 8.2 and Table 8.2).

In contemporary Australian society, ways of thinking about the environment and the species that live in it are strongly influenced by the Western scientific tradition. This tradition has emphasised ‘reductionist’ science, which analyses and categorises the natural world in ways that simplify the complexity of interactions among species and the nonliving environment. The drivers–pressures–state–impact–response (DPSIR) model used in this report is an example of such a simplified, but informative and powerful, way of analysing the state of the environment. We also recognise that there are other philosophies of the environment that are more holistic and that do not separate humans from the natural environment (Box 8.1).

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**Box 8.1 Indigenous views on biodiversity and ecosystem services**

Many Indigenous people continue to have a close and multifaceted relationship with their land through particular plant and animal species and places of spiritual significance that may also be important habitats. In northern Australia and in coastal regions, in particular, Indigenous people also continue to harvest food, as well as fibre and other materials for art and craft production, from the land and seas. There are customs that govern harvesting, setting out the rights and responsibilities of harvester, as well as governing relationships among and between people, and governing particular areas of land, and plant and animal species. The intersecting web of rights and responsibilities creates cross-accountabilities that monitor the behaviour of individuals so that plants and animal populations are not only used as a resource, but also managed with an eye to sustainability.

The effectiveness of these customary mechanisms for biodiversity conservation has been under serious challenge for many decades. As well as external pressures, such as land clearing, climate change and introduced species, there are changes within Indigenous societies, such as a shift to more sedentary lifestyles and store-bought foods, and increased assertion of individual preferences over customs for collective responsibility.

Against this background, the Indigenous land and sea management movement stands out for its growing professionalism and the capacity it has developed to address threats to biodiversity. Engagement in land and sea management is building the skills and knowledge of new generations of Indigenous people. Experiential learning draws from both the Indigenous ecological knowledge of their elders, and from science and applied conservation management, to observe and learn the effects that use and management have on key resources. Hallmarks of the growth of the movement are that 25% of the area of the Australian National Reserve System comprises Indigenous-owned land voluntarily dedicated for biodiversity conservation and associated cultural goals, and that more than 600 Indigenous rangers are employed to deliver environmental outcomes on these and other lands.

Australian Government facilitation and support has been important for the recent rapid growth and consolidation of Indigenous land management. Relationships between Indigenous people, researchers and staff of government agencies, regional-scale Indigenous organisations, catchment management boards, mining companies and nongovernment organisations have built recognition and respect for the strong role that Indigenous people can play as custodians and managers of biodiversity.

Source: Jocelyn Davies, CSIRO Ecosystem Sciences, Alice Springs—Biodiversity Portfolio, www.csiro.au/org/Biodiversity-Portfolio.html
1.2 Assessing and interpreting changes in biodiversity

We can interpret the state of biodiversity by:

• assessing whether objectives for biodiversity management set in policies and plans have been achieved

• assessing whether the state of biodiversity is adequate to ensure that the processes that occur in ecosystems meet the needs of those ecosystems and of humans who depend on ecosystems for life fulfilment and life support

• comparing the current state of biodiversity with some reference points in the past to establish trends.

The term ‘ecosystem services’ has been coined to describe benefits from the environment to humans, and to acknowledge that these benefits usually require interacting suites of species (i.e. ecosystems) rather than individual species. These benefits include services fundamental to human life, such as regulation of the atmosphere, maintenance of soil fertility, food production, regulation of water flows, filtration of water, pest control and waste disposal; and those that are social and cultural, such as experiencing nature. Figure 8.2 illustrates one framework for considering how ecosystem services link with human population growth and economic and other activities that consume natural resources.

Interpreting the relationship between the current state of biodiversity and the ecosystem services the environment provides is complicated, for two reasons:

• Our understanding of the relationships between biodiversity and ecosystem functions is not yet good enough to predict in detail the effects of changes in biodiversity on benefits to humans.

• Our understanding of the needs that humans have for benefits from biodiversity is still too poor for us to be able to assess whether current or future states of biodiversity will be adequate to meet those needs.

Evidence suggests that, while at any point in time human needs might be met by only some of the species currently in existence, some species that currently play a minor role might become more important as the environment changes.8-9

Many species can thus be seen as backups or ‘insurance’ against future changes in the environment or human needs. Related evidence suggests that the amount and types of benefits to humans change as components of biodiversity change (Table 8.2).10 This uncertainty and lack of knowledge about the relationship between biodiversity and human wellbeing suggests an imperative to retain options and to make decisions that do not foreclose on future opportunities. This translates into the widely adopted policy goal of protecting existing species, ecosystems and ecosystem processes, and the conditions for them to persist and evolve. This policy goal is recognised internationally in the Convention on Biological Diversitya and nationally in Australia’s Biodiversity Conservation Strategy 2010–2030.11

1.3 In this chapter

A commonly used historical reference point for State of the Environment (SoE) and related assessments is the biodiversity understood to exist immediately before European settlement of Australia (approximately 1750). This reference point has been accepted as the basis for planning Australia’s National Reserve System and biodiversity conservation strategies. In this report, we consider, where possible, changes in biodiversity over the past 15 years (the period of the previous national SoE reports), but also reference current conditions to those thought to exist in 1750.

This chapter draws on information on biodiversity that is reported in other chapters and in research papers; summarises and synthesises assessments from state and territory SoE reports; and presents additional analyses. The Assessment of Australia’s terrestrial biodiversity 2008 is a key source.

Biodiversity indicators for national SoE reporting were developed in the first (1996) and subsequent reports. While these remain valid, the indicators used since 1996 have differed from report to report, due largely to the lack of information available. There is no standardised national set of biodiversity indicators, and different states and territories use different indicators. In this report, we have considered most of the indicators used in previous reports, and used that to inform the higher level assessment summaries included in each section.

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a www.cbd.int/convention
**Figure 8.2** The classification of benefits to humans (‘ecosystem services’) adopted by the Millennium Ecosystem Assessment

The arrows illustrate the strength of the linkages between categories of ecosystem services and components of human wellbeing and the extent to which it is possible for socioeconomic factors to mediate the linkage. For example, if it is possible to purchase a substitute for a degraded ecosystem service, then there is a high potential for mediation. The strength of the linkages and the potential for mediation differ in different ecosystems and regions. In addition to the influence of ecosystem services on human wellbeing depicted here, other factors—environmental, economic, social, technological and cultural—influence human wellbeing, and ecosystems are in turn are affected by changes in human wellbeing.

Source: Adapted from Millennium Ecosystem Assessment
## Table 8.2 Ecosystem services and their ecosystem service providers

<table>
<thead>
<tr>
<th>Service</th>
<th>Ecosystem service providers or trophic level</th>
<th>Functional units</th>
<th>Spatial scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aesthetic, cultural</td>
<td>All biodiversity</td>
<td>Populations, species, communities, ecosystems</td>
<td>Local–global</td>
</tr>
<tr>
<td>Ecosystem goods</td>
<td>Diverse species</td>
<td>Populations, species, communities, ecosystems</td>
<td>Local–global</td>
</tr>
<tr>
<td>Ultraviolet protection</td>
<td>Biogeochemical cycles, microorganisms, plants</td>
<td>Biogeochemical cycles, functional groups</td>
<td>Global</td>
</tr>
<tr>
<td>Purification of air</td>
<td>Microorganisms, plants</td>
<td>Biogeochemical cycles, populations, species, functional groups</td>
<td>Regional–global</td>
</tr>
<tr>
<td>Flood mitigation</td>
<td>Vegetation</td>
<td>Communities, habitats</td>
<td>Local–regional</td>
</tr>
<tr>
<td>Drought mitigation</td>
<td>Vegetation</td>
<td>Communities, habitats</td>
<td>Local–regional</td>
</tr>
<tr>
<td>Climate stability</td>
<td>Vegetation</td>
<td>Communities, habitats</td>
<td>Local–global</td>
</tr>
<tr>
<td>Pollination</td>
<td>Insects, birds, mammals</td>
<td>Populations, species, functional groups</td>
<td>Local</td>
</tr>
<tr>
<td>Seed dispersal</td>
<td>Insects, birds, mammals, reptiles(^b)</td>
<td>Populations, species, functional groups</td>
<td>Local</td>
</tr>
<tr>
<td>Pest control</td>
<td>Invertebrate parasitoids and predators, and vertebrate predators</td>
<td>Populations, species, functional groups</td>
<td>Local</td>
</tr>
<tr>
<td>Purification of water</td>
<td>Vegetation, soil microorganisms, aquatic microorganisms, aquatic invertebrates</td>
<td>Populations, species, functional groups, communities, habitats</td>
<td>Local–regional</td>
</tr>
<tr>
<td>Detoxification and decomposition of wastes</td>
<td>Leaf litter and soil invertebrates; soil microorganisms; aquatic microorganisms</td>
<td>Populations, species, functional groups, communities, habitats</td>
<td>Local–regional</td>
</tr>
<tr>
<td>Soil generation and soil fertility</td>
<td>Leaf litter and soil invertebrates; soil microorganisms; nitrogen-fixing plants; plant and animal production of waste products</td>
<td>Populations, species, functional groups</td>
<td>Local</td>
</tr>
</tbody>
</table>

\(^a\) ‘Functional units’ refer to the unit of study for assessing functional contributions of ecosystem service providers; spatial scale indicates the scale(s) of operation of the service. The author’s assessment of the potential to apply this conceptual framework to the service was purposefully conservative and is based on the degree to which the contributions of individual species or communities can currently be quantified.

\(^b\) Reptiles were not included in the original paper, but have been shown to be effective seed dispersers. \cite{12,13}

Source: Kremen\cite{14}
State and trends of biodiversity

When many people think of biodiversity, they usually think of the number of individual species, especially those that are very visible. ‘Species diversity’, however, is only one part of biodiversity, and it depends on other types of diversity. The short and long-term survival of species depends in part on the options that their genetic diversity gives them for adapting to change. The capacity of animals to find food and mates and successfully raise young is also influenced by the extent, diversity and quality of the habitat that is available, interrelationships with other species at a range of scales from a few millimetres to whole landscapes (and even at global scales for migratory species), and interactions with nonliving components of the environment, like temperature, rainfall, fire regimes and soil type.

Therefore, at least three levels of information are considered in this section on the state of Australia’s biodiversity:

- an assessment of the degree to which ecosystems—suites of species interacting with one another and the nonliving environment—continue to exist across their past ranges
- an assessment of the quality of remaining native vegetation (e.g. whether it contains a diversity of structure, minor and major species, resources and ecological processes)
- information on the distribution and abundance of individual species and particular groups of species (e.g. ecological communities).

2.1 Availability of information

Australia’s states and territories have the primary responsibility for biodiversity management, and for monitoring the state and trends in biodiversity in their jurisdictions. In this assessment, we have recognised the role of jurisdictional SoE reports in informing the state and trends in biodiversity nationally. The jurisdictional reports differ from one another in terms of indicators used, approaches taken, and styles and periods of reporting; we have not sought to standardise these reports. We have also drawn on national-level assessments where they are available, and on the scientific literature where relevant.

We have limited information on the state of many individual species or groups of species. However, the evidence from changes in extent, composition and quality of vegetation communities, and from case studies on selected species, points towards continuing decreases in population sizes, geographic ranges and genetic diversity, and increasing risks of population collapses in substantial proportions of most groups of plants, animals and other forms of life across much of Australia. This trend is variable, because components of biodiversity appear to be persisting well in some areas, especially where human impacts are minimal, but declining significantly in others. Historically, problems have been greater in southern Australia than in the north, especially in woodlands and grasslands of the agricultural zones of the south-east and south-west. However, recent reports of significant decreases in abundance in small mammals and birds in northern Australia suggest that at least some components of biodiversity in the north are less secure than previously thought.

The limited amount of long-term data on virtually all groups of plants, animals and other organisms means that Australia has a very poor ability to assess rates and directions of change in elements of biodiversity, and to assess whether or not some components might be approaching points at which much more rapid change might occur, beyond which return to previous conditions might be very difficult or impossible. Research from around the world and case studies within Australia suggest that such threshold change is a possibility in a number of places and ecological systems. Where it occurs, it is likely to lead to irreversible loss of biodiversity.

Australia’s capacity to report against biodiversity state and trends was assessed by the recent Assessment of Australia’s terrestrial biodiversity (Table 8.3). As pointed out in successive SoE reports at both state and territory levels and nationally for over a decade, information on individual species, groups of species and habitat quality remains very poor in general, although information on the extent of broad vegetation types is good in many respects and improving.
Table 8.3  Capacity to report on biodiversity state and trends

<table>
<thead>
<tr>
<th>Aspect of biodiversity (indicator)</th>
<th>Capacity to report&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species and communities</td>
<td></td>
</tr>
<tr>
<td>(Trends in the conservation status of species and ecological communities)</td>
<td>Poor for national trends</td>
</tr>
<tr>
<td></td>
<td>Good at case study level</td>
</tr>
<tr>
<td></td>
<td>Moderate at national level for numbers of threatened taxa and ecological communities</td>
</tr>
<tr>
<td></td>
<td>Average for listing and recovery plan statistics</td>
</tr>
<tr>
<td>Terrestrial ecosystems</td>
<td></td>
</tr>
<tr>
<td>(The extent and distribution of native vegetation)</td>
<td>Good nationally for extent&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Moderate nationally for type</td>
</tr>
<tr>
<td>(Change in the extent and distribution of native vegetation)</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Good nationally for forest (Kyoto definition)</td>
</tr>
<tr>
<td></td>
<td>Good in Queensland for woody vegetation</td>
</tr>
<tr>
<td></td>
<td>Good in Victoria for native vegetation cover</td>
</tr>
<tr>
<td>(Status and trends in native vegetation condition)</td>
<td>Good in Victoria</td>
</tr>
<tr>
<td></td>
<td>In areas where native vegetation is monitored, there is evidence of decline in condition</td>
</tr>
<tr>
<td>Aquatic ecosystems</td>
<td></td>
</tr>
<tr>
<td>(The extent and distribution of wetlands)</td>
<td>Moderate for important wetlands nationally</td>
</tr>
<tr>
<td></td>
<td>Good for some states</td>
</tr>
<tr>
<td>(Trends in river and wetland health)</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Good for the Murray–Darling Basin (rivers)</td>
</tr>
<tr>
<td></td>
<td>Good in some states (rivers)</td>
</tr>
</tbody>
</table>

<sup>a</sup> See original report for definition of ratings.

<sup>b</sup> Note added by authors of the current report: Good for woody vegetation but not nonwoody

Source: Summarised from Australian Government Department of the Environment, Water, Heritage and the Arts

All state and territory SoE reports recognise that their information base is inadequate in some or all areas. The development of a national environmental reporting approach<sup>26</sup> offers the prospect of improving this situation, and the Australian Natural Resource Management Ministerial Council<sup>10</sup> has committed to establishing a national long-term biodiversity monitoring and reporting system by 2015 as part of Australia’s Biodiversity Conservation Strategy 2010–2030. In addition, calls for the establishment of long-term ecological research sites have argued the need to better understand how ecological systems change under human-induced and other pressures, so that we are better able to identify signs of change and take appropriate preparatory actions to avoid or cope with it.<sup>17–19</sup> The Terrestrial Ecosystem Research Network, established with funding from the Australian government, is under development<sup>20</sup> and is likely to meet some, but not all, needs for long-term ecosystem monitoring and research in Australia.

2.2 Genetic and species diversity

Genetic diversity within species is at the heart of biodiversity, but it has been very difficult to assess directly or for more than a sample of species. New genomic technologies are beginning to change this situation, but information from them remains limited.<sup>21</sup> Instead, we use surrogates, such as assessments of the current range of species compared with their previous range.

Forest of karri (<i>Eucalyptus diversicolor</i>) along the Warren River, Warren National Park, Western Australia

Photo by Jean-Paul Ferrero
Two surrogate measures currently used in assessments of threats to species are the extent of occupation (EOO), which is the overall area within which a species or community is found, and the area of occupation (AOO), which is the amount of area within the EOO that is actually used by the species or community. These measures are two means of incorporating threats to genetic diversity in conservation assessments, although there is some debate about how consistently these methods are applied in listing processes and about how well they are taken into account in planning for future reserve networks. Criterion 2 for listing ecological

Figure 8.3 Patterns of weighted endemism (left; a measure of the degree to which species and genes are found nowhere else) and species richness (right; the number of species found in an area) for Australian (a) plants, (b) mammals, (c) birds, (d) reptiles and (e) frogs
communities under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act; i.e. small geographic distribution coupled with demonstrable threats) is intended to capture naturally restricted communities that are under threat.\(^{26}\) It uses EOO and AOO, as well as consideration of patch size distribution.

In theory, representation of past distributions and existing genetic diversity should be considered in assessing the representativeness of the National Reserve System, which is discussed in Section 4.4.1. Use of more direct measures of genetic diversity in biodiversity conservation planning and management will become more feasible as genomic information becomes more readily and more routinely available.\(^{27}\)

With respect to species diversity, there has been considerable progress made since the last national SoE report on collecting data on levels of endemism (how many species are native and unique to a region) nationally (Figure 8.3).

The data presented in Figure 8.3 are not corrected for sampling error (i.e. there is a greater intensity of sampling in some places than others), but they still give an indication of where priorities for conservation need to be explored in more detail. For example, some regions, such as the south-west, wet tropics and New South Wales – Queensland border ranges, are areas of high endemism and/or richness for many species. Figure 8.3 also illustrates the wide distribution and diversity of locations important for biodiversity. There is a strong overlap between many of these areas with those that have historically suffered the greatest pressures on biodiversity and contain the highest numbers of threatened species, creating a major conservation challenge.

It is worth noting that few invertebrates—a highly diverse group that comprises the majority of animal species in Australia—have been mapped in this way, illustrating the extent to which our current knowledge is incomplete.
2.3 Terrestrial ecosystems and communities

Animals, plants and other organisms aggregate in combinations that we recognise as different ‘systems’. The mixes of species in these aggregations are influenced by such factors as variations in rainfall and temperature regimes, soil type, altitude and exposure to sunlight. Historical factors, such as which species arrived first, are also important. These aggregations are useful for classifying the variety of life at a higher level than species. They are variously called ‘ecosystems’, ‘communities’, ‘vegetation types’, ‘vegetation associations’ or other similar terms (Table 8.4). These different approaches are understandable, because the aggregations are human perceptions. However, the lack of standardised terms is a challenge for collecting and assessing information and data, particularly across jurisdictional boundaries. The National Vegetation Information System (NVIS) provides a partial solution, but gaps and inconsistencies remain due to different ways of mapping and analysing vegetation in different parts of Australia.

Given the challenges of assessing variation at species and within-species level, biodiversity conservation strategies generally seek to manage these higher level aggregations of species as a means of conserving their constituent species. The importance of this ‘ecosystem approach’ to conservation was reiterated in the recent review of the EPBC Act, but there are many challenges to achieving it. For example, individual species may be threatened or vulnerable, even though the ecosystems in which they are found are protected (e.g. corroboree frogs or mountain pygmy possums in alpine ecosystems).

The classification of species aggregations is still evolving at a national scale. The NVIS has identified 23 major vegetation groups (MVGs) based on structure, growth form and floristic composition of the dominant stratum of each vegetation type, and 67 major vegetation subgroups (MVSSs), based on MVGs but including understorey characteristics and other identifying floristic affinities. Other classification systems have been based on finer scale differentiation, such as that proposed by the National Land & Water Resources Audit (NLWRA) from ecosystems identified by each Australian jurisdiction. The biodiversity theme paper for the previous national SoE report urged that this type of approach be built on as a way to identify regional priorities for action. This exercise has not been updated since, and we know of no national surveys at comparable levels of ecosystem differentiation.

### 2.3.1 Reporting by jurisdictions

States and territories define and list ecological communities in different ways from one another and from the Australian Government. Nevertheless, it is instructive to summarise trends for communities from the jurisdictional reports (Table 8.5).

### Table 8.4 Terms used to describe high-level aggregations of species

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community</td>
<td>A natural aggregate of different species of organisms existing in the same environment. While species within the community interact with each other, forming food chains and other ecological systems, they do not generally interact with species in other communities. For the purposes of the NVIS, a community is described as an assemblage of plant species that are structurally and floristically similar and form a repeating ‘unit’ across the landscape. See also vegetation type, below.</td>
</tr>
<tr>
<td>Ecosystem</td>
<td>An aggregate of animals, plants and other organisms, and the nonliving parts of the environment, that interacts and that is relatively self-contained in terms of energy flow.</td>
</tr>
<tr>
<td>Vegetation type</td>
<td>A community that has a floristically uniform structure and composition, often described by its dominant species. In NVIS, a vegetation type is commonly represented by a vegetation description.</td>
</tr>
</tbody>
</table>

NVIS = National Vegetation Information System
Source: Executive Steering Committee for Australian Vegetation Information
### Table 8.5 Summary of assessments of trends and conservation status for ecological communities and vegetation associations in state and territory state of the environment reports and the most recent national terrestrial biodiversity assessment

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>There is a relatively high level of habitat protection, including lowland woodland and grassland. 20 vegetation communities are recognised and described; 19 have more than 30% of their remaining extent well conserved; 8 have less than 30% of their pre-1750 distribution remaining; and another 3 have more than 30% remaining but are under significant threat.</td>
</tr>
<tr>
<td>NSW</td>
<td>Clearing of woody vegetation has fluctuated over the past 20 years, but has stabilised over the past 3 years. Status varies across areas and vegetation types. Native vegetation that is structurally intact (but is not necessarily in good condition) covers 61% of the state; a further 8% is derived (native vegetation that has been structurally modified, but where more than 50% of the ground cover is native species); and 20% is a mixture of native and non-native elements, which cannot be discriminated by remote sensing (mostly nonwoody grassland that is devoted to grazing). The number of listed communities increased by 14% to 91 listings since 2006, mainly due to assessment of previously unassessed entities. Most communities have experienced a reduction in range.</td>
</tr>
<tr>
<td>NT</td>
<td>Large areas have little clearing, and clearing is concentrated in a few areas around Darwin, and in the Daly River. Impacts of grazing by stock animals may have similar impacts to clearing on small mammals and birds in the territory. The process for listing threatened ecological communities is evolving, and none are currently listed by the government.</td>
</tr>
<tr>
<td>Qld</td>
<td>Most of the state has relatively continuous native vegetation, but there is concern about the more fertile landscapes in wetter parts of the state, which have been reduced to less than 30% of native vegetation cover on average. In the south-east, revegetation processes are producing a net gain in vegetation extent, but in most regions, the total area of regrowth is very small compared with the amount of clearing. Declines in the state of regional ecosystems is continuing. Of 1351 regional ecosystems, 92 are endangered, 516 are vulnerable (of concern) and 743 are not of concern. A high proportion of regional ecosystems in the New England Tableland, south-east Queensland and Brigalow Belt bioregions, and in parts of the Wet Tropics, Mulga Lands and Central Queensland Coast bioregions, are endangered and of concern. Some regional ecosystems in fragmented landscapes are poorly conserved.</td>
</tr>
<tr>
<td>SA</td>
<td>The overall trend is reported as stable; there has been limited clearing in arid areas (37 of 56 subregions), but around 75% clearing in the other 19 subregions. There is no formal process for listing threatened ecological communities, but the Department of Environment and Natural Resources has a provisional list of threatened ecosystems in the state based on expert opinion and available data. Five ecological communities occurring in the state are listed as endangered or critically endangered nationally.</td>
</tr>
<tr>
<td>Tas</td>
<td>Conversion of native forest to plantation reduced in 2007–08, but decreases in area and condition continue due to other pressures. Native nonforest vegetation decreased by 3807 ha from 2000 to 2005. Of 142 native vegetation communities, 39 are listed as threatened and 10 as endangered. A number of vegetation communities were significantly affected by conversion to plantation in the period from 1996 to 2008, and there was a significant reduction of the area that was rabbit-free compared with 1996.</td>
</tr>
<tr>
<td>Vic'</td>
<td>At least half of the state’s native vegetation has been cleared. On public land, vegetation gains have offset losses, but on private land gains have outweighed losses. Bioregions suitable for urban development and agriculture have suffered the greatest loss of vegetation; vegetation quality is low and it is highly fragmented. Plant communities are relatively intact in the Eastern Highlands and the Mallee, but condition is variable due to previous and ongoing pressures. Many ecosystems in bioregions suitable for urban development and agriculture are classified as endangered.</td>
</tr>
</tbody>
</table>

Continued next page
### 2.3.2 Extent of vegetation communities

Vegetation communities, or assemblages of plants within a region, form the basis for Australian habitats, with particular vertebrates and invertebrates being associated with particular communities. Although, at a continental scale, 87% of Australia’s native vegetation remains, there has been a substantial loss of vegetation since European settlement as land clearing for agriculture and urban development proceeded in areas of intensive use and many coastal zones (see Table 8.5 and Chapter 5: Land). Native vegetation loss continues at a rate of nearly 1 million hectares annually (see Chapter 5: Land).

The Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) has initiated an analysis of major vegetation types to identify:

- terrestrial vegetation types that are under-represented in the threatened ecological communities currently listed under the EPBC Act (Table 8.6)
- which major vegetation types and bioregions are likely priorities for further investigation (Table 8.7).

### Table 8.5 continued

| Jurisdiction | State (and trend if reported)
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WA</td>
<td>Of the 54 terrestrial subregions, 41 have 96% or more native vegetation remaining; but in the south-west bioregions, only about 40% of the pre-European settlement extent remains. There are 66 ecological communities listed as threatened, and 3 that are thought to be extinct or destroyed. The listing is incomplete and is thought to under-represent the true number of threatened communities.</td>
</tr>
<tr>
<td>National</td>
<td>About 87% of the continent still has native vegetation cover. Native vegetation has been modified and cleared substantially since European settlement, especially from intensive agricultural and urban areas (particularly in southern and eastern Australia and in south-western Australia). Native vegetation is being lost faster than it is replaced. More than 50% of pre-1750 vegetation has been lost from several IBRA subregions along the east coast of Qld and northern NSW, south-west WA, and southern Vic and SA. Less than 10% of the pre-1750 native vegetation remains in some IBRA subregions in southern Australia and south-east Qld, but more than 70% remains in most IBRA subregions of central and northern Australia. 50 ecological communities are listed as threatened nationally under the <em>Environment Protection and Biodiversity Conservation Act 1999</em>. Listed ecological communities occur in higher numbers along the east coast of Australia, in southern Australia generally, and in south-western WA.</td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; ha = hectare; IBRA = Interim Biogeographic Regionalisation of Australia; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia.

a As the aim of this table is to provide a high-level overview of the state and trends in biodiversity in each state, the information is drawn from the published state of the environment reports. Except in the case of the Northern Territory, where no state of the environment report was available and information was sourced from the threatened species website (see sources below), we have not searched state online databases. For numbers of species listed as threatened nationally (under the *Environment Protection and Biodiversity Conservation Act 1999*—EPBC Act) we also referred to the EPBC Act website (see sources below).

b Different states and territories adopt different indicators and approaches to reporting against them. We have not attempted to standardise across reports in this table. Elsewhere in this chapter and in Chapter 5: Land we report in a more standard way across Australia on aspects such as land clearing and extent of major vegetation types remaining. Where trends are not given, this is because these were not reported (usually due to data limitations). Many reports have not attempted to assess change in state or trends over the 4–6 year period between state of the environment reports, again due to data limitations and the variability of available data. Where this has been done, it is stated. Where no period for assessment is given, it is assumed to have been historical change, since the arrival of European settlers.

c In Victoria, threatened species are officially listed under the *Flora and Fauna Guarantee Act 1988*, but the Department of Sustainability and Environment also maintains an Advisory List of Threatened Vertebrate Fauna and an Advisory List of Rare and Threatened Plants based on expert opinion and information that has not yet been fully considered via the official process.

Sources: ACT, NSW, NT, Qld, SA and notes from an anonymous SA Government employee who reviewed the chapter, Tas, Vic, WA, national.
Table 8.6 Preliminary analysis of trends in National Vegetation Information System major vegetation groups among IBRA bioregions

<table>
<thead>
<tr>
<th>Major vegetation group</th>
<th>No. bioregions where present</th>
<th>Extent within bioregion No. bioregions where present (no. with &gt;70% decrease in area)</th>
<th>&gt;70% decrease in area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 million ha + 100 000 to &lt;1 million ha 10 000 to &lt;100 000 ha &lt;10 000 ha No. bioregions % total</td>
<td></td>
</tr>
<tr>
<td>1 Rainforests and vine thickets</td>
<td>36</td>
<td>1 9 (1) 13 13 (1)</td>
<td>2 5.6</td>
</tr>
<tr>
<td>2 Eucalyptus tall open forests</td>
<td>26</td>
<td>1 12 5 (1) 8</td>
<td>1 3.8</td>
</tr>
<tr>
<td>3 Eucalyptus open forests</td>
<td>50</td>
<td>14 (1) 26 (3) 6 (2) 4</td>
<td>6 12.0</td>
</tr>
<tr>
<td>4 Eucalyptus low open forests</td>
<td>22</td>
<td>0 2 5 15 (2)</td>
<td>2 9.1</td>
</tr>
<tr>
<td>5 Eucalyptus woodlands</td>
<td>79</td>
<td>32 (9) 26 (6) 18 (8) 3 (1)</td>
<td>24 30.4</td>
</tr>
<tr>
<td>6 Acacia forests and woodlands</td>
<td>68</td>
<td>13 (2) 14 (1) 15 (3) 26 (3)</td>
<td>9 13.2</td>
</tr>
<tr>
<td>7 Callitris forests and woodlands</td>
<td>27</td>
<td>1 6 6 14 (1)</td>
<td>1 3.7</td>
</tr>
<tr>
<td>8 Casuarina forests and woodland</td>
<td>53</td>
<td>4 14 (1) 16 (2) 19 (3)</td>
<td>6 11.3</td>
</tr>
<tr>
<td>9 Melaleuca forests and woodland</td>
<td>45</td>
<td>2 13 (1) 18 (2) 12 (3)</td>
<td>6 13.3</td>
</tr>
<tr>
<td>10 Other forests and woodlands</td>
<td>55</td>
<td>2 14 (1) 18 (2) 21 (2)</td>
<td>5 9.1</td>
</tr>
<tr>
<td>11 Eucalyptus open woodlands</td>
<td>68</td>
<td>14 (1) 19 (1) 20 (3) 15 (2)</td>
<td>7 10.3</td>
</tr>
<tr>
<td>12 Tropical Eucalyptus woodlands/grasslands</td>
<td>13</td>
<td>4 7 2 0</td>
<td>13 0.0</td>
</tr>
<tr>
<td>13 Acacia open woodlands</td>
<td>35</td>
<td>8 12 9 (1) 6 (1)</td>
<td>2 5.7</td>
</tr>
<tr>
<td>14 Mallee woodlands and shrublands</td>
<td>35</td>
<td>7 11 (3) 8 (1) 9 (3)</td>
<td>7 20.0</td>
</tr>
<tr>
<td>15 Low closed forests and tall closed shrublands</td>
<td>26</td>
<td>1 3 (1) 8 (1) 14 (3)</td>
<td>5 19.2</td>
</tr>
<tr>
<td>16 Acacia shrublands</td>
<td>44</td>
<td>21 (1) 11 (1) 6 6 (2)</td>
<td>4 9.1</td>
</tr>
<tr>
<td>17 Other shrublands</td>
<td>62</td>
<td>5 (1) 21 20 (1)</td>
<td>16 2.3</td>
</tr>
<tr>
<td>18 Heathlands</td>
<td>32</td>
<td>0 2 15 (2) 15 (1)</td>
<td>3 9.4</td>
</tr>
<tr>
<td>19 Tussock grasslands</td>
<td>60</td>
<td>10 23 (2) 14 (1) 13 (3)</td>
<td>6 10.0</td>
</tr>
<tr>
<td>20 Hummock grasslands</td>
<td>36</td>
<td>17 11 4 4</td>
<td>0 0.0</td>
</tr>
<tr>
<td>21 Other grasslands, herblands, sedgelands and rushlands</td>
<td>59</td>
<td>2 7 29 (2) 21</td>
<td>2 3.4</td>
</tr>
<tr>
<td>22 Chenopod shrublands, samphire shrublands and forblands</td>
<td>58</td>
<td>10 12 13 (4) 23 (10)</td>
<td>14 24.1</td>
</tr>
<tr>
<td>23 Mangroves</td>
<td>26</td>
<td>0 3 12 11 (1)</td>
<td>1 3.8</td>
</tr>
</tbody>
</table>

Note: Many major vegetation groups occur in more than one bioregion.
Table 8.7 Preliminary analysis of regions characterised by the decrease in area of multiple major vegetation groups within and among adjacent bioregions

<table>
<thead>
<tr>
<th>Region</th>
<th>IBRA bioregions&lt;sup&gt;a&lt;/sup&gt;</th>
<th>MVGs identified as decreasing in area by &gt;50% within the bioregion&lt;sup&gt;b&lt;/sup&gt;</th>
<th>MVGs identified as decreasing in area by &gt;70% within the bioregion&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>South West Western Australia</td>
<td>AW  3, 11, 22</td>
<td>5, 6, 8, 9, 10, 14, 15, 16, 17, 18</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SWA 11, 17</td>
<td>3, 5, 7, 8, 9, 15, 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>GS  10, 14, 17, 18</td>
<td>5, 6, 11, 16, 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAL 16, 17, 21</td>
<td>8, 10, 11, 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>JF  5, 8, 17</td>
<td>10, 14, 15,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ESP  9, 14</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Southern Victoria</td>
<td>VVP 3, 5, 6, 8, 9, 10, 18, 19, 21, 23</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SCP 1, 3, 5, 10, 17, 18, 19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern and Eastern South Australia</td>
<td>NCP 17, 18</td>
<td>3, 5, 9, 14, 19</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EYB 14</td>
<td>5, 9, 11, 13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KAN 3, 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FLB 5, 11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern New South Wales and Northern Victoria</td>
<td>RIV 7, 10</td>
<td>5, 6, 14</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEH 5, 19</td>
<td>4, 14, 21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NSS 14</td>
<td>3, 5, 6</td>
<td></td>
</tr>
<tr>
<td>Northern and Central Tasmania</td>
<td>FLI 2, 5, 11, 22</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TNM 3</td>
<td>5, 15, 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>KIN 4, 5</td>
<td>4, 5, 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TNS 5, 15, 22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Eastern New South Wales</td>
<td>SB 5, 17</td>
<td>8, 14, 22</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEC 11</td>
<td>8, 14, 19</td>
<td></td>
</tr>
<tr>
<td>Brigalow Belt and South East Queensland</td>
<td>SEQ 1, 3, 5, 15, 18</td>
<td>6, 16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BBS 5, 19, 23</td>
<td>1, 6, 9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BBN 1, 19</td>
<td>6, 10, 13</td>
<td></td>
</tr>
</tbody>
</table>

AW = Avon Wheatbelt; BBN = Brigalow Belt North; BBS = Brigalow Belt South; ESP = Esperance Plains; EYB = Eyre York Block; FLB = Flinders Lofty Block; FLI = Flinders; GS = Geraldton Sandplains; IBRA = Interim Biogeographic Regionalisation of Australia; JF = Jarrah Forest; KAN = Kanmantoo; KIN = King; MAL = Mallee; MVG = major vegetation group; NCP = Naracoorte Coastal Plain; NSS = New South Wales South Western Slopes; RIV = Riverina; SB = Sydney Basin; SCP = South East Coastal Plain; SEC = South East Corner; SEH = South Eastern Highlands; SEQ = South Eastern Queensland; SWA = Swan Coastal Plain; TCH = Tasmanian Central Highlands; TNS = Tasmanian Northern Slopes; VVP = Victorian Volcanic Plain

<sup>a</sup> Abbreviations are standard for IBRA regions.<sup>48</sup>

<sup>b</sup> Number codes for MVGs are shown in Table 8.6.

Note: Many MVGs occur in more than one bioregion.
Table 8.6 illustrates the decrease in extent of major vegetation groups by their bioregional extent. It is notable that some extensive occurrences of 1 million hectares or more have declined in some bioregions, particularly for *Eucalyptus* woodlands. Some of the MVGs that have declined are presently under-represented on the national list of threatened ecological communities. For example, components of MVGs 14, 15 and 22 have suffered extensive declines in some bioregions but are not yet listed or under assessment. Table 8.7 supports the conclusions of the most recent national assessment of Australia’s terrestrial biodiversity that:

... over 50% of pre-1750 vegetation has been lost from several IBRA [Interim Biogeographic Regionalisation of Australia] subregions along the east coast of Queensland and northern New South Wales, south-west Western Australia, and southern Victoria and South Australia. Less than 10% of the pre-1750 native vegetation remains in some IBRA subregions in southern Australia and south-east Queensland, but more than 70% remains in the majority of IBRA subregions of central and northern Australia.\(^{15}\)

2.3.3 Quality of habitat

Habitat ‘quality’ is also an important determinant of biodiversity status, and research has sought to identify cost-effective ways to assess the quality of habitat, in terms of such attributes as its ‘condition’ and the degree of connections between patches of habitat.\(^{15}\) Although few data have been reported on habitat quality in SoE reports to date, apart from in Victoria (Table 8.8), a number of approaches have been developed and are in at least limited use by jurisdictions, including being tested in case studies in New South Wales and Queensland.\(^{56-54}\) The Australian Government intends to develop nationally consistent measures to assess habitat quality that could be used in future national reporting.\(^{15}\) Summary statements from the most recent state and territory SoE reports are presented in Table 8.8.

Since 2006, EPBC-listed ecological communities have increasingly taken condition of remnants into account, partly to provide guidance on when a patch of an ecological community may be too degraded to be considered for EPBC referral or compliance. Condition and decline in integrity is also one of the criteria for assessing an ecological community as threatened. It allows for qualitative assessment of decline where reliable quantitative evidence for decline may be lacking, or in addition to it, as further support for listings. Most of the items listed since 2006 are broadscale listings covering much of the south-eastern agricultural and urban zones. Although this evidence relating to the community integrity trigger does not provide quantitative estimates of how much remains in good versus poor condition, it provides sufficient evidence that there has been qualitative decline to some extent across a community’s range.

2.3.4 Capacity to meet human needs or resource demands

The capacity of ecosystems to meet human needs depends on both the functionality of those ecosystems and the needs that people have (see Section 1.2). Information on what people—including those outside Australia—need or demand from Australian ecosystems is limited. Measures such as ecological footprint, for example, give a broad estimate of how much productive land the average Australian needs to maintain their current lifestyle (see Section 3.6.2). However, it is difficult to identify where that land is located in Australia or, indeed, in other countries. Detailed analyses of the stocks of natural resources and flows of those resources into and out of processes that support human activity are very useful. They have been used to identify where there are risks of resource shortages in relation to population size and resource consumption behaviour.\(^{55-56}\)

There has been considerable analysis to suggest that current levels of some natural resources, such as water, oil, coal, gas and land for food production, might become limiting in the near or medium-term future, depending on rates of population growth and resource use per person.\(^{56-57}\) However, there has been little detailed consideration of the costs associated with replacing ecosystem services such as water filtration, pest control, waste assimilation and pollination as biodiversity declines.\(^{58}\) These complex interrelationships need to be better understood in order to assess whether the current state of Australia’s environment, and the biodiversity within it, are adequate to meet human needs now and into the future.
### Table 8.8 Summary of assessments of habitat quality in state and territory state of the environment reports and the most recent national terrestrial biodiversity assessment

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>There is continued decline in woodlands and grasslands</td>
</tr>
<tr>
<td>NSW</td>
<td>The trend is unknown, and information is limited. Pressures on condition are likely to remain for the foreseeable future due to the lag effects of fragmentation following clearing, coupled with increasing pressures from invasive species and climate change</td>
</tr>
<tr>
<td>NT</td>
<td>High proportions of area are burned. There is a high density of bores throughout much of the territory. Most bioregions have 3–9% exotic plants (some have 9–15%)</td>
</tr>
<tr>
<td>Qld</td>
<td>The condition of native vegetation is variable (depending on the bioregion, 0.7–60% of ecosystems in the region are considered endangered and 5.4–51.7% of concern); intact areas are in better condition than fragmented areas. The condition of regional ecosystems in bioregions subject to little or no clearing has still declined due to other factors</td>
</tr>
<tr>
<td>SA</td>
<td>The condition is unknown overall but there has been documented improvement in some pastoral areas</td>
</tr>
<tr>
<td>Tas</td>
<td>Baseline assessments are under way. At least 270 forest-associated plant species are at risk from isolation and loss of genetic diversity</td>
</tr>
<tr>
<td>Vic</td>
<td>Native vegetation is fragmented over much of the state and is declining in quality, but the quality of largely intact landscapes is generally high. Native grasslands retain less than 1% of their original extent in good condition. Assessments of vegetation quality are modelled at a landscape scale across the state based on assessment of site condition and landscape context. These components contribute to a habitat score. Statewide, it is estimated that there have been gains and losses of habitat hectares on both public and private land resulting in a net loss of approximately 4090 habitat hectares per year (a net gain of 5900 habitat hectares per year on public land but a net loss of 9990 habitat hectares per year on private land)</td>
</tr>
<tr>
<td>WA</td>
<td>The south-west wheatbelt has the highest 'continental stress class' score. (Continental stress class is a method of describing landscape health; Class 1 contains the most stressed regions and Class 6 the least stressed.) Other coastal parts of the south-west and mid-west also show high levels of stress. Much of the Kimberley region and the central desert areas have the lowest stress</td>
</tr>
<tr>
<td>National</td>
<td>Information is currently limited but progress has been made towards a national approach to assessing habitat condition. Trials in Victoria have produced a statewide map</td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

*See notes below Table 8.5 for caveats and sources.*

Recent research and practice suggest a number of starting points for these assessments. The state of ecosystems in relation to land uses was assessed in Victoria’s Goulburn–Broken catchment in 2001. The assessment found that most land uses in that catchment rely on most ecosystem services, and that there are several situations in which the state of biodiversity might be approaching the point at which it will start to limit benefits to humans below their needs. For example, it was considered that the service of waste absorption—the breaking down of human and animal wastes by soil organisms—was at a critically low level and that this was affecting all but two land uses.

Research in the Gwydir catchment in New South Wales has shown that strategic management of remnant vegetation to improve elements of biodiversity makes major contributions to carbon sequestration, erosion prevention, improved grazing on flood plains, bird breeding events and biodiversity conservation generally. The benefits of only these four ecosystem services were estimated at $94 million over 30 years.

Information such as this has been used in Victoria to prioritise the purchase of specific ecosystem services—the protection of habitat of biodiversity and enhancement of carbon sequestration—from land managers.
The public benefits of environmental services from agricultural land are estimated to be in the tens of millions of dollars for individual industries, and several billion dollars overall.\textsuperscript{62} Research by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) has shown the importance of soil biodiversity in supporting horticulture\textsuperscript{63} and other industries (Box 8.2). Pollination by bees and other animals increases the size, quality or stability of harvests for 70\% of leading global crops.\textsuperscript{64} A recent analysis of 23 studies, representing 16 crops on 5 continents, concluded that pollinator richness and visitation rate on crops show general and significant exponential declines with increasing distance from natural habitat, and that for many crops this results in decline in fruit and seed set.\textsuperscript{64} Concerns have been raised about effects such as this in Australia if populations of introduced honeybees, the main pollinator of many crops, decline and if retention of native vegetation is inadequate to supply enough native pollinators to replace the ecosystem service.\textsuperscript{65}

Although economic valuation of benefits from ecosystems is an important tool for understanding the importance of biodiversity, economic value itself is not a good indicator of the state of biodiversity. This is because economic value is influenced by many factors, including both the rarity of the benefit and the cost of replacing it.

Over the past decade, a number of studies have investigated approaches to assessing the contributions of ecosystems to human wellbeing using an ecosystem services framework.\textsuperscript{59,71-78} Australia does not currently have a formal approach to collecting information on the state of ecosystem services, although this need is being considered as part of the National Plan for Environmental Information\textsuperscript{16} and examples are now emerging from other countries.\textsuperscript{79}

Box 8.2 The role of soil biodiversity in providing ecosystem services

While a start was made some years ago on consolidating national information on major groups of soil invertebrates,\textsuperscript{66} to date soil biodiversity has rarely been given much attention in state of the environment reporting.

Soil organisms affect important ecosystem processes, including soil formation, decomposition and nutrient cycling, carbon and nitrogen fixation and sequestration, infiltration, purification and storage of water. Bacteria are responsible for by far the greatest diversity of biogeochemical transformations of any group of organisms—they are the chemical factories that underpin soil ecosystems. The invertebrates, especially the larger arthropods like insects and spiders, play critical roles in burrowing, drilling, mixing and processing the soil substrate: filling its matrix with a spatial complexity of networks of burrows, pores, tunnels and tubes. These ‘ecosystem engineers’ provide the soil with access to water and air that are critical requisites for biogeochemical reactions to occur. Other arthropods harvest organic matter and build compost heaps in their nests and burrows, inoculating them with fungi to break down otherwise intractable plant material into food for their colonies. Australian soils have a high diversity of insects, spiders, earthworms and other species in contrast to the earthworm-dominated soils of many parts of the Northern Hemisphere.

The important ecosystem functions performed by soil organisms can be restored to degraded grazing soils in less than a decade through revegetation of landscapes.\textsuperscript{67} A new and exciting discovery is that the presence of ants and termites in certain cropping soils has a direct effect on improving yields of wheat.\textsuperscript{68}

Several soil invertebrates are considered of conservation significance, including the giant Gippsland earthworm, massive mound building termites, the honey-pot ant and several burrowing spiders. But the distribution and abundance of these organisms is still relatively poorly known and specific conservation management strategies that go beyond simply maintaining habitat integrity have not been developed.

Other soil organisms are invasive species that are important in terms of management. These include several exotic earthworms and termites, the yellow crazy ant, the red fire ant and the tropical fire ant.

Soil invertebrates have complex interrelationships with agriculture and other land uses. At a time when carbon storage on agricultural land is a major issue,\textsuperscript{69} soil organisms may prove to be major beneficiaries from management practices aimed at soil carbon sequestration and storage. Recent work has highlighted the impact of agricultural land-use practices on diversity and abundance of functional groups of soil bacteria,\textsuperscript{70} highlighting the need to consider a broader conservation framework that includes the protection of ecosystem processes and functions, as well as biodiversity.

2.4 Plant and animal species

Species diversity is a key component of biodiversity. In this subsection, we review what general conclusions can be drawn about the state and trends of specific groups of animal and plant species at national and subnational scales.

2.4.1 Threatened species lists

Each Australian state and territory has a legislated process for listing species as threatened (with categories such as rare, vulnerable, endangered and extinct) if the size and trend in populations and the pressures that the species face satisfy certain scientifically established criteria. Some jurisdictions also have the capacity to list threatened ecological communities. SoE reports usually report total numbers of species listed as threatened (Figure 8.4) as well as changes since previous reports.

Changes in numbers of listed species must be interpreted with care, because they are only partly due to declines or improvements in the status of species. Often they are due more to the effort put into collecting information, the groups of organisms that are focused on in a particular period and reviews of listed species (conducted by the Australian and state and territory governments), as well as differences in how species are listed by different jurisdictions. A recent analysis of taxa listed under the EPBC Act found that the formal status of 75 nationally listed flora taxa and 44 fauna taxa changed between 2002 and 2007. It was concluded that about 46% of these changes occurred because of improved knowledge and 36% were due to taxonomic updates. Real change attributed to decline accounted for 21.3% of flora taxa and 52.3% of fauna taxa. There were no cases of real improvement in the status of listed taxa at the national level.

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities

Figure 8.4 Numbers of species listed as threatened nationally under the Environment Protection and Biodiversity Conservation Act 1999 (includes terrestrial and marine species and species on Australian external territories)
Another consideration when interpreting total numbers of threatened species is that they partly reflect the overall number of species in a group (e.g. there are many threatened plants but also many species of plants) and so numbers of threatened species should be considered in relation to total numbers of known species. This is done wherever possible in the following sections.

Figure 8.5 shows the geographic distribution of all terrestrial species listed as threatened under the EPBC Act. The highest numbers occur down the east coast and in the south-west of Western Australia. As will be discussed in Section 3, these areas represent areas of high historical and current pressures.

Figure 8.5 Threatened species by Interim Biogeographic Regionalisation of Australia subregion

The numbers refer to species currently listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999. This does not include species that are already regarded as extinct. Known species extinctions in Australia have occurred primarily in arid and semi-arid parts of the continent—areas that in this figure are shown as having only small numbers of threatened species currently. As discussed elsewhere in this chapter, there are growing concerns that large parts of northern Australia in particular are showing signs of approaching another wave of extinctions that is happening faster than can be recognised in formal listing processes.
As well as the Australian continent, the Australian external territories should also be mentioned: although these territories comprise a small proportion of Australia by area, they include some unique environments. The territories include Christmas Island, Norfolk Island, Cocos (Keeling) Islands, Heard Island and McDonald Islands, Ashmore and Cartier Islands, Coral Sea Islands, the Australian Antarctic Territory and some Indian Ocean territories. We have been unable to compile detailed information on the state of biodiversity in each of these territories (some aspects are covered in other chapters, including Chapter 6: Marine environment and Chapter 7: Antarctic environment). The Director of National Parks reported on the state of national parks on three external territories in 2009–10 (Table 8.9).

### Table 8.9 Summary of species listed as threatened under the Environment Protection and Biodiversity Conservation Act 1999 in national parks in three Australian external territories in 2009–10

<table>
<thead>
<tr>
<th>Territory</th>
<th>Fauna</th>
<th>Flora</th>
<th>Total species recorded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulu Keeling National Park</td>
<td>1 critically endangered</td>
<td>None</td>
<td>5 mammals</td>
</tr>
<tr>
<td></td>
<td>4 endangered</td>
<td></td>
<td>24 birds</td>
</tr>
<tr>
<td></td>
<td>5 vulnerable</td>
<td></td>
<td>6 reptiles</td>
</tr>
<tr>
<td></td>
<td>24 migratory</td>
<td></td>
<td>31 plants</td>
</tr>
<tr>
<td></td>
<td>36 marine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Christmas Island National Park</td>
<td>2 extinct</td>
<td>2 critically endangered</td>
<td>3 mammals</td>
</tr>
<tr>
<td></td>
<td>1 critically endangered</td>
<td>1 endangered</td>
<td>95 birds</td>
</tr>
<tr>
<td></td>
<td>4 endangered</td>
<td></td>
<td>9 reptiles</td>
</tr>
<tr>
<td></td>
<td>7 vulnerable</td>
<td></td>
<td>More than 2000 invertebrates</td>
</tr>
<tr>
<td></td>
<td>63 migratory</td>
<td></td>
<td>213 plants</td>
</tr>
<tr>
<td></td>
<td>92 marine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norfolk Island National Park and Botanic Garden</td>
<td>5 extinct</td>
<td>15 critically endangered</td>
<td>2 mammals</td>
</tr>
<tr>
<td></td>
<td>5 critically endangered</td>
<td>16 endangered</td>
<td>50 birds</td>
</tr>
<tr>
<td></td>
<td>2 endangered</td>
<td>15 vulnerable</td>
<td>2 reptiles</td>
</tr>
<tr>
<td></td>
<td>5 vulnerable</td>
<td></td>
<td>180 plants</td>
</tr>
<tr>
<td></td>
<td>37 migratory</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>57 marine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities

2.4.2 Plant species

Although information on state and trends for some plant species in some parts of Australia is good, most jurisdictions report that survey information overall is inadequate to establish recent trends (Table 8.10). For example, in New South Wales, where gaps in information have been particularly well documented, no data are available for 73% of threatened plant species, let alone other plant species. Especially in areas of high species diversity, new species are still being discovered or described. In Queensland, for example, more than 50 previously unknown plant species are being described every year.
### Table 8.10 Summary of assessments of terrestrial plant species in state and territory state of the environment reports and the most recent national terrestrial biodiversity assessment

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State and trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>Continued decline in woodlands and grasslands</td>
</tr>
</tbody>
</table>
| NSW          | Status is variable among plant groups and the overall trend is unknown  
Plant species diversity has declined significantly since settlement, but there are limited suitable data to quantify the rate or magnitude of decline. Since European settlement, 35 plant species have become extinct |
| NT           | The government website lists 65 species of plants as threatened                                                                                                                                                                                                                                                                                   |
| Qld          | There are 428 plant species listed as threatened. Numbers have generally increased but are highly variable between bioregions                                                                                                                                                                                                                   |
| SA           | The number of threatened plant species is increasing. In 2007, 187 plant species were listed as presumed extinct, endangered and critically endangered, and 196 were listed as vulnerable (around 7% of known plant species in the state)                                                                                                                                         |
| Tas          | Trend is unknown but probably declining. There are 270 forest-associated vascular plant species considered to be at risk from isolation and loss of genetic diversity. Species listed as threatened in 1995, 2000 and 2007 were 465, 460 and 487, respectively |
| Vic          | Of 3140 known species of vascular plants, 1826 (58%) are included on the Advisory List of Rare and Threatened Plants, of which 49 are considered extinct, while only 288 are listed under the Flora and Fauna Guarantee Act 1988. In 2007 (compared with 2002), 20 bioregions had more threatened species, 4 had the same number and 4 had fewer |
| WA           | The number of threatened and priority taxa increased by 14% between 1998 and 2007 (from 2309 to 2625 taxa)                                                                                                                                                                                                                                       |
| National     | The proportion of threatened taxa is up to around 30% of total taxa for vascular plants in the best surveyed regions                                                                                                                                                                                                                              |

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia  

a See notes below Table 8.5 for caveats and sources.
Figure 8.6 shows the proportion of EPBC-listed plant species in Interim Biogeographic Regionalisation of Australia (IBRA) bioregions. Given the limitations on listing data discussed above, it is unwise to draw detailed inferences from this figure. The general trend is for higher proportions of plants to be threatened along the east coast and Cape York, and in the south-west. While the maximum proportion shown in this figure is 15.1%, higher proportions are reported for state and territory-listed species (up to around 30%).

Figure 8.6 Percentages of known plant taxa listed as threatened in each Interim Biogeographic Regionalisation of Australia subregion as at June 2007, (a) nationally (i.e. under the Environment Protection and Biodiversity Conservation Act 1999), and (b) in individual states or territories (i.e. under the listing processes of those jurisdictions).

Extinct species are excluded in both analyses. Note that numbers for South Australia are artificially high, because threatened species includes rare species.
30% in the best surveyed bioregions). In Victoria, where some of the greatest survey effort has been made, it is reported that 58% of all known plants are either threatened or under assessment for listing (Table 8.10). Different patterns between national and jurisdictional listings are not unexpected, because some species can be threatened in one state or territory but not nationally (because they are secure in other states or territories).

2.4.3 Fungi and other nonplant, nonanimal species

Very few data are reported by any jurisdiction on fungi or other species not classified as plants or animals (Table 8.11). This is a major data gap, because many of these species, especially fungi, play vital roles in ecological processes such as the distribution of carbon and nutrients throughout plant–soil systems. Although the evidence is limited, it is highly likely that native fungal species are declining in cleared landscapes and being replaced by introduced species in many areas.\textsuperscript{32}
### Table 8.11 Summary of assessments of fungi and other nonplant, nonanimal species in state and territory state of the environment reports and the most recent national terrestrial biodiversity assessment

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>The new plant list for the ACT, when published, is expected to include cryptogams (fungi) (about 600 species), lichens (about 405 species), liverworts and hornworts (about 107 species) and mosses (about 208 species)</td>
</tr>
<tr>
<td>NSW</td>
<td>There are an estimated 30,000 species of fungi in NSW. Nine communities are listed as threatened. Of an unknown number of aquatic and terrestrial algae, 2 are listed as threatened</td>
</tr>
<tr>
<td>NT</td>
<td>No information on website</td>
</tr>
<tr>
<td>Qld</td>
<td>No mention in report</td>
</tr>
<tr>
<td>SA</td>
<td>No mention in report (sampling and curating of fungi has been progressing but data are not available electronically)</td>
</tr>
<tr>
<td>Tas</td>
<td>Ecological importance is recognised in report but no assessment is given</td>
</tr>
<tr>
<td>Vic</td>
<td>Of an unknown number of fungi, nonvascular plants and lichens, 146 were included on the Victorian Advisory List, 2 of which are considered extinct, while 15 are listed under the <em>Flora and Fauna Guarantee Act 1988</em></td>
</tr>
<tr>
<td>WA</td>
<td>Noted in the report as being poorly understood</td>
</tr>
<tr>
<td>National</td>
<td>Fungi are the most diverse group of organisms apart from the insects. Australia is estimated to have 160,000–250,000 fungal species, of which less than 5% have been described. There appear to be no fungi listed as threatened nationally under the <em>Environment Protection and Biodiversity Conservation Act 1999</em></td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a See notes below Table 8.5 for caveats and sources.

### 2.4.4 Animal species overall

Recent SoE reports from around Australia, as well as previous national reports for over a decade, have expressed moderate to high levels of concern about a decline in many groups of fauna in their jurisdictions, although frequently it is acknowledged that data are inadequate to draw firm conclusions about which groups are declining and by how much. Many of the concerns are based on the pressures that exist and the known effects of these pressures on biota, rather than reliable data on the distribution and abundance of the species themselves.

The state and territory SoE reports reviewed in the following sections, together with the recent national assessment of Australia's terrestrial biodiversity, conclude that data on species of animals around Australia are very limited for most groups in most jurisdictions. In many cases, it is not possible to draw conclusions about trends in the state of animal species groups and sometimes it is not even possible to draw confident conclusions about the state of the taxon itself. The most recent New South Wales SoE report presented this lack of data very clearly (Figure 8.7).
Figure 8.7  State and trends for vertebrate fauna in New South Wales, showing (a) the historical decline and (b) estimates of future sustainability

The figures are from the most recent New South Wales state of the environment report and the situation is likely to be broadly similar across most jurisdictions.
Figure 8.7 continued

Source: New South Wales Department of Environment, Climate Change and Water"
2.4.5 Mammals

Mammals have been the best studied group of animals and major extinctions since European settlement have been documented. Assessments from state and territory SoE reports are summarised in Table 8.12. Excluding extinct species, it is estimated that in many subregions of Australia, more than 15% of known mammal species are listed as threatened nationally, and in many this proportion is 25–50% (Figure 8.8).

Table 8.12 Summary of assessments of mammals in state and territory state of the environment reports and the most recent national terrestrial biodiversity assessment

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>Numbers of some kangaroos are growing to problematic levels. Since 2003, one new mammal species has been listed as vulnerable or endangered</td>
</tr>
<tr>
<td>NSW</td>
<td>Mammals have experienced the greatest rate of extinction among flora and fauna since European settlement (26 of 138 species [19%] now extinct). A further 10% of species (18% of those assessable) have lost at least half their distribution. Currently, 1% of species is considered at high risk of being unsustainable, another 1% to be at moderate risk, 3% at low risk and 76% had no data available. A general pattern of decline over the longer term is evident, although some species have flourished</td>
</tr>
<tr>
<td>NT</td>
<td>14 species are listed as extinct, 1 as extinct in the wild, and 23 as threatened There have been reports of major declines in numbers of small mammals</td>
</tr>
<tr>
<td>Qld</td>
<td>Around 70% of Australia’s native mammals (210 species) live in the state; 38 species are listed as threatened Assessments of trends are based on a few target species and are variable; northern hairy-nosed wombats appear to be recovering while koalas have declined in some areas</td>
</tr>
<tr>
<td>SA</td>
<td>At least 28 species have become extinct since European settlement Currently, 47 species are listed as endangered and 20 as vulnerable (together, 38% of the total known)</td>
</tr>
<tr>
<td>Tas</td>
<td>The most ecologically diverse group of large marsupial carnivores in Australia occur in the state. Among selected species, some populations are increasing, some are declining and some are stable 5 forest-dwelling species have been assessed as being at risk from loss of genetic diversity</td>
</tr>
<tr>
<td>Vic</td>
<td>18 species are listed as extinct The Advisory List of Threatened Vertebrate Fauna lists 41 extant species compared with 34 listed under the Flora and Fauna Guarantee Act 1988</td>
</tr>
<tr>
<td>WA</td>
<td>Medium-sized mammals have undergone considerable decline in the north-west; of an estimated total of 220 mammal species, 11 are presumed extinct and 42 are listed as threatened</td>
</tr>
<tr>
<td>National</td>
<td>There is accumulating evidence of a decline in small mammals in northern Australia. Almost every bioregion of Australia contains numerous threatened taxa. Threatened taxa range up to around 60% for mammals in the best surveyed regions Modern mammal extinctions have mostly occurred in central and northern bioregions, with losses of up to 12 taxa recorded</td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a See notes below Table 8.5 for caveats and sources.
Figure 8.8 Percentages of known mammal taxa listed as threatened in each Interim Biogeographic Regionalisation of Australia subregion as at June 2007, (a) nationally (i.e. under the Environment Protection and Biodiversity Conservation Act 1999) and (b) in individual states or territories (i.e. under the listing processes of those jurisdictions)

Extinct species are excluded in both analyses.
For EPBC-listed mammals, the highest proportions of threatened to total species occur throughout central Australia, in Western Australia and in the south and south-west of the continent. A broadly similar pattern is seen for mammal species listed as threatened in states and territories, but the proportions in most subregions are greater than 15% and the highest proportions range up to around 70%.

Recent reports of major declines in mammals in northern Australia, where it had previously been assumed that impacts of humans were less, were unexpected and are raising concerns among ecologists (Box 8.3).
Since European settlement, the greatest loss of Australian biodiversity has been the spate of extinctions of endemic mammals. Historically, these losses occurred mostly in inland and temperate parts of the country, and largely between 1890 and 1950. A new wave of extinctions is now threatening Australian mammals in northern Australia. Many mammal species are in sharp decline across the north, even in extensive natural areas managed primarily for conservation. The main evidence of this decline comes consistently from two contrasting sources: robust scientific monitoring programs and more broadscale Indigenous knowledge.

The main drivers of the mammal decline in northern Australia include inappropriate fire regimes and predation by feral cats. Cane toads are also implicated, particularly in the recent catastrophic decline of the northern quoll. Some impacts are due to vegetation changes associated with the pastoral industry. Disease could also be a factor, but there is little evidence for or against it.

Based on current trends, many native mammals will become extinct in northern Australia in the next 10–20 years, and even the largest and most iconic national parks in northern Australia will lose native mammal species. This problem needs to be solved. The first step towards a solution is to recognise the problem, and this report seeks to alert the Australian community and decision-makers to this urgent issue. Targeted management of known threats, based on the evidence currently available, is urgently required to ensure the survival of northern Australian mammal species. In part, the answer lies in more rigour and accountability in the management of conservation reserves, but it also lies in seeking to identify and deliver more conservation outcomes from all other areas. In the shorter term, strengthening the safeguards on islands off northern Australia would enable their use as a temporary refuge for ‘at risk’ species until a more comprehensive solution can be reached on the mainland.

Source: Fitzsimons et al.83
2.4.6 Birds

The status of birds, and the information available to establish that status, is highly variable between different parts of Australia (Table 8.13). Threatened taxa range up to 30% for birds in the best surveyed regions. At least part of this variation might be due to differences in survey effort, which has been greater in the south and centre of the country and in the Northern Territory.15

On a statewide scale, the proportions of known bird species considered to be threatened in South Australia and New South Wales are 34% and 25%, respectively (Figure 8.9). In Victoria, 17% are listed as threatened under the formal state-listing process, but an additional 11% are included on the advisory list of species under consideration. In Queensland, which claims to be home to 80% of Australia’s bird species, 6% are listed as threatened but there are concerns that the legacy of past loss of habitat might not yet be fully evident.40 In Western Australia, 7% of bird species are listed as threatened.

Table 8.13 Summary of assessments of birds in state and territory state of the environment reports and the most recent national terrestrial biodiversity assessment

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>There are large fluctuations in different species, partly due to habitat changes after the 2003 bushfires and prolonged drought, and possible declines in some woodland species</td>
</tr>
<tr>
<td>NSW</td>
<td>Historical data show that birds have been relatively resilient to declines compared with other vertebrate groups; however, over the shorter timeframe of the past decade, the distribution of many birds has declined and the prospects for sustainability of many species are at risk. Status is given as poor. Of 452 known species, 126 species or populations are listed as threatened (28% of the total or 25% if the 12 extinct species are excluded). Of the total species, 2% are presumed to be extinct, 4% in severe decline, 7% in moderate decline, 40% in no significant decline and no data are available for the other 47%. There are adequate data to assess future sustainability for around half of all known species, but only 16% are considered sustainable or at low risk of being unsustainable—the rest being at moderate to severe risk or extinct</td>
</tr>
<tr>
<td>NT</td>
<td>19 species are listed as threatened and 1 is regarded as extinct</td>
</tr>
<tr>
<td>Qld</td>
<td>Around 80% of Australia’s bird species (594 species) live in the state; 35 species are listed as threatened. There are concerns that for some long-lived bird species there is a time lag between loss of habitat and consequent loss of species, a process that has been referred to as ‘extinction debt’</td>
</tr>
<tr>
<td>SA</td>
<td>42 species are listed as endangered and 32 as vulnerable (together, 16% of all recorded species); and 7 species are reported to have become extinct</td>
</tr>
<tr>
<td>Tas</td>
<td>Few general conclusions are possible due to high variability of populations and limited long-term data sets</td>
</tr>
<tr>
<td>Vic</td>
<td>There are concerns about declines in forest and woodland birds where these habitats have been disturbed. Of 447 total recorded species, 126 are included on the Advisory List of Threatened Vertebrate Fauna (versus 78 listed under the Flora and Fauna Guarantee Act 1988)</td>
</tr>
<tr>
<td>WA</td>
<td>Of 611 species recorded, 45 are listed as threatened and 2 are extinct</td>
</tr>
<tr>
<td>National</td>
<td>Mammals and birds account for the high numbers of threatened species in central and northern Australia. Threatened taxa range up to around 30% for birds in the best surveyed regions. Threatened birds occur in high numbers along the east coast, in Vic and SA, in the centre of the continent and in the south-west of WA</td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a See notes below Table 8.5 for caveats and sources.
Birds Australia produces regular national assessments of the state of Australia's birds, using methods for surveying the presence or absence of birds that can be used by volunteers and that are amenable to rigorous statistical analysis. The 2008 report, *The state of Australia’s birds*, presented the results of around 50 continuous monitoring studies of birds undertaken from as early as 1967. It reported both favourable and unfavourable conclusions.

Favourable conclusions included the following:

- Knowledge of long-term patterns and trends in bird populations is improving.
- Of the 18 threatened taxa with long-term monitoring programs, the populations of 4 have increased, 2 are more or less stable and 12 have decreased.

Source: Australian Government Department of the Environment, Water, Heritage and the Arts

**Figure 8.9** Proportions of known bird taxa listed as threatened under state and territory processes in each Interim Biogeographic Regionalisation of Australia subregion as at June 2007

For subregions that cross state borders, the estimated total number of bird taxa for a state or territory’s portion of the subregion was taken as the total number of a bird taxa recorded by the state or territory in their portion of the subregion. Extinct species are excluded.
- Numbers of Gould's petrel, glossy black cockatoo, superb parrot and Tasman parrot have all increased since their monitoring programs and management began, while populations of the orange-bellied parrot and Lord Howe Island woodhen have stayed about the same.

- Interventions to address key pressures is improving the status of threatened and nonthreatened species (see Section 3).

Unfavourable conclusions included the following:

- Since 2003, observed numbers of common and widespread birds have sharply declined, most notably across the Murray–Darling Basin.

- Studies point to major change in Australia’s bird communities, with many species declining (those of woodland, forest, grassland, heathland and wetland habitats) and a very few increasing (e.g. larger, more aggressive honeyeaters).

- A number of robins, thornbills, fantails, shrike-thrushes, treecreepers and other small insectivores, particularly those that feed on or near the ground, are decreasing in various south-east woodlands.

- At least two intercontinental migrants show steeply declining trends at all sites reported on and a third is of concern. Numbers of eastern Australian waterbirds in general, and some resident shorebirds in particular, have fallen significantly.

- Gaps in monitoring include forest and island birds, both of which are suspected or predicted to be suffering declines. Studies are only just beginning to track changes in birds (particularly seed-eaters) of the tropical savannas and uplands. The arid and semi-arid zones are also poorly covered.

- Apart from the studies reported on by Birds Australia, monitoring is generally piecemeal and too short term to detect meaningful trends in bird populations.

### 2.4.7 Freshwater fish

Freshwater fish are discussed in detail in Chapter 4: Inland water. For comparison with other groups in this section, Table 8.14 summarises what jurisdictional reports have said about freshwater fish.

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>Significant threats to survival of local populations of some threatened fish species remain</td>
</tr>
<tr>
<td>NSW</td>
<td>Of 55 known species of freshwater fish, 12 are listed as threatened</td>
</tr>
<tr>
<td>NT</td>
<td>8 river-dwelling fish species are listed as threatened</td>
</tr>
<tr>
<td>Qld</td>
<td>6 species of fish are listed as threatened</td>
</tr>
<tr>
<td>SA</td>
<td>Freshwater fish are included in broader biodiversity assessment and not discussed separately</td>
</tr>
<tr>
<td>Tas</td>
<td>Freshwater fish are the most threatened group in inland waters. Several species are listed as threatened in the last state of the environment reporting period, bringing the total listed to 11 of the 25 Tasmanian native species</td>
</tr>
<tr>
<td>Vic</td>
<td>21 freshwater and estuarine fish species are considered to be threatened</td>
</tr>
<tr>
<td>WA</td>
<td>Marine and aquatic biodiversity is generally less well known and described than terrestrial taxa, and the lack of knowledge remains a significant shortcoming</td>
</tr>
<tr>
<td>National</td>
<td>In the Sustainable Rivers Audit of the Murray–Darling Basin, native fish species were found in only 43% of valley zones where they were predicted to occur under reference condition, indicating a decline of native fish in the Basin. The Lake Eyre Basin (LEB) Rivers Assessment found the rivers and catchments of the LEB to be in generally good condition, with critical aquatic ecosystem processes remaining intact</td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a See also Chapter 4: Inland water.
b See notes below Table 8.5 for caveats and sources.
### 2.4.8 Reptiles and Amphibians

Data on the state of reptiles and amphibians are extremely variable across Australia. The combination of sightings, survey efforts and knowledge about pressures has led to the expression of general concern about many species in these groups in SoE reports from most jurisdictions (Table 8.15). This is especially true of species that live in native grasslands and woodlands.

**Table 8.15 Summary of assessments of reptiles and amphibians in state and territory state of the environment reports and the most recent national terrestrial biodiversity assessment**

#### Reptiles

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>There is a continued decline in species reliant on woodland and grassland</td>
</tr>
<tr>
<td>NSW</td>
<td>Of the 230 known species, 42 (18%) are listed as threatened, of which 1 is listed as presumed extinct. 8% of all reptile species are assessed as in severe decline, 14% as in moderate decline, 21% as in no significant decline and no data are available for the other 57%. There are inadequate data to assess the sustainability of over 99% of species</td>
</tr>
<tr>
<td>NT</td>
<td>11 species are listed as threatened</td>
</tr>
<tr>
<td>Qld</td>
<td>A little over half of Australia’s reptile species (429) live in the state; 21 are listed as threatened</td>
</tr>
<tr>
<td>SA</td>
<td>9 species are listed as endangered and another 9 as vulnerable (together, 8% of the total known)</td>
</tr>
<tr>
<td>Tas</td>
<td>No assessment is reported</td>
</tr>
<tr>
<td>Vic</td>
<td>Declines are noted, especially in some disturbed forests; of 133 known species, 49 are on the Advisory List of Threatened Vertebrate Fauna, of which none are listed as extinct, while 29 are listed under the <em>Flora and Fauna Guarantee Act 1988</em></td>
</tr>
<tr>
<td>WA</td>
<td>Of 510 known species, 23 are listed as threatened (none as extinct)</td>
</tr>
</tbody>
</table>

**National**  

Threatened taxa range up to around 25% of known species for reptiles in the best surveyed regions.

#### Amphibians

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>There is a decline in records, probably due to drought</td>
</tr>
<tr>
<td>NSW</td>
<td>Of 83 known species, 28 (34%) are listed as threatened, none of which are considered extinct. 10% of all species are considered to be in severe decline, 7% in moderate decline, 28% in no significant decline and no data are available for 55%. Data are inadequate to assess future sustainability for over 96% of species</td>
</tr>
<tr>
<td>NT</td>
<td>Only 1 species is listed as threatened (vulnerable)</td>
</tr>
<tr>
<td>Qld</td>
<td>Around half of Australia’s frog species (114) live in the state; 25 are listed as threatened</td>
</tr>
<tr>
<td>SA</td>
<td>No species are listed as endangered, but 4 are listed as vulnerable (15% of total recorded); a further 2 are extinct</td>
</tr>
<tr>
<td>Tas</td>
<td>Few data are available, but there is concern about effects of drought and fungal infections</td>
</tr>
<tr>
<td>Vic</td>
<td>Of 33 known species, 17 are included on the Advisory List of Threatened Vertebrate Fauna, none of which are considered extinct</td>
</tr>
<tr>
<td>WA</td>
<td>Of 77 recorded species, 3 are listed as threatened</td>
</tr>
</tbody>
</table>

**National**  

Amphibians are represented in relatively low numbers in all jurisdictions; many have become regionally extinct in the past decade.

---

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a See notes below Table 8.5 for caveats and sources.
In those states that have reported proportions of known species that are listed as threatened or are of concern (i.e. New South Wales, Queensland, Victoria and Western Australia) the estimates range widely and some are very high (i.e. 5–37% for reptiles and 4–52% for amphibians) (Table 8.15).

2.4.9 Invertebrates

Despite their importance in many ecological processes like carbon and nutrient cycling in soils, pest control and pollination, there has been very limited assessment of the state of invertebrate species and populations across most of Australia (Table 8.16).

2.5 Aquatic species and ecosystems

The state of, and trends in, aquatic species and ecosystems are dealt with in detail in Chapter 4: Inland water. Here we draw briefly on that chapter and summarise what state and territory SoE reports say about aquatic species and ecosystems.

The attention given to aquatic systems in SoE reports by the states and territories ranges from no specific mention to some detail (Table 8.17). The national assessment of terrestrial biodiversity reported that only 17% of Australia has comprehensive mapping of wetlands. In the well-studied Murray–Darling Basin—an example of a system whose lands and rivers have been largely developed for agricultural and other industries and for human settlements—there is evidence of major declines (Table 8.17). Native fish species in the Murray–Darling Basin were found in only 43% of valley zones where they were expected to occur. By contrast, in the less-developed Lake Eyre Basin, rivers have been assessed as being generally good condition and ecologically functional.

Ecological processes in inland waters have been altered to some degree across most parts of Australia. For much of northern and remote Australia, these changes do not affect ecosystem function significantly and, with a few exceptions, there is little evidence that populations of aquatic species are declining. By contrast, in most southern regions, inland water ecological processes have changed substantially and ecosystem function is significantly affected, with significant declines in many native species populations. The Eastern Australian

Table 8.16 Summary of assessments of invertebrates in state and territory state of the environment reports and the most recent national terrestrial biodiversity assessment

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>Some research is under way but no data are presented</td>
</tr>
<tr>
<td>NSW</td>
<td>Of an unknown total number of species, 19 species and 2 populations are listed as threatened</td>
</tr>
<tr>
<td>NT</td>
<td>35 species (mostly snails) are listed as threatened</td>
</tr>
<tr>
<td>Qld</td>
<td>Invertebrates are not mentioned in the report</td>
</tr>
<tr>
<td>SA</td>
<td>Invertebrates are mentioned but not specifically reported on</td>
</tr>
<tr>
<td>Tas</td>
<td>The state has an estimated 35 000 nonmarine invertebrate species; approximately one-third are endemic</td>
</tr>
<tr>
<td>Vic</td>
<td>Knowledge of the status of invertebrates is extremely poor</td>
</tr>
<tr>
<td>WA</td>
<td>Poorly understood in general. Many species are threatened by changes to plant communities caused by Phytophthora dieback</td>
</tr>
<tr>
<td>National</td>
<td>The counts for invertebrates are patchy, reflecting the lower intensity of survey for invertebrates relative to other taxonomic groups</td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a See notes below Table 8.5 for caveats and sources.
Waterbird Surveys covering 1983–2009 found a consistent decline in waterbird numbers after 1999 below the long-term mean. This decline was associated with the millennium drought (lasting from 2000 to 2010 in southern Australia, but starting as early as 1997 in some areas), but also with long-term effects of river regulation, which has reduced water flow. There was also a significant decline in the number of breeding waterbirds and the number of breeding species estimated over time.

### Table 8.17 Summary of assessments of aquatic ecosystems in state and territory state of the environment reports and the most recent national terrestrial biodiversity assessment

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>State (and trend if reported)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>Tableland wetlands are under considerable threat even though they are largely included in reserves</td>
</tr>
<tr>
<td>NSW</td>
<td>Historically, clearing and grazing have had major detrimental impacts on many wetlands</td>
</tr>
<tr>
<td></td>
<td>There is little mention of current state or trends in the report</td>
</tr>
<tr>
<td>NT</td>
<td>Wetlands are a feature of both wet and arid parts of the territory, but there are limited published data on their extent or condition on a territory-wide basis</td>
</tr>
<tr>
<td>Qld</td>
<td>The loss of wetlands continued to occur at approximately 7000 hectares per year (0.34% of 1997 total) from 1997 to 2003; palustrine and riverine wetland systems have experienced the greatest percentage annual reduction in extent. Relatively, estuarine and lacustrine systems have been least affected</td>
</tr>
<tr>
<td></td>
<td>There were insufficient data to report on the condition of wetlands</td>
</tr>
<tr>
<td></td>
<td>Between 1997 and 2003 there was an overall loss of approximately 370 hectares per year of wetlands in the coastal zone</td>
</tr>
<tr>
<td>SA</td>
<td>Aquatic systems are included in the broader biodiversity assessment and not discussed separately</td>
</tr>
<tr>
<td>Tas</td>
<td>There are an estimated 20 597 wetlands with a total area of 206 790 hectares</td>
</tr>
<tr>
<td></td>
<td>Overall, 59% of the state’s wetlands and 74% of their total area are still in natural or near natural condition; however, 35% (15% by area) have been severely altered and 6% (11% by area) have been significantly altered</td>
</tr>
<tr>
<td>Vic</td>
<td>Many aquatic species are now considered threatened, including 21 freshwater and estuarine fish species, 11 frog species and 29 species of waterbirds</td>
</tr>
<tr>
<td></td>
<td>Macroinvertebrate communities were found to be in good condition across almost half the reach length assessed as part of the 2004 Index of Stream Condition; the total index of abundance for waterbirds in eastern Australia has shown a declining trend over past decades, with 2007 having the second lowest abundance on record</td>
</tr>
<tr>
<td></td>
<td>Survival and diversity of the native aquatic fauna of inland waters is declining</td>
</tr>
<tr>
<td>WA</td>
<td>Aquatic and marine biodiversity is generally less well known and described than terrestrial taxa, and the lack of knowledge remains a significant shortcoming</td>
</tr>
<tr>
<td>National</td>
<td>Only 17% of Australia has comprehensive mapping of wetlands, and case studies indicate a widespread decline in their extent</td>
</tr>
<tr>
<td></td>
<td>There has been a loss of 90% of floodplain wetlands in the Murray–Darling Basin (MDB). The Sustainable Rivers Audit of the MDB found 13 river valleys to be in very poor health, 7 in poor health, 2 in moderate health and 1 in good health</td>
</tr>
<tr>
<td></td>
<td>The Lake Eyre Basin (LEB) Rivers Assessment found the rivers and catchments of the LEB to be in generally good condition, with critical aquatic ecosystem processes remaining intact</td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

a See also Chapter 4: Inland water.
b See notes below Table 8.5 for caveats and sources.
2.6 Marine species and ecosystems

The information in this section is summarised from Chapter 6: Marine environment and Chapter 7: Antarctic environment.

Overall, biodiversity in Australia’s marine regions is in good condition. However, biodiversity is very poor in some coastal places and areas on the continental shelf and upper slope, as a result of human activities. A number of iconic species have failed to recover or continue to decline from earlier impacts of excessive hunting and fishing. These include Australian sea lions, which are endemic to temperate southern Australian waters and are showing no substantial signs of population recovery from the hunting of previous centuries; the whale shark, only smaller specimens of which appear to be visiting Western Australian waters; and southern bluefin tuna, formerly a major predator in our regional seas that has been fished to the edge of population survival and is continuing to be fished. In addition, there are many more habitat and species issues in smaller local areas. As for all species, more detailed national assessment of marine biodiversity is required to clarify the nature, extent and significance of the biodiversity condition.

In the Antarctic region, some populations of seals and penguins that were slaughtered in huge numbers in the late 19th and early 20th centuries have recovered. Other populations, especially among the seabirds, suffer great losses as bycatch in commercial fishing operations. Most whale species that visit the Southern Ocean are still on the list of endangered species. Many subantarctic islands harbour alien plant species that often thrive and outcompete endemic species, and these threats are increasing as the climate warms. Changes in the ocean due to climate change, such as rising sea surface temperatures and ocean acidification, are also bringing about change as northern species start to move south, and key biological processes such as shell calcification are disrupted for existing endemic species.

Further substantiation of this summary and more details of the state of, and trends in, marine species and ecosystems can be found in Chapter 6: Marine environment and Chapter 7: Antarctic environment.

2.7 Assessing the state and trends of biodiversity

For most groups of organisms, there appear to be substantial proportions of Australia where species and populations are in a good to very good state. However, in the assessment summary, in these cases, if there is also a substantial proportion where the state is considered to be poor or very poor, one of these grades is assigned. The presence of half circles in the confidence in grade and confidence in trend columns in the summary table usually indicates that direct data on grade or trend are limited, but that consensus is high or moderately high. This consensus comes about because the limited grade or trend data for a sample of species is complemented by data on pressures and ecological research on the likely effects of those pressures. The period over which assessments of trends is made varies depending on the data available—it is at least a decade in most cases.
### State and trends of biodiversity

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
</table>
| Terrestrial ecosystem (native vegetation) extent | **Northern and central Australia:** Native vegetation largely intact throughout much of this area (with a degree of modification in rangelands and high levels of clearing in 1997–2005 in some parts of north-east Queensland and the Northern Territory)  
**Southern, eastern and south-western Australia:** Historical losses most apparent in these areas (especially eucalypt woodlands, eucalypt open forest, and mallee woodlands and shrublands). Rates of loss are declining but loss still exceeds gains in many areas | Poor             | Medium     |
| Terrestrial ecosystem (native vegetation) quality | **Remote areas and areas where agricultural and urban development have been minimal:** Even in areas where vegetation is largely intact there are suggestions of some declining quality  
**Agricultural regions and around urban development:** Very limited wide-scale data in all states and nationally, but strong evidence of decline from case studies in agricultural regions and around urban development | Poor             | Medium     |
| Terrestrial plant species                      | **High-altitude, remote and/or very dry parts of Australia:** Plant species appear to be largely secure (although all have been affected to some degree by human-induced pressures and most are potentially susceptible to effects of climate change), but there are examples of threatened or declining communities and species  
**Areas most suitable for urban development and/or agriculture:** There have been substantial historical effects of human activities on plant species. Some pressures are ongoing and the legacies of land clearing will cause declines for some decades. Woodland and grassland species are most at risk | Poor             | Medium     |
<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Species other than plants and animals (e.g. fungi, algae, some microorganisms)</strong></td>
<td>Areas where vegetation remains largely intact: It is likely that fungi, soil microorganisms and other species are minimally degraded but there is very little information. It is possible that fungal communities might be impacted by declines in animals that play a role in dispersal of fungal spores</td>
<td>Very poor Poor Good Very good</td>
<td>In grade In trend</td>
</tr>
<tr>
<td></td>
<td>Agricultural lands: Information is limited, but research results on fungi raise major concerns in agricultural lands</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Terrestrial animals—mammals</strong></td>
<td>Declines in a large proportion of species across taxa in all states. Particular concern about mammals in northern Australia. Data collection is still too inadequate in all states and nationally to make a confident statement about which groups are secure and which are not</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Terrestrial animals—birds</strong></td>
<td>Relatively resilient historically but threatened species make up a large proportion of known species in some areas. Large fluctuations in numbers over the past decade due to climate variation. Several states raise concerns about recent declines, especially in forests and woodlands, and the potential for legacy effects from past pressures that have not yet been seen</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Terrestrial animals—reptiles</strong></td>
<td>Very limited data, but concerns have been raised about ongoing decline, including in grasslands and woodlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Terrestrial animals—amphibians</strong></td>
<td>Survey information is very limited but research consistently points towards major declines in many areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Terrestrial animals—invertebrates</strong></td>
<td>Survey data are very limited. Research suggests that some groups are likely to be thriving while others decline</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Continued next page
State and trends of biodiversity continued

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquatic species and ecosystems (see Chapter 4: Inland water)</td>
<td><strong>Northern and central Australia:</strong> Much of northern and central Australian freshwater ecosystems appear to be in good condition. <strong>Southern, eastern and south-western Australia:</strong> Information on wetlands is limited but there is good evidence of losses and poor health of rivers in large areas of south-eastern and south-western Australia. Freshwater ecosystems appear to be in a poor and declining state in areas that have been heavily developed for agriculture.</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>Marine species and ecosystems (see Chapter 6: Marine environment)</td>
<td><strong>Overall:</strong> Marine biodiversity overall is in good condition. <strong>In a few areas:</strong> Nationally there are a number of coastal places and areas on the continental shelf and upper slope where the condition of some biodiversity is very poor, as a result of the effects of specific human activities.</td>
<td>Poor</td>
<td></td>
</tr>
</tbody>
</table>

### Recent trends
- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**

### Grades
- **Very good:** The vast majority of taxa appear to have good prospects for long-term survival and any declines are limited in spatial extent and severity and are unlikely to threaten future viability of taxa.
- **Good:** Most taxa appear to have good prospects for long-term survival, although a small proportion have suffered declines that might threaten long-term survival.
- **Poor:** A significant proportion of taxa have suffered declines across most or all of Australia that potentially threaten their long-term persistence.
- **Very poor:** A large proportion of taxa have suffered declines across most or all of Australia.

### Confidence
- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment
At a glance

The main pressures negatively affecting biodiversity have not changed greatly over the past three national State of the Environment reports, except that climate change has received greater recognition as a current and future driver of environmental change, and local climate has become a more prominent pressure as the nation has faced a decade of drought. The most significant past and present pressures are clearing and fragmentation of native ecosystems, invasive species and pathogens, inappropriate fire regimes, grazing pressure and changed hydrology. Steps have been taken to limit clearing of native vegetation, but it remains a significant pressure in some areas, and the legacy effects of past clearing mean that the impacts are not yet reducing. Inadequacy of systematic information limits our ability to assess trends in other pressures with confidence, but available evidence and expert consensus suggests that pressures from grazing, invasive species, altered fire regimes and changed hydrology are still major and have been growing worse over the past decade.

For some or all of these pressures, improvements are possible once remedial actions start to take effect, but there is as yet no strong evidence of that improvement. Three major interacting drivers affecting all these pressures have been (and will be) climate, human population growth and the demands placed on the environment to support human lifestyles. It will be important to address all three of these drivers if pressures on biodiversity are to be reduced to desirable levels.

Pressures affecting biodiversity

The Assessment of Australia’s terrestrial biodiversity 2008 has been drawn on extensively in this section as it is a recent and comprehensive review of pressures on Australia’s terrestrial biodiversity. That study drew on syntheses of jurisdictional analyses, listings of threatened species under the EPBC Act, and a series of case studies on representative species to conclude that the key threats to biodiversity in Australia are:

- fragmentation of habitat
- climate change
- land-use change
- invasive species and pathogens
- grazing pressure
- altered fire regimes
- changed hydrology.

The most frequently cited threats in listings under the EPBC Act and resulting recovery plans are habitat fragmentation and the spread of invasive species.

Additional pressures identified for marine species include the extraction of resources through fishing; introduction of marine invasive species; disturbance to habitats through shipping, and oil and gas exploration and production; habitat alteration through urban expansion or aquaculture facilities; and pollution including catchment run-off (see Chapter 6: Marine environment).

3.1 Drivers versus pressures

A drivers–pressures–state–impact–response (DPSIR) framework distinguishes between drivers and pressures. Drivers are the ultimate factors that cause change, and pressures are the more immediate factors that affect the environment. Chapter 2 of this report identified the main drivers of environmental change—climate change, population growth and economic growth. Each of these drivers has direct and indirect effects on biodiversity via the pressures that they cause (Figure 8.10). A number of recent publications have analysed and categorised drivers and pressures on biodiversity in Australia. These do not lead to a standard classification; therefore, we have used a classification similar to that used previously in national SoE reports—recognising that while it might not be optimal, it is sufficient to describe the key issues at a national scale.
It can be difficult to separate drivers from pressures. For example, expansion of urban areas might be seen as a pressure arising from population growth or as an intermediate driver of land-use change. We have interpreted it as an intermediate driver in this chapter. Similarly, we have considered pollution to be a pressure arising from population and economic growth that acts as an intermediate driver of decline in habitat quality.

As has been emphasised in previous SoE reports, the factors affecting biodiversity rarely act alone (see Section 3.13) and their interactive effects are difficult to predict. This means that it is difficult to attribute changes in biodiversity unequivocally to single pressures.

3.2 Availability of information

SoE reports from all jurisdictions report that the pressures on biodiversity identified above are ongoing and significant. The strength of different pressures differs from place to place and through time, as well as within and between jurisdictions. The evidence that these pressures are having effects comes mainly from research on particular species and groups of species in particular situations (e.g. effects of diseases on particular native plant or animal species or effects of habitat fragmentation on forest or woodland animals). Information on which to base assessments of trends in the strength or consequences of these pressures regionally or nationally is, however, very limited (Table 8.18).
3.3 Spatial distribution of pressures

Listings of threatened species under the EPBC Act include identification of the pressures that are considered to cause the threat. Evans et al. analysed data on plant, animal and other species to report the numbers of species affected by the main pressures on biodiversity (Figure 8.11). They used a slightly different categorisation of pressures from that used in the current report. Two of their categories—‘native species interactions’ and ‘natural causes’—are not dealt with separately in this report. Evans et al. use ‘native species interactions’ to refer to ‘changes in the interactions with native plants or animals resulting in hybridisation or increased predation or competition’ (p. 282) and ‘natural causes’ to refer to ‘biological factors (low genetic diversity, low recruitment), natural disasters, and extreme weather’ (p. 282). Here we consider these types of interactions to be consequences of other pressures, especially clearing and fragmentation of ecosystems, climate, grazing pressure and altered fire regimes.

Consistent with other data synthesised in this report, habitat loss (clearing and fragmentation of native ecosystems in the current report) and introduced species (invasive species and pathogens in the current report) were the pressures most commonly associated with threatened species and the most widespread (Figure 8.11). Inappropriate fire regimes also affected a high proportion of subcatchments.

Figure 8.12, which is based on the same data as Figure 8.11, shows the proportion of threatened species affected by each of the pressures, for each Australian subcatchment that contains threatened species. The three most prominent pressures affecting threatened species at a national scale (habitat loss, inappropriate fire regimes and introduced species) were widespread. The other five threatening processes are distributed more unevenly and less extensively. Although there are limitations to using data on only species that have been listed as threatened (i.e. many other species are likely to be affected adversely by these pressures), these analyses give at least a coarse indication of the magnitude and spread of pressures on biodiversity.

<table>
<thead>
<tr>
<th>Pressures</th>
<th>Current report capacity rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trends in habitat fragmentation and decline in ecosystem function</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Moderate at case-study level</td>
</tr>
<tr>
<td>The range and relative importance of threats to biodiversity over time</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Moderate for listed species and communities</td>
</tr>
<tr>
<td>Trends in the impacts of climate change on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Poor at case-study level</td>
</tr>
<tr>
<td>Trends in the impacts of land-use change on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Good for clearing rates in Queensland</td>
</tr>
<tr>
<td></td>
<td>Moderate at case-study level</td>
</tr>
<tr>
<td>Trends in the impacts of invasive species and pathogens on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Good at case-study level</td>
</tr>
<tr>
<td>Trends in the impacts of grazing pressure on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Moderate at case-study level</td>
</tr>
<tr>
<td>Trends in the impacts of altered fire regimes on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Good at case-study level</td>
</tr>
</tbody>
</table>

Source: Australian Government Department of the Environment, Water, Heritage and the Arts

Table 8.18 Availability of information for reporting on pressures on biodiversity nationally

<table>
<thead>
<tr>
<th>Pressures</th>
<th>Current report capacity rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trends in habitat fragmentation and decline in ecosystem function</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Moderate at case-study level</td>
</tr>
<tr>
<td>The range and relative importance of threats to biodiversity over time</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Moderate for listed species and communities</td>
</tr>
<tr>
<td>Trends in the impacts of climate change on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Poor at case-study level</td>
</tr>
<tr>
<td>Trends in the impacts of land-use change on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Good for clearing rates in Queensland</td>
</tr>
<tr>
<td></td>
<td>Moderate at case-study level</td>
</tr>
<tr>
<td>Trends in the impacts of invasive species and pathogens on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Good at case-study level</td>
</tr>
<tr>
<td>Trends in the impacts of grazing pressure on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Moderate at case-study level</td>
</tr>
<tr>
<td>Trends in the impacts of altered fire regimes on biodiversity</td>
<td>Poor nationally</td>
</tr>
<tr>
<td></td>
<td>Good at case-study level</td>
</tr>
</tbody>
</table>

Source: Australian Government Department of the Environment, Water, Heritage and the Arts
Figure 8.11  Pressures affecting species listed as threatened nationally under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

Only species for which spatial data were available were used (i.e. 1137 of 1298 listed species). At the time of the analysis, there were 1700 species listed under the EPBC Act, 1590 of which were extant. Of these, 1298 had available threat data and 1137 had both threat data and spatial data. Therefore, there were about 300 species that could not be assessed because of a lack of threat data.
Figure 8.12  The percentage of threatened freshwater and terrestrial species in each subcatchment affected by (a) habitat loss, (b) introduced species, (c) inappropriate fire regimes, (d) disease, (e) pollution, (f) overexploitation, (g) native species interactions and (h) natural causes; the distribution of threatened species richness is shown in (i)

Source: Evans et al. 87
3.4 Local climate

In this chapter, climate change is considered to be a driver of change and climate itself is the pressure. Australia’s biodiversity has evolved in a climate of extremes in heat and cold, wetness and dryness (see Chapter 3: Atmosphere). However, when climate changes within the geographic range of any individual species, the species can have difficulty adapting, especially if it is prevented from moving with its preferred climate by, for example, lack of suitable habitat or the presence of other species that compete for resources. Climate change is recognised widely as a future pressure on biodiversity—an issue discussed further in Section 6. Here we focus on evidence that changing climate has been a pressure for at least the past several decades (Tables 8.19 and 8.20).

All recent SoE reports from the states and territories discuss climate change as an emerging and/or present pressure on biodiversity (Table 8.20). Most focus on likely future effects of climate change, particularly a worsening of existing pressures. Two examples from the 2009 Victorian SoE report illustrate recent consequences of climatic extremes that might or might not be due to long-term climate change, but that exemplify what is expected from climate change in coming decades. In east Gippsland in 2007, extensive soil loss occurred when severe winter flooding followed major wildfires, which had removed most of the vegetation that would usually absorb and slow the flow of water. Similarly, severe dust storms in western Victoria in 2008, which occurred despite the widespread adoption of improved land-management practices, were an example of the effects of the prolonged dry period experienced over the past decade.

Populations of several species of birds (e.g. rainbow lorikeet and long-billed corella, both native, and the introduced common starling, common blackbird, common myna and spotted dove) have shifted from the north-east to south-east, suggesting a response to climate change and demonstrating the superior adaptability of such species.

Given the extensive rainfall and floods in large parts of Australia in 2010–11, it might be expected that the next SoE reports will observe responses in biodiversity related to wetness rather than drought.

Table 8.19 Example of observed changes in Australian species and communities consistent with climate change

<table>
<thead>
<tr>
<th>Type of change</th>
<th>Examples of responses observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genetic constitution</td>
<td>Shifts in genetic composition of fruit flies</td>
</tr>
<tr>
<td>Geographic ranges</td>
<td>Migration of several bird species to higher altitudes or higher latitudes</td>
</tr>
<tr>
<td>Lifecycles</td>
<td>Earlier mating and longer pairing of the large skink, <em>Tiliqua rugosa</em></td>
</tr>
<tr>
<td>Populations</td>
<td>Reduced reproduction in wedge-tailed shearwaters on Great Barrier Reef islands associated with higher sea temperatures</td>
</tr>
<tr>
<td>Ecotonal boundaries (changes to the boundaries between ecosystems)</td>
<td>Expansion of rainforest at the expense of eucalypt savanna woodland and grassland in the Northern Territory, Queensland and New South Wales (other nonclimatic factors have likely contributed to the observed shift)</td>
</tr>
<tr>
<td>Ecosystems</td>
<td>Eight mass bleaching events since 1979 on the Great Barrier Reef triggered by unusually high sea surface temperatures</td>
</tr>
<tr>
<td>Disturbance regimes</td>
<td>Changing fire regimes in southern Australia, consistent with drier and hotter climate</td>
</tr>
</tbody>
</table>

Source: Steffen et al.1
Table 8.20 Impacts of recent climate on biodiversity from state of the environment reports by the states and territories\(^a\)

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>Prolonged drought, combined with the 2003 bushfires, has had a major effect on ecological communities (which are showing signs of recovery) and especially bird species (some of which have decreased in numbers and some of which have increased due to drought)</td>
</tr>
<tr>
<td>NSW</td>
<td>Climate change is the most pervasive threat that continues to intensify with an increasing impact across all classes of native plants—alpine, coastal, rainforest, wetland and arid classes are the most sensitive. Periods of drought exacerbate incompatibilities between production and conservation objectives of land management; climate change is likely to exacerbate the impacts of other threats on flora and fauna</td>
</tr>
<tr>
<td>Qld</td>
<td>Drought is suggested as a contributor to declines in many regional ecosystems</td>
</tr>
<tr>
<td>SA</td>
<td>Several species of birds, frogs, reptiles and fish are reported as being affected by drought along the Murray River. Drought has had a major impact on native species (e.g. fish, birds) and habitat quality in the Coorong and Lower Lakes as well as the Murray River. Prolonged drought (from 2000) resulted in extensive lake acidification and extreme salinisation of the Coorong. Recent rains have provided some mitigation of these impacts but the recovery of crucial ecosystems remains uncertain.</td>
</tr>
<tr>
<td>Tas</td>
<td>All frog species in the state are in families expected to be susceptible to climate change. Recent changes that appear to have affected frogs include changes in streamflows, loss of wetlands and shifts towards temperatures optimal for infectious diseases of frogs. Droughts draw many animal species towards roads and bias population estimates (upwards). Evidence of changes in biodiversity due to climatic change include increased woodiness in the alpine zone that is likely to lead to greater fire risk; an advancing treeline (above the established treeline) at monitoring sites; and evidence of dieback related to drought or sustained high temperatures in conifers. Drought has caused locally severe dieback of trees and understorey species in eastern Tasmanian forests and on the Central Plateau, particularly on areas of shallow soil.</td>
</tr>
<tr>
<td>Vic</td>
<td>Six plant species are threatened by drought. Extended drought has decreased livestock populations (thereby alleviating grazing pressure), but increased the combined effects of water stress, fires and wind on loss of vegetation and soil.</td>
</tr>
<tr>
<td>WA</td>
<td>Seedlings are vulnerable to climate stressors in combination with changed fire regimes.</td>
</tr>
<tr>
<td>National</td>
<td>Changes in climate are at least partly implicated in real declines of 14 species listed as nationally threatened (8 birds, 1 reptile, 2 amphibians, 2 fish and 1 insect). Evidence of changes related to climate warming over the past few decades is reported (reduced snow cover, ice melt in lakes, eucalypt recruitment above the alpine treeline, altitudinal expansion of the range of rabbits and the timing of arrival of migratory species).</td>
</tr>
</tbody>
</table>

\(^a\)ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia.
3.5 Pollution

Pollution is mentioned as a significant pressure in most jurisdictional SoE reports, especially in relation to coastal settlements and chemical run-off from farmland into rivers and the ocean. Few generalisations can be made, because the effect varies from place to place and from situation to situation. Pollution is a contributing factor to the decline of several threatened species. Kingsford et al.\textsuperscript{89} reported, on the basis of a literature review, that pollution was a major pressure on 18\% of species on the 2007 International Union for Conservation of Nature (IUCN) Red List of species (species of significance for conservation) and on 30\% of species on that list that are classed as threatened.

Forms of pollution that affect marine biodiversity include sediment, nutrient and chemical run-off from agricultural and urban land; alterations to natural water temperature in waterways due to the release of colder water from dams; accumulation of plastics; discarded or lost fishing gear; and dredging and release of oil and other chemicals from commercial shipping in marine and coastal systems. Most state and territory SoE reports express most concern about urban and agricultural run-off. Carbon is also widely regarded as an atmospheric pollutant in relation to biodiversity, because it directly affects the functioning of plants and the composition of plants as food for native herbivores.

A particularly concerning emerging pollution problem is ‘micropollutants’, which include:

- chemical residues potentially affecting growth, causing birth defects and having other toxic effects on humans and other animals and plants at low concentrations\textsuperscript{92-93}
- the build-up of microscopically small particles of plastics in waterways\textsuperscript{94}
- nanometre-sized particles of silver, which are components of many nanotechnology products and are likely to have effects on all living organisms, from microbes to vertebrates.\textsuperscript{94}

3.6 Consumption and extraction of natural resources

Humans have both direct and indirect effects on biodiversity. Direct effects mainly involve taking species (e.g. taking animals and plants as food, harvesting plants for ornamental purposes, or removing plants or animals that have become pests). Indirect effects happen as a result of other activities associated with human existence, such as growing food, using industrial processes that either consume natural resources or introduce heat or chemicals into the environment, and clearing land for urban development, agriculture, mining or other activities.

3.6.1 Harvesting of species

Since European settlement, harvesting has had major detrimental effects on many terrestrial species, including red cedar, koalas, and various kangaroos and wallabies. Harvesting of fish and other species is issues in inland water and marine environments (see Chapter 4: Inland water and Chapter 6: Marine environment). Forestry and firewood collection are discussed in Chapter 5: Land. Salvage logging (logging of trees after wildfires) is partly a harvesting issue and partly a habitat modification issue. It has major effects on wildlife, especially species that live in tree hollows.\textsuperscript{95-96}

Harvesting of native terrestrial species—such as kangaroos, wildflowers or marine species—is strictly regulated (Box 8.4). Illegal harvesting of some species, such as orchids, is frequently mentioned as a threat in species listing. In some cases, harvesting is used as a tool to manage populations of native species that are becoming pests due to changes in their environment that remove previous restrictions on population size.\textsuperscript{34}

Harvesting of native seeds from the wild is one aspect of biodiversity harvesting that is becoming increasingly important. Seeds can be collected for conservation and restoration purposes as well as for commercial gain.\textsuperscript{95} Seed harvesting can potentially cause damage to the parent plants or reduce the viability of the source population through repeated harvesting. Attention needs to be paid to how this industry functions to enable restoration of biodiversity and improve the extent and condition of native vegetation.
Box 8.4 Direct use of native species

International movement of wildlife and wildlife products is regulated under Part 13A of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Commercial export of regulated wildlife and wildlife products (see www.environment.gov.au/biodiversity/wildlife-trade/lists/exempt/index.html for exemptions) may occur only where the specimens have been derived from a captive breeding program, artificial propagation program, aquaculture program, wildlife trade operation (WTO) or wildlife trade management plan (WTMP) approved under the EPBC Act.

Most WTOs and WTMPs involve the wild harvest of native wildlife. WTOs are approved for a maximum period of three years and WTMPs are approved for a maximum period of five years. As of July 2011, there are three small-scale WTOs for harvesting whole plants (ferns), one small-scale WTO for cut flowers, five small-scale WTOs for invertebrates (mostly insects but one is for hermit crabs), one small-scale WTO for mammals (wallaby skin and fur) and one existing stock WTO for taxidermied specimens (primarily birds and mammals) (see www.environment.gov.au/biodiversity/wildlife-trade/sources/operations/index.html). The environment minister or their delegate must not approve a WTO unless satisfied that the operation is not detrimental to the survival of the taxon or the conservation status of the taxon to which the operation relates, and that it will not threaten any relevant ecosystem.

WTMPs are generally developed and implemented by state or territory authorities (Table A). Plans must address the legislative context of the proposed trade; general management procedures, such as licensing; the different types of harvest or production covered under the plan; monitoring and assessment; and reporting and compliance. The minister or their delegate may not approve a management plan as a WTMP unless they are satisfied that the application has appropriately assessed the environmental impact of the actions covered by the plan. WTMPs must be ecologically sustainable, and not detrimental to the survival of the taxa, the conservation status of the taxa and any relevant ecosystem.

Table A Approved wildlife trade management plans as of July 2011

<table>
<thead>
<tr>
<th>Management plan</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW cut flowers</td>
<td>NSW</td>
</tr>
<tr>
<td>Cycads</td>
<td>NT</td>
</tr>
<tr>
<td>Tree ferns</td>
<td>Tas</td>
</tr>
<tr>
<td>WA flora</td>
<td>WA</td>
</tr>
<tr>
<td>Qld flora</td>
<td>Qld</td>
</tr>
<tr>
<td>Kangaroos (four plans)</td>
<td>NSW, Qld, SA and WA</td>
</tr>
<tr>
<td>Crocodiles (three plans)</td>
<td>WA, NT (NT has separate plans for freshwater and saltwater crocodiles)</td>
</tr>
<tr>
<td>Brushtail possums</td>
<td>Tas</td>
</tr>
</tbody>
</table>

NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia


3.6.2 Pressures related to population size and lifestyles

Various measures of a society’s ecological footprint, the amount of natural resources consumed by people and the area of land required to support that consumption are available; one of these is the Global Footprint Network (Figure 8.13). In the most recent data, Australia ranks as having the eighth largest ecological footprint of all nations. It is difficult to translate this into an effect on biodiversity, partly because the land from which Australians obtain their resources is not all within Australia, partly because people in other countries obtain their resources from Australia, and partly because the calculations do not reveal in detail which resources are being taken from which ecosystems and which species are being affected. Nevertheless, there is a strong message that lifestyles of Australians are exerting relatively strong pressures on ecosystems compared with people in many other countries.
Sources: Australian data from Global Footprint Network Australia page and data for other countries from 2010 data tables downloadable from Global Footprint Network.

Figure 8.13  Ecological footprint for consumption for a range of high-consuming and low-consuming countries

There are 81 countries omitted from the figure.
In another international comparison, based on a set of measures of environmental degradation, Australia had the ninth worst absolute environmental impact out of 171 countries.\textsuperscript{100}

More than a decade of research using CSIRO’s Australian Stocks and Flows Framework, together with ecological footprint analysis and local-scale modelling, emphasises the importance for all Australian cities of managing not only population growth, but where and how people live, and the consumption of natural resources per person.\textsuperscript{56}

This research suggests, for example, that Sydney will have trouble avoiding further losses of biodiversity, because growth will require conversion of relatively undegraded habitat. However, Perth and Melbourne have the scope to minimise losses, because they can develop previously cleared areas where the major effects on biodiversity have already been felt.

Australia’s high footprint is largely caused by our lifestyles, which use high levels of natural resources in an inefficient way. In the Northern Territory, for example, the average ecological footprint of the Indigenous population is 6.4 global hectares per person, while the footprint for the non-Indigenous population is around 9 global hectares per person.\textsuperscript{101} (Global hectares are a measure of biocapacity—one global hectare is an average of all hectare measurements of biologically productive areas on Earth.) These analyses were based on various data sources from 1998 to 2004. The lower footprint of the Indigenous population is partly due to traditional use of ecosystem resources, but it is also due to poverty.

3.6.3 Consumption of water

Use of inland water for agricultural and other purposes is considered in detail in Chapter 4: Inland water. Here we summarise key points in relation to biodiversity.

Water is extracted from the environment by households and businesses and in agricultural and other production industries for a range of purposes, including direct consumption by humans (e.g. drinking, cooking) and indirect consumption (e.g. use in production of food, manufacturing of goods that contain water or rely on inputs that use water, cooling systems, transport).\textsuperscript{102}

Extraction of water from the environment places pressures on biodiversity by affecting flow rates in waterways, which affects the habitat for plants and animals living in those waterways, as well as the wetting and drying cycles that are important for many species’ breeding. It also affects the provision of food for waterway-dependent species. Indirect pressures include effects on hydrological cycles, which affect the levels and condition of underground water on which many species of plants and animals depend. The condition of soils is affected when rising watertables bring salt to the surface. Water consumption is considered in the analyses of ecological footprints.

Australia’s water consumption was 14 101 gigalitres in 2008–09, a decrease of 25% from 2004–05. Agricultural activities accounted for 7589 gigalitres or 54% of total Australian water consumption in 2008–09. This is a decrease from 2004–05 when it was 65% of water consumption, reflecting restricted supplies during southern Australia’s extended drought.

The major impacts of water consumption, changed flow regimes and changed hydrology are on wetlands and the species that depend on them, on animals and plants that live in and around waterways, and in some cases on the landscape more broadly. These impacts are discussed further in Chapter 4: Inland water and Chapter 5: Land.

3.7 Clearing and fragmentation of native ecosystems

Overall, national rates of broadscale land clearing have fallen dramatically. However, substantial clearing continues in many areas. In addition, the legacies of past land clearing will continue to operate for some decades as old trees and small remnants of native ecosystems isolated in mostly cleared landscapes die, and recruitment of new plant seedlings, fungi and animals is hindered by changed fire regimes, altered soil properties, exposure to predators and reduced ability to find mates. Addressing these legacy effects will be complex, long term and potentially expensive.

3.7.1 Land clearing

The Assessment of Australia’s terrestrial biodiversity 2008\textsuperscript{15} concluded that:

… broad-scale land clearing has been largely brought under control in the jurisdictions that accounted for most of the clearing in 2002. New regulatory frameworks in Queensland and New South Wales have dramatically reduced the level of approved clearing of remnant vegetation nationally in the past five years. (p. 150)
While this statement remains generally true, the additional analyses reported in Chapter 5: Land reveal a slightly more complex situation:

The annual rate of forest loss in the mapped intensive-use zone over the decade to 2010 averages 1.1 million hectares (range 0.7 million – 1.5 million hectares). This loss has been offset by forest expansion averaging 1 million hectares annually (range 0.6 million – 1.3 million hectares).

As a consequence, there was a small net gain of forest in Australia in 2007–10, for the first time since the early 1990s. The overall average net rate of forest change in the area mapped over the decade to 2010 was a loss of around 160 000 hectares annually. As the 2006 SoE report noted, ‘regrowth’ vegetation and its environmental values are generally different in many respects from the vegetation that has been cleared.

Consistent with the conclusion by the Assessment of Australia’s terrestrial biodiversity 2008, Chapter 5: Land concludes that:

- Rates of land clearing averaged around one million hectares annually over the period 2000–10, and were balanced by the extent of regrowth—although the character and values of the original and regrowth vegetation are often different.

Although average figures suggest that the pressure on biodiversity from land clearing is reducing or stable in many parts of Australia, more detailed data are needed to assess the significance of these changes for biodiversity. For example, relatively high levels of clearing have continued in parts of north-eastern Queensland and in the headwaters of the Murray–Darling Basin, which could have far-reaching impacts.

Research in the Northern Territory suggests that rates of land clearing there, in conjunction with changed fire regimes and invasive species, have been sufficient to cause major, and somewhat unexpected, changes in biodiversity. Although there have been major advances in re-establishing vegetation cover (see Chapter 5: Land), replacing mature native vegetation with regrowth seldom provides the same environmental values as the original vegetation.

Decreases in broadscale clearing have been beneficial for many bird species; however, clearing of northern woodlands and of forests is an emerging threat. Continued clearing of old growth native forest in Tasmania and the legacy of past clearing across large parts of Australia are two major factors degrading the remaining habitat for birds.

The Queensland Herbarium has collected and published some of the most detailed data on land clearing of any state. These data demonstrate the level of detail necessary to identify where pressures are highest and where interventions might be needed. Past clearing has been uneven across the state—it is concentrated in the south-east, as is most of Queensland’s population. Clearing since 1997 has also been greatest in the south-eastern and southern parts of the state and there is a wide range in extent of clearing, from virtually zero to more than 3.5% annually.

Clearing of some of the subregions at the top of the Murray–Darling Basin has been much more extensive than the Queensland average (Figure 8.14). Understanding clearing at this scale is important for understanding and managing ecological processes that operate at a range of scales. For example, the clearing in the top of the Murray–Darling Basin is likely to have implications not only for biodiversity in those subregions, but also for freshwater-dependent biodiversity living lower in the Basin.

Fragmentation of habitat is one of the two most frequently cited pressures for EPBC-listed species (the other being invasive species). Figure 8.14 shows the highly fragmented nature of vegetation systems to the west of the Great Dividing Range in eastern Australia, across much of southern Australia and in the south-west. These areas, not surprisingly, coincide with the areas in which numbers and proportions of threatened species occur (Figures 8.5, 8.6, 8.8 and 8.9).

Research is starting to provide guidance on how to interpret data on the connectivity of remnant vegetation. However, we do not yet have enough data to draw strong conclusions, other than recognising that strong environmental pressures (generated by various forces, such as land clearing) are causing habitat fragmentation. Although many of these forces have been reduced (e.g. as land clearing becomes more strongly regulated), there is a strong legacy effect that is likely to see the extent and condition of native vegetation continue to decline for several decades.

### 3.7.2 Urban development

Urbanisation is arguably one of the strongest and most expanding forms of human pressure on biodiversity. Urbanisation directly removes habitat. It can also reduce habitat quality by fragmenting it, simplifying its structure, or altering the composition of ecosystems embedded in urban landscapes.
3.7.3 Extractive industries

The impacts of mining on soils and other environmental assets and values are considered in detail in Chapter 5: Land. Mining has direct local impacts on habitat extent and quality, as vegetation is removed to varying degrees depending on the type of mine. Mining can also pollute waterways and disrupt agriculture through competition for land, or by directly

Source: Australian Government Department of the Environment, Water, Heritage and the Arts

Figure 8.14 Analysis of the sizes of remnant patches of native vegetation in Australia
affecting the land itself (e.g. through subsidence). The same processes that cause rare minerals to accumulate could also lead to a high endemism of native species (especially plants), which, in turn, could cause conflict between conservation and mining interests.110

Mining currently occupies a very small proportion of the land area of Australia, but the mining industries are growing and their impacts are becoming more extensive. There have been some reports of highly successful rehabilitation of mine sites, which may allow substantial offset of initial impacts in the long term.111

3.8 Pressures from livestock production

Land management for agricultural production is reviewed in Chapter 5: Land. Each land-use system entails some degree of clearing and fragmenting of native ecosystems, and grazing systems have the added impact of large introduced animals on landscapes and species. Research reported in previous national SoE reports has found that artificial watering points allow domestic stock to forage in areas that would otherwise be too dry for them and this has spread the impacts of grazing widely across arid Australia.15,112

Williams and Price113 recently reviewed the literature on impacts of livestock and other industries that produce protein from domestic animals, or from wild animals (e.g. kangaroos or wild-caught fish). Their conclusions (Table 8.21) illustrate the wide range of direct and indirect impacts of these industries and particularly the high relative impacts of beef production. The authors point out, however, that management in the red meat industries, which once had very high impacts on biodiversity, has improved greatly.

Grazing pressure, together with the effects of invasive species like cats and foxes, and changed fire regimes, have been implicated in the major recent declines in mammals and birds in central and northern Australia (Box 8.3).15,117-118

Grazing is one example of a pressure that interacts strongly with a range of others. For example, most land clearing is to produce pasture for stock; livestock are a major reason for the introduction of invasive plants like gamba grass and buffel grass; suppression of top predators (e.g. dingoes—see above) is primarily to protect stock; watering points for stock in arid areas also encourage feral pest populations; stock remove the fuel that cool fires need, and encourage woody thickening which can result in stand-replacing fires; catchment-scale soil compaction changes catchment hydrology; and selective grazing removes protective cover, changes the composition of vegetation communities and exposes soils to erosion. These types of interactions apply for most pressures on biodiversity (see Section 3.13).

The control of dingoes is one of the activities of livestock production that has an increasing impact on biodiversity. Recent research has suggested that when dingo numbers are kept in check, other biodiversity suffers because the impacts of introduced cats and foxes increases, and the impacts of these predators is far greater than that of dingoes.116 Dingoes also appear to keep numbers of cats and foxes in check. Grazing pressure, together with the effects of invasive species like cats and foxes, and changed fire regimes, have been implicated in the major recent declines in mammals and birds in central and northern Australia (Box 8.3).15,117-118

Grazing is one example of a pressure that interacts strongly with a range of others. For example, most land clearing is to produce pasture for stock; livestock are a major reason for the introduction of invasive plants like gamba grass and buffel grass; suppression of top predators (e.g. dingoes—see above) is primarily to protect stock; watering points for stock in arid areas also encourage feral pest populations; stock remove the fuel that cool fires need, and encourage woody thickening which can result in stand-replacing fires; catchment-scale soil compaction changes catchment hydrology; and selective grazing removes protective cover, changes the composition of vegetation communities and exposes soils to erosion. These types of interactions apply for most pressures on biodiversity (see Section 3.13).

The recent assessment of Australia’s rangelands (Bastin et al.,119 see Chapter 5: Land) reported mixed impacts of grazing on environmental values,
Table 8.21 Potential relative contribution of different protein sources to the pressures on biodiversity at a national scale

Note that the pressures exerted by any individual industry are relative to other industries, and that high relative pressures do not necessarily imply high absolute pressures on biodiversity.

<table>
<thead>
<tr>
<th>Protein source</th>
<th>Vegetation clearance</th>
<th>Altered fire regime</th>
<th>Altered grazing regime</th>
<th>Altered hydrology</th>
<th>Trampling and compaction</th>
<th>Invasive species</th>
<th>Pollution (air, water, land)</th>
<th>Disease and pathogens</th>
<th>Climate changes</th>
<th>Direct loss of biota</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef (extensive)</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>L</td>
</tr>
<tr>
<td>Beef (feedlot)</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>M</td>
<td>M</td>
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<td>L</td>
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<tr>
<td>Lamb (extensive)</td>
<td>M</td>
<td>M</td>
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<td>L</td>
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<td>Lamb (feedlot)</td>
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<tr>
<td>Goat</td>
<td>L</td>
<td>L</td>
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<tr>
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<td>L</td>
<td>L</td>
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<tr>
<td>Pork (indoor)</td>
<td>L</td>
<td>L</td>
<td>L</td>
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<td>L</td>
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<td>Pork (outdoor)</td>
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<tr>
<td>Chicken (indoor)</td>
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<tr>
<td>Chicken (outdoor)</td>
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<td>Fish (wild catch)</td>
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<td>L</td>
<td>L</td>
<td>L</td>
<td>H*</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>H*</td>
</tr>
<tr>
<td>Fish (aquaculture)</td>
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<td>L</td>
<td>M</td>
<td>L</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Plant-based</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Dairy</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>L</td>
</tr>
<tr>
<td>Eggs (indoor)</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>M</td>
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<td>L</td>
</tr>
<tr>
<td>Eggs (outdoor)</td>
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</tr>
</tbody>
</table>

H = high; L = low; M = medium; ° = ocean floor dragging; * = wild catch or harvest
Source: Williams & Price

632
including biodiversity. Similar to other pressures on biodiversity, information on which to base assessments is limited across most of Australia, but several conclusions seem defensible:\textsuperscript{15}

- Grazing pressure is a long-standing and complex threat to biodiversity over much of Australia, with significant impacts related to the extent, duration and management of grazing.
- The greatest effects of grazing occurred rapidly after initial pastoral settlement, but its effects are still evident except where the most biodiversity-sensitive practices are used.
- There is no reason to believe that the history of biodiversity decline in the rangelands has been arrested, and there is evidence that it is accelerating in some areas.
- In the intensive agriculture zones throughout much of southern Australia, native biodiversity has been severely reduced and isolated in mostly small remnant populations that struggle to compete with introduced species under existing land-management regimes and are therefore highly vulnerable to other threats, including invasive species, pathogens, fire and climate change.

3.9 Invasive species and pathogens

Invasive species are one of the two most frequently cited pressures for EPBC-listed species (the other being fragmentation of habitat).\textsuperscript{15} Invasive species and pathogens include plants, animals, fungi and a range of pathogenic microorganisms; their significance and impacts are also discussed in Chapter 5: Land.

3.9.1 Weeds

Invasive plants (weeds) affect biodiversity in many ways: they may outcompete native plants, they may reduce or alter the resources available to native animals and they may markedly affect fire regimes. In 2007, more than 2800 of the 27 000 alien plant species that had been imported into Australia had become established in the wild, and that number was growing at around 10 species per year.\textsuperscript{120} The number is now much higher. As part of the National Land & Water Resources Audit phase II, the jurisdictions mapped 98 major weeds nationally.\textsuperscript{121} Of these 98 species, 20 are Weeds of National Significance (WoNS).

The remaining 78 are either candidate WoNS, on the national environmental alert list, targets for biocontrol (control of an invasive species by other species, usually by the managed introduction of predators or pathogens), or a combination of these three categories.

As with many threatening processes, the mechanisms by which weeds have impacts are poorly defined, and processes for determining which species they affect and their relative importance compared with other pressures are inconsistent and often unclear.\textsuperscript{88,122} Scott and Grice\textsuperscript{122} recently reviewed the state of research on weeds in Australia. Since 1995, the number of quantitative studies of the impact of weeds on the Australian environment has more than doubled to more than 70 studies, covering 30 species. Most studies show that weeds reduce plant biodiversity by reducing native species richness and changing community composition and structure. Weed invasion is considered to be a threatening process for one-third of rare species in Australia. Scott and Grice conclude that the measures currently adopted to understand the invasion of weeds in Australia are not at the level required to plan strategies to mitigate the problems they create.

3.9.2 Invasive fungi

Many introduced fungi have become established in Australian ecosystems, especially in soils. Several are known to have become invasive species, and the list is likely to grow in the future as a result of more research and as climate changes. Three invasive fungi are of particular concern nationally: chytrid amphibian fungus (\textit{Batrachochytrium dendrobatidis}), myrtle rust (\textit{Uredo rangelii}) and \textit{Phytophthora cinnamomi}.\textsuperscript{123} The chytrid fungus\textsuperscript{124} has been responsible for mass deaths of frogs worldwide and is widespread in Australia. A significant association between amphibian declines in upland rainforests of northern Queensland and three consecutive years of warm weather\textsuperscript{125} suggests future warming could increase the vulnerability of frogs to the fungus.

Myrtle rust is of particular concern, because it affects a wide range of plant species in the Myrtaceae family of plants, including Australian natives like bottlebrush (\textit{Callistemon} spp.), tea tree (\textit{Melaleuca} spp.) and eucalypts (\textit{Eucalyptus} spp.).\textsuperscript{126} There are fears that this emerging invasive species could transform the Australian environment in major ways, especially if its impacts are magnified by climate change.
**3.9.3 Invasive animals**

The most significant invasive vertebrate animal species are the European fox (*Vulpes vulpes*), domestic cat (*Felis catus*), European rabbit (*Oryctolagus cuniculus*), feral goat (*Capra hircus*), feral pig (*Sus scrofa*) and cane toad (*Bufo marinus*). Significant invertebrate invasive species include the red fire ant (*Solenopsis invicta*), the yellow crazy ant (*Anoplolepis gracilipes*) and a range of tramp ant species. European wasps, bumblebees and European honeybees are also widely cited species of concern. Asian honeybees are a recent threat that appears to have potential for major impacts (Box 8.5).

**3.9.4 Invasive species affecting inland aquatic environments**

A wide range of invasive species affect inland aquatic environments, including non-native freshwater fish species (which represent more than a quarter of the total number of fish species in river systems), feral pigs, the cane toad, red-eared slider turtles and around 10 major invasive plant species nationally (see Chapter 4: Inland water for details).

**3.9.5 Marine invasive species**

Many marine pests are introduced to Australian waters in ballast water discharged by commercial shipping, biofouling on hulls, aquaculture operations and aquarium imports, as well as marine debris and ocean currents. Viruses and a range of invertebrates, including starfish, algae, plankton, molluscs, crustaceans and worms are of high concern in some regions but not others (see Chapter 6: Marine environment for details).

**3.9.6 Jurisdictional reporting on invasive species and pathogens**

The *Assessment of Australia’s terrestrial biodiversity 2008* concluded that data on invasive species is poor nationally but good for some case studies. Table 8.22 summarises reports from Australian states and territories on invasive species and pathogens.
Table 8.22 Effects of invasive species on biodiversity reported in recent state of the environment reports by the states and territories

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>A wide range of pest plants is established in the territory and some have harmful impacts on native vegetation and biodiversity. Especially after the 2003 fires, control of pest plants, such as exotic grasses, woody weeds, willows and blackberry, continues to be a major task for land managers. Established pest animals include mammals (feral cats, goats, pigs and deer, as well as foxes, rabbits, wild dogs and small numbers of feral horses), fish (carp, oriental weatherloach, redfin, goldfish), birds (common myna, common blackbird, common starling) and insects (European wasp). Under continuing dry conditions, management of eastern grey kangaroo populations on some land in the ACT has become a contentious issue.</td>
</tr>
<tr>
<td>NSW</td>
<td>Pressures are generally increasing, especially in fragmented landscapes. Invasive species form the second most pervasive threat to native vegetation, affecting 90% of all classes, an increase from 75% in 2006. This threat has intensified due to invasion and establishment of weeds and diseases in new areas. Invasive species, especially foxes and cats, and habitat loss are the two major threats to vertebrate fauna.</td>
</tr>
<tr>
<td>NT</td>
<td>Although native plants dominate most of the landscape, exotic plants are now a major component of some environments, with 13 of the 20 WoNS either already found in the territory or representing a serious threat: alligator weed, athel pine, cabomba, olive hymenachne, lantana, mesquite, mimosa, parkinsonia, parthenium weed, pond apple, prickly acacia, rubber vine and salvinia. Many exotic animal species present serious threats to native species and environments. Cattle and feral animals, such as camels, donkeys, pigs, horses and buffalo, can cause widespread damage through fouling waterholes, selectively grazing and damaging vegetation, spreading declared weeds or ecologically invasive plants, trampling the nests of ground-dwelling animals, and causing erosion. Some feral animals have direct impacts on native species: foxes and feral cats contributed to the extinction of central Australian mammals and continue to impact a range of other species; competition from rabbits is thought to have caused the demise of the burrowing bettong; poisoning by cane toads appears to have led to local extinctions of the northern quoll; and infestations of crazy ants and big-headed ants have caused significant losses in invertebrate diversity. These threatening processes operate across lands of all tenures.</td>
</tr>
<tr>
<td>Qld</td>
<td>Terrestrial pest animals and invasive terrestrial plants (weeds) cost the state at least $110 million and $600 million a year, respectively. Invasive animals and plant pests have become established in inland waters, but there are no recorded established invasive marine pests.</td>
</tr>
<tr>
<td>SA</td>
<td>Invasive species, including vertebrates, invertebrates, plants, algae, and fungal, bacterial and viral pathogens, pose current and potential threats in terrestrial, riparian and marine environments statewide. Some invasive species can irreversibly transform ecosystems by changing water, nutrient, soil and/or fire cycles. Invasive animal species are estimated to be common and widespread over the following percentage areas of SA: rabbits 86%, foxes 56%, feral deer 1%, feral camels 35%, feral goats 11%, wild dogs (including dingoes) 48%, feral cats 60% and starlings 11%. Abundance of rabbits, feral cats, camels and feral goats is increasing; abundance of foxes is decreasing; feral pigs are stable; marine pests are stable; distribution of feral olives and silverleaf nightshade is increasing; distribution of blackberry is stable; boneseed is declining. The total cost of weeds is over $600 million per year.</td>
</tr>
</tbody>
</table>

Continued next page
Jurisdiction Summary

**Tas**
Weeds are among the most serious threats to Tasmania’s natural biodiversity. In 2007, around 30% of the 2626 known plant species in the state were weeds. Several diseases of plants are having major impacts: the introduced soilborne rootrot disease *Phytophthora* is a major threat to the health of native vegetation; the naturally occurring pathogenic fungus myrtle wilt attacks mature myrtle beech trees; and *Armillaria* rootrot fungus attacks eucalypts.

There are limited data for introduced animal species and native animal diseases. Of 447 introduced animal species, 34 vertebrates and 13 invertebrates are considered key environmental pests. Cats are a major problem, and foxes have been introduced recently and are spreading. Introduced invertebrates pose a significant but unknown threat to plants, animals and ecosystems. Introduced diseases are also affecting native animals (Tasmanian devils, platypus, seals and other mammals, frogs and birds).

**Vic**
The total cost of pest species is around $900 million per year.

Exotic species represent around 30% of the state’s flora (this is 1.7 times the number in 1984).

Foxes and rabbits are widespread, but wild dogs and feral pigs are absent or unknown over large areas. Wild dogs occur mainly in East Gippsland and the north-east, as well as in the southern Mallee, while feral pigs are localised to relatively small areas, mostly in the east. Pest animals are monitored locally but no statewide data exist.

**WA**
More than 1200 recognised weed species occur in the state, with the Swan Coastal Plain and the Jarrah Forest in the south-west having the highest number (700–800 identified species).

11 of the 20 WoNS are present and an additional 7 weed species pose an imminent threat.

The distribution and abundance of cats and pigs increased between 2000 and 2005, and the population of camels in the central deserts is large and rapidly increasing. Improved monitoring is needed to determine the extent and density of introduced animal species.

**National**
See Box 8.6

Invasive species affect all tenures. In New South Wales, for example, it is estimated that around 18% of national parks are affected by weeds and 36% by pests. Figure 8.15 shows the coincidence between invasive species and threatened species across Australia (compare Figure 8.15 with Figures 8.5, 8.6, 8.8 and 8.9).

Examples of the impacts of invasive species are given in Box 8.6.

No institutions currently conduct ongoing assessments of the impacts of weeds on biodiversity, but data are collected and action taken in particular cases where the impact can be mitigated or where important assets are threatened. The National Weed Incursion Plan (NWIP) is an operational plan and guideline for managing national responses to weed incursions.

Application of the NWIP is triggered by the detection of a high-risk weed species. The NWIP sits within the Australian Biosecurity System (AusBIOSEC) framework and provides the essential steps required to execute a response to a high-risk weed incursion.

The *Assessment of Australia’s terrestrial biodiversity 2008* commissioned eight case studies to show the effects of invasive species and pathogens on biodiversity, and to highlight examples where the threats are expanding and impacting on relatively common species. The key messages from these case studies were as follows:

- Invasive species and pathogens represent one of the most potent, persistent and widespread threats to Australian biodiversity. They have both a direct negative impact on species and communities through losses and extinctions, and an indirect impact on ecosystems and biodiversity through ecological changes brought by those losses and extinctions.
Box 8.6 Impacts of invasive species

Biodiversity benefits from managing feral animals

Removing grazing livestock, trapping feral predators and building feral-proof enclosures are proving to be highly valuable mechanisms for halting local biodiversity decline. Australian Wildlife Conservation enclosures have shown 4–7-fold increases in targeted marsupial populations at the 5000-hectare Yookamurra and 8000-hectare Scotia sanctuaries in South Australia, and at the 40 000-hectare Mornington Wildlife Sanctuary in the Kimberley, after the removal of introduced herbivores. These examples show that active land management can increase the diversity and abundance of small mammals. Mornington Wildlife Sanctuary is the only protected area in northern Australia where a recovery in mammal populations has been recorded. Similar observations are seen for island introductions for northern quolls onto Astell and Pobassoo islands in the Northern Territory and bandicoots onto Faure Island off Western Australia. Feral trapping has also led to significant, but so far limited, local successes in marsupial populations through the ‘Ark’ projects in Victoria and the Western Shield Fauna Recovery program in Western Australia.

Rabbit grazing and native shrub regeneration

Several studies have shown that even quite low rabbit population densities can significantly prevent native shrub regeneration. Recruitment of arid zone acacias and other arid zone shrubs is significantly affected by low post-myxomatosis and post–rabbit calicivirus disease population densities to the point where near nil recruitment was observed.

a  www.australianwildlife.org/Home.aspx
• Invasive species and pathogens alter entire ecosystem compositions and have directly led to extinctions in most bioregions of Australia.

• These losses include loss of entire species from mainland Australia and their contraction to neighbouring islands where the particular invasive threat is not established.

• Establishment and persistence of invasive species and pathogens are promoted by a range of other threats, including fire, all forms of disturbance and climate change.

• There are major gaps in our understanding of the impacts of invasive species and pathogens on biodiversity.

The interaction between invasive species and other pressures not only make it very difficult to assess separately the impact of invasive species, but also means that strategies to address invasive species are unlikely to succeed unless they also address other interacting pressures.

3.10 Altered fire regimes

Changes to fire regimes around Australia are discussed in detail in Chapter 5: Land. The two factors most influencing these changes have been climate and land-use changes, and climate variability. Whereas climate affects the likelihood and intensity of fires, many of the land-use changes—such as land clearing, changes to the balance of trees, shrubs and grasses, and introduced versus native species—affect the amount and type of fuel available for fires, how quickly and evenly or patchily they spread, and their effects on biodiversity.

Birds Australia reports that fire is becoming an increasing threat to birds of isolated forests and heathlands, and that inappropriate burning regimes potentially threaten many birds of northern savannas. Conversely, Birds Australia also acknowledges that improved fire management in many places is improving the status of threatened and nonthreatened bird species.

3.11 Changed hydrology

Changes to the hydrology of Australian landscapes are discussed in detail in Chapter 4: Inland water and Chapter 5: Land. The many alterations to Australian landscapes since European settlement (especially clearing of land for agricultural and urban development) have affected the processes by which rainwater enters the soil and flows into underground channels or creeks and rivers. Throughout large parts of Australia, vegetation removal has caused watertables to rise to the surface, bringing salt with them. Changed hydrology has directly affected biodiversity associated with inland waters through, for example, salinisation, impacts on flow rates in rivers, and drying of wetlands as overland and below-ground water provision is reduced.

Despite substantial literature on the processes by which salinisation affects native and introduced vegetation, there is little information on the spatial extent to which changed hydrology has affected terrestrial ecosystems. Concern has been expressed for several years about the lack of information on the combined effects of water extraction for irrigation and changed hydrology on groundwater (underground water) systems, and the biota that rely on them. However, there is still very limited information on the extent or distribution of pressures on groundwater-dependent biota.

3.12 Pressures on marine ecosystems

As discussed in Chapter 6: Marine environment, the Australian marine environment is experiencing a broad range of pressures that affect the quality of the habitats, species and environmental health. The main pressures are in coastal areas and particularly in sheltered enclosed bays, estuaries and lagoons, where flushing of land-based sources of pollution and wastes is most limited. Present-day pressures are interacting with the effects of past activities. In the case of fishing and coastal development, while today’s management practices are much improved, a number of ecosystems, habitats and species have been heavily impacted in previous centuries and will continue in their degraded condition under current management policies and practices. Exploitation of marine resources has overtaken waste disposal as the major source of impacts in the world’s oceans.

3.13 Interactions among pressures

The drivers–pressures–state–impact–response (DPSIR) model adopted in this report tends to portray pressures as acting individually. Our personal communications
with those preparing SoE reports in states and territories indicate that most researchers are thinking about ways to take account of the interactions among pressures.

While there are many interactions among pressures, emerging and future climate change is likely to magnify the effects of all previously identified pressures.\textsuperscript{140}

An analysis of which pressures are most commonly found acting together on Australian plants identified a set of ‘threat syndromes’:\textsuperscript{88}

- **Syndrome 1.** Species with small to medium geographic ranges (usually less than 100 kilometres) intersecting regions developed for extensive crops (e.g. *Verticordia plumosa* var. *pleiobotrya*).
- **Syndrome 2.** Species with small to medium geographic ranges that intersect urban areas (e.g. *Grevillea caleyi*).
- **Syndrome 3.** Narrow endemics with specific habitat requirements threatened by fire, weeds, disease, hydrological changes, salinity or other landscape-scale ecological changes (e.g. *Lambertia echinata* subsp. *occidentalis*).
- **Syndrome 4.** Species adapted to rock outcrops threatened by grazers (sheep, rabbits, goats), introduced weeds, fires, dams or other human activities (e.g. *Zieria parisiiae*).

The interaction between fire regimes and climate change will be particularly significant.\textsuperscript{141} Climate change is expected to affect fire regimes through its effects on temperature, rainfall, humidity and wind, and also through impacts on vegetation growth and litter accumulation.\textsuperscript{142}

Interactions between climate change and invasive species have been mentioned (e.g. effects of soil warming on invasive fungi), but as species are forced to move around landscapes the distinction between natural and invasive may become less clear, and species previously seen as native might be considered as invading the ranges of other native species.\textsuperscript{1}

In much of Australia, interactions among climate change, agriculture and biodiversity are already emerging, as declines in biodiversity are partly driven by agricultural practices and also affect agricultural productivity, while climate change affects both.\textsuperscript{143}
## Pressures affecting biodiversity

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Local climate</strong></td>
<td>Drought has been a major pressure on all components of biodiversity in all jurisdictions over the past decade. The effects differ with location and types of biota. Some species move, while less mobile ones have suffered decreases in numbers. It is difficult to assess the long-term implications of the past decade of climate variability.</td>
<td>Very high impact</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Pollution</strong></td>
<td><strong>Point-source pollution (e.g. from factories):</strong> Regulations are frequently effective for point-source pollution, but this is still listed as a source of concern in state and territory SoE reports. Biodiversity is highly susceptible to major pollution events like oil spills, especially when they occur near areas of unique diversity. <strong>Diffuse and broadscale pollution:</strong> Pollution pressures range from local (point source) to national and global (e.g. carbon pollution and ocean acidification). Most jurisdictions express concern about pollution, especially from urban and agricultural sources. The grade is based on the impacts of broadscale pollution, such as accumulation of atmospheric carbon and ocean acidification.</td>
<td>Low impact</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Consumption/extraction of biodiversity and/or other natural resources</strong></td>
<td>Direct harvesting of wildlife around Australia is well regulated and has a minor effect on biodiversity. However, the average per-person consumption of natural resources overall by Australians is one of the highest in the world, and several analyses suggest that consumption will need to be reduced considerably if biodiversity and other resources are to be sustained as Australia’s population grows.</td>
<td>Low impact</td>
<td>Moderate</td>
</tr>
<tr>
<td><strong>Clearing and fragmentation of native ecosystems</strong></td>
<td>Past clearing for agriculture and urban development has been a major driver of biodiversity decline around Australia. Impacts of urban development per capita appear to be falling, but overall impact is growing or stable as the population has been growing. Extent of land clearing is declining but it remains a significant pressure in some places, and the legacy of past clearing means that impacts have continued to rise and will do so for some time. The upward arrow reflects a general reduction in the clearing of land in recent years and therefore a trend towards reducing the pressure from recent practices.</td>
<td>Low impact</td>
<td>Moderate</td>
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</tbody>
</table>
### Component Summary

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pressures from livestock production</strong></td>
<td>Grazing continues to be a major pressure on biodiversity, especially in the rangelands and in combination with drought and fire. There is little information to allow assessment of whether new approaches to grazing are having a significant impact yet.</td>
<td>Very high impact</td>
<td>Low impact</td>
</tr>
<tr>
<td><strong>Invasive species and pathogens</strong></td>
<td>All jurisdictions report invasive species and pathogens as one of the most significant current and future problems, potentially exacerbated by climate change. There are very limited data on which to assess whether efforts to address problems are having an impact.</td>
<td>Very high impact</td>
<td>Low impact</td>
</tr>
<tr>
<td><strong>Altered fire regimes</strong></td>
<td>Effects have been Australia-wide, they have been particularly significant in northern savannas and fire-sensitive and fire-dependent communities (e.g. monsoon vine thickets).</td>
<td>Very high impact</td>
<td>Low impact</td>
</tr>
<tr>
<td><strong>Changed hydrology</strong></td>
<td>There have been major effects on wetlands and river health. Loss of terrestrial vegetation due to salinity has been considerable. Actions to address known issues have not had time to show outcomes. The problems have been worst in the most developed catchments.</td>
<td>Very high impact</td>
<td>Low impact</td>
</tr>
</tbody>
</table>

### Recent Trends

- **Improving**
- **Stable**
- **Deteriorating**
- **Unclear**

### Grades

- **Very low impact**: Few, if any, species and/or ecosystems are suffering substantial adverse effects from this pressure.
- **Low impact**: A small proportion of species and/or ecosystems are suffering substantial adverse effects from this pressure.
- **High impact**: A significant proportion of species and/or ecosystems are suffering substantial adverse effects from this pressure.
- **Very high impact**: A large proportion of species and/or ecosystems are suffering substantial adverse effects from this pressure.

### Confidence

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment
Effectiveness of biodiversity management

A detailed assessment of the management responses to biodiversity challenges was beyond the scope of this report. Instead, we have relied on assessments made in a range of recent reports. Key documents included the SoE reports by each of the states and territories, the Assessment of Australia’s terrestrial biodiversity 2008 and the interim and final reports of the Hawke review of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

To assess management effectiveness, we have adopted the approach outlined in Chapter 1: Approach that is based on the principles of management effectiveness applied in the Great Barrier Reef outlook report 2009.

Conservation efforts in Australia are spread across a wide range of state and territory government programs as well as Australian Government initiatives. A national framework is provided by Australia’s Biodiversity Conservation Strategy 2010–2030, which serves as a policy umbrella over several other more specific national frameworks, including the National Framework for the Management and Monitoring of Australia’s Native Vegetation (1999), Australian Weeds Strategy (2007), Australian Pest Animal Strategy (2007) and Australia’s Strategy for the National Reserve System 2009–2030 (2009). The exposure draft of this latter strategy was criticised by a range of scientists. Among their concerns were that the strategy failed to clearly affirm some previous principles, such as commitment to a comprehensive, adequate and representative reserve system (this is still not mentioned in the final version), and lack of clear and measurable targets (only partly addressed in the final version). Although we acknowledge the validity of many of these criticisms, we also recognise the strong focus on promoting resilience in social–ecological systems as a means of better managing biodiversity. The success of this approach will depend strongly on the regular assessment of progress towards better biodiversity outcomes and, as discussed below, it is not clear whether adequate processes are in place to achieve such monitoring and evaluation.

In addition to government actions, conservation efforts are increasingly being provided by nongovernment groups. National assessments of management effectiveness often focus on Australian Government programs such as Caring for our Country or its predecessor, the Natural Heritage Trust, yet the investment in these programs is only around 10% of total nationwide investment. It is unrealistic to expect Australian Government programs alone to significantly improve the state of biodiversity, although they provide important catalysts for other investments at a range of spatial and temporal scales.
Australia has many opportunities for effective environmental planning and management, including opportunities to build more adaptive (polycentric) governance systems and to build on processes already emerging to deal with lack of information and a range of other pressures. Significant new opportunities might emerge from new technologies that allow pressures to be addressed more effectively, including decreasing the deleterious effects of humans on the environment further than is currently imagined, and a degree of decoupling of economic prosperity from the consumption of natural resources. Two examples that are already seen as plausible are the production of synthetic foods, including meats, and the use of next-generation mobile communication devices to allow the public to engage in the collection and reporting of environmental information.94

4.1 Management context

Assessing the management context component of management effectiveness considers the availability of information to understand and address environmental issues (understanding) and the adequacy of plans and policies (planning). In relation to biodiversity management, we would expect that managers would have access to adequate information on:

- the environmental and social significance of biodiversity
- current pressures and emerging risks to biodiversity
- resilience of biodiversity to expected and unexpected risks.

We would also expect that policies and plans are in place to clarify objectives, roles and responsibilities for managing biodiversity.

4.1.1 Adequacy of information and understanding

All jurisdictions have reported concerns about the adequacy of information on which to base assessment of the state and trends in biodiversity and to identify priorities for action. We conclude that not only is information inadequate nationally, but that investment in filling gaps is also inadequate in relation to the potential benefits of having that information. Box 8.7 provides some insights on monitoring and prioritisation of investment from a leading researcher in these fields. One key point made is that there is a need for strategic thinking in the collection of information. Where information collection is not strategic—or worse, is used as an excuse to delay decisions—there is a high risk that it will simply document ongoing decline. Every recent state and territory report has:

- argued that halting the decline in biodiversity (and eventually enabling an increase) is important for ethical and moral reasons, and for the survival and wellbeing of humans
- identified the same set of driving factors (except that awareness and concern about climate change has risen)
- expressed concern that levels of information are inadequate to make robust assessments of states and trends and, hence, to assess the effectiveness of mitigation measures
- recognised that measures taken in the previous reporting period have not achieved their objectives of slowing or reversing drivers of biodiversity decline.

An exception to the inadequacy of biodiversity information is the substantial collection of data held by Birds Australia and collected by its volunteer network. However, while monitoring is detecting trends in bird populations, it may not be frequent enough to isolate the underlying causes.85 Furthermore, monitoring to assess whether management interventions work is either lacking or not strategic, and may be better done using targeted bird monitoring.85

As part of the implementation of the National Plan for Environmental Information,16 data held by government agencies are being reviewed to improve the relevance and scope of data collection, and to make it available to the public. A recent review of datasets held by the Australian Bureau of Agricultural and Resource Economics and Sciences149 is an example of this approach.

As well as understanding the state and trends in biodiversity, it is important for planning that we understand the pressures and risks to biodiversity. All jurisdictions appear to be successfully identifying the main risks to biodiversity, even if there is not enough information on these risks to assess trends or identify effective prevention and mitigation...
Box 8.7 Addressing information gaps

Decision science, policy projection and monitoring

Concerns about ongoing rates of decline in biodiversity, and increases in those rates due to climate change, has caused scientists in diverse fields to call for a move from documentary and predictive science to decision science. By integrating information and ideas from ecology, economics and other social sciences, decision science provides the tools necessary for rational decision-making in uncertain or complex situations.

Decision science has many specific applications in conservation and environmental management. It has been used to identify the best places to locate conservation reserves, to develop strategies for learning about and managing facial tumour disease latency in Tasmanian devils, to evaluate recovery planning expenditure, to determine when to declare a weed species eradicated, to prioritise spending on global biodiversity hot spots and many others.

One of the great opportunities for improved conservation investment outcomes at a national level is in the use of scientific decision-making methods for predicting, monitoring and evaluating the benefits of biodiversity policy and investment. The role of monitoring and reporting in policy evaluation is becoming more widely acknowledged. Scenario modelling is a less widely acknowledged key to successful policy implementation. Thomas et al. provide a sample of models for predicting extinction rates under various global warming scenarios. Their work suggests that 36% of biodiversity is likely to become extinct by 2050 under status quo warming scenarios. Recent developments in extinction-risk modelling show promise as tractable methods for predicting the fate of biodiversity and likely response to policy initiatives at a range of scales, including national and state. Such models could be used to evaluate the cost-efficiency of broadscale climate adaptation options, such as initiatives to connect habitat or environmental stewardship or broadscale restoration programs.

Our ability to develop and test models such as these will depend on the choice of indicators and metrics measured and collated through state of the environment reporting and the National Environmental Accounts initiative. The data that are useful for long-term policy evaluation may not necessarily exist already and may need to be collected. Monitoring can absorb a large amount of resources, so care must be taken to ensure that measured indicators provide the best information for policy evaluation and improvement.

Source: Brendan Wintle, Applied Environmental Decision Analysis Commonwealth Environment Research Facility (www.aeda.edu.au), now the ARC Centre for Excellence for Environmental Decisions (ceed.edu.au)

Harnessing continent-wide biodiversity datasets for prioritising national conservation investment

A recent project between the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) modelled and mapped fine-scale patterns in biodiversity composition across the Australian continent based on millions of records for more than 20 000 species of plants, vertebrates and invertebrates (from DSEWPaC’s Australian Natural Heritage Assessment Tool database) and best-available climate, terrain, soils and vegetation layers. The project showed strong potential for linking this mapping to remotely sensed land-cover and land-use data to assess change in biodiversity status, and to downscaled climate scenarios to forecast potential climate change impacts on biodiversity.

CSIRO, in collaboration with the National Plan for Environmental Information and the Atlas of Living Australia (ALA), is currently exploring the potential for extending this approach to take advantage of major recent advances in data availability for the Australian continent. These include primary biological observations (and environmental variables needed for modelling these observations) through the ALA, and remotely sensed land-cover change data gathered through initiatives such as Geoscience Australia’s dynamic land-cover mapping.

Source: Simon Ferrier, CSIRO Ecosystem Sciences
We noted in Section 1.2 that assessing the capacity of ecosystems to provide benefits for humans requires an assessment of the functionality of Australian ecosystems, as well as an assessment of the demands and needs of Australians. Several experts have highlighted the need to make substantial progress in the next few years on understanding, and taking action about, the benefits that people derive from the environment and the consequences of our impacts on the environment. The need to understand this relationship is critical to major policy decisions, such as immigration and population policy, as well as environmental policy.58,165

Dealing constructively with the pressures of the future will also require improved understanding to be communicated to the public so that innovative policies can be enacted with public support. Overall, the general public has only limited understanding of the demands that Australians place on the environment,166-168 despite a very well-developed understanding among some groups, including regional natural resource management groups and an increasing number of landowners and land managers.

4.1.2 Planning

All jurisdictions have biodiversity management plans in place that set high-level goals consistent with achieving sustainability and resilience.15 To at least some degree, all of these plans recognise the need to address the major pressures of land clearing, invasive species, adverse effects of land-management practices, altered fire regimes and altered hydrology through combinations of:

- improving knowledge
- engaging with a range of stakeholders
- balancing on-reserve and off-reserve conservation
- setting strategic objectives
- making the best use of a range of incentive and regulatory mechanisms to assist conservation
- taking account of climatic variation now and climate change in the longer term
- coordinating efforts of all individuals and groups engaged in biodiversity conservation
- taking account of Indigenous values and expertise
- working at ecosystem and landscape scales.

At a national scale, the Caring for our Country program recognises all of the above and has made resilient communities and ecosystems part of an overarching goal. Resilience is also emerging as an objective in many plans at state and territory level. The collective objectives of plans for biodiversity management around Australia, if achieved, should put Australia in a strong position to use the full range of skills and resources of its people to:

- cooperatively address risk, uncertainties and trade-offs between biodiversity conservation and other objectives for land use
- bring most native species back to a state for which sustainable management is possible
- make it possible to manage strategically rather than reactively.

From 2004–05 to 2010–11, the Australian Government invested in a series of Commonwealth Environmental Research Facilities (CERF) to investigate better approaches to biodiversity management. (CERF has since been replaced by the National Environmental Research Program.) The Landscape Logic CERF (Box 8.8) investigated planning and management at landscape scales; this is one of the key challenges for future management, especially in the face of climate change.

www.nrm.gov.au
Box 8.8 Measuring change at landscape scales

Over the past 15 years, four audits have cast doubt on the effectiveness of the $4.2 billion of public funds invested through public environmental programs since 1997. There are several reasonable explanations for this lack of effectiveness. The scale of intervention has been too small and fragmented. There are long lag times between intervention and response. Human intervention is frequently overwhelmed by forces outside our influence, such as climate variability, markets and extreme events. We are frequently dealing with complex, nonlinear processes that involve undefined thresholds of change, and all this is occurring in a social context with many different managers, often with competing interests and values.

The Landscape Logic project, a partnership between six regional organisations, five research institutions and state land-management agencies in Tasmania and Victoria, was set up to see whether we could measure the effects of past human intervention on the environment using a combination of biophysical and social evidence, and the experience of land and water managers. The types of evidence available for retrospective studies include historical aerial photos; long-term datasets from stream-gauging stations; water quality and vegetation surveys; historical records of land tenure, land use and land management; and contemporary studies capable of assembling landscape histories from experiments, social surveys and interviews. There are also the historical records laid down in the landscape itself that can be interpreted through techniques such as stable isotope analysis of lake, stream and estuarine sediments, groundwater and vegetation.

Five key messages emerged from this experience:

**Have clear end points or goals.** It was not possible to track the state of the environment or the effects of intervention where there were no clear objectives or measurements. In our case, water quality was more clearly defined and measurable than vegetation condition, which generally lacks agreed definitions and measures. However, setting goals is not a task for researchers only, because it almost inevitably involves a mixture of fact and value.

**Develop conceptual models.** A model of how a system works, particularly graphical models developed in collaboration with managers, helps us to agree on the key processes and variables that need to be understood and the interventions that are most likely to have been influential.

**Investigate at multiple scales.** To measure response to intervention and attribute change, we found it was necessary to investigate at three scales: at the landscape scale to establish patterns of change such as correlations between ecosystem response variables and human and natural drivers of change; at the property scale to distinguish between human and other influences (who did what, when and why); and at the site scale to understand the ecological processes responsible for the observed change.

**Understand the social context.** Being aware of the social context in which natural resources are used and managed helps to identify cost-effective pathways for change. For example, we found that demographic change is resulting in a substantial cohort of land managers who have high conservation values but are not commercial farmers by occupation and have relatively low levels of conservation knowledge or activity. This suggested an untapped audience for environmental programs.

**Manage expectations.** A major challenge for researchers and environmental managers is managing the expectations of government at all levels regarding the timescales within which they are likely to see response to intervention. Our studies provide evidence of 30–40-year timescales required to achieve measurable change in indicators of vegetation change (e.g. recruitment opportunities in a variable climate, survival to maturity) and water quality (e.g. revegetation to filter sediment, shade streams to shut down algal production and restore trophic pathways).

4.2 Management capacity

Management capacity is about the adequacy of resources and management processes for implementing plans and policies. With respect to biodiversity, we would expect that:

- resources are available to implement plans and policies (including financial resources, human resources and information)
- a governance system is in place that provides for appropriate stakeholder engagement, adaptive management, and transparency and accountability
- monitoring and evaluation is in place to assess whether outcomes are being achieved.

Although all jurisdictions have appropriate plans in place for managing biodiversity and the pressures on it, the adequacy of resourcing for these objectives is questionable, given that the same risks reappear in successive SoE reports and are assessed as worsening in many cases. All jurisdictions report low levels of completion of recovery plans for threatened species. Birds Australia suggests that the development and implementation of recovery plans for most threatened bird species are poorly supported by governments and do little more than help species to persist without addressing underlying problems.

Concerns have also been raised about declines in numbers of skilled and experienced staff in regional environmental management organisations, and it has been suggested that this has decreased the autonomy and ability of these organisations to meet particular regional challenges. During this transition, core funding for regional bodies was maintained, but a greater proportion of Australian Government grant funding was allocated only for approved projects. This is an area of major concern, but addressing it requires much more than adjusting settings in Australian Government grant programs. As discussed earlier, these grant programs are a small proportion of Australia’s overall environmental investments. They receive significant attention because of their high leverage and the catalytic effects they are having on changes in environmental governance. However, again, improved governance arrangements will require cooperation and collective action across all levels of government and communities.

In July 2011, the Australian Government released its Clean Energy Future plan, which includes funding that is targeted at addressing many of the issues raised in Section 3, such as the need to increase the resilience of communities and ecosystems to climate change. The plan includes around $44 million over five years to make regional natural resource management (NRM) plans ‘climate ready’, working through regional NRM organisations. The focus is to be on ‘carbon farming’, including developing detailed scenarios on climate change impacts on a regional level, and biosequestration projects to maximise the benefits for biodiversity, water and agricultural production.

An ongoing Biodiversity Fund has been allocated $946 million over six years to support projects that establish, restore, protect or manage biodiverse carbon stores. Funding will be provided for establishing mixed species plantings in targeted areas, such as areas of high conservation value including wildlife corridors, riparian zones and wetlands. The fund will also support action to prevent the spread of invasive species across connected landscapes.
4.3 Management achievements

Management achievement is about delivering expected outputs and outcomes. In relation to biodiversity, we might hope that program objectives are being met with:

- timely delivery of products and services
- reduction of current pressures and emerging risks to biodiversity
- improvements to resilience of biodiversity (and coupled social–ecological systems).

These issues have been discussed above to some extent. The Assessment of Australia’s terrestrial biodiversity 2008, while drawing a number of complimentary conclusions about the responses of Australian governments to the challenges of biodiversity conservation, also came to the following conclusions:

- We have few effective and systematic monitoring systems for evaluation and limited resources invested in responses to threats compared with the scale and nature of the threats.
- The scale of the impacts from threatening processes is such that the voluntary and uncoordinated approaches adopted to date will not be effective.
- Getting the mix of responses right will require levels of cooperation hitherto not fully demonstrated.
- The move to large-scale, multipartner responses that take a systems approach and focus on ecological processes is an encouraging development.
- Key lessons from the large-scale intensive threat abatement case studies include building on and integrating with existing programs; the need for cross-tenure delivery; and having well-designed monitoring and evaluation for adaptive management.
- Promising features of private land biodiversity conservation programs include the use of economic instruments and incentive-based policies to achieve biodiversity objectives; incorporation of biodiversity conservation in whole-farm or property management plans; and bioregional and catchment planning.

- Growth in protected areas from 2002 to 2006 represents a substantial increase on the rate for the previous decade, but still falls well below what would be required to meet a target of 10% reservation for every bioregion by 2010 (see Section 4.4.1).
- Ultimately, the long-term future of biodiversity on private land will rely on land managers valuing the protection and maintenance of biodiversity.
- Most regional organisations have built on a history of catchment planning to successfully develop a strong strategic basis for delivering programs that are based on the specific conditions and circumstances of the region.
- The regional model provides for negotiated target setting that can operate within, but is relatively unimpeded by, an often highly contested and adversarial regulatory setting for biodiversity conservation. The resulting regional biodiversity targets are more likely to be understood, owned and accepted by the people who need to be engaged in biodiversity conservation on the ground, especially landholders. (Note that negotiated target setting is no longer a feature under the recently implemented Caring for our Country program—targets are determined nationally and articulated in the business plan.)

4.4 Examples of key responses

Effective management of biodiversity requires not only effective management of individual pressures but also effective integration across those pressures, including management of their interactions with one another. Therefore, in the previous subsections, we have discussed aspects of management effectiveness across all pressures. In this subsection, we focus specifically on a few key responses that address a range of pressures simultaneously, especially the two pressures concluded to have had the strongest and most widespread effects on biodiversity in the recent and longer term past: clearance and fragmentation of native ecosystems, and invasive species and pathogens. These two pressures are also the two most complicated to assess, because there are so many different dimensions to addressing each of them, both within and between jurisdictions.

The impacts of climate change are emerging as major future pressures and preparation for these will be considered in Section 6 of this chapter.
4.4.1 The National Reserve System

The National Reserve System (NRS) is the main instrument by which Australia seeks to protect a representative sample of remaining intact, native ecosystems. The NRS includes conservation parks and reserves on both public and private land, as well as Indigenous protected areas. Since 2005, development of the NRS has been guided by a national, state and territory collaborative strategy: Directions for the National Reserve System: a partnership approach.183 This was followed in 2009 by Australia’s strategy for the National Reserve System 2009–2030.147 In the latter document, the focus of the NRS is said to be:

... to secure long-term protection for samples of all our diverse ecosystems and the plants and animals they support. It also complements measures to achieve conservation and sustainable use of biodiversity across the landscape, which are increasingly important under conditions of climate change. (p. 2)

The NRS has grown steadily over the past 15 years (Figure 8.16). In 2008, protected areas covered around 98.5 million hectares (12.8%) of Australia’s landmass.147 As discussed below, however, assessing the effectiveness of this growth is complicated.

Central to the NRS strategy are the principles of comprehensiveness, adequacy and representativeness (CAR) (Table 8.23). These criteria were established by the Implementation Sub-Committee for Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests (commonly known as the JANIS criteria).184

The NRS does not include clearly defined CAR targets, making it difficult to assess whether ecosystems are being managed effectively under the scheme. For example, the targets set for comprehensiveness and representativeness in the 2009 strategy for the NRS147 called for the inclusion of ‘examples’ of ecosystems, but little guidance was given about the size, quality or landscape context of samples that should be counted as ‘examples’. The targets set in that strategy were:

- Progressing comprehensiveness—Include examples of at least 80% of the number of regional ecosystems in each IBRA region. Priority will be given to under-represented IBRA bioregions with less than 10% protected in the NRS. (Responsibility: all jurisdictions by 2015 with reports on progress every two years.)

![Figure 8.16 Proportion of IBRA bioregions included in the National Reserve System, 1995–2008](image-url)
• Progressing representativeness—Include examples of at least 80% of the number of regional ecosystems in each IBRA subregion. (Responsibility: all jurisdictions by 2025 with reports on progress every two years.)

However, the NRS does give some guidance for specific groups and purposes:

• Protecting threatened species and ecosystems—Include critical habitats and core areas important for the survival of rare, migratory, threatened or other priority species and ecological communities, including those listed under federal, state or territory legislation in each IBRA bioregion. (Responsibility: all jurisdictions by 2030 with reports on progress every two years.)

• Protecting critical sites for climate change resilience—Include critical areas to ensure the viability, resilience and integrity of ecosystem function in response to a changing climate, such as large and small refuges, critical habitats, broad landscape-scale corridors, places of species and ecosystem richness, sites of endemism and sites that support threatened species or ecological communities, and places important for the stages in the life cycle of migratory or nomadic species, to act as core lands of a broader whole-of-landscape approach to biodiversity conservation. (Responsibility: all jurisdictions by 2030 with reports on progress every two years.)

Two recent independent assessments of progress towards NRS objectives used different interpretations of ‘example’ and reached different conclusions about what degree of protection has been achieved (Table 8.23).

Assessing adequacy (i.e. whether enough of each ecosystem has been protected to ensure their viability) is even more difficult, because there is no nationally agreed approach to its assessment. In the 2009 strategy for the NRS, the main target for adequacy is:

By 2030, include critical areas to ensure the viability, resilience and integrity of ecosystem function in response to a changing climate, including large and small refuges, critical habitats, broad landscape-scale corridors, places of species and ecosystem richness, sites of endemism and sites that support threatened species and or ecological communities, and places important for the stages in the life cycle of migratory or nomadic species, to act as core lands of a broader whole of landscape approach to biodiversity conservation. (p. 13)

This target recognises that the NRS must be of adequate size and quality to ensure the viability of Australia’s biodiversity under current conditions, and that it must also be able to support future protection measures when climate and other conditions will likely be very different. This is uncertainty that cannot be avoided; we can, however, work to clarify the targets for how large the NRS should be. The JANIS committee recommended protection of at least 15% of the area of all extant ecosystems, with allowance for some flexibility and greater protection for threatened species and ecosystems. The Convention on Biological Diversity (CBD), to which Australia is a signatory, includes a target of ‘at least 10% of each of the world’s ecological regions effectively conserved’, which Australia has applied to bioregions. Australia has since adopted the CBD Strategy for 2011–20, which includes a new target of 17% of terrestrial ecosystems and inland waters in protected areas by 2020.

It is not surprising, therefore, that the two major recent assessments of the progress of the NRS reported different results, largely due to different assumptions about ‘examples’ and targets. Nevertheless, both had similar main conclusions: the NRS has grown in important ways in the past decade or so, but a substantial gap remains to be filled before comprehensiveness, adequacy and representativeness can be said to have been achieved (Table 8.23 and Figure 8.17).

The WWF-Australia assessment suggests that Australia is nearly halfway towards 15% representation of ecosystem diversity, but that around 70 million hectares still need to be added to the stock of highly protected land to achieve the target (Figure 8.17). More would be needed if a 17% target is to be realised. It appears possible to meet most of that target; WWF-Australia estimates that all but about 2% of the gap can be met from largely intact or remnant ecosystems, with the rest requiring rehabilitation of degraded systems. The Assessment of Australia’s terrestrial biodiversity 2008 estimated that there may be difficulty meeting the 10% targets in only 5 of the 85 bioregions.

At the scale of jurisdictions, management effectiveness was assessed as highly variable, ranging from 20% secure protection in Queensland to 99% in the Australian Capital Territory (Figure 8.17).

Assessing the adequacy of the NRS with respect to nationally threatened species is also complicated by the lack of clear criteria and by different
Table 8.23 Two assessments of progress of the National Reserve System (NRS) towards comprehensiveness, adequacy and representativeness

<table>
<thead>
<tr>
<th>Definitions</th>
<th>National assessment in 2008\textsuperscript{15,a}</th>
<th>WWF-Australia in 2011\textsuperscript{146,b}</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comprehensiveness</strong> refers to the aim of including samples of the full range of regional ecosystems recognisable at an appropriate scale within and across each IBRA bioregion</td>
<td>Of Australia’s 85 bioregions, 45 had low or very low ratings for comprehensiveness and only 11 met the Australian Government’s target (see text above) based on presence or absence of examples of ecosystems\textsuperscript{c}</td>
<td>Five bioregions met the Australian Government’s target based on an ‘example’ meeting minimum size criteria\textsuperscript{d}</td>
</tr>
<tr>
<td>Adequacy refers to how much of each ecosystem should be sampled to provide ecological viability and integrity of populations, species and ecological communities at a bioregional scale. The concept of adequacy incorporates ecological viability and resilience for ecosystems for individual protected areas and for the protected area system as a whole</td>
<td>No adequacy measure has been agreed nationally 49 bioregions have 10% or more of their area in protection, and 36 fall below this level The total area of the NRS falls short of a 10% target by 27 million hectares The gap falls mainly in rangelands</td>
<td>This study proposed an interim standard of 15% based on the JANIS criteria and assessed against this (see Figure 8.17) The NRS falls about 70 million hectares short of adequacy, based on the proposed interim standard The gap falls mainly in rangelands and also in relation to inland wetlands (see Figure 8.17)</td>
</tr>
<tr>
<td>Representativeness is comprehensiveness considered at a finer scale (IBRA subregion), and recognises that the regional variability within ecosystems is sampled within the reserve system. One way of achieving this is to aim to represent each regional ecosystem within each IBRA subregion</td>
<td>Of Australia’s 403 subregions, 52 met the Australian Government’s target based on presence/absence criteria\textsuperscript{c} Another 196 had low or very low ratings for representativeness In 64 subregions, native ecosystems had no representation in protected areas</td>
<td>20 subregions met the Australian Government’s target based on an ‘example’, meeting minimum size criteria\textsuperscript{d}</td>
</tr>
</tbody>
</table>

IBRA = Interim Biogeographic Regionalisation of Australia; NRS = National Reserve System  
\textsuperscript{a} This assessment was based primarily on data collected up to and including 2006.  
\textsuperscript{b} This assessment was based primarily on data collected up to and including 2008.  
\textsuperscript{c} This assessment concluded that an ‘example’ of an ecosystem was protected if that ecosystem was present, to any extent, in protected areas in a region or subregion.  
\textsuperscript{d} This assessment only counted ecosystems as being included in protected areas if: (1) an area greater than 1000 hectares was included; or (2) if 100% of the existing area was included if the remaining regional or subregional extent was less than 1000 hectares.  
Source: Taylor et al.\textsuperscript{146}

Interpretations of existing data. The *Assessment of Australia’s terrestrial biodiversity 2008*\textsuperscript{15} noted that the distributions and natures of many threatened species do not fit well with the protected areas management model, which is based around discrete protected areas. Considering progress at developing recovery plans for species listed as threatened under state, territory and national legislation, it was noted that the long lag times between action and results make it hard to assess success of programs for managing these species, but that: Overall resourcing, however, has been inadequate and commonly short term. Development of recovery plans, and particularly their implementation, lags well behind listing of threatened species and communities. As there is no consistent national monitoring system in place, it is difficult to comprehensively assess the success of this important and widespread institutional response. (p. 234)

A recent Australian Government assessment\textsuperscript{146} reported the proportion of records for 13 463 threatened and nonthreatened species that fell within the NRS, but these data are difficult to interpret, both because of the unknown biases in where data were collected, and because threatened species were not considered separately. However, this assessment represents a further step towards addressing the limitations noted above.
WWF-Australia\textsuperscript{186} analysed the extent to which the NRS includes an adequate proportion of the remaining distribution of threatened species (Figure 8.18). They used an interim standard of 30%, and found that most species listed as threatened nationally had some part of their distribution in the NRS, but only 28% had 30% or more of that distribution in strictly protected areas. Significant proportions of threatened species in all jurisdictions, and around 14% nationally, had none of their distribution in strictly protected areas.

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Percentage of target area</th>
<th>Gap (million hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACT</td>
<td>99%</td>
<td>0.001</td>
</tr>
<tr>
<td>Tas</td>
<td>85%</td>
<td>0.33</td>
</tr>
<tr>
<td>Vic</td>
<td>58%</td>
<td>1.42</td>
</tr>
<tr>
<td>WA</td>
<td>46%</td>
<td>9.62</td>
</tr>
<tr>
<td>SA</td>
<td>42%</td>
<td>4.45</td>
</tr>
<tr>
<td>NSW</td>
<td>35%</td>
<td>16.03</td>
</tr>
<tr>
<td>NT</td>
<td>34%</td>
<td>20.12</td>
</tr>
<tr>
<td>Qld</td>
<td>20%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Percentage of target area</th>
<th>Gap (million hectares)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainforest</td>
<td>75%</td>
<td>0.19</td>
</tr>
<tr>
<td>Forest</td>
<td>47%</td>
<td>8.32</td>
</tr>
<tr>
<td>Wetlands</td>
<td>43%</td>
<td>1.44</td>
</tr>
<tr>
<td>Woodlands</td>
<td>34%</td>
<td>33.08</td>
</tr>
<tr>
<td>Grass/shrublands</td>
<td>33%</td>
<td>27.00</td>
</tr>
<tr>
<td>GBR catchments</td>
<td>32%</td>
<td>4.33</td>
</tr>
<tr>
<td>SW Australia</td>
<td>71%</td>
<td>1.81</td>
</tr>
<tr>
<td>Australia</td>
<td>36%</td>
<td>70.03</td>
</tr>
</tbody>
</table>

ACT = Australian Capital Territory; GBR = Great Barrier Reef; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; SW = south-west; Tas = Tasmania; Vic = Victoria; WA = Western Australia

**Figure 8.17** WWF-Australia’s estimates of how well area-based targets for protection of terrestrial ecosystems have been met and how much area is still required (i.e. the gap between actual area in highly protected areas and the target)

The left of the figure shows the overall percentages by area of ecosystems attaining the minimum standard of 15% of original total area in highly protected areas (i.e. IUCN categories I-II) (dark green). Also shown are the areas in other protected areas (IUCN categories III-VI) (light green). These types of reserves allow a range of nonconservation activities, but they could be considered towards conservation targets if the level of protection is high enough. The remainder of the bar (yellow) is the percentage of the target still needing to be protected if targets are to be met (i.e. the gap). The right of the figure shows the absolute area of the gap.
In summary, at the national level, objectives for the NRS are only partly articulated in clear terms. Long-term achievement of comprehensiveness, adequacy and representativeness are clearly challenging, partly due to the costs of acquiring land and availability of land for purchase, but even interim targets are not being achieved. This suggests a mismatch between targets and allocation of resources for achieving them. There is still a considerable expansion of the reserve system needed to achieve adequate protection of threatened species within that system; at present, a significant proportion of threatened species are not represented in strictly protected areas. This also emphasises the importance of effective conservation outside reserves.

The data show proportions of 1449 nationally threatened species with 30% or more of their distribution included in highly protected areas (strict Protected Areas or Specially Protected Areas); with less than 30% in highly protected areas but with 30% or more in all protected areas; with less than 30% protected in any protected area; and finally, with no representation in highly protected areas. Jurisdictions are ordered in decreasing proportions meeting the standard, with numbers of species in brackets. Note that the Australian Capital Territory was included in New South Wales figures for this analysis.
4.4.2 Conservation outside reserves

Over the past decade, important steps have been taken towards better managing native ecosystems outside reserves for conservation objectives. These have been largely through nongovernment groups investing philanthropic funds, and through government grants for projects to protect or manage remnant vegetation under the Natural Heritage Trust and Caring for our Country programs nationally, and various state and territory programs.

Nongovernment conservation organisations are helping to build the NRS and their contributions are the fastest growing sector. In the past decade, nongovernment organisations have raised and spent more than $20 million on buying and protecting land of high conservation significance, maintaining that land and investing in research. The area protected in this way during this decade is estimated at more than 1.8 million hectares. Birds Australia concludes that ‘a concerted effort by dedicated individuals, recovery teams, landholders and governments has improved the prospects of several threatened species’ (Olsen, p. 2).

Land stewardship programs, which pay landowners and managers to enter into agreements to protect remnant ecosystems, have been increasingly used by many Australian governments. These agreements include requirements to manage pressures on biodiversity in those ecosystems. They have been seen as a way to address the absence of market-based signals to protect biodiversity by creating markets for conservation actions. Although there are now figures on the amounts of priority ecosystems secured under stewardship programs in Australia, it is too soon to assess what effect they are having on the long-term sustainability of biodiversity.

Taylor et al. recently published an evaluation of alternative conservation actions (protected areas versus stewardship) based on the outcomes for populations of threatened species around Australia. These authors argued that the limitations of stewardship approaches are that they are expensive per hectare compared with the outright purchase of land, and the duration of protection is limited. Proponents of stewardship approaches argue that there are situations in which ecologically important land cannot be purchased, and that there are ongoing benefits in encouraging landowner behaviours that may be emulated by others.

Taylor et al. found that only 28% of the 606 species examined had stable or improving status, and that species with greater distributional overlap with strictly protected areas had proportionately more populations that were increasing or stable. Measures other than strictly protected areas showed no positive associations with stable or increasing trends. They stressed that these results do not demonstrate unequivocally that protected areas are better than stewardship approaches. Similarly, the lack of observed recovery of threatened species in association with stewardship approaches could be at least partly due to these approaches being applied in landscapes that have already been highly modified and where threatened species are mostly in decline. Nevertheless, the analyses suggest that monitoring and assessment of investments in different approaches to biodiversity conservation has been worthwhile and that allocations to protected areas might warrant greater attention than the current 10% of overall conservation funding in Australia.

We note the conclusion from Section 5 in this chapter, which states that a diversity of approaches is important for the resilience of the social–ecological systems of which biodiversity is a part. Therefore, while debate about the relative benefits of investments in protected areas versus stewardship is important, so too is ensuring that the merits of both approaches are not judged only on simple economic efficiency criteria.

‘Connectivity conservation’ is a key emerging approach that is trying to encourage strategic management of protected areas and other land uses within a ‘landscape matrix’ (Box 8.9). This approach builds on many decades of research that have developed an understanding of how the structure, species composition and landscape configuration of native vegetation remnants combine with management practices to influence the viability of species at landscape scales (see also Chapter 5: Land). Such approaches offer the flexibility and potential resilience to allow biodiversity and biodiversity managers to cope with future uncertainties, such as climate change. It should be noted, however, that we still have only limited information to allow managers to predict how to restore, keep or manage for functional connectivity, and that ongoing research is essential in this key area. For example, not all species use connected habitat networks in the ways anticipated by humans, so designing connections in an informed way will require better understanding of landscapes from the perspective of diverse species or at least empirical evidence about what works and what does not.
Box 8.9 Connectivity conservation and the Great Eastern Ranges corridor

Connectivity conservation is based around the concept of large-scale ‘connectivity corridors’ that maintain or establish multidirectional and multiscale connections over entire landscapes and can encompass up to thousands of square kilometres. They extend over many degrees of latitude and longitude, they include lands of many tenures and ownership, they interconnect and embed protected areas, and they help maintain opportunities for the movement of species and evolutionary interactions at a time of climate change. Connectivity corridors are a continental-scale response to climate change. Elements of a connectivity corridor include dispersal corridors (such as corridor networks and habitat corridors) and ecological corridors (which focus on landscape permeability for ecosystem processes).

The Steering Committee of the Natural Resource Management Ministerial Council approved the public release of a ‘proof of concept’ report on the idea of a continental-scale conservation corridor extending along Australia’s Great Eastern Ranges, from Victoria through New South Wales to Atherton in Queensland. Case studies from the Bega Valley, north-eastern New South Wales and central Queensland help illustrate the conservation challenges facing much of the Great Eastern Ranges corridor.

Appropriate conservation management can enable the corridor to make a significant contribution to Australia’s national carbon accounts by protecting forest and other ecosystem carbon stocks and avoiding depletion of these stocks from emissions associated with land-use activities. This will allow forests and other ecosystems with depleted carbon stocks to regrow to reach their carbon-carrying capacity, and further increase the stock of carbon stored in the Great Eastern Ranges corridor ecosystems by promoting permanent native revegetation.

4.4.3 Invasive species and pathogens

The Assessment of Australia’s terrestrial biodiversity 2008 concluded, from a series of case studies (mostly on invasive species), that:

... [there is] a lack of effective and systematic monitoring systems for evaluation and limited resources invested in responses to threats compared with the scale and nature of the threats. The scale of the impacts from threatening processes is such that the voluntary and uncoordinated approaches adopted to date will not be effective. (p. 8)

It is extremely difficult to assess the effectiveness of management in relation to invasive species and pathogens from SoE reports from most states and territories (Table 8.24). These reports mostly list plans, strategies and inputs to management, but rarely report on the effectiveness of processes or on outputs and outcomes (see Table 8.22 for information on state and trends of invasive species). Some SoE reports state that actions are not achieving desired results, while this conclusion is implicit in other SoE reports since the effects of invasive species are assessed as getting worse. Some SoE reports conclude that there is not enough information to assess trends or the magnitude of effects.
Table 8.24 Key elements of state and territory management strategies in relation to invasive species and pathogens

These descriptions are taken from the most recent state of the environment reports. Although some details may have changed recently, the details here reflect what was in place for much of the previous reporting period.

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ACT</strong></td>
<td>The ACT Vertebrate Pest Management Strategy forms the basis for vertebrate pest control in the ACT. An annual program report outlines pest management activities for the preceding year and scheduled activities for the coming year. An important part of the strategy is preventing new exotic species from establishing in the wild; therefore, early management of emerging pest species is a priority of the program. The principles of the strategy for managing established vertebrate pests are also generally applicable to invertebrates. From 2007–08, vertebrate pest control was guided by a five-year plan founded on the principles set out in the strategy. The five-year plan promotes better continuity of control programs (necessary for sustained pest management). An important initiative has been the introduction of the <em>Pest Plants and Animals Act 2005</em>. The Act strengthens the legislative framework for dealing with pest plants by setting out requirements for controlling listed species and prohibits the supply of a large proportion of them, meaning that nurseries can no longer sell listed species. Weed control has been coordinated through the ACT Weeds Strategy 1996–2006 and a revised strategy has been prepared to cover 2007–17.</td>
</tr>
<tr>
<td><strong>NSW</strong></td>
<td>The monitoring, evaluating, reporting and improvement (MERI) strategy is being implemented to monitor progress towards all targets in the state plan (note: the state plan has been updated since the most recent state SoE report). A variety of laws, policies and programs are administered by a range of government agencies to manage invasive species in the state. The response of the government to invasive species impacts is set out in the <em>New South Wales invasive species plan 2008–2015</em>, which describes a range of strategies to control or reduce the impacts of invasive species that are most effective at different stages in the cycle of incursion and establishment of an invasive species. The latest state SoE report describes plans and strategies in detail, but provides little assessment of progress.</td>
</tr>
<tr>
<td><strong>NT</strong></td>
<td>Management of the territory’s terrestrial biodiversity is based on commitments in territory, Australian and international legislation, agreements and policies. Off-reserve conservation management is being implemented on many Aboriginal lands through Indigenous Ranger groups, coordinated by various land councils and Aboriginal resource centres. The potential importance of such coordinated management in maintaining biodiversity values through active fire management and invasive species control cannot be overstated. On other lands, and especially the pastoral estate, Landcare and related groups also coordinate important conservation management activities in association with landholders, particularly in weed and feral animal control, erosion mitigation and protecting sensitive habitats from overgrazing. Government agencies foster territory-wide management of weeds, fire and feral animals by working with landholders and other stakeholders to implement control measures.</td>
</tr>
<tr>
<td><strong>Qld</strong></td>
<td>Most exotic vertebrate pests have long been established in the state and have broad distributions. Eradication is not feasible for these species, so their management must focus on restricting their spread, preventing new introductions and controlling their impacts. Control needs to be sustained and well coordinated, and target areas of high actual or potential impact. One national and five state strategies are implemented to manage pest animals. Increased transport of people and goods will continue to test border security. Recent introductions include three tramp ant species for which eradication is being attempted. The pet trade is another source of introductions despite legislation prohibiting the keeping of likely invasive animals as pets. New control methods are being developed, because there is an increasing need for techniques that are humane, target-specific and cost-effective in reducing the impacts of pests. Invasive terrestrial plants (weeds) cost the state an estimated $600 million a year in lost primary production and control in the most recent SoE period up to 2009; more than 100 plant species are declared weeds in Qld, and 7 of these are terrestrial WoNS. Four strategies are currently implemented to combat weeds, as well as a strategy for each of the WoNS. Local government area pest management plans endorsed in 119 of 157 local government areas at 30 June 2007 can deal with both declared and nondeclared weeds that threaten the area.</td>
</tr>
</tbody>
</table>

Continued next page
Effectiveness of management | Biodiversity

Jurisdiction | Progress
---|---
SA | The Natural Resources Management Act 2004 provides the framework for managing key pest plants and terrestrial pest animals in the state. Former Animal and Plant Control boards have been consolidated into eight NRM boards, allowing an integration of management responses to water, soil and pest issues. Declarations are enforced by NRM boards through coordinated control programs, with technical and policy support from the Department of Water, Land and Biodiversity Conservation (DWLBC) and overseen by the state NRM Council.

NRM boards, DWLBC and the Department for Environment and Heritage (now combined into the Department of Environment and Natural Resources—DENR), the Department of Primary Industries and Resources, and industry and community groups also collaborate on education and awareness activities, research, planning and strategic control programs for particular pests, industries or regions. At the national level, the Vertebrate Pests Committee sets policy directions to achieve better outcomes for managing pest animals and led the development of the Australian Pest Animal Strategy. The implementation of this strategy within SA is being led by DENR. The Australian Weeds Committee and the Australian Weeds Strategy provide policy and investment frameworks for national weed management, implemented in this state through DENR.

Tas | Various legislative changes and reviews have clarified interpretation and enforcement in relation to weeds, updated quarantine schedules, established threat abatement plans for *Phytophthora cinnamomi*, strengthened import regulations with respect to weeds, added a listing of animal pests, and created new bylaws for cat management by local councils. Among them, several government departments (Forestry Tasmania; Hydro Tasmania; Department of Primary Industries, Parks, Water and Environment; Parks and Wildlife Service; and Cradle Coast NRM) have developed and released plans to manage weeds, pests and diseases in forests; weeds in hydro-related activities; priority weeds across Tasmania’s road network; weeds in wilderness areas; *Phytophthora cinnamomi* impacts on Tasmanian plant species and communities statewide; new weeds in the Cradle Coast region; foxes, rabbits and rodents; and wildlife diseases including psittacine circovirus disease and devil facial tumour disease. The plans will also include a review of wildlife monitoring priorities, and allow for biosecurity and strategic pest management. Other land-management groups such as Greening Australia, and environmental programs such as Landcare, Bushcare and Rivercare, have developed weed-related strategies, plans, processes and procedures, and have undertaken on-ground works. In 2003, Agricultural Contractors of Tasmania established a code of practice to encourage agricultural workers to adopt best-practice hygiene principles to reduce the spread of weeds and plant diseases.

Vic | The Catchment and Land Protection Act 1994 is the primary legislation relating to control of pest plants and animals in Vic. This Act sets out landowners’ roles and responsibilities in relation to weeds and pests. Discrepancies in coverage of weed control between public and private tenure creates a situation where there is a lack of enforceable legislation for some weed species on private land.

Vic takes a biosecurity approach to the management of pest plant and animal species. The key objective of this approach is to limit the establishment of new introduced species. The Victorian Pest Management Framework (VPMF) was developed in 2002 to provide strategic direction for the management of declared and potential pests in Vic. It recognises the impacts of weeds and pest animals on economic productivity, the value of the state’s natural resources and biodiversity. As part of the VPMF, specific management strategies have been developed for weeds, rabbits, wild dogs, foxes, feral pigs and feral goats, and public land management. Biosecurity Victoria is a business group formed within the Department of Primary Industries in 2004, whose role is to develop and manage the delivery of the Victorian Government’s biosecurity and market access programs for the livestock, plant, fisheries and forestry industries. Its functions include developing the state’s capacity to monitor, detect and respond to pest plant and animal disease threats.

A biosecurity strategy, intended to update the VPMF, is under development and will provide a new policy framework for managing weeds and pest animals in Victoria. The Australian Quarantine and Inspection Service manages quarantine controls at our borders to minimise the risk of exotic pests and diseases entering the country. The Victorian Government acknowledges that, despite substantial public and private investment, weeds and pest animals remain a significant threat to the state’s land and biodiversity resources. To address this, a number of projects aimed at encouraging public engagement with weed and pest control have been developed in recent years.
Jurisdictiona Progress

WA Improved monitoring is needed to determine the extent and density of introduced animal species in the state. Western Shield, a predator-control program, has been credited with bringing at least 13 native fauna species back from the brink of extinction. To date, quarantine and preventative procedures have excluded some invasive species present in other Australian states (e.g. Indian mynas, red-eared slider turtles and imported red fire ants).

In addition to quarantine, legislation, policies and strategies for managing weeds, many government agencies (including the Department of Agriculture and Food, Department of Environment and Conservation, Main Roads, Westrail and local governments) have programs to remove weeds on land under their jurisdiction. Individual landholders are responsible for controlling weeds on their land (including declared plants). Many community groups, notably the Environmental Weeds Action Network and its associated clubs and societies, conduct removal and management of weeds. The Saving Our Species program began in 2006 and the weed eradication and control component builds on the Environmental Weed Strategy for WA. Forty weed species are being targeted in the initial 18 projects to eradicate entire weed populations at a local scale, where possible.

Six exotic mammals (fox, feral cat, goat, rabbit, black rat and house mouse) have been eradicated from more than 45 islands in a series of projects since the 1960s.

National Key findings from seven case studies (five of which were on invasive species) are that cross-tenure delivery (park, forests, other Crown and private land) of programs to abate threats is necessary for landscape-scale approaches, and that a sound understanding of the biology and ecology of the target species and communities is needed to be able to design and evaluate threat abatement programs. Long-term investment is essential for controlling threats that extend, and are well established, over vast areas. Partnerships, engagement and good communication with all key stakeholders will contribute to the success of threat abatement programs. Integrating threat abatement programs and recovery actions for threatened species and communities provides important opportunities to scale up and maximise outcomes for biodiversity.

Nationally, biosecurity (the processes, programs and structures in place to prevent entry by, or to protect people and animals from, the adverse impacts of invasive species and pathogens) is complex. It has a broad spectrum of stakeholders; includes public health, livestock health, plant health and wildlife disease; and has pre-border, border and post-border dimensions.\textsuperscript{196} As Table 8.24 shows, successfully dealing with invasive species and pathogens requires extensive engagement and cooperation of communities.

The Australian Government and the state governments, working with key stakeholders in agricultural industries and the public health sector, establish the national framework. Turning the framework into plans and strategies is done through cooperation between the Australian Government and state government agencies, drawing on expertise from CSIRO and industry or government agencies, such as Animal Health Australia and Plant Health Australia. Other stakeholders (e.g. environmental groups) and research providers (e.g. universities, research institutes, CSIRO, the biosecurity cooperative research centres), and a number of private companies, also play significant roles.

Biosecurity faces many challenges, mostly due to the diversity of the potential invasive organisms and the complexity of the institutional arrangements needed to detect and deal with them and then assess the effectiveness of the response.\textsuperscript{196} There are increasing risks of disease epidemics or pandemics affecting large parts of the Australian population and industries. Much of the attention of the biosecurity community is therefore focused on these broadscale risks, and the response to the persistent effects of invasive species that affect biodiversity is often one of containment rather than eradication. Over the past two decades, there has been increased pressure on resources in the biosecurity sector and a shift in responsibility to industry and government industry partnerships (e.g. Animal Health Australia and Plant Health Australia). Steps have been taken to improve consistency of biosecurity arrangements across Australia. The National Biosecurity Committee (NBC), established in 2008, provides strategic leadership in managing national approaches to emerging and ongoing biosecurity policy issues across jurisdictions and sectors. All biosecurity issues, including...
environmental, animal and plant biosecurity issues, are considered by the NBC. The Australian Government, and state and territory governments, have also developed the Intergovernmental Agreement on Biosecurity, which sets out roles and responsibilities to create a stronger working partnership to improve the national biosecurity system. It is expected to formally come into effect by the end of 2011. In addition, an agreement is being developed to establish national arrangements for responses to nationally significant biosecurity incidents with predominantly public (rather than industry) benefits. This agreement is known as the National Environmental Biosecurity Response Agreement. Many of the state-based processes outlined in Table 8.24 link with national frameworks and strategies, but there are ongoing challenges related to efficient allocation of limited resources, effective communication and information sharing, and recruiting and maintaining a skilled workforce.196

In 2008, an independent review of Australia’s quarantine and biosecurity arrangements by a panel chaired by Mr Roger Beale AO concluded that Australia’s biosecurity system is good—often the envy of other countries—but far from perfect.197 The review recommended significant changes to improve the system’s ability to deal with changing and increasing biosecurity risks. The changes included:

- improved partnerships with the states and territories and with industry
- improved governance structures, including an independent commission to assess the biosecurity risks of imports, a national authority to undertake biosecurity operations, and an Inspector General of Biosecurity to audit the authority’s work
- a risk–return approach to biosecurity operational activities
- new biosecurity legislation to replace the Quarantine Act 1908
- more funding for biosecurity activities and upgraded information technology systems.

The Australian Government has agreed in principle with the proposed reforms and work has begun within the Australian Government Department of Agriculture, Fisheries and Forestry to implement the reforms and interim arrangements.197

Global-scale drivers of biosecurity issues are important. There is growing concern about movements of species between countries, which occur at rates several orders of magnitude greater than prehistoric rates of range expansion.140 Non-native species entering new countries have the potential to become pests and to have enormous impacts on native species. The spread of potentially invasive species globally is driven in part by industries such as grazing, nurseries and the pet trade, intentionally or unintentionally, but also by policies of governments. At the beginning of the 2000s, for example, there were calls to review policies of the World Trade Organization (WTO) that promote free trade but are considered to encourage species invasions.198 The WTO Agreement on the Application of Sanitary and Phytosanitary Measures allows countries to preclude importation of new species if they impact adversely on human, plant or animal health, but there is ongoing dispute about levels of evidence required and so the measures have little effect.140 Over the coming decades, there will need to be greater attention to these types of global drivers if Australia is to successfully manage invasive species within its borders.

4.5 Assessing the effectiveness of biodiversity management

We have assessed components of management effectiveness in relation to each of the pressures on biodiversity identified in Section 3 (see Assessment summary 8.3). Managing these pressures separately is highly undesirable, because they are driven by similar factors and they interact with one another in complex ways. This is taken into account in the assessment summary by considering whether the policies and plans in place are achieving desired outcomes. The large number of half-circles in the two right-hand columns indicate the low consensus among other experts—there has rarely been full consensus on the exact grade, although there was usually consensus on whether the situation is at the effective or ineffective end of the scale.
Effectiveness of biodiversity management

Summary

<table>
<thead>
<tr>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding: Strategies around Australia acknowledge the need to plan for drought as a usual rather than exceptional circumstance. Climate variability is recognised in all jurisdictions as a key pressure to be addressed. Thinking about the governance context for addressing climate change is not well developed nationally.</td>
<td>Ineffective</td>
<td>Partially effective</td>
</tr>
<tr>
<td>Planning: National and jurisdictional plans for addressing future climate change are emerging, as are plans to address year-to-year variation in water availability. Most of these plans are still struggling with how to move from emergency management to proactive management that engages the spectrum of key stakeholders. There remains a lack of clarity about mitigation versus adaptation and policy makers are still struggling with how to deal with uncertainty about climate.</td>
<td>In grade</td>
<td>In trend</td>
</tr>
<tr>
<td>Inputs: Investment in data collection nationally is increasing, but many stakeholders argue it is still inadequate.</td>
<td>In grade</td>
<td>In trend</td>
</tr>
<tr>
<td>Processes: Processes for dealing with drought and other aspects of climate variability are still highly reactive and based on emergency management. The Murray–Darling Basin (MDB) Commission and the MDB Authority have demonstrated models for interjurisdictional cooperation, but many stakeholders are calling for greater engagement with a wider range of stakeholders.</td>
<td>In grade</td>
<td>In trend</td>
</tr>
<tr>
<td>Outputs and outcomes: The effects of recent droughts in eastern Australia on businesses and communities have been managed to the satisfaction of many stakeholders, but biodiversity was given a lower priority during emergency management. Plans under development for the MDB promise to give biodiversity a higher priority, but it is too early to see results. Recent developments illustrate that there is still considerable debate among interest groups.</td>
<td>In grade</td>
<td>In trend</td>
</tr>
</tbody>
</table>

Pollution

Understanding: Sources of pollution and the need for incentive regulatory frameworks are well established for many pollutants. Concerns have been raised that the effects of micropollutants—chemical residues affecting humans and other animals and plants at low concentrations (e.g. breakdown products from medications, including birth-control drugs, and a range of hormone analogues) are under-recognised. If carbon pollution and acidification of oceans are considered, our assessment of the understanding of the issues is reduced.
Pollution continued

Planning: Many key industries have been working closely with governments to develop policies, plans and codes of practice to manage their effects on biodiversity, including pollution from off-farm run-off. Plans for addressing carbon pollution and ocean acidification are at early stages of development and may need to be accelerated to address looming challenges.

Inputs: Resourcing the implementation of pollution-management plans requires allocation of funds and a willingness to adopt best practice by both large companies and individual landowners. It appears that this is happening across most parts of Australia and most industries with respect to point-based pollution and some diffuse sources like agriculture and urban pollution. However, inputs to implementing plans to address carbon pollution and ocean acidification are arguably inadequate considering the potential challenges ahead. Micropollutants appear to be receiving inadequate attention.

Processes: Best-practice guidelines have been developed for most key industries and it appears they are being applied by a large proportion of land managers. Few processes have been put in place to deal with carbon pollution and ocean acidification. Processes for detecting and dealing with micropollutants are poorly developed.

Outputs and outcomes: All jurisdictions list pollution as a significant concern, especially in the contamination of waterways. Most suggest that regulation and best practice are keeping most pollutants within acceptable limits. Fertiliser run-off into waterways in many agricultural areas remains a concern. Very few tangible outputs or outcomes can be cited in relation to carbon pollution and ocean acidification. Micronutrients remain an emerging problem that has probably been underestimated.

Consumption and extraction of biodiversity and/or other natural resources

Understanding: The need to carefully plan and monitor harvesting of native species is well recognised. However, the relationship between population size and distribution and demands of humans on natural processes mediated by elements of biodiversity is poorly understood and inadequately discussed. For example, debate about a population policy for Australia over the past 10 years has rarely considered environmental impacts in a sophisticated way.
Effectiveness of biodiversity management continued

### Consumption and extraction of biodiversity and/or other natural resources continued

**Planning:** Overall pressure of the human population on the environment is discussed in some plans at the state level, but detailed plans to manage such pressures are poorly developed. The recent moves to discuss a national population policy promises to lead to planning that includes human–environment interactions.

**Inputs:** Inputs to regulating and monitoring the harvesting of terrestrial biodiversity appear adequate (but see Chapter 6: Marine environment for discussion of the regulation of fisheries). Most jurisdictions have invested in understanding the demands of humans on the environment and communicating that information to stakeholders, but progress appears to be limited by funding and inadequate research in most jurisdictions, including nationally.

**Processes:** Processes for regulating and monitoring native species harvesting appear to work well (but see Chapter 6: Marine environment for discussion of the regulation of fisheries). There are very few processes for assessing human demands on the environment more generally and most efforts are made by nongovernment organisations.

**Outputs and outcomes:** Regulation and monitoring of the harvesting of native species appears to be effective (but see Chapter 6: Marine environment for discussion of the regulation of fisheries). Although limited attention has been given to the broader demand of humans on the environment, government and nongovernment agencies have been moderately successful in drawing attention to issues in this area.

### Clearing and fragmentation of native ecosystems

**Understanding:** The significance of this pressure has been recognised nationwide.

**Planning:** Legislation, policies and plans are in place in most jurisdictions to address this pressure. Concerns are expressed that there are still ways to circumvent clearing restrictions. Plans to address the effects of past clearing include protecting remaining intact landscapes, investing in stewardship of intact remnants by land managers, and/or investing in or encouraging revegetation. Generally, these plans recognise that reversing the effects will take a long time, major investments, and changes in a range of attitudes (of all Australians) and practices relating to land management.
Clearing and fragmentation of native ecosystems continued

**Inputs:** Reports of illegal clearing suggest that resources to enforce restrictions are inadequate. Although all jurisdictions report additions to state and national reserve networks over the past decade, all recognise that these are still inadequate. Inputs to stewardship programs have been increasing at the national scale and in some jurisdictions. Investments in revegetation have been considerable at national and state or territory scales under various government and nongovernment programs. We have not assessed the effectiveness of these inputs against the objectives set by each program (most include performance monitoring criteria). Inputs are still inadequate to halt or reverse the effects of land clearance.

**Processes:** Processes for implementing land clearing restrictions appear to be partially effective. Processes for investing in protection of remaining intact ecosystems or encouraging stewardship on private land have been evolving and changing over the past decade. This has been frustrating and overly confusing for many land managers, but it can also be seen as a step towards increasing Australia’s resilience in that governments have been prepared to work with stakeholders to explore new approaches.

**Outputs and outcomes:** The rate of land clearing has reduced nationally, but it remains a significant pressure in some places, and the legacy effects of past clearing will continue for some decades. Overall, efforts to arrest or reverse the impacts of clearing have yet to show positive results nationally. The National Reserve System has grown, but is still a long way from being comprehensive, adequate or representative. Efforts by governments and nongovernment groups to encourage complementary conservation outside protected areas have increased protection of moderate areas and added to acceptance of the importance of off-reserve conservation. However, the efficiency and effectiveness of investments in these areas is still strongly debated. For example, we are not sure whether investment in protecting and managing habitat for particular species and groups of species is achieving the best result for all biodiversity. Similarly, we do not know whether the cost-effectiveness of stewardship programs is more efficient and effective than buying and protecting remaining intact ecosystems in perpetuity. The fact that these issues are being debated on the basis of emerging evidence is a positive step. Exploring multiple options is also consistent with maintaining the resilience of the social-ecological systems of which biodiversity is a part.
## Effectiveness of biodiversity management continued

### Pressures from livestock production

**Understanding:** Understanding the impacts of grazing has increased dramatically over the past decade, especially the role of watering points in spreading the influence of grazing animals. The context in which grazing is managed has also changed as drought and markets have placed pressure on grazing industries. (The uncertainty shown in the right-hand columns reflects differing views among experts and stakeholders, some of whom think that our grades for all components of pressures from livestock production are too optimistic)

**Planning:** Interactions between grazing and biodiversity have been the focus of some major research projects over the past decade, including the Grain and Graze program in Land and Water Australia. This research has produced recommendations on how to plan grazing to minimise effects on biodiversity

**Inputs:** The past decade of drought has reduced stocking rates in many places, but other aspects of drought have worked against biodiversity. There is limited information on what efforts graziers have made to apply biodiversity-friendly practices, but their focus has likely been more on economic survival than biodiversity

**Processes:** As grazing has been listed as a major pressure across Australia for more than a decade, and major new concerns have arisen about its role in the decline of small mammals and birds in northern Australia, it must be concluded that processes for managing the impacts of livestock production on biodiversity are ineffective. It is perhaps optimistic to suggest that these processes are improving in all parts of Australia, but we conclude that this is an average trajectory

**Outputs and outcomes:** It is reported that reductions in the impact of grazing are only observed in the most sophisticated biodiversity-friendly management regimes

### Invasive species and pathogens

**Understanding:** Understanding the effects of invasive species and potential methods of control has been increasing due to research in state and Commonwealth agencies and especially in the cooperative research centre system, but the emergence of several new pressures suggests that understanding is not yet effective. Some reviewers of this document suggested that this situation is deteriorating, not improving as we have suggested

**Planning:** All jurisdictions have multiple plans for detecting invasive species and especially preventing establishment of new invasive species. Plans for reducing the impacts of existing invasive species vary in ambition from containment to eradication

### Summary

<table>
<thead>
<tr>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressures from livestock production</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Invasive species and pathogens (continued)

Inputs: Most jurisdictions admit that they are unable to provide sufficient resources to control existing invasive species and most now focus on preventing establishment of new invasive species. New pressures are emerging and are of high concern due to the limited resources available for control.

Processes: Fragmentation of efforts and lack of ability to focus skills and resources strategically at a national scale have been concerns, but these areas appear to be improving.

Outputs and outcomes: Although the impacts of some invasive species have been contained, many long-standing pressures persist and several new ones are emerging or are on the verge of doing so. Our upward-trending grade reflects the improvement of understanding and technologies for addressing invasive species, but resourcing does not appear to be improving at an adequate rate and could threaten progress.

Altered fire regimes

See Chapter 5: Land

Changed hydrology

See Chapter 4: Inland water
Resilience of biodiversity

The definition of resilience that we have used in this report is:

... the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks. Walker et al.,199 p. 1

The resilience of Australia’s genes, species, ecosystems and landscapes depends not only on the characteristics of what most people think of as ‘natural places’, but also on the human social, cultural and economic systems that depend on elements of biodiversity and affect biodiversity directly and indirectly. Various assessments in Australia and elsewhere have argued that the resilience of ecological systems cannot sensibly be considered in isolation from the human social systems that are coupled with them.200-202 The focus of the following resilience discussion is on coupled social–ecological systems.

We cannot assess resilience quantitatively, based on our current understanding and information. To an extent, this can never be possible, because neither the nature and timing of shocks nor the ways in which systems will respond can ever be fully anticipated. However, it is possible to identify aspects of coupled social–ecological systems that are likely to add to or detract from resilience, and this can help to guide long-term decision-making.

Based on a range of studies around the world, the Resilience Alliance concludes that the resilience of coupled social–ecological systems is based on three criteria:199,203-204

- the amount of change the system can undergo and still retain the same controls on function and structure
- the degree to which the system is capable of self-organisation
- the ability to build and increase the capacity for learning and adaptation.

These criteria in turn are based on the system’s:

- diversity (including diversity of ideas, resources, responses, skills and experience, as well as diversity of species)
- modularity (connections and redundancies between parts of the systems such that a collapse of one part does not cause collapse of the whole system)
- tightness of feedbacks (how quickly and strongly the consequences of change in one part of the system are felt and responded to in other parts).201

Aspects that contribute significantly to the above elements of resilience include levels of reserves, levels of capitals (financial, human, natural and built), leadership, overlapping institutions, social networks and trust.

The following discussion of the resilience of biodiversity and biodiversity management is based on these considerations.

5.1 Evidence of past resilience

Thinking about resilience of coupled social–ecological systems in Australia is relatively new. Resilience assessments have been made in a small number of places and several more are under way. Figure 8.19 summarises historical changes in the Goulburn–Broken catchment in Victoria and shows a model of 10 slow-changing processes that are thought to be major determinants of the future characteristics of the
### PHASES OF CHANGE

**Pre-European phase**
- Resources minimally exploited; many options open
- Biophysical systems regulated by a combination of ecological processes and intervention by Indigenous people with fire management that maintained a mosaic of woodland and grassland supporting high biodiversity

**From European colonisation, about 1830 to 1960s**
- Widely shared values favoured development and resource exploitation
- Options were gradually reduced due to modification of landscapes, reduction in ecological regulation of biophysical processes, and governance and land management becoming tightly constrained
- There were few incentives for efficient use of water and other resources

**1960s to 2009**
- Increasingly complex rules, investments and organisational structures were deployed to address problems initiated during the growth phase
- The system had insufficient spare capacity to cope with the drought of the early 2000s so the resilience of parts of the system was overcome and parts of the system (e.g. wetlands along the Murray) shifted to a new regime

**Present**
- State and federal institutions, politicians, lobbyists for different values, voters and bureaucrats interact in a political–bureaucratic network of microdecisions and constant consultation
- The authors argue that this institutional complexity is dysfunctional and prone to collapse

Source: Walker et al.202

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**Figure 8.19** Historical changes in the resilience of the Goulburn–Broken catchment and major slow-changing processes that help to determine resilience
The resilience of this system is largely determined by how close these slow-changing variables get to thresholds of change that could fundamentally alter the characteristics of the catchment, and how well prepared decision-makers and land managers are to detect change and take timely action at relevant scales. Similarly, a resilience analysis in the Namoi catchment in New South Wales identified key slow-changing variables and suggested that social wellbeing and the adaptive capacity of human residents of the catchment were major determinants of the state and trends in biodiversity and other resources, and were dependent on those resources.

5.2 Preparedness for known or anticipated future pressures

Specified resilience is the resilience of a system to known or expected pressures. The adaptive capacity of species and ecosystems is the extent to which they can maintain their resilience in the face of these pressures. The process of natural selection has meant that species and ecosystems are well adapted to the pressures they have experienced in the past. They are not necessarily adapted to future pressures if these are different from those of the past. Steffen et al. concluded that a wide range of species is potentially vulnerable to aspects of climate change, because species could be exposed to conditions that are outside their capacity to adapt. Table 8.25 summarises conclusions from a major recent national study about the characteristics of Australian native species that are likely to make them more or less vulnerable to the impacts of climate change.

Similarly, pressures like altered fire regimes, pests and diseases, grazing, altered hydrological regimes and land clearing potentially have impacts on species and ecosystems that are outside their capacity to adapt.

<table>
<thead>
<tr>
<th>Aspects of species’ physiology and life history</th>
<th>Characteristics of species least at risk</th>
<th>Characteristics of species most at risk</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological tolerance to environmental factors such as temperature, water availability and fire</td>
<td>Broad tolerance</td>
<td>Narrow tolerance</td>
<td>Many diseases and pests are likely to become more invasive, while many native species may become more susceptible (e.g. amphibians are likely to become more susceptible to attack by the chytrid fungus); some reptiles (e.g. crocodiles and turtles) change the ratio of male to female offspring as temperature rises; plants and slow-moving animals are likely to be especially vulnerable to changed fire regimes</td>
</tr>
<tr>
<td>Phenotypic plasticity (the ability of individuals to vary aspects of their physiology and/or life history in response to environmental changes, without changes to their genetic makeup)</td>
<td>High plasticity</td>
<td>Low plasticity</td>
<td>Weeds and pests are often species with high phenotypic plasticity (be they introduced or native species). Native species can become widespread and abundant when environmental conditions change (e.g. some kangaroos when watering points are available, some parrots in cities and towns, bush flies in agricultural areas)</td>
</tr>
<tr>
<td>Genetic variability (the variation in genes between individuals of a species, which affects the range of physiological and life history attributes that may be present in future generations)</td>
<td>High variability</td>
<td>Low variability</td>
<td>The ability of species to thrive over wide ranges or adapt to changed environments (such as those in the row above) are due partly to genetic variation that allows for natural selection of individuals that do well in a new environment. Species that have gone through major declines in numbers (e.g. many rare and threatened species) have often suffered reductions in genetic variability</td>
</tr>
</tbody>
</table>
Aspects of species’ physiology and life history | Characteristics of species least at risk | Characteristics of species most at risk | Examples
--- | --- | --- | ---
Generation times (time from conception to independence) and time to sexual maturity | Short generation time | Long generation time | Invertebrates (e.g. insects, spiders and others) are likely to be more responsive due to short generation times and the ability to disperse rapidly; long-lived trees are likely to be more vulnerable than short-lived plants; faster growing corals may cope with rising sea levels better than slower growing species

Fecundity (ability to reproduce) | High fecundity | Low fecundity | Species that produce many eggs may be at an advantage, but their survival might be affected and species that focus more on nurturing few young (e.g. mammals) might be advantaged in some situations; plants that rely on insect pollinators are susceptible if those pollinators are not present at the required time; species that require seasonal food supplies, such as fruit, to support breeding could suffer declines in fecundity; diseases and parasites can affect fecundity of many species

Requirements for food, nesting sites, etc. | General (broad) food requirements | Specific (narrow) food requirements | Vulnerable species include species specialised to eat certain foods (e.g. kangaroos adapted to eat low-quality grasses or birds specialising on certain seeds and fruits); a range of birds, fish, mammals, amphibians, invertebrates and other species whose food and nesting requirements are linked with flow regimes on waterways; and species (e.g. some birds and turtles) that nest on sandy shorelines

Dispersal capacity (ability to move through landscapes to find food, mates, nests, suitable climate, etc.) | Good capacity | Poor capacity | Species adapted to rare habitats (e.g. plants and fungi with specific soil requirements) are likely to have to travel further than others; some species will be more susceptible to predation by other species during dispersal

Geographic ranges | Broad ranges | Narrow ranges | Vulnerable species include species adapted to a narrow range of environments (e.g. plants and animals living in high-altitude environments, and plants adapted to specific soil types)

Source: Adapted from Steffen et al.1

In theory, assessing specified resilience requires an understanding of known pressures and what is required for a system to cope with them. Methods to assess the specified resilience of biodiversity and biodiversity management include assessing:

- the ecological processes that allow species and ecosystems to maintain and adapt their structures and functions in the face of change (e.g. ability to move in landscapes to find food, mates and suitable climates, ability to adapt aspects of form and function to survive in changing environments, and levels and types of genetic variation that is maintained in populations as they undergo change)
  - the processes in place to identify likely pressures and possible future changes in them
  - how well the dynamic relationships between the forces that cause pressures (indirect drivers of change), the pressures themselves (direct drivers) and the responses of genes, species and ecosystems are understood
  - the success of strategies to manage the adaptability of biodiversity and/or pressures on it.
We have not attempted to assess these aspects in detail in this report, but their consideration in future data collection at a national scale for SoE and other reporting would be a valuable resource to support managing for resilience.

The fact that most SoE reports from the states and territories over the past several reporting periods have consistently reported that the same set of pressures persist, and that efforts to reduce some of the pressures seem to be having little effect, suggests that the resilience of at least some major parts of biodiversity to these pressures is being exceeded. However, it must also be acknowledged that measures are in place for some pressures (e.g. land clearing) that would be expected to take some time to deliver positive change.

5.3 Factors affecting potential capacity to deal with surprises

General resilience is resilience to a wide range of pressures, many of which might be unknown and likely to come as a surprise. Assessing general resilience is particularly difficult, because its attributes interact with one another and different attributes might be more or less important for dealing with different future shocks.

As mentioned above, key attributes that contribute to a system’s general resilience are diversity, modularity and tightness of feedbacks. (These same attributes are also relevant to specified resilience [Section 5.2], but general resilience is likely to require greater diversity, because it means having the potential to deal with a wider range of unknown shocks.)

In management, the resilience of an ecological or a coupled social–ecological system can be improved by building the resilience of the system itself, or by reducing pressures to levels that the system can cope with. Examples of institutional processes that would be expected to maintain or build the general resilience of Australia’s biodiversity are:

- processes for looking forward to anticipate possible sources of new pressures and shocks; for example, foresighting by natural resource management groups and by natural resource management agencies, such as the Namoi Catchment Management Authority in New South Wales\(^{160}\) or irrigators in the Goulburn–Broken catchment in Victoria\(^{162}\)
- processes to understand the dynamics of social–ecological systems at a system level, including understanding of slowly changing variables; thresholds; implications of different governance arrangements; and the interactions between human, social, natural, physical and financial forms of capita\(^{205-206}\)
- processes that maintain a diversity of response options for biodiversity by maintaining population sizes that allow for fluctuations in births and deaths and provide a diversity of genes, and by maintaining adequate extent and quality of habitat and connections between pieces of habitat to allow species to continue to find suitable climatic conditions, food, shelter and mates
- processes that ensure that governance arrangements encourage diversity of ideas and potential solutions, allow for early detection of change in pressures and the state of species and ecosystems, facilitate timely and effective action by those best placed to take it, and ensure that networks are not vulnerable to collapse if key individuals or groups fail.

Some of these processes are built into policies and biodiversity management plans around Australia. By seeking to maximise the diversity of genes, species and ecosystems, or at least minimise their decline, previous policies and strategies have contributed to the diversity component of resilience. Similarly, previous SoE reports have acknowledged the role of programs like Landcare, Bushcare, the Natural Heritage Trust and a range of state government programs in building networks and capacity for biodiversity management and networks in regional Australia.

Only recently, however, has significant attention been given in policies and management planning to the concept of nonlinear change in ecological systems. Resilience is identified as a key objective of the most recent natural resource management strategies around Australia, but it remains to be seen how concepts such as awareness of cross-scale processes and the importance of monitoring are translated into policy and management. In both New South Wales and Victoria, catchment management authorities have been encouraged to employ resilience frameworks in revising their catchment management plans.

There is a growing awareness of the need to apply systems approaches to understanding relationships between pressures, biodiversity and biodiversity
management, which could yield improved strategies for addressing specified and general resilience in the future. Most of the measures required to address biodiversity decline are likely to also increase resilience, but several recent discussions have suggested that more needs to be done to address resilience of human social systems, including governance for natural resource management.207

A key way in which governments can maximise the chance of effective information flows and tight feedbacks is through effective engagement with stakeholders. Many government strategies incorporate this as an objective, but there is ongoing debate both about what government engagement should be trying to achieve and how well it is doing that.

A substantial body of theory and observational research is emerging that suggests that management of natural resources, including biodiversity, in Australia and elsewhere could be made more effective, and more responsive to climatic and other variations, if responsibility, authority and resourcing for decisions and action were spread more evenly between central governments and regional bodies (see Section 4.2 and Table 8.26). This means a move from monocentric to polycentric governance—also called adaptive governance—and application of the principle of ‘subsidiarity’, or giving decision-making ability to those most able to detect challenges and opportunities and take appropriate and timely action.1,169,177

Australian governments have made moves in this direction over the past four decades, especially through programs such as the Natural Heritage Trust, which created 54 natural resource management bodies around Australia. This approach has been termed the ‘regional model’ of natural resource management.107 Although there are shortcomings in this model’s application, it is widely considered to be the best approach currently available for moving towards adaptive governance, and that it requires more time to mature.179,201 Part of the reasoning behind this conclusion is that there are no quick fixes or simple solutions for managing biodiversity and the broader social–ecological systems. Involving the full range of stakeholders is considered the best chance of finding ways forward.

It should also be acknowledged that there are aspects associated with polycentric governance that some would consider to be costs, such as duplication and reinvention of approaches and concepts. However, resilience theory suggests that a level of duplication and ‘redundancy’ (where there are many species that perform similar functions) is essential to give a system resilience and adaptive capacity. We also acknowledge that other disciplines are addressing questions of efficiency in natural resource management, including the discipline of decision theory.

<table>
<thead>
<tr>
<th>Key elements of resilience</th>
<th>Effects of limited efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diversity (of ideas, skills, resources, etc.)</td>
<td>Elimination of spare capacity; focus on what we need now, leaving us unprepared for later</td>
</tr>
<tr>
<td>Modularity (failure in one part does not bring down the whole)</td>
<td>Centralised functions can leave a system vulnerable if the centre fails; humans tend to create unstable networks—nature tests their vulnerabilities constantly</td>
</tr>
<tr>
<td>Tight feedbacks (effective two-way information flows)</td>
<td>Centralised control can reduce intelligence from those working most directly with emerging issues and delay response</td>
</tr>
<tr>
<td>Self-organisation</td>
<td>The more we try to control a system, the more we risk reducing resilience</td>
</tr>
</tbody>
</table>

Sources: Cork,165 Walker et al.,199 Walker & Salt201
Risks to biodiversity

New risks to biodiversity that might emerge in the next few decades may be from pressures not previously seen, or from changes in the severity or expression of existing pressures. In addition, some of the risks relate to failure to take actions that we believe are vital for desirable biodiversity outcomes. For example, a number of experts have highlighted the need to make substantial progress in the next few years on understanding, and taking action about, the benefits that people derive from the environment and the consequences of our impacts on the environment. At the same time, some opportunities that might emerge in coming decades could provide possibilities to address current and emerging pressures substantially better than we currently anticipate. In this section, we have identified risks and opportunities primarily from scanning the literature, with particular reliance on a small number of recent studies that have reviewed risks to biodiversity and natural resource management. We restrict ourselves in the assessment summary to those that we consider most significant.

6.1 Escalation of existing pressures

There is very little published analysis on which to base an assessment of the relative impacts of different pressures, or the ways in which their absolute or relative impacts might change in the future. The 2006 SoE report drew on an analysis of the numbers of times that different pressures were mentioned in the National Land & Water Resources Audit as an indicator of their relative importance. More recently, Burgman et al. analysed published data on the past, present and future threats to Australian plants and the severity of those threats. They concluded:

- land clearance is likely to continue to be a major pressure but of a lesser severity than in the past, while the edge effects of farms and farm activities, and grazing pressures from domestic, feral and native species are likely to increase
- more species are likely to be threatened in the future by reductions in the numbers of populations, size of range and numbers of individuals

- pressures from landscape-scale factors, especially weeds, fire, fragmentation of habitat, diseases and hydrology, are likely to dramatically increase in the future
- management of human activities and needs that affect biodiversity is likely to become much more important (including managing road and rail verges, mining, forestry, collecting, trampling and recreation impacts).

Existing pressures on biodiversity from human energy needs could become even more significant if the availability of oil declines rapidly and the transition to alternative energy sources is not managed in an orderly fashion. An associated risk is that future development of biofuels and carbon sequestration technologies like biochar might move forward and require land conversion faster than research can be done to anticipate and manage their impacts on biodiversity.
6.2 Escalating interactions among existing pressures

As well as existing pressures continuing to act, it is likely that new or more intense interactions among existing pressures will lead to new challenges.

Climate change is likely to magnify the effects of existing pressures manyfold in coming decades. For example, interactions of climate change with newly arrived pests and diseases also has the potential to create pressures that are far stronger and more widespread than those currently experienced in Australia. The interaction of climate change with ocean circulation, ocean acidification and processes that are reducing the level of oxygen in marine environments could drastically affect marine ecosystems.

6.3 Emerging risks

Pollution is an ongoing pressure on biodiversity, but there is potential for new pollutants, such as micropollutants (see Section 3.5), to emerge that increase the pressure manyfold. Known pollutants that threaten to become major problems include a range of byproducts of industry and pharmaceutical consumption that are accumulating in waterways and animal tissues, and that disrupt hormonal function in a range of species—even at the low concentrations currently detected.

Large-scale functional shifts appear to be occurring in soils worldwide, including increased respiration rates and elevated emissions of carbon. It is not yet clear what the significance is of this trend, or the extent to which it might be a problem for Australian soil processes and the plants and animals that depend on those processes.

The past few years have seen increasing suggestions for large-scale engineering of natural systems as ways to combat climate change and other environmental problems. Such approaches include the release of particles (e.g. sulfate aerosols) into the stratosphere to scatter sunlight back into space, deployment of large sunshades in space and seeding of the oceans with iron or fertilisers to increase carbon uptake by marine organisms. Serious concern has been expressed about the possibility of such approaches having unintended and disastrous effects.

Some of the less likely risks, but ones that have potentially major impacts, include the:

- increased availability of genetic engineering technologies used to modify species that can then interact with wild species
- wholesale failure of protected areas, due to climate change and associated effects (which would undermine the foundations of Australia’s conservation strategies)
- widespread denial of biodiversity loss, due to the combination of natural human tendencies to deny major problems and effective anti-information campaigns.

Finally, there is a high likelihood of surprises in the future. Some of these will be in the form of new understanding of Australia’s social–ecological systems, just as ecology has produced a number of surprises over the past century that are now regarded as common knowledge. Some will be unwelcome shocks, but their impact can be lessened by good processes of scanning for emerging change and building and maintaining resilience.

Several recent examples have shown the potential value of formal approaches to horizon scanning and strategic foresight for anticipating and preparing for future environmental challenges, including those to biodiversity. Such processes may help us anticipate and mitigate the impacts of future challenges to Australia’s biodiversity.
## Current and emerging risks to biodiversity

<table>
<thead>
<tr>
<th>Already certain</th>
<th>Likely</th>
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</thead>
<tbody>
<tr>
<td>Slow progress on understanding the relationships between population, economy, technology and biodiversity, and communicating this to the public</td>
<td>Inadequate progress in scaling climate change models down to provide robust forecasts at local scales</td>
<td>Shifts in the 'geography' of agriculture (e.g. increasing intensity of agriculture in the relatively intact landscapes of the north-west in response to increasing rainfall there and decreasing rainfall in the south-west and south-east)</td>
<td>Emergence of more unexpected effects of human activities in northern Australia</td>
<td>Failure of technological advances to keep pace with pressures on biodiversity</td>
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<td>Deoxygenation of oceans (major effect possible in long term)</td>
<td>Increased pressure on Australia to provide wood as deforestation is reduced in other countries</td>
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<td>Increasing hard engineering 'solutions' to cope with rising sea levels, such as groyne and sea walls, impacting on beach and intertidal biodiversity</td>
<td>Increased water allocation to artificial snowmaking in alpine areas</td>
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### Biodiversity | Risks

<table>
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<tr>
<th>Catastrophic</th>
<th>Major</th>
<th>Moderate</th>
<th>Minor</th>
<th>Insignificant</th>
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<tr>
<td>Crossing one or more major thresholds of irreversible change in soil fertility, connectedness and quality of vegetation as habitat, or ability of species to adapt to climate change</td>
<td>Failure to improve ability of regional communities to manage their links with biodiversity</td>
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<td>Emergence of one or more major pests or diseases that spread widely among native plants or animals</td>
<td>Large-scale functional shifts in Australian soils</td>
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<td>Major interactions between altered ocean circulation and ocean acidification, drastically modifying marine ecosystems</td>
<td>Geoengineering causing unexpected and undesired effects on ecosystems</td>
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<tr>
<td>Climate change that is so fast and severe that mass extinctions occur</td>
<td>Increased pressure on coastal ecosystems from rising sea level combined with extreme events and decline of coral buffers due to ocean acidification</td>
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<td>Major changes in food-production technologies reducing the numbers of people living in regional Australia and managing the land for personal and public benefit</td>
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<td></td>
<td>Change in fire regimes to the point that major trade-offs between human safety and biodiversity are necessary</td>
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<td></td>
<td>Failure to achieve integrated and cooperative management of water for environment</td>
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<td></td>
<td>Urban and peri-urban pressure jumping to a much higher level due to population growth and failure to manage human demands on the environment</td>
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</table>

- Negative impacts on biodiversity from development of biofuels and biochar
- Pollutants currently considered minor being found to have major biodiversity impacts (e.g. hormone analogues)
- Unintended negative consequences of translocating species as a response to the climate change threat (e.g. competition or predation with other species at the transplant site)

Continued next page
## Current and emerging risks to biodiversity *continued*

<table>
<thead>
<tr>
<th>Catastrophic</th>
<th>Major</th>
<th>Moderate</th>
<th>Minor</th>
<th>Insignificant</th>
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<tr>
<td>- Policy and/or technological responses to climate change and/or water shortages having unintended consequences (e.g. alternative energy technologies have impacts on biodiversity, desalination projects generate pollution)</td>
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<td>- Increased allocation and storage of water to cope with more intense droughts</td>
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<td>- Interaction of climate change and increased costs of energy creating major trade-offs between food production and biodiversity conservation</td>
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<td>- Failure to establish processes for collecting relevant and adequate data to provide early warning of threats and opportunities for biodiversity management</td>
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<td>- Market-based approaches to managing biodiversity driving decline rather than sustainability</td>
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<tr>
<td>- Ability to genetically engineer new species becoming widely available and used by a range of skilled and unskilled people</td>
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<table>
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<th>Unlikely</th>
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<tr>
<td>- Market-based approaches to managing biodiversity driving decline rather than sustainability</td>
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<tr>
<td>- Ability to genetically engineer new species becoming widely available and used by a range of skilled and unskilled people</td>
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<tr>
<td>- Not considered</td>
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Outlook for biodiversity

It is never possible to predict the future with certainty. Furthermore, it is even less wise now—in a time of major environmental, economic and social change globally—than in the past to try to predict the future of biodiversity in Australia. Much of Australia is at the end of a long period of drought and a time in which various new approaches to environmental governance have been tried with a range of successes. Opinions about the likely long-term suitability of different governance approaches differ and it is by no means clear what policy and management strategies will be adopted by the Australian Government, and by state and territory governments, in the coming decade and beyond. However, there is consensus about several aspects of biodiversity:

- Biodiversity has declined since European settlement, and information on environmental pressures suggests that many species continue to decrease in both population size and genetic diversity.
- Most pressures on biodiversity that arise directly or indirectly from human activities appear to still be strong and those that have declined in some areas, such as land clearing, continue to have legacy effects that will continue for some years or decades.
- Despite promising investment by all jurisdictions in addressing the main pressures on biodiversity, pressures are not being reduced substantially, nor is the decline in biodiversity being arrested or reversed.
- The major future drivers of change—climate change, population growth, economic development and associated consumption of natural resources—must be managed carefully if a sustainable relationship between biodiversity and human societies is to be achieved.
- The impacts of human activities on biodiversity have the potential to generate negative feedbacks that could decrease genetic, species and ecosystem biodiversity, which will seriously affect the delivery of environmental benefits to Australians and reduce our quality of life.

• Data on long-term trends in biodiversity are limited, making it difficult to interpret the state or trends of major animal and plant groups in most jurisdictions.

Below, we offer our views about two alternative scenarios, one pessimistic and one optimistic, for the future of biodiversity in Australia. These are at the extremes of the range of plausible futures. The reality is likely to be somewhere in-between.
7.1 A pessimistic outlook

The legacy of past land clearance will continue to see habitat decline on private land through much of the sheep–wheat belt of Australia. Current efforts to reverse this effect are having only small success. If the current level of investment in reducing habitat decline continues or declines, then much of the sheep–wheat belt will see massive further loss of native vegetation due to death of old trees and limited recruitment of seedlings, and reduction in most species of mammals, birds and reptiles, and many species of amphibians and invertebrates. This is likely to be associated with increased rates of soil erosion and other negative effects of extreme weather. The diversity of soil organisms, such as fungi, earthworms, beetles, spiders and a range of other invertebrates responsible for maintaining soil fertility and controlling pest outbreaks, is likely to decline. The current replacement of native species with a smaller number of introduced species capable of supporting a narrower range of ecological functions will intensify.

An explosion in the number and impacts of invasive species is plausible due to climate change and inadequate investment in understanding the interactions between climate change and outbreaks, and/or in detection and early intervention when an outbreak occurs. These problems are likely to be compounded if effective agreements are not reached to control the global movement of potentially invasive species, which could see Australia as the recipient of many species that are pre-adapted to outcompete Australian native species.

The current trend of declining resources for managing protected areas on public land and minimal investment in connecting protected areas is likely to result in a deterioration of these resources and an inability to cope with the effects of climate change. There is likely to be increased incidence and severity of pest and disease outbreaks and changes in where different species can find suitable climatic conditions.

Failure to manage native vegetation around urban centres is likely to see natural control of pests and diseases by native animals decrease and the costs of control by chemical methods increase. Impacts from extreme weather (including damage from floods and winds) are likely to increase. Costs of water purification are likely to increase due to the decline of native vegetation in water catchments and increased movement of soils into water supplies. As the area and quality of remnant native vegetation decline, a tipping point is likely to be reached beyond which decline is hastened by reduced numbers and diversity of pollinating species.

Climate change is likely to exacerbate most of these trends, while increasing the extremes of impacts and the uncertainty of challenges and opportunities. There is a risk that progress will not be made on governance approaches that allow better anticipation of, and preparation for, future shocks, or on effective cooperation and synergy between governments at all levels and communities to detect and respond to challenges and opportunities. If this progress is not achieved, then both ecosystems and the social systems whose prosperity is coupled with them are likely to become increasingly unresilient and vulnerable to environmental shocks, as well as market volatility and other economic fluctuations.

Finally, as the Australian population grows, periods of resource deficiency and stresses on quality of life in both urban and regional communities are likely if we do not pay serious attention to our dependence on biodiversity and natural resources.

7.2 An optimistic outlook

The legacy of past land clearance will continue to see habitat decline through much of the sheep–wheat belt of Australia. Major increases in investment in offsetting this legacy and returning native vegetation to landscapes, such as those envisaged under climate change mitigation initiatives, might see the current decline in biodiversity and ecosystem function move significantly towards stabilisation. This could be achieved within two decades if lessons learnt by researchers and land managers in the past few decades are built on and the benefits of better biodiversity management for businesses and communities are fully recognised and built into taxation, market and other incentive mechanisms. Early progress towards these goals is apparent in a few areas and aspects of biodiversity conservation now, but progress will need to spread much more widely and it will require unprecedented support by governments, industries and communities. This will need to happen within the next few years to maximise our chances of preparing Australia’s biodiversity and biodiversity management systems for the challenges of climate change and other challenges of the coming few
decades. These aspirations are articulated in Australia’s Biodiversity Conservation Strategy 2010–2030.11

As these improvements are made, tipping points are likely to be reached beyond which returns on investment will increase much more rapidly, although this might require a decade or more of sustained investment and optimism—reversing the effects of past declines is likely to take longer than the original decline.

Improved understanding of how to restore and connect habitat could be built on to improve the ability of native species to adapt to climate change. Returning structural complexity to habitat could help native species cope with growing pressures from pests and diseases. Synergies between managing public and private land for conservation and other public benefits are a possible outcome of advances that nongovernment groups are currently making.

A key step in achieving an optimistic scenario would be effective management of global movements of potentially invasive species. This would require Australia to play a key role in negotiating new agreements and interpreting old ones, because this nation has more to lose than most.

Another potential driver of desirable change in biodiversity is the linking of biodiversity outcomes to market-driven programs. For example, placing a price on carbon can potentially lead to co-benefits for biodiversity, salinity mitigation, water quality, soil restoration and other effects. These approaches do have inherent risks that will need to be managed to achieve a desirable future for biodiversity. For example, unintended negative environmental impacts could be generated if extensive vegetation planting occurs on salinised areas where hydrological conditions are not well understood or are misunderstood. The risks of such unintended consequences are likely to be strongest in the early days of new market opportunities, when investors are rushing to gain advantage. Optimistically, landscape plans that seek to simultaneously achieve a spectrum of natural resource benefits could become standard practice, similar to programming for income generation on farms.

Over the past few decades, state and national governments in Australia have, in a sense, experimented with different approaches to polycentric governance (governance in which responsibility, authority and resourcing is shared across levels of government and society so that people who are best placed to detect and deal with issues in a timely and efficient fashion are empowered to do so). In the future, these experiments might give rise to successful approaches that allow governments, industries and communities to cooperate in anticipating, preparing for and responding to gradual change as well as environmental, social and economic shocks at a range of spatial scales. In another example of a beneficial tipping point, Australia’s ability to cope with uncertainty might allow it to take market advantages and provide assistance to other countries that are less able to manage aspects of their environment or food production.

Optimistically, as Australia’s population grows, serious thought will be given to the dependence of people on biodiversity and natural resources in general. Although there might be some tough decisions to make about adjusting lifestyles and consumption patterns, it might be possible for Australians to maintain a high quality of life while having minimal negative impacts on biodiversity and the environment. How this might be achieved is still unclear, but at least there is hope of desirable outcomes, whereas failure to take the relationship between population and environment seriously carries great risks.
References


18 Lindenmayer D. Australia’s biodiversity: count it or lose it. If you’re serious about conserving biodiversity, get serious. Decision Point 2011;48:4–6.


70 Lindsay EL, Colloff MJ, Gibb NL, Wakelin SA. Microbial functional gene abundance in grassy woodlands is influenced more by soil nutrient enrichment than recent weed invasion or livestock exclusion. Applied and Environmental Microbiology 2010;76:5547–55.


References

Biodiversity


132 Hill B, Ward S. National recovery plan for the northern quoll Dasyurus hallucatus. Darwin: Northern Territory Department of Natural Resources, Environment, the Arts and Sport, 2010.


References


Key findings

Our extraordinary and diverse natural and cultural heritage generally remains in good condition.

Australia is a complex, layered natural and cultural landscape in which unique geodiversity and biodiversity provide the palette for an ancient Indigenous culture and two centuries of post-colonial settlement history. Our heritage can be experienced at different levels and through different encounters: at grand and minute scales, in both tangible and intangible ways. The current condition and integrity of Australia’s listed heritage generally appear to be good, with some deterioration evident over recent years. However, it is challenging to draw a single cohesive conclusion about the condition of Australia’s natural and cultural heritage, given the diverse and fragmented nature of available information.

Australia is recognised internationally for leadership in heritage management.

We have a range of well-resolved processes for identification, protection, management and celebration of our heritage that should reduce pressures, minimise risk and retain those values that make our heritage places special.

Our heritage is being threatened by natural and human processes and a lack of public sector resourcing that does not reflect the true value of heritage to the Australian community.

The nation’s protected natural and cultural resource does not include all the places with heritage value, nor is it truly representative. Management and protection of Australia’s heritage is under-resourced and, despite our internationally recognised processes, the systems used to manage our heritage are cumbersome. This is out of line with community perceptions of heritage value. Consequently, our heritage is at great risk from the impacts of climate change, threats arising from development, and pressures that flow from population growth.

Improvement will require change.

The future for Australia’s heritage will depend on government leadership in two key areas: undertaking thorough and comprehensive assessments that lead to adequate areas of protected land and comprehensive heritage inventories, and changing heritage management paradigms and resource allocation in response to emerging threats.
## Contents

### 1 Introduction

1.1 Heritage listings  
1.2 Types of heritage  
1.2.1 Natural heritage  
1.2.2 Indigenous heritage  
1.2.3 Historic heritage  
1.3 In this chapter  

### 2 State and trends of heritage

2.1 Identification  
2.1.1 World Heritage  
2.1.2 National heritage  
2.1.3 State heritage  
2.1.4 Local heritage  
2.1.5 Natural heritage  
2.1.6 Indigenous heritage  
2.1.7 Historic heritage  

2.2 Condition and integrity  
2.2.1 World Heritage  
2.2.2 National heritage  
2.2.3 State heritage  
2.2.4 Local heritage  
2.2.5 Natural heritage  
2.2.6 Indigenous heritage  
2.2.7 Historic heritage  

- **Assessment summary 9.1—state and trends of heritage values**  

---

**Australia: State of the Environment 2011**

693
3 Pressures affecting heritage

3.1 Climate change
  3.1.1 Rising temperatures
  3.1.2 Changing rainfall
  3.1.3 Rising sea levels
  3.1.4 Altered fire regimes
  3.1.5 More frequent extreme weather events

3.2 Population growth
  3.2.1 Community perceptions of value
  3.2.2 Population shift

3.3 Economic growth
  3.3.1 Resource extraction
  3.3.2 Development
  3.3.3 Tourism

3.4 Pressures on natural heritage
  3.4.1 Invasive species
  3.4.2 Loss of habitat
  3.4.3 Land use
  3.4.4 Soil erosion

3.5 Pressures on Indigenous heritage
  3.5.1 Loss of knowledge
  3.5.2 Loss of traditional cultural practice and social connections
  3.5.3 Incremental destruction

3.6 Pressures on historic heritage
  Assessment summary 9.2—pressures affecting heritage values

4 Effectiveness of heritage management

4.1 Understanding
  4.1.1 Understanding values
  4.1.2 Understanding threats

4.2 Planning
  4.2.1 Leadership
  4.2.2 Jurisdictional arrangements
  4.2.3 Statutory protection
  4.2.4 More flexible approaches

4.3 Inputs
  4.3.1 Financial resources
  4.3.2 Human resources

4.4 Processes
  4.4.1 Statutory responses
  4.4.2 Adaptive management

4.5 Outcomes
  4.5.1 Natural heritage
  4.5.2 Indigenous heritage
  4.5.3 Historic heritage
  Assessment summary 9.3—effectiveness of heritage management
Resilience of heritage 780

5.1 Approaches to resilience 780
5.2 Evidence of past resilience 781
5.3 Preparedness for future pressures 782
5.4 Factors affecting resilience capacity 783

Risks to heritage 784

Assessment summary 9.4—current and emerging risks 785

Outlook for heritage 787

7.1 Likely trends in key factors 788
7.1.1 Climate change 788
7.1.2 Population growth 788
7.1.3 Economic growth 789
7.2 Natural heritage 789
7.3 Indigenous heritage 791
7.4 Historic heritage 791

References 793
Places of cultural significance reflect the diversity of our communities, telling us about who we are and the past that has formed us and the Australian landscape. They are irreplaceable and precious.

Meredith Walker and Peter Marquis-Kyle, *The Illustrated Burra Charter: good practice for heritage places*, 2004

Wandjina rock art figures, the Kimberley, Western Australia

Photo by Nick Rains
Introduction

Australia has a rich natural and cultural heritage that underpins our sense of place and national identity. Australia’s heritage is an important element of the environment—the valued places that we have inherited and will pass on to future generations bridge natural and cultural boundaries. Our land features extraordinary geodiversity, with unique ecosystems and profound cultural traditions that extend back thousands of years. Layered across this ancient landscape is the evidence of more than two centuries of colonial and post-colonial history—young in global terms, but a vital part of our cultural environment. Some of this heritage has been recognised through land reservation or statutory listing, but many heritage places are not formally identified or protected. Indeed, some of the values of Australia’s heritage places are intangible and relate to traditions, use or meaning, so they may be less evident in physical form.

Heritage can be most simply defined as those parts of the environment that have intergenerational value. Statutory definitions of heritage typically refer to ‘aesthetic, historic, scientific, or social significance or other special value for future generations as well as for the present community’. Our heritage comprises both natural and cultural places with tangible (physical) and intangible (associative) values.

For many Australians, particularly those from Indigenous backgrounds, the divide between nature and culture is artificial because the environment is perceived as one interlinked, complex cultural landscape, created and lived in by ancestors and the contemporary community. This chapter recognises this complexity, but considers heritage in accordance with the statutory and bureaucratic listing and identification processes. Like the rest of this report, this chapter adopts a national perspective. However, it also recognises that local heritage items may be critical to a community’s sense of place, and thus assessing the state of the nation’s heritage demands an understanding of local heritage. In addition, at a national level, heritage is a broad construct that overlaps with other environmental components such as biodiversity, the land, inland waters, marine environments or urban areas, covered in other chapters in this report. Loss of condition or integrity in any of these areas would be a loss for Australia’s heritage.

1.1 Heritage listings

In Australia, heritage is identified, assessed and listed through multilayered and overlapping statutory and bureaucratic processes that broadly parallel our multitiered systems of government. Heritage listing has a range of purposes and functions, including recognising and celebrating values, protecting heritage under the law, and informing management decisions and resource allocation. Heritage can be listed in a number of ways and by various authorities:

- **World Heritage List**—World Heritage sites are places that are important to and belong to everyone, irrespective of where they are. They have outstanding universal value that transcends the value they hold for a particular
These qualities are expressed in the Convention Concerning the Protection of the World Cultural and Natural Heritage (the World Heritage Convention). Australia’s obligations under this convention are met through provisions in the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act).

- **National Heritage List**—The National Heritage List, established under the EPBC Act, includes natural, historic and Indigenous places that are of outstanding national heritage value to Australia (see Box 9.1).

- **Commonwealth Heritage List**—The Commonwealth Heritage List, established under the EPBC Act, comprises natural, Indigenous and historic heritage places that are either entirely within a Commonwealth area, or are owned or leased by the Australian Government or an Australian Government authority.

- **The Register of the National Estate**—The Register of the National Estate is a list of important natural, Indigenous and historic heritage places throughout Australia, originally established under the Australian Heritage Commission Act 1975. The Australian Heritage Commission entered more than 13,000 places in the Register of the National Estate. In 2004, responsibility for maintaining the register shifted to the Australian Heritage Council, under the Australian Heritage Council Act 2003. The register will only continue as a statutory register until February 2012.

- **The Australian National Shipwrecks Database**—The Australian National Shipwrecks Database was launched in December 2009 and includes all known shipwrecks in Australian waters. Australia protects shipwrecks and their associated relics that are more than 75 years old through the Historic Shipwrecks Act 1976. This Act applies to Australian waters that extend from the low tide mark to the end of the continental shelf and is administered by the Australian Government, in collaboration with the state and territory governments.

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**Box 9.1 The National Heritage List—Lark Quarry dinosaur stampede**

Palaeontology plays an important role in highlighting Australian geodiversity and evolutionary processes. The Dinosaur Stampede National Monument, in Lark Quarry Conservation Park in central Queensland, provides unparalleled evidence of a dinosaur stampede that took place 95 million years ago. Almost 4000 footprints have been preserved in the former mudflats and are visible over an area of 210 square metres. Palaeontologists interpret these footprints as being caused by approximately 150 bipedal dinosaurs who fled a carnivorous *Tyrannosaurus rex*.2

![Dinosaur footprints, Lark Quarry, Queensland (photo by Jaime Rankin and the Australian Government Department of Sustainability, Environment, Water, Population and Communities)](image_url)
Box 9.2 The Freedom Ride—part of our national inheritance

In 1965, a group of students from the University of Sydney, led by Indigenous activist Charles Perkins, travelled through regional New South Wales to highlight the inequalities and racism experienced by the Aboriginal population. This protest and its consequences were of pivotal importance in the history of Australian race relations. The spirit of the Freedom Ride is clearly part of our national story; however, it is not listed on any statutory heritage register.

Many Australian heritage places have not been formally identified or listed. The route of the 1965 Freedom Ride embodies part of our rich social history—a history that helps us understand where we have come from and that we should transmit to future generations of Australians.

• **State heritage registers**—At the state and territory level, the process for listing heritage places is varied. All jurisdictions have dedicated national parks and reserves. Some jurisdictions establish additional registers of Indigenous sites, whereas others protect Indigenous heritage through blanket statutory control. Each state or territory also has a statutory list of historic places, but the criteria and threshold for listing vary, and these registers are generally acknowledged as incomplete.

• **Local heritage**—Heritage identification at the local level varies between many thousands of heritage or contributory items in dense urban areas to a complete absence of any statutory listing or controls for some local government areas. There are many locally managed reserves, generally dedicated for reasons of natural heritage or amenity, but some of these also contain significant Indigenous places. Mostly, however, Indigenous heritage is neither identified nor protected at a local level, and comprehensive national data for local heritage listings are not available.

• **Nonstatutory lists**—Heritage lists are also maintained by nongovernment organisations such as the National Trust of Australia, the Institution of Engineers and the Royal Australian Institute of Architects. While these lists have no direct statutory force, they are sometimes used to inform decision-making processes such as development consent or statutory listing.

Heritage can also be unlisted. Our national inheritance includes vast areas and many places that have not been formally identified or listed, but nevertheless contribute to the nation’s heritage, especially at the local level (see Box 9.2). This will always be the case, since resources dedicated to survey and assessment projects are never sufficient to allow comprehensive coverage, and notions of what constitutes intergenerational value and cultural heritage resources are constantly changing. Effective heritage management requires an all-encompassing understanding and respect for both listed and unlisted heritage, so that change and development occur in a way that respects all heritage values.
1.2 Types of heritage

For the purposes of this State of the Environment (SoE) report, heritage has been categorised as natural, Indigenous or historic (consistent with the management framework used at the national level). Although movable objects, collections and records are widely recognised as ‘heritage’, they are excluded from this report, except where they form part of a heritage place.

1.2.1 Natural heritage

Natural heritage comprises the components of the natural environment that have aesthetic, historical, scientific or social significance, or other special value for the present community, as well as for future generations. One important factor that distinguishes natural heritage places from broader natural or social values is that natural heritage places relate to definable and valued locations or areas of land. For example, the values of a particular national park can be identified and defined as heritage values by applying assessment criteria such as those used to assess places for the National Heritage List (see Box 9.3).

Another factor that distinguishes natural heritage from general natural resources is that the place either has been or should be formally identified and set aside for conservation purposes or actively managed for these purposes (along with other uses). Such places might include national parks, reserves, botanic gardens and private conservancies, as well as significant fauna and flora habitats or geological sites. Although our natural heritage includes both reserved and unreserved lands, and listed and unlisted places, this chapter focuses on natural heritage that has been identified and protected. Other aspects of the natural environment are addressed in other chapters of this report.

Box 9.3 Natural heritage—Porongurup National Park

Natural places can be listed as heritage items at the local, state, national or international level. In Western Australia, for example, Porongurup National Park was included on the National Heritage List in 2009 as a place of outstanding geological and natural value. The park contains distinctive granite domes that are remains of the ancient Porongurup pluton, a bubble of molten rock that rose from Earth’s core and pushed upward into the overlying base rock of the park. Located within the traditional lands of the Minang group of the Nyungar people, Porongurup is a living landscape of outstanding biological and ecological significance. As part of an internationally recognised biodiversity hot spot in the south-west region of Western Australia, the park contains an exceptionally high concentration of plants and animals in a relatively small area. Porongurup National Park is also significant for a number of invertebrates that have links to the Gondwana supercontinent, when Australia was joined to present-day Africa, South America and Antarctica before these land masses broke apart some 150 million years ago.
1.2.2 Indigenous heritage

Aboriginal and Torres Strait Islander heritage extends back over many tens of thousands of years and is of continuing significance, creating and maintaining links with the people and the land. Human occupation of the Australian continent has left a rich legacy of places that bear witness to our evolving human history. Indigenous heritage places include occupation sites, rock art, carved trees, places with known spiritual values, important waters or landscapes laden with meaning to people from that country, and places with contemporary value to Indigenous people (Box 9.4).

Box 9.4 The Wunambal Gaambera Healthy Country Plan

For Indigenous people, the divide between the natural and cultural environment is artificial, because there is a continuing connection between people and country that requires ongoing nurturing and management through traditional cultural practices. This interrelationship is increasingly recognised through Indigenous land and sea management plans, as well as by specific management arrangements in particular places.

The Wunambal Gaambera Healthy Country Plan 2010–2020 was prepared through a collaborative, participative process at the instigation of traditional owners, building on work that started in the 1990s. The plan covers a huge area of around two million hectares in the northern part of the Kimberley, and provides a modern way to honour ancestors, share the story of how the land ‘Uunguu’ was made and look after the country in accordance with Wanjina Wunggurr law. The plan sets out how Wunambal Gaambera can live on country and make business, and use both traditional knowledge and western science to care for country and provide a healthy life to the place and to current and future generations.

- A seasonal calendar from the Wunambal Gaambera Healthy Country Plan 2010–2020, showing the integrated relationship between natural and cultural aspects of the environment and the consequent importance of traditional Indigenous land and sea management (graphic design by Lois Haywood, ECI Insitu Pty Ltd, and the Wunambal Gaambera Aboriginal Corporation)
- A planning workshop at Garmbemirri, from the Wunambal Gaambera Healthy Country Plan 2010–2020; the traditional owners used a conservation action planning process to involve relevant people (photo by the Wunambal Gaambera Aboriginal Corporation)
- Uunguu Ranger Raphael Karadada on a freshwater turtle survey (photo by Robert Warren and the Wunambal Gaambera Aboriginal Corporation)
The fauna and flora are also part of a country’s heritage, the product of millions of years of evolution centered on that time and place and hence as much a reason for national concern as the particularities of language and culture.

Edward O Wilson, *The diversity of life*, 1992
1.2.3 Historic heritage

Historic sites relate particularly to the occupation and use of the continent since the arrival of European and other migrants, including pre-1788 Asian and European exploration, contact and settlement sites. Historic places tell us about the society we have formed in Australia over the past two centuries, and provide a tangible link to past events, processes and people. The Australian environment includes rare remnants of early convict history, pastoral properties and small remote settlements, as well as large urban areas, engineering works, factories and defence facilities. Historic heritage illustrates the way in which the many cultures of Australian people (both Indigenous and non-Indigenous) have modified, shaped and created our cultural environment. By its nature, it will continue to evolve to represent the flow of history and changing community perceptions.

1.3 In this chapter

Assessing the condition of Australia’s heritage places is hampered by an incomplete and unrepresentative set of formally identified heritage places, and by the absence of a comprehensive body of reliable national data. Available information tends to relate to inputs such as the number of protected places or funding levels, rather than outcomes such as the actual physical condition and integrity of listed places. However, some conclusions may be drawn from sample surveys, surrogate data and indicators. The SoE reports for 2001 and 2006 both relied on a set of natural and cultural heritage indicators, originally prepared in 1998, as the basis for summary assessment. The same approach has been used here, augmented by some selected case studies and additional information now available from the national data collection project of the former Environment Protection Heritage Council, and Heritage Chairs and Officials of Australia and New Zealand, which has provided some consistent information about heritage listings and human and financial resources.

It is recognised that this is a piecemeal approach that may not thoroughly address some of the complexities and subtleties in the heritage system, including multivalue cultural landscapes, regional perspectives and unlisted sites. However, the approach uses the available data and offers relevant observations.

The assessments in this chapter were also informed by a series of workshops held with relevant stakeholder groups, including the Australian Heritage Council; Heritage Chairs and Officials of Australia and New Zealand; the heads of Australian, state and territory parks agencies; the Australian Government Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) Indigenous Advisory Committee; Australian representatives from the International Council on Monuments and Sites (Australia ICOMOS); and the Australian Committee of the International Union for Conservation of Nature (ACIUCN). Although these workshops cannot replace empirical evidence, they have allowed a high degree of confidence in assessment based on consensus. In addition to workshops and literature reviews, three specialist consulting projects were commissioned to evaluate the condition and integrity of a small sample of places with natural, Indigenous and historic values. The information in this chapter presents a snapshot based on observation, rather than a longitudinal analysis based on comprehensive information.
State and trends of heritage

The current condition and integrity of Australia’s reserved and listed heritage are generally good, with some deterioration evident over recent years. However, the nation’s protected natural and cultural resource is not adequately identified and protected, nor is its conservation adequately resourced.

Unlike other aspects of the Australian environment, heritage places are already a discrete subset, defined by having natural or cultural ‘value’. Therefore, a description of the current state of Australian heritage cannot be a description of the resources themselves (as might occur with coasts, inland waters or land), but rather must be an assessment of what values have been identified and their current condition. Similarly, while it may be possible to measure the condition of other environmental aspects according to a nominal benchmark year of 1750 (representing European settlement), the appropriate benchmark for heritage places is not a particular former condition, but a measure of whether the place retains its heritage values. Retaining heritage values creates the opportunity to transmit value to other generations—an aim that aligns closely with the notion of heritage as our ‘inheritance’.

Identification and assessment can be described according to the different jurisdictions under which heritage places receive listing and statutory protection (i.e. world, national, state or local) and according to the nature of heritage places (i.e. natural, Indigenous or historic). The following assessments and commentary present information for both of these frameworks. In reality, of course, such distinctions are arbitrary and often blurred, as heritage places and their values transcend jurisdictional boundaries and site types. Assessment components used in this section relate to natural and cultural heritage indicators (see Section 1.3).

Australia’s heritage listing structure is complex and reflects both land tenure and governance arrangements. Heritage registers list natural and cultural places at national, state and local levels, but in an inconsistent manner and with disparate levels of resourcing and control.

Australia’s listed natural heritage and reserved lands are in good condition but continue to face threats from invasive species, fire, erosion, use and impacts on threatened species. There are differences in condition according to land tenure and listing status. Available national information relates to a select sample and may not be truly representative.

Of the 85 bioregions in Australia, more than half have at least 10% of their area within reserved land. Although having 10% of each bioregion within reserved land is the current national target, it does not necessarily reflect the fine grain of significant ecosystems and habitats. The Convention on Biological Diversity suggests that a more appropriate target may be 17% of protected land (and 10% for inland waters). There may be merit in considering an even greater percentage, comprising both protected and privately held lands, which should be selected and managed as an interconnected system to help maintain large-scale landscapes and ecosystem processes.

Interest in Indigenous heritage in Australia has increased. There have been many positive developments, but also some trends that significantly undermine the protection of Indigenous heritage. Recognition of the role of Indigenous people in managing Indigenous heritage has expanded, but individual assessment and development decisions cause incremental destruction of the Indigenous cultural resource.

A survey of a national sample of historic heritage places indicates that the majority are in good condition and retain their identified values. Variation in the observed condition is likely to reflect maintenance and repair cycles. Places that are both vacant and in poor condition remain under threat.
2.1 Identification

In Australia, heritage is defined by both statutory and nonstatutory listing processes, which result in inventories and areas of reserved lands. There is an inherent tension in the philosophical difference between identifying a series of individual sites as heritage (a ‘dots on the map’ approach) and listing whole cultural landscapes or reserving areas that may incorporate individual significant places, but that may also have layered multiple values. Nowhere is this tension more apparent than in the difference between a single Indigenous site and the broader Indigenous perspective of country.

2.1.1 World Heritage

Australia has 19 World Heritage sites inscribed on the World Heritage List in accordance with the 1972 World Heritage Convention, to which Australia is a State Party. These places (some of which incorporate more than one land or sea area) are shown in Figure 9.1. Four of these places—the Sydney Opera House, Purnululu, the Australian Convict Sites and the Ningaloo Coast—were inscribed on the World Heritage List between 2006 and 2011, and the Gondwana Rainforests of Australia was renamed. Australian state and territory governments have been preparing a tentative list for future World Heritage nominations.

Source: World Heritage Areas, Australia (2011), Environmental Resources Information Network, Australian Government Department of Sustainability, Environment, Water, Population and Communities, based on Australian Coastline and State Borders 1:100 000 (1990), Geoscience Australia

Figure 9.1 Australian World Heritage sites
1 Heard and McDonald Islands
2 HMAS Sydney II and HSK Kormoran Shipwreck Sites
3 Dirk Hartog Landing Site 1616—Cape Inscription Area
4 Shark Bay, Western Australia
5 Batavia Shipwreck Site and Survivor Camps Area 1629—Houtman Abrolhos
6 The Ningaloo Coast
7 Fremantle Prison (former)
8 Goldfields Water Supply Scheme
9 Dampier Archipelago (including Burrup Peninsula)
10 Wiljde Mia Aboriginal Ochre Mine
11 Porongurup National Park
12 Stirling Range National Park
13 Cheeptop Rock Shelter
14 The West Kimberley
15 Purnululu National Park
16 Wave Hill Walk Off Route
17 Ulku–Kata Tjuta National Park
18 Kakadu National Park
19 Hermannsburg Historic Precinct
20 Great Artesian Basin Springs: Witjira–Dalhousie
21 Ediacara Fossil Site
22 South Australian Old and New Parliament Houses
23 The Adelaide Park Lands and City Layout
24 Australian Fossil Mammal Sites: Riversleigh
25 Great Artesian Basin Springs: Elizabeth Springs
26 Australian Fossil Mammal Sites: Naracoorte
27 Budj Bim National Heritage Landscape—Tyrendarra Area
28 Budj Bim National Heritage Landscape—Mt Eccles Lake Condah Area
29 Dinosaur Stampede National Monument
30 Grampians National Park (Garwan)
31 Mawson’s Huts and Mawson’s Huts Historic Site
32 Great Ocean Road and Scenic Environments
33 Willandra Lakes Region
34 Eureka Stockade Gardens
35 Castlemaine Diggings National Heritage Park
36 QANTAS Hangar, Longreach
37 Point Nepean Defence Sites and Quarantine Station Area
38 Echuca Wharf
39 Ngarrabullgan
40 Point Cook Air Base
41 Mount William Stone Hatchet Quarry
42 Flemington Racecourse
43 High Court of Australia (former)
44 Newman College
45 Royal Exhibition Building and Carlton Gardens
46 IC Building (former)
47 Sidney Myer Music Bowl
48 Melbourne Cricket Ground
49 Rippon Lea House and Garden
50 HMAS Cerberus
51 Tree of Knowledge and curtilage
52 Flora Fossil Site—Yea
53 Coranderrk
54 Wet Tropics of Queensland
55 Tasmanian Wilderness
56 Glenrowan Heritage Precinct
57 Brewhoona Aboriginal Fish Traps (Baarmes Ngurnhu)
58 Recherche Bay (North East Peninsula) Area
59 Bonegilla Migrant Camp—Block 19
60 Brickendon Estate
61 Woolmers Estate
62 Cascades Female Factory
63 Cascade Female Factory Yard 4 North
64 Richmond Bridge
65 Australian Alps National Parks and Reserves
66 Coal Mines Historic Site
67 Port Arthur Historic Site
68 Darlington Probation Station
69 Great Barrier Reef
70 Warumbungle National Park
71 Australian Academy of Science Building
72 Old Parliament House and curtilage
73 High Court—National Gallery Precinct
74 Australian War Memorial and the Memorial Parade
75 The Greater Blue Mountains Area
76 Myall Creek Massacre and Memorial Site
77 Old Great North Road
78 Old Government House and the Government Domain
79 Royal National Park and Garawarra State Conservation Area
80 Cockatoo Island
81 Cyprus Hellene Club—Australian Hall
82 Sydney Harbour Bridge
83 First Government House Site
84 Hyde Park Barracks
85 Sydney Opera House
86 Ku-ring-gai Chase National Park; Lion, Long and Spectacle Island nature reserves
87 Kumell Peninsula Headland
88 Bondi Beach
89 North Head, Sydney
90 Gondwana Rainforests of Australia
91 Glass House Mountains National Landscape
92 Fraser Island
93 Macquarie Island
94 Lord Howe Island Group
95 Kingston and Arthurs Vale Historic Area

Source: National Heritage Spatial Database (2011), Environmental Resources Information Network, Australian Government Department of Sustainability, Environment, Water, Population and Communities, based on Australian Coastline and State Borders 1:100 000 (1990), Geoscience Australia

Figure 9.2 Places on the National Heritage List
2.1.2 National heritage

**The National Heritage List**

The National Heritage List includes natural, historic and Indigenous places throughout Australia (Figure 9.2).

The National Heritage List now contains 95 places, most of which were added between 2005 and 2008 (Figure 9.3). The most recent addition was the west Kimberley, added on 31 August 2011. Following amendments to the EPBC Act in 2007, the national heritage listing program is now confined to places on a ‘priority assessment list’ determined by the minister. In practice, this means that the majority of National Heritage List nominations received since 2007 have lapsed without being assessed. Although some exceedingly important places have been added to the list, the resources available for documentation and assessment, and the rate at which places are being added to the National Heritage List, are declining. Community enthusiasm for the national heritage listing process has also declined as a result of the frustrating experience of seemingly comprehensive and credible nominations not being assessed. Further reductions to the resources available for national heritage listing announced in the 2011–12 Budget will continue this trend (see Section 4.3.1).

**The Commonwealth Heritage List**

The EPBC Act provides that heritage places under Commonwealth ownership should be included on the Commonwealth Heritage List and should have plans of management. There are currently 338 places on the Commonwealth Heritage List, of which only 10 were added between 2005–06 and 2010–11 (Figure 9.4). This small number of recent additions reflects the intensive initial listing phase after the list was established, as well as more recent declines in identification of Commonwealth heritage places by Australian Government agencies.

![Figure 9.3 Number of places added to National Heritage List, 2005–06 to 2010–11](source: Heritage Division, Australian Government Department of Sustainability, Environment, Water, Population and Communities, 2011)
The Register of the National Estate

The Register of the National Estate was established under the Australian Heritage Commission Act 1975 as a list of important natural, Indigenous and historic heritage places. Following amendments to the Australian Heritage Council Act 2003, no new places can be added to or removed from the register. The register will cease to be a statutory register after February 2012 but will be maintained on a nonstatutory basis as a publicly available archive; until then, the minister is required to continue considering the register when making some decisions under the EPBC Act. This transition period was intended to allow governments across all jurisdictions to transfer places from the Register of the National Estate to appropriate heritage registers. However, this process has not been resourced and has not occurred.

The pending demise of the statutory role of the Register of the National Estate will leave many ‘listed’ places without any statutory status. The discontinuation of active management of the register through assessment, addition and removal leaves a significant gap in the national perspective of Australia’s heritage.

2.1.3 State heritage

Australian states and territories also maintain statutory heritage registers. In 2008, the former Environment Protection Heritage Council (the meeting of Australian, state and territory ministers responsible for heritage) agreed that a consistent set of criteria would be developed and used to assess places for inclusion in these registers. However, only the Australian and Victorian governments have adopted and commenced using consistent heritage assessment criteria. Further, the coverage and thresholds vary greatly. Some registers (such as the Australian Capital Territory Heritage Register) include natural, Indigenous and historic places, whereas others include only historic places. In most jurisdictions, the threshold for listing is significance at the state level, although the Tasmanian Heritage Register includes a vast array of locally significant places (see Box 9.20). There are also disparities in the listing programs between states; for example, in 2009–10, relatively high numbers of state listings occurred in both Queensland and Tasmania (Figure 9.5). These proportions may reflect specific assessment projects (see Box 9.6) or different resource allocations.

At the state and territory level, it is possible to examine the different values for which individual places have been listed. Figure 9.6 presents an overview of state and territory statutory registers according to assessment criteria. Care should be exercised in interpreting this chart (as places may be listed for more than one value and different criteria frequencies may apply to natural, Indigenous and historic places), but the data do suggest a skew towards criterion D (places that demonstrate principal characteristics) and criterion G (places that have strong or special association with community or cultural groups), and away from criterion F (places that demonstrate creative or technical achievement) and criterion C (places with significant research value). This pattern may reflect the underlying nature of the heritage resource or a particular focus in the current assessment and listing process. Ongoing collection of similar information and separate analysis of natural, Indigenous and historic places may provide useful insight into bias or gaps in current heritage listing programs.

Figure 9.4 Number of places added to Commonwealth Heritage List, 2005–06 to 2010–11

Source: Heritage Division, Australian Government Department of Sustainability, Environment, Water, Population and Communities, 2011
ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities Heritage Division: Heritage Chairs and Officials of Australia and New Zealand National Data Collection Standards project, unpublished data

### Figure 9.5
Places added to the state heritage registers, 2009–10

### Figure 9.6
Criteria under which heritage places were added to the state heritage registers, 2009–10

#### 2.1.4 Local heritage

The vast majority of heritage listing in Australia occurs at the local level by local government agencies. The diversity in council areas across the nation and differences in planning statutes and approaches make it difficult to aggregate comparable data. Some local heritage lists include places of state, national or world heritage value; others do not. Most local lists are exclusively comprised of historic places. Local heritage places are included on the Tasmanian Heritage Register, but not on other state heritage registers. Victorian data relate to individual properties (a number of which may be incorporated in a single listing), whereas other state and territory data relate to listed places. A general picture of what is locally listed in Australia is provided in Figures 9.7 and 9.8.

The raw listing data illustrate several points. Not surprisingly, heritage listing is most intensive in coastal areas, and concentrated in and around urban centres. Very high densities in Victoria reflect the approach of measuring individual properties rather than heritage items. Blank areas are generally those for which reliable information has not been sourced, rather than an indication that nothing is listed. However, some parts of the nation seem severely under-represented.
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**Figure 9.7 Number of heritage places listed by local government area**

Data for New South Wales, Victoria, Queensland, South Australia and Western Australia are from local government planning mechanisms. Tasmanian data are from the Tasmanian Heritage Register, which includes places of local and state heritage significance. Data for the Northern Territory and the Australian Capital Territory are for places listed in territory registers. Data are not captured at the local government level.

**Figure 9.8** presents the local listing data from Figure 9.7 adjusted to show heritage listing at the local level per hundred people. This adjustment provides an indicative relative measure that takes different population densities into account. The picture that emerges differs in some interesting respects from the raw information. The apparent density of listings in coastal and urban areas is reduced; the national spread of listings is more even and arguably does reflect the relative intensity of historical land use. It also emerges that particular rural areas in New South Wales, Queensland, South Australia and northern parts of Western Australia may be under-represented.

### 2.1.5 Natural heritage

**Natural and cultural heritage indicator 1 considers the process of listing, area and distribution of identified natural heritage places**

Appropriate statutory protection of Australia’s natural heritage requires a combination of individually listed places and an adequate, representative set of reserved lands. The National Heritage List includes 54 places that were predominantly included for natural heritage values. At the state and local level, information on
Figure 9.8 Number of heritage places listed per hundred people by local government area

Data for New South Wales, Victoria, Queensland, South Australia and Western Australia are from local government planning mechanisms. Tasmanian data are from the Tasmanian Heritage Register, which includes places of local and state heritage significance. Data for the Northern Territory and the Australian Capital Territory are for places listed in territory registers. Data are not captured at the local government level.

places included in heritage lists for natural values is inconsistent between jurisdictions. Australia’s National Reserve System includes Australian and state national parks, other lands reserved for conservation purposes, Indigenous protected areas, areas managed by conservation organisations and ecosystems protected by farmers on their private working properties—together comprising more than 9300 protected areas covering nearly 13% of Australia. The National Reserve System is being actively developed to reserve lands across 85 bioregions, each of which is a large, geographically distinct area of similar climate, geology, landform, vegetation and animal communities. These bioregions are presented in a bioregional map: the Interim Biogeographic Regionalisation for Australia (IBRA) (Figure 9.9). The aim of the National Reserve System is to protect a comprehensive range of ecosystem and other important environmental values within each of the 85 bioregions. Priority is given to increasing the area that is protected in under-represented bioregions (less than 10% protected).15
approximately half of the natural heritage areas reserved lands are also a relevant consideration. However, the size and resilience of reserved lands are also a relevant consideration: approximately half of the natural heritage areas in Australia that occur in public reserved lands are in pockets of less than 100 hectares. By contrast, 82% of the total area of public reserved lands occurs in blocks of more than 100,000 hectares.\(^b\)

\(^b\) Workshop discussion with the heads of national, state and territory parks agencies, 27 August 2010

Although the National Reserve System is recognised as the major current instrument for protection of intact ecosystems (see also Chapter 8: Biodiversity), issues arise in relation to what constitutes a comprehensive, adequate and representative system. Protected lands need to support biodiversity conservation under current and future climatic conditions. The Convention on Biological
Diversity suggests a target of 17% of each kind of terrestrial ecosystem by area. Recent assessment by WWF-Australia takes a more fine-grained approach to individual ecosystems, based on consideration of vegetation communities as an indicator of ecosystems, and concludes that at present only approximately one-third of the required areas are reserved (Figure 9.11; see also Chapter 8: Biodiversity).

Areas of natural heritage occur in both publicly and privately owned and managed lands, and their heritage values may transcend ownership boundaries. Australia’s natural heritage would benefit from a whole-of-landscape approach that addresses management regimes across land tenure d www.cbd.int/convention

and considers individual places, different land holdings and subregions within the National Reserve System as part of a broadly interconnected system. The need for linking landscape conservation across tenures is now widely recognised, and there have been welcome initiatives, including the nomination of large-scale conservation areas, which, in conjunction with the National Reserve System, should help to maintain natural Australian landscapes and ecosystem processes. Cross-tenure identification of values—coupled with management that is focused on the resource and its values, rather than its ownership—would be consistent with global trends in natural heritage management. e

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d www.cbd.int/convention

In Victoria, objects and places with Indigenous heritage value are protected through the Aboriginal Heritage Act 2006, which began in May 2007 and is administered by Aboriginal Affairs, Victoria. (Some post-contact places with Indigenous values may also be protected and managed under the Heritage Act 1995.)

The Aboriginal Heritage Act established the Victorian Aboriginal Heritage Register, which includes records of all known Aboriginal places in Victoria, as well as known private collections of Aboriginal objects. The register was established in the 1970s under the Archaeological and Aboriginal Relics Preservation Act 1972. As at June 2011, there were 32,599 registrations, with approximately 1000 new registrations being added each year. It is estimated that the existing records represent a survey of approximately 3% of the state’s land area.

The Aboriginal Heritage Act includes a range of protective mechanisms. A key aspect of these provisions is the positive value placed on the protection of Aboriginal cultural heritage. Activities that may harm Aboriginal heritage can only be carried out in accordance with an approved cultural heritage management plan or a cultural heritage permit. A cultural heritage management plan is a written report containing the results of an assessment and recommendations for measures to be taken before, during and after an activity, to manage and protect Aboriginal cultural heritage. Cultural heritage management plans are prepared for projects subject to an ‘environmental effects statement’ process, if required by the minister responsible for the Act or under regulations that make them mandatory for listed high-impact activities.

A cultural heritage permit cannot be used if a cultural heritage management plan is mandated, so there has been a move away from permits since 2007. In this period, permits have been issued for excavating land (19 permits); carrying out an activity that will, or is likely to, harm Aboriginal cultural heritage (139); buying or selling an Aboriginal object (40); undertaking scientific research (7); and removing an Aboriginal object from Victoria (2). There has been one successful prosecution (for selling an Aboriginal object without a permit), and four stop orders were issued.

Between May 2007 and June 2011, approximately 4000 Aboriginal places were registered in Victoria, 1190 cultural heritage management plans were approved and 207 permits were issued.

Box 9.5 Victorian Indigenous heritage—listing and management of Aboriginal places

In Victoria, objects and places with Indigenous heritage value are protected through the Aboriginal Heritage Act 2006, which began in May 2007 and is administered by Aboriginal Affairs, Victoria. (Some post-contact places with Indigenous values may also be protected and managed under the Heritage Act 1995.)

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The Aboriginal Heritage Act includes a range of protective mechanisms. A key aspect of these provisions is the positive value placed on the protection of Aboriginal cultural heritage. Activities that may harm Aboriginal heritage can only be carried out in accordance with an approved cultural heritage management plan or a cultural heritage permit. A cultural heritage management plan is a written report containing the results of an assessment and recommendations for measures to be taken before, during and after an activity, to manage and protect Aboriginal cultural heritage. Cultural heritage management plans are prepared for projects subject to an ‘environmental effects statement’ process, if required by the minister responsible for the Act or under regulations that make them mandatory for listed high-impact activities.

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Between May 2007 and June 2011, approximately 4000 Aboriginal places were registered in Victoria, 1190 cultural heritage management plans were approved and 207 permits were issued.

Other initiatives taken to assist with conservation of the state’s Indigenous heritage include establishment of the Aboriginal Cultural Heritage and Registry Information System, which provides real-time online access to the register for approved users, and a nationally accredited Certificate IV in Aboriginal Cultural Heritage Management course offered by La Trobe University.

Source: Aboriginal Affairs Victoria, 30 June 2011

2.1.6 Indigenous heritage

Natural and cultural heritage indicator 2 considers the process of listing, area and distribution of identified Indigenous heritage places

Survey, assessment and listing of Indigenous heritage places are inconsistent around Australia. Some Indigenous places are included separately on the National Heritage List, but many more are included within large areas of reserved lands—the Uluru–Kata Tjuṯa, Kakadu and Willandra Lakes World Heritage areas being prominent among these. In addition, almost all national parks include significant Indigenous heritage places (which are thereby afforded some statutory protection). At the state level, some jurisdictions proactively prepare registers or statutory lists of Indigenous sites (Box 9.5), whereas others rely on ‘blanket’ protective provisions in legislation. The result is that there is no readily available national perspective on the nature and extent of the Indigenous resource—neither what is being listed nor what is potentially being destroyed. Survey and assessment programs for Indigenous heritage are often resourced and undertaken in response to threats from development projects. Overall, it is likely that the representation of Indigenous places within reserved lands and on major statutory heritage lists is inadequate. This is especially the case for the National Heritage List.

2.1.7 Historic heritage

Natural and cultural heritage indicator 3 considers the process of listing, area and distribution of identified historic heritage places

Australian historic place statutory registers are well established in all jurisdictions, but have been populated in an ad hoc manner, initially with a strong architectural focus and then in response to specific development threats. More recent practice in historic heritage listing has included a wider range of site types, such as historic archaeological sites, cultural landscapes and cultural routes, with increasing numbers of systematic survey and assessment programs, according to either geographic areas or historic theme. There has also been far greater direct involvement of local communities and incorporation of heritage lists within planning statutes (Box 9.6). Where applied, these approaches will lead towards more comprehensive and representative heritage lists and a more flexible system that can change in response to evolving community perceptions and needs.

2.2 Condition and integrity

This section examines the condition and integrity of Australian heritage places according to both jurisdiction and nature.

2.2.1 World Heritage

In 2011, the Australian Government, in consultation with state governments produced a periodic report on our World Heritage sites. An obligation of the World Heritage Convention, the report assesses whether the World Heritage values of our 19 properties inscribed on the World Heritage List are being maintained. Australia’s report synthesised information and views provided by World Heritage property managers, Australian and state government agencies, consultative committees, Australian representatives from the International Council on Monuments and Sites, and the Australian Committee of the International Union for Conservation of Nature.

Australia’s periodic report is generally very positive, acknowledging Australia’s expertise in World Heritage management, available human and financial resources, and the legislative protection of the EPBC Act. Nonetheless, the report found that the three most significant factors affecting World Heritage properties in Australia are:

- invasive and alien species or hyperabundant species
- climate change and severe weather events
- social or cultural impacts on heritage (including changes in traditional ways of life, as well as impacts of tourism).

Management needs identified in the report include further work on indicators and monitoring, and improved education, information and awareness building.

Box 9.6 Rediscovering Queensland—how major improvement can be achieved by focusing resources on systematic survey and assessment

In 2005, the Queensland Environmental Protection Agency commissioned an overall methodology and historical context study as preparation for a statewide survey of heritage resources. The methodology was based on facilitating early and ongoing community engagement in identifying heritage. Techniques developed included exemplar communication and community consultation strategies, an electronic fieldwork recording system, and an analysis process to feed outcomes into local and state heritage protection mechanisms and celebrations. In 2006, regional studies began in far north Queensland. By providing resources and directly engaging local people in the process of heritage identification, the Queensland Government has encouraged communities to take greater responsibility for identifying, conserving and managing their heritage places.

A proactive approach to identifying places of heritage significance has given the community, local government and owners certainty around heritage issues and has provided an opportunity for constructive engagement about the management of heritage places with local government, owners and the community. Fiona Gardiner, Director Heritage, Department of Environment and Resource Management, Queensland
In 2008, an Australian World Heritage Advisory Committee was appointed to provide a forum for liaison between the individual World Heritage area advisory committees and advice to the government on cross-cutting issues. The committee has met face to face on three occasions, and has provided advice and recommendations to Australian Government and state officials and to the Environment Protection and Heritage Ministerial Council (now abolished), but its activities are constrained by limited Australian Government staff support and other resources.

2.2.2 National heritage

National heritage is identified and managed by the Australian Government under the EPBC Act, in accordance with amendments made in 2003, which created the National Heritage List and the Commonwealth Heritage List. The first review report on these lists, covering the period from 1 January 2004 to 30 June 2008, was published in 2008. In accordance with requirements specified in the EPBC Act, this report is highly focused on the processes followed and compliance with them, rather than providing an independent assessment of the condition and integrity of listed places.

Studies of natural, Indigenous and historic heritage completed for this SoE report suggest that identified places with national heritage values (including all of Australia’s World Heritage places) are in good condition and retain a high degree of integrity. This finding reflects that the overwhelming majority of these places are in public ownership, were often subject to conservation planning as part of the listing process, and in many cases are specifically managed for conservation purposes.

However, there have been a number of instances of adverse impact on condition or heritage value, including, for example, the poisoning of the Tree of Knowledge in the central western Queensland town of Barcaldine, and damage to Indigenous rock art on the Burrup Peninsula. Incremental damage is also wrought by the continuing presence of threats, including site-specific issues such as rabbits and rodents on Macquarie Island, and more general challenges posed by climate change, population growth and economic development. Although, in theory, the Australian Government should be alerted to the prospect of adverse impacts on the condition and integrity of nationally significant places, the reality is that available resources confine government activities to generally reactive processes and place limits on the national assessment and listing process.

For the Commonwealth Heritage List, the EPBC Act requires Australian Government agencies to prepare heritage strategies and management plans directed towards retaining Commonwealth heritage values. Although a number of such plans and strategies are in place, reliable data—based on monitoring of the condition of Commonwealth heritage places—are not available, so the outcome of this management cannot be meaningfully assessed.

2.2.3 State heritage

At the state level, efforts and resources continue to focus on listing and impact assessment processes, rather than on monitoring and evaluating condition and integrity. There is also considerable variation in scope and approach to state SoE reporting. However, it is possible to glean some general understanding from individual state and territory SoE reports:

- The Australian Capital Territory regards its heritage as in good condition, but notes the need for adequate protection when changes are made to the responsibilities of the National Capital Authority, to ensure compliance with Australian Capital Territory heritage legislation.

- New South Wales notes that knowledge is increasing and information gathering is continuing, as are efforts to improve the protection of natural and cultural heritage assets and values through a range of related tools, including regulation, nonstatutory agreements and partnerships. There has been a significant increase in land protected for Aboriginal cultural values and continuing reliance on heritage listing as a major mechanism for managing heritage across the state.

- In Queensland, development pressures continue to degrade both natural and cultural heritage, in combination with more recent impacts of drought, fire, flood and major weather events. The majority of places identified as being endangered by the Australian Council of National Trusts in the early 2000s remain under threat, or are even damaged and destroyed. Initiatives such as Rediscovering Queensland (see Box 9.6) seek to address the challenges of managing and protecting heritage values posed by lack of knowledge and information about the condition of natural and cultural heritage places.
• **In South Australia**, measures of the state of heritage are strongly focused on the listing process, rather than monitoring condition and integrity. Available information shows a significant increase in the number of listed places and increased protection for Indigenous sites and objects, and shipwrecks, but decreasing documentation of geological heritage.27

• **Tasmania** is in the process of major reviews for both Indigenous and historic heritage management, and state-level reporting acknowledges the need to develop clear indicators that can be used to measure condition, trends and changes. A range of environmental indicators have been suggested: knowledge of heritage places and objects, visual condition and integrity of heritage areas and objects, availability and distribution of skills, and community awareness and involvement.28 (See Box 9.7.)

• **In Victoria**, heritage is covered through a separate ‘state of heritage’ report, which generally concludes that the state of heritage is good, with some significant deterioration in condition and integrity at particular places.29

  The correlation between good condition and high integrity is obvious, with public heritage places having noticeably the highest integrity. The places with poorest condition also have the lowest integrity, with privately owned places faring worse. Just over a third of rural places have good condition and condition deteriorates significantly as distance from Melbourne increases. *Marshall et al.*29

• **In Western Australia**, reporting on the state of heritage acknowledges that government arrangements are fragmented, impeding adequate protection and management. There is no single list of heritage places, nor an adequate program for monitoring and reporting, which affects heritage management decisions. Anecdotal evidence suggests that the condition of a number of heritage places is declining, but there is no empirical data to support this observation.30

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**Box 9.7 A government-funded conservation program improves the condition of a state-listed heritage place**

Rotten Row, the married quarters of the Cascades Probation Station in south-east Tasmania, was a much-photographed ruin on the Tasman Peninsula. As an abandoned structure for more than 50 years, it was uneconomical to conserve or maintain as a ruin. However, the property owners decided to conserve and adapt the building for accommodation use. The underlying need was for access to appropriate expertise and funding. Expertise in conservation repairs was found locally, and funding from the National Heritage Investment Initiative was secured to allow the structure to be rebuilt. An enthusiastic owner, skilled tradespeople, professional advice and government funding combined to retain and recover the heritage values of this state-significant place from the convict period.

![Rotten Row before (left) and after (right) conservation work (photos by Peter Rigozzi)](image_url)
2.2.4 Local heritage

At the local level, comprehensive national data about the condition and integrity of Australia’s heritage are not available. However, it is evident that several key factors influence local heritage:

- The identification process, which is inconsistent and incomplete on a national basis, leads to inadequate information for good decision-making.
- Processes for impact assessment and considerations of development consent are almost invariably framed in terms of one-off adverse effects on local heritage, with a likely (but unproven) cumulative adverse effect, potentially leading to progressive, incremental destruction.
- The establishment of clear up-front heritage policies and guidelines can foster outcomes for condition and integrity that are commensurate with the level of heritage significance, enabling better heritage outcomes.
- Many local and state authorities have instigated incentive programs, including access to information, grants and award schemes, which improve the condition and values of some local heritage places (Box 9.8).
- Community stewardship programs, such as Landcare, Hands on Heritage and Working on Country, also play a significant role in heritage conservation at the local level.

2.2.5 Natural heritage

Natural and cultural heritage indicator 5 considers the physical condition and integrity of a sample of natural heritage places

There is no ‘central’ picture of the condition and integrity of natural heritage places, although this is an issue that has been identified in Australia’s Strategy for the National Reserve System 2009–30. An assessment of natural heritage places for this report focused on the current condition and integrity of 75 places located on public and private lands across Australia. Many of these places form part of the National Reserve System, which includes more than 9300 protected areas.

Box 9.8 Heritage incentives at the local government level

The Shire of Busselton is committed to helping owners conserve heritage places wherever possible. Its Environment and Heritage Conservation Policy includes a range of incentives that can be offered to owners in return for a commitment to conservation of the heritage place. Incentives can be offered to owners of places on the Heritage List, on the Municipal Heritage Inventory or located in a heritage area.

Incentives take the form of relaxation or modification of one or more of the planning requirements for that place that would normally apply under Town Planning Scheme 20 or the Residential Design Codes. This includes but is not limited to:

- parking requirements
- plot ratio
- residential density
- use categories
- the requirement for only one dwelling on a rural lot (which can be relaxed if an owner wishes to construct a new dwelling and the existing dwelling is a listed heritage place).

The shire may, in certain circumstances, allow a reduction of rates in return for conservation works to a heritage place. This will apply in the year the work is carried out or a subsequent year and for the following four years (a total of five years), at the discretion of the shire.

In return for incentives, the shire may require the owner of a heritage place to enter into a heritage agreement under the Heritage of Western Australia Act 1990 or a heritage agreement under the Local Town Planning Scheme with the Shire of Busselton. This policy was adopted in 2010. Proposals are considered on a case-by-case basis, with the Regional Heritage Adviser advising on and negotiating appropriate heritage outcomes.
We Aboriginal people have obligations to care for our country, to look after djang, to communicate with our ancestors when on country and to teach all of this to future generations.

The study analysed the condition and integrity of natural heritage places by reviewing specific factors, including their natural heritage values; effects such as erosion, climate change and weeds; presence of threatened species; place use (including recreational and other activities); documented management regimes; and wildfire and weather events. The limited sample size for the study means that, at best, it provides only an anecdotal indication of the natural heritage condition of the surveyed places. For many places, information was not readily available.

The study suggests that places on the World Heritage List and National Heritage List have great threats to their condition, mainly due to their higher use and associated impacts. Similarly, higher use meant that places in New South Wales and Victoria recorded a larger number of threats, reflecting population pressures and visitation. The places assessed also faced a range of threats from both natural and anthropogenic factors, including weather events, wildfires, invasive species, soil erosion, and deficiencies in general management frameworks or particular plans and resources for issues such as threatened species.10

2.2.6 Indigenous heritage

Traditional owners should have an unqualified right to refuse a cultural heritage management plan, permit or any other form of authorisation that relates to the protection or destruction of cultural heritage. Schnierer

Natural and cultural heritage indicator 7 considers the physical condition and integrity of a sample of Indigenous heritage places

Indigenous heritage is managed through multiple jurisdictions, and a cohesive picture is difficult to achieve. This fragmented view has been exacerbated by the progressive demise of the Register of the National Estate.

The State of Indigenous cultural heritage 2011 report considered two important indicators of the state of Indigenous heritage: the physical condition and integrity of Indigenous heritage places, and the use of Indigenous languages.12 This report found that the trend towards an increasing interest in Indigenous heritage in Australia has continued, and listing of Indigenous heritage places on the national and state heritage lists has continued to grow—in some jurisdictions, more strongly than other forms of heritage listing.

Overall, there have been a large number of positive developments, but also some trends that significantly undermine the protection of Indigenous heritage. Conflicts about destruction of Indigenous heritage by industry activities remain common, as do debates about whether the support available for Indigenous culture and heritage programs is adequate. One of the main threats to Indigenous heritage places is conscious destruction through government-approved development—that is, development for which decision-makers are aware of (or obliged to be informed about) Indigenous heritage impacts, yet choose to authorise the destruction of Indigenous heritage.12 This widespread process, combined with a general lack of understanding of physical Indigenous heritage, means that individual decisions on assessment and development result in progressive, cumulative destruction of the Indigenous cultural resource.

The State of Indigenous cultural heritage 2011 report particularly noted that increased regulation and reporting of Indigenous heritage, required as part of environmental assessment for development approvals, had not reduced the rate of approved destruction of significant Indigenous heritage sites, which is generally opposed by Indigenous communities.12

Indigenous people play an important role in managing Indigenous heritage and sustainably managing Australia’s natural resources, including an increasing percentage of Australia’s reserves. Indigenous traditional knowledge for environmental management is a growing area of research,12 with a number of partnership programs between Indigenous groups and governments. Policies are beginning to recognise the relationship between natural, cultural and historic heritage, and how these are integrated under Indigenous definitions of heritage. Some jurisdictions also recognise Indigenous people’s rights to use, access and manage lands, waters and natural resources for cultural purposes.

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The Tjilbruke dreaming trails are in the traditional lands of the Kaurna nation in South Australia. Tjilbruke dreaming relates to the journey taken by Tjilbruke, ancestral creator being of the Kaurna people, who shaped the land into the formation that people know today. Tjilbruke dreaming is the predominant dreaming of southern Kaurna country. Among other things, the dreaming explains the creation of seven freshwater springs along the coast of the Fleurieu Peninsula between Crystal Brook in the north, through the Adelaide plains, to Parewarangga (Cape Jervis) in the south (Figure A). The dreaming is a complex story that speaks of creation, the law and human relationships for Kaurna people.

The trails are spread over large tracts of public and privately owned lands, extending through four local government areas and some national parks.12 The trails are managed by the four local councils along the trails, in some cases in partnership with the Kaurna nation. The trails are widely regarded by non-Aboriginal South Australians as an important feature of the region.

However, the involvement of Indigenous people in heritage management remains primarily in the form of consultants and advisers, rather than formal decision-makers. The capacity of Indigenous people to care for their own heritage, exercise responsibility for country and transmit cultural practice to new generations also continues to be hindered by local government arrangements (Box 9.9), as well as social and economic disadvantage, as acknowledged in the Australian Government’s Closing the Gap initiative.33

**Box 9.9 Tjilbruke dreaming trails, South Australia**

The Tjilbruke dreaming trails are in the traditional lands of the Kaurna nation in South Australia. Tjilbruke dreaming relates to the journey taken by Tjilbruke, ancestral creator being of the Kaurna people, who shaped the land into the formation that people know today. Tjilbruke dreaming is the predominant dreaming of southern Kaurna country. Among other things, the dreaming explains the creation of seven freshwater springs along the coast of the Fleurieu Peninsula between Crystal Brook in the north, through the Adelaide plains, to Parewarangga (Cape Jervis) in the south (Figure A). The dreaming is a complex story that speaks of creation, the law and human relationships for Kaurna people.

The trails are spread over large tracts of public and privately owned lands, extending through four local government areas and some national parks.12 The trails are managed by the four local councils along the trails, in some cases in partnership with the Kaurna nation. The trails are widely regarded by non-Aboriginal South Australians as an important feature of the region.
The sites along the Tjilbruke dreaming trails are still used by local Kaurna people today as part of their living culture, and the Kaurna people have a customary responsibility to manage and maintain the trails. Although there is widespread recognition of the significance of the trails and the need for access for the Kaurna to continue cultural practices, their ability to fulfil their responsibility to manage the sites is severely limited because the trails are located on public and private lands, none of which are Aboriginal owned or controlled. The traditional owners are therefore heavily reliant on landowners to manage and maintain the trails and sacred sites.

The trails are reportedly in fair physical condition overall, although some sections are in better condition than others. There is ongoing maintenance on some sections of the trails located on public land, but funding for site maintenance and upkeep is an ongoing issue. The integrity of the cultural practices associated with the trails is affected by the proximity of residential housing to some places used for secret men’s and women’s business.

Source: Schnierer et al.12

Natural and cultural heritage indicator 24 is a survey of use of Indigenous languages

Indigenous language is an extraordinarily important indicator of the health of Indigenous culture and thus the condition of the nation’s Indigenous heritage.\(^h\)

Reporting on Indigenous language has focused on numbers and proportions of speakers, using data collected by the Australian Bureau of Statistics and the National Aboriginal and Torres Strait Islander Social Survey (NATSISS) and, more recently, from the National Indigenous Languages Survey, a comparative assessment of the endangerment status of individual Indigenous languages across the country (National Indigenous Languages Survey, as cited in Schnierer et al.12). Work for this report focuses on indicators of the vitality of Indigenous language, including:

- intergenerational language transmissions
- absolute number of speakers
- official attitudes and policies towards languages
- language programs
- proportion of Indigenous people whose main language spoken at home is an Indigenous language
- proportion of Indigenous people who speak an Indigenous language.

Indigenous Australian languages have rapidly declined since European settlement and have been replaced by English or creoles. Today, Australian society is effectively monolingual. Although English is not officially recognised as the national language, it is the language of every societal institution, including government, legal and education systems.

At the time of European settlement, there were more than 250 Aboriginal languages. Today there are just 145 languages, most of which are no longer fully or fluently spoken. Only three to six languages are still spoken by all members of all generations in all domains (Table 9.1), although some Indigenous communities still use fragments of their language even when it is not fully spoken. The endangered status of Indigenous Australian languages is also illustrated by the slow but steady decline in the number of Indigenous people who speak an Indigenous language at home. In the 2008 NATSISS, 11.5% of Indigenous people aged 15 years or over spoke an Indigenous language at home, compared with 12% in 2002 (National Indigenous Languages Survey, as cited in Schnierer et al.12).

The majority of the widely spoken Indigenous languages are spoken in remote areas of Western Australia, the Northern Territory and Queensland, where it was difficult for the non-Indigenous colonists to establish settlements. In these areas, the focus of language policy and programs is on maintenance and preservation. In other parts of the country, particularly in the south-east and along the south-east coast, Indigenous languages are no longer fully or fluently spoken. The focus in these regions is on language revitalisation—a process that has been the subject of increasing interest and support from the Indigenous community over the past five years.

In 2009, the Australian Government launched a new national Indigenous languages policy. This aims to maintain critically endangered languages and reclaim unspoken Indigenous languages by providing a framework for coordinated action among the bodies involved, including government, Indigenous language organisations, cultural institutions, and educational and research institutions. However, the new national policy was not accompanied by a boost to the funding program that underpins it.

Ironically, at the same time as the Australian Government was launching its new Indigenous languages policy, the Northern Territory Government withdrew funding for bilingual education from the remaining bilingual schools, effectively ending bilingual education. The division between the national and territory policy is a major obstacle to implementing a coherent direction for Indigenous languages, especially in areas such as education.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Endangerment description</th>
<th>Number of languages</th>
<th>Languages include</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Safe</td>
<td>3–6</td>
<td>Alyawarr, Girramay, Nyangumarta, Walmajarri, Walpiri, Yanyuwa</td>
</tr>
<tr>
<td>4</td>
<td>Unsafe</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Definitely endangered</td>
<td>2</td>
<td>Garrwa, Kuku Yalaji</td>
</tr>
<tr>
<td>2</td>
<td>Severely endangered</td>
<td>9</td>
<td>Adnyamathanha, Kayardild, Kaytetye, Koko Bera, Mudburra, Rembarrnga, Tainikult, Waanyi, Warlmanpa</td>
</tr>
<tr>
<td>1</td>
<td>Critically endangered</td>
<td>14</td>
<td>Alawa, Bardi, Kalaw Lagaw Ya, Kalaw Kawaw Ya, Lardil, Meriam Mir, Ngarlawangka, Tjungundji, Umbindhamu, Wajarri, Wambaya, Wangkatha, Wargamay, Yidiny</td>
</tr>
<tr>
<td>0</td>
<td>No longer fully spoken</td>
<td>155</td>
<td></td>
</tr>
</tbody>
</table>

Note: The NILS in 2005 was the first comprehensive national survey of Indigenous Australian languages, and assigned the following endangerment ratings:

- ‘Safe’ means the language is regularly used by all age groups, including children.
- ‘Unsafe’ means the language is used by 30–70% of the under-20 age group part of the time or in a partial fashion, and is used by the parental generation and upwards.
- ‘Definitely endangered’ means the language is most used by the parental generation (20+ years) and upwards.
- ‘Severely endangered’ means the language is mostly used by the grandparental generation (40+ years) and upwards.
- ‘Critically endangered’ means the language is known to very few speakers, in the great-grandparental (60+ years) generation.
- ‘No longer fully spoken’ means there are no speakers left.

Source: National Indigenous Languages Survey, as cited in Schnierer et al.

2.2.7 Historic heritage

Natural and cultural heritage indicator 6 considers the physical condition and integrity of a sample of historic heritage places

The study of condition and integrity of historic heritage places for this report took the form of a physical survey of a proportion of the places entered in the Register of the National Estate and, in some cases, the various state and territory heritage registers. The survey covered every state and territory, and included as wide a regional coverage as the existing heritage registers allow, with a particular emphasis on an equal spread of places in rural and urban environments. The study recognised the importance of including local places, as these are often where the majority of Australians interact with heritage. The places included in the survey were predominantly buildings, with some other types of places, such as industrial sites.
Owing to resource limitations, the survey considered physical condition and integrity rather than intangible values.

The survey provides a simple overview of the continued existence, condition, integrity and use of a sample of the nation’s historic heritage, and allows trends in the health of that heritage to be identified (Figure 9.12). The study repeated a survey first undertaken for the 2001 SoE report and repeated in 2004, and was therefore able to identify trends apparent over the intervening period. The study found that the majority of historic heritage places are in fair to good condition and retain integrity of their identified values, with relatively little change in the condition or integrity of the survey sample.

The report notes that there is a substantial gap in the process of monitoring the state of the historic environment, as the health of heritage in a huge area of the continent has not been included in samples used for SoE reporting. The authors note that this gap in the data might be addressed, or at least tested, by studying or surveying specific, selected nonurban and remote areas in each jurisdiction.11

The authors also observe that natural cycles in heritage place maintenance might skew the observation of their condition. Historic places particularly may be conserved as funds become available to the owner or manager. For example, grant funds may instigate a one-off major conservation exercise. Alternatively, after a long period with no maintenance, an owner may decide that works cannot be deferred any longer, or a place may change ownership and deferred maintenance then takes place, with or without additional conservation works. The effect on the results of condition monitoring is that, if maintenance is deferred, the condition of the place is reported as deteriorating, when in fact it is part of a relatively normal cycle of maintenance. The authors suggest that more refined observation of this cycle and the drivers that lengthen or shorten the interval between maintenance events might help distinguish between monitoring of the normal cycle and identification of deterioration in the nation’s historic environment. This in turn could lead to better targeted or better designed government conservation funding programs.11

![Figure 9.12 Changes in integrity and condition of historic heritage places, 2000–11](image)

Source: Pearson & Marshall11
## 9.1 Assessment summary

### State and trends of heritage values

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Natural heritage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process of listing, area and distribution of identified natural heritage places</td>
<td>Statutory heritage lists are inconsistent in coverage of natural heritage places, both between jurisdictions and across site types. Geodiversity is poorly represented. The National Reserve System focuses on incorporating examples of the full range of ecosystems and other important environmental values across each of the 85 bioregions. Although there are known gaps and alternative targets that are greater and more refined, 51 of the 85 bioregions have more than 10% of their area protected in the reserve network.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical condition and integrity of natural heritage places</td>
<td>Data relating to natural heritage values, environmental threats and management plans for a sample of natural heritage places indicate that Australia’s reserved lands are in good condition but continue to face threats from invasive species, fires, erosion, use and effects on threatened species. There are differences in condition according to land tenure and listing status. Available national information relates to a select sample and may not be truly representative.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Indigenous heritage</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process of listing, area and distribution of identified Indigenous heritage places</td>
<td>There is no nationally coordinated inventory of significant Indigenous places. Survey and assessment programs for Indigenous heritage are most often resourced and undertaken in response to threats from development projects. There is inadequate representation of Indigenous places within public sector reserved lands and on the major statutory heritage lists, particularly the National Heritage List.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical condition and integrity of Indigenous heritage places</td>
<td>Interest in Indigenous heritage in Australia has increased. There have been many positive developments, but also some trends that significantly undermine the protection of Indigenous heritage. Recognition of the role of Indigenous people in managing Indigenous heritage has expanded, but individual assessment and development decisions cause cumulative incremental destruction of the Indigenous cultural resource.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Indigenous heritage continued

#### Use of Indigenous languages

Indigenous languages remain highly endangered, although there have been some improvements in the number of speakers and additional language revitalisation programs.

#### Historic heritage

**Process of listing, area and distribution of identified historic heritage places**

Significant progress has been made in the collection of data relating to statutory listing processes for historic heritage at the national and state level. Although inconsistencies remain, the number of listed places has increased and there have been more systematic, thematic historic heritage assessment projects.

**Physical condition and integrity of historic heritage places**

Survey of a national sample of historic heritage places indicates that the majority are in good condition and retain integrity of their identified values. Variation in the observed condition, indicating minor improvement, is likely to reflect maintenance and repair cycles, although places that are both vacant and in poor condition remain under threat.

### Recent trends

<table>
<thead>
<tr>
<th>Trends</th>
<th>Grade</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improving</td>
<td>Very good</td>
<td>Places with heritage values have been systematically and comprehensively identified and included in relevant inventories or reserves. Heritage places are in very good condition with identified values retaining a high degree of integrity.</td>
</tr>
<tr>
<td>Deteriorating</td>
<td>Good</td>
<td>Places with heritage values have been systematically identified and included in relevant inventories or reserves. Heritage places are in good condition with identified values generally retaining their integrity.</td>
</tr>
<tr>
<td>Stable</td>
<td>Poor</td>
<td>Places with heritage values have not been systematically identified. Heritage places are in poor condition and/or their values lack integrity.</td>
</tr>
<tr>
<td>Unclear</td>
<td>Very poor</td>
<td>Places with heritage values have not been identified. Heritage places are in degraded condition and their values lack integrity.</td>
</tr>
</tbody>
</table>

### Confidence

- **High-quality evidence and high level of consensus** (Adequate)
- **Limited evidence or limited consensus** (Limited)
- **Evidence and consensus too low to make an assessment** (Uncertain)
Pressures affecting heritage

In this section, pressures on Australian heritage are categorised and considered, firstly according to their major drivers: climate change, population growth and economic growth. Resource-specific pressures that relate particularly to natural, Indigenous or historic heritage are considered separately.

3.1 Climate change

Climate change has potentially serious implications for Australia’s heritage. Heritage managers cannot alter climate change itself, but must respond to the symptoms or pressures that arise. In particular, opportunities should be embraced to facilitate appropriate adaptation and increase resilience as a proactive response (see Section 5).

3.1.1 Rising temperatures

Rising temperatures will alter ecosystems, with potentially devastating effects on niche-adapted rare and endangered species. Changes include the arrival or range expansion of other native species that are likely to have negative effects on local species.
Higher air temperatures will cause deterioration of external finishes and building fabric, as well as changes to lifestyles and cultural practices. More frequent extreme temperature events may affect the population in some areas, leading to increased human pressure on heritage sites and places, including the negative effect of abandonment.36

3.1.2 Changing rainfall

Higher rainfall in northern Australia may result in flooding and erosion of heritage places and archaeological sites, and possible destabilisation of historic buildings. Lower rainfall elsewhere in Australia will inevitably change vegetation communities and increase erosion, leading to destabilisation of structures and archaeological sites. It will also reduce economic viability as rural communities are abandoned because of drought.

3.1.3 Rising sea levels

Rising sea levels are expected to place major pressure on Australia’s coastal heritage, not only on natural heritage places, but also on cultural sites such as Aboriginal middens, sea-cave deposits, archaeological sites, rock art and cave art sites. All of these are highly dependent on the maintenance and protection of their underlying landforms. Indirect pressures will arise from changes to settlement patterns, including loss of viability for some coastal areas. Changes to hydrology, soil migration and damage from storm washes may also affect historic coastal sites, such as the Sydney Opera House, as well as smaller coastal historic heritage places.36

3.1.4 Altered fire regimes

Fire presents a major threat to reserved lands and their constituent species and ecosystems, but also to a wide variety of cultural heritage assets. Wildfire science is complex, and the pressures and impacts depend on a combination of management regimes and the responses of different plant groups.37 These factors will be affected by climate change, which will change the nature, intensity and frequency of fires.

Climate change can lead to broadscale changes in vegetation. For example, a number of eucalypt species in the Greater Blue Mountains are adapted and specialised for different climate and habitat niches.37-38 The silvertop ash (Eucalyptus sieberi) grows at altitudes from sea level to more than 1000 metres, as a tall forest tree on protected slopes or a short multistemmed tree on exposed ridges.37,38 The wide distribution of the species makes it resilient to wildfire impact. In contrast, eucalypts that have highly restricted distributions, such as the Faulconbridge mallee ash (Eucalyptus burgessiana), are more vulnerable.

Fire management regimes and emergency response procedures have become increasingly sophisticated and responsive to the complex issues involved. While focus understandably remains on protecting people and property, natural and cultural heritage values are increasingly recognised. Wildfire abatement programs arguably reduce pressure on biodiversity, and Indigenous and historic values. In western Arnhem Land, there is mounting evidence that patchy, more traditional fire regimes are likely to have far less impact on biodiversity—particularly for long-lived, obligate seeding plants that require fire to germinate and mature rapidly following a fire, such as cypress pine (Callitris intratropica)—than the frequent intense wildfires experienced in recent decades. It is recognised that reducing the frequency of wildfires in western Arnhem Land will also better protect globally significant rock art and bush food resources.40

3.1.5 More frequent extreme weather events

Climate change is likely to increase the frequency of damaging extreme climatic events such as tropical cyclones, and affect droughts and floods by changing the intensity of El Niño (a periodic warming climate pattern). All these events will cause direct damage to natural and cultural heritage places. Damage and destruction may also result from rescue and clean-up activities. Some places will suffer further deterioration with a loss of economic viability, and some places and communities may be abandoned.

3.2 Population growth

Australia’s population is increasing, and the distribution of people around the Australian landscape is changing. This will affect all aspects of the environment, including heritage.

Along with population growth, the increasing recognition and prominence of heritage places results in increased visitation to heritage places. Ironically,
this has the potential to lead to damage or vandalism. Pressures from damage are greatest in popular heritage areas, and pressures from vandalism are greatest in remote, unregulated areas and where there is poor communication about heritage values and appropriate visitor behaviour.

3.2.1 Community perceptions of value

Australia is a young nation, and we continue to grapple with our heritage and how it fits into the national narrative—our perception of who we are, and the places that create our national identity. Australia’s national heritage narrative is not well told. Indeed, despite strong community interest and support for heritage, it seldom becomes a major agenda item in national debate and suffers seriously from under-resourcing.

Value … remains at the centre of all heritage practice; it is what justifies legal protection, funding or regulation; it is what inspires people to get involved with heritage. Indeed, in public value terms, something is only of value if citizens—either individually or collectively—are willing to give something up in return for it. Kelly et al.

Heritage places become neglected if they are not adequately identified and recognised, if they become redundant or if they are not directly connected with economic activity.

In 2006, a survey-based study of community interest and participation in Australian heritage by Deakin University found that interest in heritage is high, even though direct participation is not (Figures 9.13 and 9.14). The respondents saw heritage management as a shared responsibility, not solely a government function, and preferred broad, inclusive heritage management that retains the use and functionality of protected items.

The review of heritage in the study went well beyond stereotypical colonial architecture to include natural items such as native animals, intangible concepts such as the contribution of immigration, experiences such as cultural festivals, and even very recent buildings and architecture. Elements rated as most important to protect and preserve, such as native fauna and waterways, were seen as being important to all Australians, as well as vulnerable and irreplaceable.

Despite the findings of this study and anecdotal evidence such as high levels of community participation in annual Heritage Week activities, regular media coverage of heritage issues or active opposition to developments that threaten heritage places, these opinions do not appear to translate into government policy or resources for heritage conservation.
3.2.2 Population shift

The Australian population is not only growing, it is shifting away from rural centres and towards cities and coasts. This is causing significant pressures to which governments at all levels are seeking to respond. In Melbourne, for example, the Melbourne 2030 strategy supports steady population growth on an environmentally sustainable basis, recognising the uneven distribution of population growth and particularly the decline in rural areas. Similar factors are at play in Sydney and throughout New South Wales. Regional and rural [New South Wales] have experienced substantial changes in their population over recent years and further changes are anticipated. Regional centres are growing while many smaller towns are experiencing population losses. New South Wales Department of Planning, p. 23

The growth of urban and coastal populations places direct pressure on existing cultural sites, particularly those in areas of open space and historic buildings. Construction of new infrastructure (such as roads, airports, energy supply facilities and telecommunications networks) can affect both natural and cultural heritage. Communities are under pressure to allow residential densities to increase—freestanding dwellings are replaced by apartment blocks, open areas are subdivided and developed, and heritage items are demolished to make way for new projects. Meanwhile, in rural areas, significant heritage places become redundant or vacant, and local communities struggle to find resources to conserve them.

3.3 Economic growth

Economic growth involves changes, usually to create some type of product, which in turn leads to consumption and waste generation. Heritage places are susceptible to loss of values through inappropriate change, impact from production activities and damage from waste disposal. These pressures can be exacerbated or reduced by factors such as the adequacy of statutory protection and the allocation of financial resources.

3.3.1 Resource extraction

Resource extraction industries place pressure on heritage places directly and indirectly. Mining, gas exploration or logging may result in actual removal of features of heritage value, adverse change to geological substructures, erosion or changes to groundwater. These activities may also cause indirect pressures, such as loss of access to the heritage place for the people to whom it is important, visual scarring or loss of habitat corridors. Hunting and fishing can
3.3.2 Development

Many heritage places are also valuable assets, and this underlying value can be a threat to conservation. Development at all scales exerts direct pressure on heritage places. Development may involve construction of new buildings or infrastructure, or changes to existing structures. New developments may affect land, require removal of existing ecosystems or cultural sites, or introduce uses that are incompatible with heritage values. Development projects such as mining, forestry and substantial infrastructure may result in total destruction or removal of heritage resources. Pressures also arise where developments have an adverse effect on the heritage setting, or restrict access or use.

Box 9.10 Indigenous heritage in the Wet Tropics World Heritage Area, Queensland

Indigenous heritage faces multiple risks, such as loss of cultural and traditional knowledge, economic pressure, development and inadequate statutory frameworks. The Wet Tropics World Heritage Area provides an example. This is one of the largest rainforest areas in Australia, covering 8940 square kilometres of public and privately owned lands along the north-east coast of Queensland, including the oldest continually surviving tropical rainforests on Earth. The area is well known as a biodiversity hot spot and is home to 18 individual Aboriginal traditional owner groups with connections to land, collectively referred to as Rainforest Aboriginal people.

To Rainforest Aboriginal people, the Wet Tropics is a series of complex, living cultural landscapes, where natural features are interwoven with spirituality, economic use (including food, medicines and tools), and social and moral organisation. Rainforest Aboriginal people have customary obligations for managing their country under Aboriginal law. They are tied to their country through story places, birthing places, naming places (it is cultural practice to be named after significant sites), animals and plants. This connection to country is valued above all else.

There have been no formal or consent determinations of native title in the Wet Tropics, although there are 16 active native title claims. The area is managed by the Wet Tropics Management Authority in partnership with government agencies, land managers, land owners, Rainforest Aboriginal people, the tourism industry, conservation and community groups, and the broader community. However, the customary responsibility of Rainforest Aboriginal people to maintain and manage the Wet Tropics is a contentious issue. Nine individual Rainforest Aboriginal traditional owner groups are strongly represented by the Girringun Aboriginal Corporation, a land and sea management group. These groups enjoy fairly unrestricted access to, and use of, the rainforests, although they feel that acknowledgement of native title would give them more power to make decisions about access, use, maintenance and management of their country.

Rainforest Aboriginal people are particularly concerned about the lack of acknowledgement of shared values in the Wet Tropics, and have been pushing for many years to have the area listed on the World Heritage List and National Heritage List for its cultural values, as well as natural values. Recognition of cultural values would provide better protection of Rainforest Aboriginal cultures and ensure equal emphasis on managing the region for all its values.

Listing the Wet Tropics for its cultural value on the World Heritage List would send a clear message to the world that Aboriginal people are a really significant culture to the whole world. Traditional owner

Although access to, and use of, the rainforests by Rainforest Aboriginal people is largely unrestricted, it is increasingly affected by large-scale development. Rainforest Aboriginal people feel that economic interests always seem to outrank cultural interests, and little significance is given to the social impacts of development. For example, a proposed upgrade of the Bruce Highway will go through a culturally significant marine area and restrict access to a place used by generations of Rainforest Aboriginal people to hunt, and teach children to hunt, turtle and dugong.

How do you quantify that impact? How do you measure that? What’s the dollar figure on that? The social impact is immense. If we can’t go there anymore, if we can’t teach our children to hunt there anymore, then part of our culture is gone. Traditional owner

Source: Schnierer et al.12

affect individual species or create conflict in land use, but may also be a significant and appropriate part of Indigenous heritage. Resource extraction pressures apply to both listed and unlisted heritage places.
The pressures of development are compounded by two factors. Firstly, a major problem with the process used to approve new development in Australia is that consideration of heritage impact (and other environmental factors) is often reactive—the linear nature of the development consent process sees the project announced (based on a financial feasibility study) and only then is a heritage survey completed. At this point, heritage is perceived as ‘the problem’, even though the heritage was always there and always a relevant constraint.

The second factor is a prejudice against nature and culture in favour of perceived economic benefits. In addition to these major risks, local heritage places suffer risks from destruction to make way for new development projects and the associated impacts of new development in the vicinity. In the case of Indigenous heritage, where native title and ownership rights are tightly connected with important traditional cultural practices, the underlying land value can act as a barrier to decisions based on culture rather than economics, with consequent adverse effects for the heritage value of the place (Box 9.10).

### 3.3.3 Tourism

Heritage conservation is widely recognised as including presentation, interpretation and celebration.\(^{45-46}\) Encouraging people to visit important places to learn stories and enjoy experiences connects them with their heritage. However, visitation and tourism have a downside—the additional pressure on the resource itself. Tourism pressures can cause physical damage (from construction of visitor facilities, increased erosion, vandalism or simply excessive use), loss of amenity (noise, visual intrusion, pollution) or loss of intangible value (disconnection of local people or inappropriate visitor behaviour).

### 3.4 Pressures on natural heritage

Natural heritage is susceptible to the general pressures arising from climate change outlined above, as well as some of the pressures that flow from population and economic growth. However, other pressures apply, particularly to natural heritage.

#### 3.4.1 Invasive species

Invasive species and organisms that cause disease place major pressure on natural ecosystems and their natural heritage values. Australia has a considerable legacy of such invasions—some species, such as cane toads, mimosa and feral cats, have firmly established themselves over wide areas. Others, like myrtle rust or *Phytophthora*, pose very serious emerging threats. Government responses to invasive species are uncoordinated at the national level, reactive, focused on larger animals, biased towards potential impact on primary industry at the expense of the total ecosystem, and critically under-resourced. This is not only poor environmental and heritage management, but poor economics, as prevention and rapid response to new arrivals and incursions can save vast expense over time (Box 9.11).

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**Box 9.11 Response to invasive species—prevention is better than cure**

As with preventative health in human society, relatively small interventions to address hazards in these areas, done soon, will be many times more cost-effective than if left until later. *Prime Minister’s Science, Engineering and Innovation Council*\(^{47}\)

Preventing major ecological damage is far less expensive than resolving the issues afterwards. The spread of invasive species can cause major, expensive environmental impacts. For example, fire ant infestations in Texas have cost the United States Government an estimated $1.2 billion per year. Following the discovery of fire ant infestations in Queensland, the Natural Resource Management Ministerial Council undertook a major eradication program that cost close to $150 million.\(^{48}\) No other fire ant eradication program has obtained the level of success that has been observed in Queensland.

Another similar invasive species is also subject to a national eradication program. Electric ants are an aggressive environmental pest that have the potential to seriously affect Queensland ecological and agricultural systems. The government response to this ecological threat has been far smaller. Funding of only $4.067 million for 2006–08 was agreed, with a review to follow to validate the continuation of the program.\(^{49}\) In 2010, detection of electric ant infestations in new areas means that additional work will be required to ensure that the ants are eradicated.
3.4.2 Loss of habitat

Australia’s extraordinary flora and fauna are directly threatened by progressive loss of habitat. Two major drivers of habitat are land clearing and climate change. Land clearing is a legacy pressure that represents past human activity. Climate change will continue to exert pressure and will increase the severity of fires, invasive species and other events, such as droughts, floods, coral bleaching and saltwater intrusion into coastal freshwater systems. All these pressures reduce habitat and expose our biodiversity to greater risk.

3.4.3 Land use

Changing land use places pressures on both natural and cultural heritage. Changes may reduce compatibility with reserve values and connectivity between different reserves, alter wildlife corridors or reduce critical mass for niche ecosystems. There may be physical impacts from resource extraction or indirect effects such as from run-off or subsidence. Even within reserves, changes to allow new recreation uses can lead to unintended pressures and damage to the resource if they are not well planned and carefully managed. The pressure from changing land use may be greatly reduced by strategic land-use planning and decision-making that is informed by thorough natural resource assessment and inventory.

3.4.4 Soil erosion

Erosion is the process by which the surface of the earth is worn away by the action of water, wind, vehicles and recreational activities. Natural heritage places are affected by a variety of erosion forms: streambank, roadside, beach, track, gully, wind, mass movement and sheet erosion. Mass movement and sheet erosion have far greater potential adverse impacts on natural heritage values than other forms. Erosion is exacerbated by changing climate, especially desiccation and increased wind, but can also arise from economic factors such as development, changing land use and increased tourism.

3.5 Pressures on Indigenous heritage

There is a recognised gap between Indigenous Australians and the wider Australian community across many areas of economic and social activity, including cultural heritage. Indigenous communities still need to fight for access to their heritage places, and permission to pursue traditional practices and prevent incremental damage.

Indigenous heritage faces two main pressures, both of which result from European settlement. One is a direct pressure on the Aboriginal community: disruption to Aboriginal knowledge and culture. The other is a pressure on Aboriginal heritage areas and country: the disturbance or destruction of sites due to urban or industrial development, including resource extraction.

3.5.1 Loss of knowledge

Indigenous heritage has not been comprehensively surveyed and assessed across any Australian jurisdiction. The assessments that have occurred tend to be development driven and localised, or occasionally part of academic or community research projects.

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Box 9.12 National Indigenous Knowledge Project

Acknowledgement of the need for a national Indigenous knowledge centre arose from the Australia 2020 Summit held in 2008. An Indigenous knowledge centre (IKC) is envisaged as a place where Indigenous cultural knowledge is kept safe to pass on to future generations and showcase to the community—both a repository for community knowledge and a place for two-way cultural learning.

The Prime Minister announced the first steps towards an IKC by initiating the National IKC Project. This project will engage with Indigenous communities and organisations, the wider Australian community and cultural institutions to develop ideas to strengthen and support Indigenous culture and knowledge. Informed by the national consultation program and research findings into the world’s best-practice initiatives, the project will report its findings to government for consideration, including a range of possible roles and models for a national IKC.

Source: National Indigenous Knowledge Centre
Knowledge of the nature and extent of Indigenous heritage resources is therefore incomplete, and decisions made on the basis of this incomplete, picture place pressure on an unknown but finite resource. Pressures related to knowledge also arise where the intangible values of Indigenous heritage places are directly degraded because the knowledge relating to associated belief and traditional practices has been lost. Loss of traditional knowledge poses a major and continuing threat to Australia’s Indigenous cultural heritage (Box 9.12).

3.5.2 Loss of traditional cultural practice and social connections

Traditional land and sea management practices are crucial to the wellbeing of Indigenous people and maintaining the values of their country. Traditional ecological knowledge is also increasingly recognised for its potential contribution to contemporary natural resource management. Where people are disconnected from country or prevented from pursuing traditional practice, or where the knowledge of place, spirit or traditional practice is not passed on, the Indigenous values of the place diminish. Traditional practice can range from special ceremonies for a few individuals to wider land management:

Aboriginal people burn to hunt, to promote new grass which attracts game, to make the Country easier to travel through, to clear Country of spiritual pollution after death, to create fire breaks for later in the dry season and a variety of other reasons which overall 'bring the Country alive again'. Yibarbuk

One consideration, sometimes overlooked in relation to Indigenous land and sea management, is that traditional Indigenous practices may not be relevant to new post-colonial pressures such as invasive species, because they were not developed in response to these types of threats. Effective traditional management must therefore adapt and evolve by using and incorporating new knowledge and techniques if it is to cope with these new pressures:

Caring for Country is when Indigenous people use their rights and carry out their responsibilities to manage their Country and the environment through their Traditional Knowledge systems, cultural values, working together with Western science, integrating expertise and technological knowledge. Grant, p. 1

3.5.3 Incremental destruction

... heritage, once destroyed or sullied, can rarely be recovered. As well, it is important for avoiding the tyranny of little decisions, whereby incremental developments—perhaps done under the aegis of improving access—end up destroying the attractions for which the place was set up in the first place. Australian Senate Committee, cited in Lennon

Destruction of Indigenous sites occurs through:

- lack of listing or recognition
- conscious, informed decisions by development consent authorities
- prioritisation of economic considerations over heritage protection
- little to no assessment or public reporting of the cumulative impact of development—that is, how much of the Indigenous heritage estate has already been destroyed through past activities in the region
- insufficient consultation with Indigenous communities.

The high level of approved destruction remains a major threat to Indigenous heritage. Although nearly all jurisdictions have introduced stronger requirements to assess Indigenous heritage and consult with Indigenous people about development, there is little evidence that this has led to improved protection for Indigenous heritage sites.

The past five years have been remarkable for the number of high-profile conflicts between Indigenous people, government decision-makers and industries (including mining, forestry and urban development) about developments that destroy significant and sacred sites (Box 9.13). A number of recent legal challenges by Indigenous people have highlighted the lack of legal avenues or formal rights for Indigenous people seeking to enforce protection of their heritage.

The economic imperatives of development and infrastructure delivery can place enormous pressure on sensitive Indigenous heritage sites. Regional planning is often done by commercial industries seeking to undertake activities that will affect Indigenous heritage. Although in-principle support for cultural landscape planning exists, it has not been resourced or actively implemented by policy makers. If sites are not listed and identified before developments are proposed,
There has been ongoing action by the Aboriginal community in Tasmania regarding the construction of the Brighton bypass over the Jordan Levee. The project is a $176-million investment upgrading the Midland Highway to the north of Hobart. However, a highly significant archaeological site has been identified in the path of the roadworks. Archaeological investigation suggests that it is possibly the oldest known Aboriginal site in Tasmania, and among the oldest in Australia. Although the original design of the highway was modified to mitigate some of the impacts of the highway construction, irreparable damage will be done to the site.

The Tasmanian Aboriginal community, through the Tasmanian Aboriginal Centre (TAC) and Aboriginal heritage officers, has imposed a ban on all survey work for Aboriginal heritage in Tasmania, thereby blocking informed development consent. The TAC has said that the moratorium will remain in place until such time as decent legislation protecting Aboriginal heritage is put in place and the new protection has Aboriginal community support.

The procedures published in Ask first are the best-practice guidelines for addressing Indigenous heritage issues. They assert that sensitive consultation and negotiation with Indigenous stakeholders is the best means of addressing Indigenous heritage issues. Failure to engage in this process can deny traditional owners their right to informed consent. Acknowledgement of the pressures on Indigenous heritage sites and their custodians is important in areas of fast-paced development and industrialisation. Failure to understand the heritage issues of sensitive cultural landscapes can lead to their incremental destruction (Box 9.14). The Burrup Peninsula in Western Australia (see Box 9.17) is one example among many of the needs of the resources industry placing enormous pressure on the local Indigenous community and the cultural landscape.

Consideration of their cultural value is relegated to reactive impact assessment. Despite an increase in recording and listing of Indigenous heritage sites, it is desirable that this process is more proactive.

3.6 Pressures on historic heritage

Particular pressures on historic heritage include changing use and economic values. Poor management practices (including loss of skills and expertise) that can also threaten historic heritage are dealt with in Section 4 of this chapter.

For many historic sites, the current use of the site may itself be significant in a heritage context. Churches, war memorials, community halls and post offices fall into this category. Pressures for change of use may arise in response to altered economic conditions, changing demographics, new commercial opportunities or other factors. Sometimes a new use is compatible with the heritage value of a place, but sometimes it is not. For some historic sites, direct tension arises between cultural and economic values, with likely prejudice being to favour economics over culture. The recent sale of many Australian post offices and their replacement by smaller agency postal outlets, often in the same suburb or town, is a case in point.
The rapid rate of development activity in Western Australia has threatened many sites of significance to Aboriginal people. The cumulative impacts on Aboriginal heritage in Western Australia are of immense concern, especially where mining and infrastructure development in remote areas like the Pilbara takes precedence over the preservation of Aboriginal heritage. The Woodstock Abydos experience is perhaps one of the most striking examples of development incrementally disturbing an area of recognised outstanding heritage significance.

Woodstock Abydos is a protected area under Western Australia’s Aboriginal Heritage Act 1972. More than 500 Aboriginal sites within the Woodstock Abydos Protected Area are listed with the Department of Indigenous Affairs. Only 57% of the reserve area has been surveyed, so there are potentially many more sites not yet recorded. These sites include mythological and ceremonial sites, engraved rock art, painted rock art, stone artefacts, stone quarry sites, stone arrangements, grinding patches, rock shelters, water sources, modified trees, built structures, camps and many others.

Woodstock Abydos Reserve was initially vested with the Western Australian Museum for the preservation of Aboriginal cultural materials and historic buildings from the impacts of mining and infrastructure development. The Western Australian Governor at the time made particular reference to a ‘rock art and occupation site complex of outstanding significance’. The reserve was declared a protected area in 1979 and added to the Register of the National Estate in 1980.

In the 1960s, the mining company BHP applied for and was granted an excision from the reserve for a rail infrastructure corridor. In 2006, Fortescue Metals Group was granted an excision for a 200-metre rail infrastructure corridor, and a third company, Hancock Prospecting, applied for and was granted an excision from the reserve for a rail infrastructure corridor in 2010. There are now three separate railroads operating through this protected area.

These developments have a range of cumulative impacts on heritage sites in the area. There are many sites very close to rail tracks and maintenance roads, so dust accumulation on rock art poses an ongoing, serious threat. Sites suffer from neglect, poor fencing and lack of protective measures. There is no program of monitoring of the sites or individual images, and there have been reports that additional rail corridors are planned in the years ahead.

Woodstock Abydos shows that even the highest form of protection available for Aboriginal heritage sites under Western Australian law may not be a guarantee of protection, and that individual approvals can have a serious cumulative adverse effect.

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The Woodstock Abydos landscape, illustrating typical boulder outcrops that are covered with engravings (photo by Liam M Brady, University of Western Australia)
# Pressures affecting heritage values

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Driver</strong></td>
<td><strong>Climate change</strong></td>
</tr>
<tr>
<td>Rising temperatures</td>
<td>Rising temperatures will cause loss of habitat, species extinction, changes to traditional lifestyles and physical damage to historic places</td>
</tr>
<tr>
<td>Changing rainfall</td>
<td>Rainfall is increasing in northern Australia and decreasing elsewhere, resulting in changes to habitat, flooding (which causes loss of and damage to sites), erosion, destabilisation and desiccation</td>
</tr>
<tr>
<td>Rising sea level</td>
<td>Sea level rise is predicted to cause loss of coastal habitats and sites, and changes to traditional lifestyles and historic settlement patterns, and give rise to indirect impacts through local economic effects</td>
</tr>
<tr>
<td>Altered fire regimes</td>
<td>Wildfires are increasing in frequency and intensity, causing loss of biodiversity and habitat, and damage to or destruction of sites and landscapes</td>
</tr>
<tr>
<td>More frequent extreme weather events</td>
<td>Damage and destruction is wrought by increases in the frequency and severity of events such as floods, cyclones and hail storms, as well as collateral damage caused by rescue or clean-up activities and loss of financial and human resources due to effects on local economic activity</td>
</tr>
<tr>
<td><strong>Driver</strong></td>
<td><strong>Population growth</strong></td>
</tr>
<tr>
<td>Community perceptions of value</td>
<td>The majority of Australians value both natural and cultural heritage; however, this perception is disconnected from the allocation of public resources. For some places, heritage values are perceived as expendable</td>
</tr>
<tr>
<td>Population shift</td>
<td>Decline in rural population reduces demand for facilities and infrastructure, thereby placing pressure on redundant built assets and reducing resources available for all heritage conservation activities</td>
</tr>
<tr>
<td></td>
<td>Urban and coastal population increase creates more intensive land uses and pressures from increasing land values and infrastructure demand. These factors lead to the destruction of heritage places to make way for new development, inappropriate changes to heritage places and impacts on their setting</td>
</tr>
</tbody>
</table>
### Driver: Economic growth

**Resource extraction**

Major resource extraction industries, such as mining and forestry, create pressure on both natural and cultural heritage places whose conservation would limit resource extraction activity. The disparity in perceived value between exploitable resources and heritage resources exacerbates this pressure.

**Development**

Large and small developments can threaten the survival of heritage places or jeopardise their natural and cultural values through inappropriate changes or impact on their setting. Particular issues arise in relation to development consent processes, which often characterise heritage as a barrier.

**Tourism**

There is tension between the inherent values of some heritage places and their important role as tourist attractions. Although interpretation and experience of heritage is an important conservation activity, over-visitation or inappropriate visitor behaviour can harm the very values that make the place worth visiting.

### Pressures on natural heritage

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasive species</td>
<td>Invasive species and pathogens directly affect natural heritage values. Despite Australia’s active management, the number of invasive species and the intensity of their effects are increasing.</td>
</tr>
<tr>
<td>Loss of habitat</td>
<td>Impacts from climate change, land clearing and land management continue to affect ecosystems, especially those represented by small remnants within larger cleared areas.</td>
</tr>
<tr>
<td>Land use</td>
<td>Australian land suffers from the relict impact of extensive land clearing. Use of land for development, urbanisation, agriculture and resource extraction may conflict with natural values.</td>
</tr>
</tbody>
</table>

Continued next page
### Pressures affecting heritage values continued

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pressures on natural heritage continued</strong></td>
<td><strong>Soil erosion</strong> Examinations of a small sample of natural heritage places suggest that they are at high risk from severe erosion types such as mass soil movement and sheet and gully erosion, and moderate risk from other erosion types. Reliable trend data are not available.</td>
<td>Very high impact</td>
<td>2</td>
</tr>
<tr>
<td><strong>Pressures on Indigenous heritage</strong></td>
<td><strong>Loss of knowledge</strong> Indigenous heritage has not been comprehensively surveyed and assessed, so knowledge of the resource is incomplete. The intangible values of Indigenous heritage places are directly degraded when the knowledge relating to associated belief and traditional practices is lost. Loss of traditional knowledge poses a major and continuing threat to Australia’s Indigenous cultural heritage</td>
<td>Very high impact</td>
<td>3</td>
</tr>
<tr>
<td><strong>Loss of traditional cultural practice and social connections</strong></td>
<td>Indigenous communities in Australia continue to suffer disconnection from country or face significant challenges in pursuing traditional land and sea management or other cultural practices; however, some significant improvements have been made that both recognise and improve management arrangements for Indigenous heritage</td>
<td>Very high impact</td>
<td>3</td>
</tr>
<tr>
<td><strong>Incremental destruction</strong></td>
<td>A major pressure on Indigenous heritage is the continuing incremental destruction of sites through an accumulation of one-off decisions associated with particular developments. The pressure is created by a combination of inadequate inventory and consent processes that identify impacts, but seldom give primacy to Indigenous site conservation</td>
<td>Very high impact</td>
<td>3</td>
</tr>
</tbody>
</table>

## Pressures on historic heritage

### Changing use and economic values

Many historic heritage items are, by their nature, ‘old’ and therefore may be perceived as redundant or incapable of new use. This perception, particularly when coupled with changes in underlying asset value, creates pressures to redevelop, sometimes through demolition. There is, however, an emerging tendency to consider retaining and adapting historic structures.

### Lack of skills and expertise

The continuing decline in availability of specialist heritage tradespeople and a looming skills shortage will place major pressures on historic heritage conservation in the immediate future.

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressures on historic heritage</td>
<td></td>
<td>Very high impact</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High impact</td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low impact</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very low impact</td>
<td></td>
</tr>
</tbody>
</table>

### Recent trends

- **Improving**
- **Stable**
- **Deteriorating**
- **Unsure**

### Grades

- **Very low impact**
  - Current and predicted impacts may have some effect on the heritage values of individual places.
- **Low impact**
  - Current and predicted impacts are likely to have some effect on the heritage values of individual places and some landscapes.
- **High impact**
  - Current and predicted impacts are wide ranging and are likely to affect the heritage values of individual places and landscapes and the whole of Australia’s heritage.
- **Very high impact**
  - Current and predicted impacts are wide ranging and, if unchecked, will irreversibly affect the heritage values of individual places and landscapes and the whole of Australia’s heritage.
Effectiveness of heritage management

And yet the Australian community continues to celebrate its heritage. National Parks are visited; Traditional Owners play a greater role in presenting Country and enthusiastic owners of historic buildings undertake private conservation projects. These positive trends underpin the importance of heritage and the need for ongoing improvement in heritage management effectiveness.

A vigorous heritage and cultural sector has significantly increased Australians’ understanding, participation in and enjoyment of our cultural and heritage assets. Australian Heritage Council

Managing Australia’s heritage involves taking action to protect heritage places from pressures, to retain their values. Effective heritage management requires a holistic approach across the spectrum of pressures identified in this chapter (and elsewhere in this report), rather than individual responses for every pressure. There is a simple, logical process for effective management: understand the place and its values, identify the issues (i.e. the pressures) and then manage the place in response to the issues. This process is set out in key documents such as the Burra Charter, the Ask first guidelines and the Australian Natural Heritage Charter, but is not always reflected in statutory requirements. The outcomes actually achieved by these processes will also depend on the resources available.

In this discussion and analysis, Australian heritage management is considered according to the components of the management process: understanding, planning, inputs, processes and outcomes. The summary table at the end of this section addresses natural, Indigenous and historic heritage according to this framework, using the current DSEWPaC heritage management themes of identification, management, protection, leadership and celebration. These themes broadly encapsulate the logic and process of key Australian heritage management charters such as the Burra Charter, the Ask first guidelines and the Australian Natural Heritage Charter.

At a glance

Australia is recognised internationally for leadership in heritage management. We have a range of systems and processes for identifying, protecting, managing and celebrating our heritage that should lead to reduced pressures, minimised risk and retention of those values that make our heritage places special. However, despite our excellent understanding of the context for heritage management and good planning processes, the resources allocated to heritage identification and protection are insufficient and fall well short of what is needed to achieve effective outcomes.

Identification processes for Australian heritage are erratic. The National Reserve System offers a proactive approach to identifying a representative system of natural heritage places. By contrast, there is no national picture for Indigenous heritage (either tangible or intangible), and reliance is placed on ‘blanket’ provisions in legislation, leading to ill-informed decisions. Many historic heritage places have been identified, but the ad hoc approach of heritage registers means that they are skewed towards particular aspects of history and a select group of values.

Heritage places in public ownership are often supported by well-prepared, values-based management plans. For nonpublic heritage places, planning systems, land zonings and related regulations do not necessarily help to achieve conservation outcomes, and some building codes and standards create pressure for demolition or inappropriate change. Decisions about development impact usually consider stakeholder perspectives, especially for Indigenous places, but the reactive nature of the process and an inadequate knowledge of the total resource tend to militate against conservation outcomes.

Resources available for heritage conservation are declining in real terms, as evidenced by the erosion of core budget funding for heritage in the 2011–12 Budget. Although some programs, such as the recent Jobs Fund initiative, have targeted heritage conservation with excellent outcomes, a combination of dwindling public sector resources (both human and financial) and the progressive erosion of the specialist skill set required for heritage management has placed cultural heritage on a precipice. An underlying cause of this resource erosion is that community perceptions of the value of heritage as public good are not reflected in public sector resourcing or incentives for private owners.
4.1 Understanding

The effectiveness of heritage management is determined by decision-makers’ understanding of the broader environmental and socioeconomic significance of heritage values and the current and emerging threats to those values. A basic issue is, therefore, the extent to which the heritage values themselves are understood.

4.1.1 Understanding values

In the absence of basic information about the nature and extent of the heritage resource, good decision-making is difficult, and proactive strategic planning is impossible. Systematic heritage assessment programs undertaken both geographically and according to theme—across both natural and cultural environments—are needed to provide the foundation for effective heritage management.

The absence of such knowledge places additional pressure on natural and cultural heritage (Box 9.15).

Inadequacies in understanding the heritage resource extend across the full spectrum of places, at all levels of jurisdiction and government. In 2004, the International Council on Monuments and Sites (ICOMOS) analysed the World Heritage List and national tentative lists to contribute to a global strategy for a credible, balanced and representative World Heritage List. The ICOMOS report, *The World Heritage List: filling the gaps—an action plan for the future*, identified two main reasons for gaps in our knowledge of heritage resources: structural (such as lack of technical capacity or management frameworks) and qualitative (such as missing themes and under-represented regions).

The analysis found that religious properties, historic towns, and architectural monuments and ensembles comprised 57% of the sites listed, while other site types (such as modern heritage) made up less than 1% of the total. When the properties included on national tentative lists were added, a shift in trends became evident, and the proportion of religious properties, historic towns and architectural monuments was reduced to 32%.

Heritage listings have not yet been analysed for Australia, but it would be a timely and valuable exercise. It is reasonable to anticipate a similar distribution of past levels of heritage identification, with ‘our glorious past’ dominating and less visible cultural, modern and Indigenous sites, cultural landscapes and industrial heritage being poorly identified, and thus poorly protected (Box 9.16). At the time the National Heritage List was established, a number of thematic and typological studies were planned. Some have been completed and published (e.g. Pearson & Lennon), but the resources and commitment to this process appear to have waned.
Box 9.15 Inadequate understanding—the National Heritage List Priority Assessment List

One of the first listings under the new Environment Protection and Biodiversity Conservation Act 1999 Priority Assessment List system was the Adelaide Park Lands and City Layout. The city was nominated as a historic landscape because it reflects the original 1837 planned layout of Adelaide by the surveyor Colonel William Light. The city is configured as it was originally planned, as a metropolitan city surrounded by parklands, with wide streets, town squares and the Torrens River separating the city areas. The city of Adelaide is now the most extensive and intact 19th century urban green landscape in Australia. Much of the city is now owned by various levels of government, who seek approval for development through the Australian Government. Although this nomination resulted in the inclusion of this highly significant site on the National Heritage List, between 2007 and mid-2011 approximately 80 nominations were excluded and will not even be assessed (DSEWPaC, Heritage Division, pers. comm., July 2011).

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities

Figure A The Adelaide Park Lands and City Layout, showing listed places in green
4.1.2 Understanding threats

A range of substantial threats to Australia’s heritage emerge from the drivers of climate change, population growth and economic growth. Many of these threats are well understood and are being addressed through management responses. Some threats, however, are beyond direct management. Legacy issues, such as the impacts from widespread land clearing or the loss of an Indigenous landscape or tradition, may threaten the integrity of a natural or cultural landscape, but are impossible to reverse. Some invasive species are now so well established that management intervention is extremely unlikely to reverse the degradation of heritage places that they cause.

Climate change itself is beyond the control of heritage place managers, but they can respond to the pressures that it causes. Altered wildfire management, active erosion control, and dune and midden stabilisation all demonstrate awareness and response to climate change threats. Awareness of population pressures and emerging threats is also high—SoE assessment workshop participants across the public and private sectors were quick to identify the impact of rural decline and urban intensification. The majority of participants in the Australian heritage sector readily recognise the threats posed by development. Despite this, regulators fail to enforce protective provisions, even when seemingly obvious breaches of legislation and substantial impacts to highly significant places occur (Box 9.17).

4.2 Planning

The adequacy of planning for heritage management can be assessed by considering the policies and plans in place that result in management actions to address major pressures and risks to heritage values. These plans and policies should also include allocation of roles and responsibilities for managing heritage issues.

4.2.1 Leadership

Australia lacks leadership in heritage management at a national level, partly through statutory limitations on the role of the Australian Heritage Council, and partly through diminution of resources and responsibilities and, in a conceptual sense, from the absence of a national heritage strategy. This latter challenge may soon be addressed, as the portfolio budget statements for DSEWPaC for 2011–12 indicate that the department will develop an Australian Heritage Strategy, which provides national leadership in heritage management, conservation and celebration. The related key performance indicators suggest that the proposed Australian Heritage Strategy will be launched by June 2012.

Box 9.16 20th century survey—proactive management of a low-visibility resource

From 1981 to 2000, South Australia pursued a systematic program of regional heritage surveys to identify and record all the non-Aboriginal heritage of the state, on a regional basis. In 1981, the South Australian Heritage Register included approximately 1800 pre–20th century places, but only around 400 places representing the 20th century and less than 40 places of the era after World War 1. A survey concentrating on the post-war era was initiated in 2003–05, beginning with historical research for 1946–59, to establish the principal events and themes that characterised the physical, cultural and social development of that period.

Building on the initial model, ongoing studies in South Australia have developed surveys over 20-year periods, which involved both survey work and thematic analyses. In 2009, the 1928–45 survey identified 31 items for the state heritage register.


The Dampier Archipelago was formed 6000–8000 years ago when rising sea levels flooded what were once coastal plains. The underlying rocks are among the oldest on Earth, and the archipelago is a sacred place, home to Indigenous Australians for tens of thousands of years. Ngarda-Ngarlie people say ancestral beings created the land during the Dreamtime, and the spirits of Ngkurr, Bardi and Gardi continue to live in the area. The Indigenous people of this area have left their mark in one of the most exciting collections of rock art in Australia. The richness and diversity of this art are remarkable, with sites ranging from small scatters to valleys with literally thousands of engravings.

In early December 2008, a mining company undertook a range of clearing, blasting and quarrying activities outside the identified mining tenement, within the Dampier Archipelago (including Burrup Peninsula) National Heritage Place (NHP). The affected area is approximately 50 metres × 200 metres, adjacent to the edge of a quarry pit and extending well into the defined NHP.

The clearing, blasting and quarrying are likely to have destroyed a number of archaeological sites in an area with generally high site density. Calculations based on the number of sites found in the immediate vicinity indicate that as many as three sites may have been in the cleared and bulldozed areas, although the exact nature and contents of these can now never be known.

An audit, systematic survey and recording of the impact area identified six new sites in the NHP. Archaeological sites were located around the margins of the disturbed areas, where intact landscapes were still visible. Sites found in the immediate vicinity of the disturbed areas included petroglyphs, a standing stone, an artefact cache and a quarry complex. The clearing, blasting and quarrying were assessed as having affected a contiguous high-density but relatively low-intensity archaeological landscape.

In attempting to prosecute this action within the NHP, the Australian Government Department of the Environment, Water, Heritage and the Arts was constrained by the fact that the exact nature of the affected sites was not known, as they had not been archaeologically documented.

In 2008, the Western Australian Government commissioned a heritage inventory methodology report, which recommended that 20% of the representative landscapes within the NHP be recorded systematically and intensively, and that a plan of management be written for petroglyph and stone structure sites (and the broader archaeological record) within the NHP. The absence of a general inventory of sites within the NHP (with the exception of a single 2 kilometre × 200 metre transect in Deep Gorge) creates a significant impediment to the implementation of the Environment Protection and Biodiversity Conservation Act 1999 because the nature of the resource within the NHP has not been thoroughly documented, and therefore the occurrence or extent of any damage cannot be assessed.
The current federal role, however, is very limited:

… it is doubtful that the Commonwealth is currently fulfilling its obligations under the COAG [Council of Australian Governments] agreement to protect the nationally significant places it has accepted onto the NHL [National Heritage List].

Australian Heritage Council, p. 27

Council believes that to make the legislation effective the Commonwealth should lead and set standards in management and care of NHL places.

Australian Heritage Council, p. 28

There has been to date a significant gap between the obligations the Commonwealth Government takes on through listing and its capacity to fulfil those obligations.

Australian Heritage Council, p. 44

While these observations are particularly directed towards National Heritage List places, the Australian Government has a potentially instrumental role in setting standards and coordinating matters of common interest and practice, in line with the principles of the Council of Australian Governments. An extremely important issue will be the inclusion of heritage within our national narrative, whether by presentation and celebration, support for projects that have national relevance (such as heritage trades training) or encouragement of proactive strategic processes that lead to better integration of natural and cultural inheritance into future planning.

The 2009–10 annual report of the then Department of the Environment, Water, Heritage and the Arts suggests that, among other responsibilities, the department will:

… develop and implement the Government’s policies, programs and legislation to identify, protect, conserve and celebrate natural, Indigenous and historic assets.

Australian Government Department of the Environment, Water, Heritage and the Arts

Unfortunately, although there is recognition and support for such national leadership, there is a distinct absence of corresponding public sector resources. The limited resources available to the department and the limits on the statutory coverage provided by the EPBC Act mean that federal efforts focus on managing federal lands and agencies, places on the National Heritage List and Commonwealth Heritage List, associated processes for listing, and EPBC Act referrals and approvals. The department undertakes very few broader actions, especially in relation to local or state heritage, and some states have initiated their own heritage strategies (Box 9.18).

Even with respect to national heritage listing, action is curtailed by both resourcing and statutory processes. For example, amendments to the EPBC Act in 2007 provide that items are assessed for

national listing only if they are placed on the Priority Assessment List after their initial nomination by the community or government. This amendment was considered necessary to cope with the volume of nominations received by the Australian Heritage Council. Nominations that are excluded from the Priority Assessment List do not proceed at all, which restricts the extent, coverage and effectiveness of the National Heritage List. From 1 January 2007 to 31 December 2010, only 23 places were added to the National Heritage List, 20 were under assessment, and 80 nominations had lapsed and were not being considered (DSEWPaC Heritage Division, pers. comm., July 2011).

The National Reserve System is an important program with an important aim, although there is debate about the size and selection of the target for a truly representative set of reserved lands. One of the major barriers to achieving the aim of the National Reserve System is the economic value of nonreserved lands that have potential high-yield uses such as extractive industry or development. This is partly due to deficiencies in accounting for the ‘ecosystem service’ value of reserved lands as the lungs of urban areas, major water catchments or recreational spaces, which provide both tourism income and contribute to the psychological health of communities (Box 9.19).

4.2.2 Jurisdictional arrangements

A broad range of Australian legislation includes provisions to list, protect and manage heritage places. However, our federal network of jurisdictional arrangements for heritage management creates overlap, inconsistencies and challenges for governments, public officials and owners. This report cannot offer a comprehensive analysis of the effectiveness of jurisdictional arrangements, but does provide observations about particular statutes and policies.

Coordinated programs at the national level include the Intergovernmental Agreement on the Environment (1992) and a forthcoming Intergovernmental Agreement on World Heritage (which has been agreed but not yet ratified by all jurisdictions). Coordination also occurs through the Environment and Water Ministerial Council, and the Heritage Chairs and Officials of Australia and New Zealand (for historic places). There are no such national bodies for reserved lands and other forms of natural heritage that is not within a reserved park, nor for Indigenous heritage.

There are a range of important statutes, national policy documents and strategies that provide an excellent foundation for holistic heritage management. Australia’s Biodiversity Conservation Strategy 2010–2020, for example, indicates:

The important role of traditional Indigenous knowledge in contributing to the maintenance of Australia’s biodiversity must be actively promoted to the whole Australian community. We also need to ensure that curricula at all levels in Australia promote an understanding of traditional Indigenous knowledge, how it has shaped Australia’s environment, and the social and economic benefits of applying it in conjunction with modern management techniques. National Biodiversity Strategy Review Task Group, p. 38

This national policy accords with Australia’s ratification of the United Nations Convention on Biological Diversity (as adopted at the 1992 Rio Earth Summit), which among other requirements specifies:

Each Contracting Party shall, as far as possible and as appropriate:

Article 8 (j) Subject to its national legislation, respect, preserve and maintain knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biological diversity and promote their wider application with the approval and involvement of the holders of such knowledge, innovations and practices and encourage the equitable sharing of the benefits arising from the utilization of such knowledge, innovations and practices,

Article 10 (c) Protect and encourage customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements.

The policy also accords in part with Australia’s recent signing of the United Nations Declaration on the Rights of Indigenous Peoples (as adopted by United Nations General Assembly Resolution 61/295 on 13 September 2007), which specifies that:

Article 11 Indigenous peoples have the right to practise and revitalise their cultural traditions and customs. This includes the right to maintain, protect and develop the past, present and future manifestations of their cultures, such as archaeological and historic sites, artefacts, designs, ceremonies, technologies and visual and performing arts and literature.

i www.cbd.int/convention
‘Ecosystem services’ can be defined as the benefits people and companies derive from ecosystems. They are the delivery mechanisms arising from nature’s capital and can cover everything from access to fresh water to climate regulation and the enjoyment of a view. *Environmental Resource Management, Australia*[^72]

The ecosystem services offered by Australia’s parks underpin the welfare and wellbeing of Australian people. Parks provide clean water catchments, vital carbon sinks and open green space, and are the lungs of the community. These values are rarely taken into account in economic terms when land acquisition or park resourcing decisions are made. They are not necessarily taken into account in determining biodiversity strategies either, although such an approach was recommended at the Nagoya meeting of the Conference of the Parties to the Convention on Biological Diversity in October 2010.[^72]

An example of ecosystem services is the Australian Alps. The Alps are extremely important for their outstanding biodiversity, remarkable geodiversity, and historic, Indigenous, landscape and scenic values. They are an iconic part of Australia and are on the National Heritage List. The high-quality water from the Australian Alps is also of national economic importance.[^73] In 2005, the 3980 gigalitres (GL) of Victorian Alps waters that flow to the Murray–Darling Basin every year were conservatively estimated to be worth $4 billion to Australia’s economy. The average annual 9600 GL in the Australian Alps catchments could now be worth as much as $9.6 billion per year to the national economy. The Alps waters help generate $15 billion worth of Australia’s agricultural produce each year, including 45% of Australia’s irrigated production ($5.5 billion), 56% of the grape crop, 42% of other fruit and nuts, and 32% of total dairy production. The water also helps support many of the 2.1 million Australians living in the Murray–Darling Basin, including Adelaide and many towns of South Australia.

Our reserves also provide indirect economic and social benefits. Nature-based tourism in Australia is valued at more than $33 billion per year.[^74] Healthy Parks Healthy People, a Victorian Government program, stresses the connection between people’s health and the viability of natural reserves and ecosystems. The program advocates that reserves should continue to be set aside and protected, not only to conserve natural heritage, but also to protect the health of the population and the tourism industry.[^75]

Kangaroo Island is renowned for its extraordinary natural heritage resources, which are fundamental to the island’s major role in both regional and national tourism. In 2009, for example, there were approximately 162 000 overnight visitors to Kangaroo Island, who stayed for more than 707 000 nights. Spending by domestic overnight visitors to the region has been estimated at approximately $100 million or an average $168 per visitor night. Activities by visitors include sightseeing (52%), visiting national or state parks (42%), going on bushwalks (28%) and other similar activities related to enjoying natural heritage.[^76]

[^72]: Environmental Resource Management, Australia
[^73]: Kangaroo Island is renowned for its extraordinary natural heritage resources, which are fundamental to the island’s major role in both regional and national tourism. In 2009, for example, there were approximately 162 000 overnight visitors to Kangaroo Island, who stayed for more than 707 000 nights. Spending by domestic overnight visitors to the region has been estimated at approximately $100 million or an average $168 per visitor night. Activities by visitors include sightseeing (52%), visiting national or state parks (42%), going on bushwalks (28%) and other similar activities related to enjoying natural heritage.
Substantial gaps remain in the legislative protective regime for Australian heritage. In particular, protection of natural and Indigenous places and values in a number of jurisdictions remains inadequate. Some jurisdictions offer little protection for natural places of significance outside the reserve system. Indigenous heritage protection continues to face significant issues relating to the recognition of ‘traditional’ as opposed to ‘scientific’ values. This situation arises from early Indigenous heritage legislation, which was designed to protect archaeological sites rather than wider Indigenous culture and therefore may not protect contemporary values held by the community, or sites where continuing tradition is expressed in intangible attributes rather than physical evidence.

This Act [National Parks and Wildlife Act 1974 (NSW)] protects Aboriginal objects as a class, but not places and landscapes of special significance to Aboriginal people unless they are specifically gazetted. A good aspect of this legislation is that it does require permits for the destruction of Aboriginal objects (which are mostly archaeological sites), but it is very hard to assess whether the intangible aspects of the significance of these places are taken into account as part of the decision making process. Prof Sharon Sullivan, AO, former Manager of Cultural Heritage for the New South Wales National Parks and Wildlife Service (and current member of the Australian Heritage Council), commenting on the National Parks and Wildlife Act 1974 (NSW), pers. comm., July 2011)

The Aboriginal and Torres Strait Islander Heritage Protection Act 1984 (ATSIHP Act) enables Aboriginal and Torres Strait Islander people to ask the Australian Government to protect areas and objects, including human remains, from injury or desecration. In response, the Australian Government can make declarations to protect areas and objects that are of particular significance in Indigenous tradition from threats of injury or desecration. However, states and territories bear the primary responsibility for protecting traditionally significant areas and objects. The Australian Government cannot make a declaration if a state or territory law has, in effect, already protected the area or object from the threat. A declaration operates for a defined period and must be revoked if state or territory protection takes effect.

The ATSIHP Act has proven to be problematic:

The ATSIHP Act has not proven to be an effective means of protecting traditional areas and objects. Few declarations have been made: 93 per cent of approximately 320 valid applications received since the Act commenced in 1984 have not resulted in declarations. Also Federal Court decisions overturned two of the five long term declarations that have been made for areas. Australian Government Department of the Environment, Water, Heritage and the Arts, p. 4

A comparison of the numbers of applications and ministerial declarations suggests that the ATSIHP Act is consuming public resources with little obvious benefit (Figure 9.15).

The ATSIHP Act was a temporary measure to encourage the states to protect sacred sites as part of a plan to introduce national land rights legislation. When the plan failed, the Act was made permanent, largely in its original form. It was not repealed or amended following the recognition of native title in Australian law.

In 2009, the Australian Government released a discussion paper on proposed reforms to the ATSIHP Act. The reforms aim to improve the protection of the traditional heritage of Indigenous Australians in all jurisdictions through accreditation of state and territory laws that meet a set of rigorous standards. This would enable the Australian Government to take a more active and coordinated approach in the protection of sacred sites and objects. However, the delay in reforming the Act is prolonging uncertainty, especially for the states and territories, most of which are reviewing their Indigenous heritage legislation.

Other gaps and inconsistencies in statutory administrative and jurisdictional arrangements also threaten heritage. For example, the Australian Heritage Council periodic report 2007–10 notes that:

In the natural environment risks are posed by feral animals or ecosystems out of balance, the effects of climate change and urban incursion. Each of these is being addressed in various ways but it is difficult to see longer term improvements that will mitigate risks at the scale needed. The exclusion of natural heritage from regional forestry agreements is an ongoing concern. Australian Heritage Council, p. 51
Even measuring federal achievements alone, the results are disappointing. For example, in 2009–10, DSEWPaC commented on only three management plans for places on the National Heritage List. Of the Australian Government agencies that are required to prepare written heritage strategies for managing places with listed or potential Commonwealth heritage values, less than half have done so.

Planning processes for heritage management would benefit from a more coordinated national approach that supports heritage conservation and management across all three levels of government. This need has been previously identified and well articulated. In 2007, a report to the Queensland Government on the lack of intergovernmental coordination and inadequate resources recommended a range of innovative incentives, including establishing a national heritage fund. State coordination of heritage is improving (Box 9.20).

One significant initiative during this SoE reporting period was progress towards ratifying the UNESCO 2001 Convention for the Protection of the Underwater Cultural Heritage. A meeting of the former Environment Protection Heritage Council in November 2009 endorsed Australia pursuing ratification, and the Australian Government is currently consulting with the states and territories. The convention aims to assist countries in managing and preserving their unique underwater cultural heritage. The convention came into force on 2 January 2009 following ratification by 20 member states, and requires all signatories to enact legislation that protects and manages underwater cultural heritage (Box 9.21).

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**Figure 9.15** Applications and ministerial declarations under each section of the *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* as at 9 August 2011

Data may be inconsistent or incomplete as they are derived from records maintained by different agencies over more than two decades and have not been checked against the original records.

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The Tasmanian Heritage Register (THR) was established by the *Tasmanian Heritage Act 1995*. In accordance with the transitional provisions of that legislation, the Tasmanian Heritage Council (THC) transferred thousands of historic sites directly to the THR from existing schedules and lists compiled by local government and the National Trust of Australia (Tasmania). Among other implications, this action immediately made the THR the most heavily populated state heritage register in Australia and made the THC the consent authority for all THR-listed places.

Historic heritage is one of Tasmania’s most important cultural resources—a special characteristic that is valued by most Tasmanians and a major contributor to the state’s economy through its role in tourism. The involvement of the state heritage agency as a regular source of expert advice was widely welcomed, but the THC Works Approvals Committee quickly became overloaded, and there were several highly contentious cases in which the decision of the THC differed from approvals issued by local authorities under the *Land Use Planning and Approvals Act 1993* (Tas.). There was also an unusual ‘upward delegation’ of heritage referrals (in contrast with the use of local heritage advisers in other states) and little incentive for accumulation of heritage expertise by local government (with the exception of Hobart and Launceston City councils).

A review of the Tasmanian Heritage Act recommended a major shift in the regulatory roles for historic heritage in Tasmania, with local government to be responsible for heritage regulation, advice and decision-making at the local level, and state government to be responsible for places of state significance.21 Under this model, local authorities could not override heritage decisions made by the state body. This approach is driven by the principle of subsidiarity (where action is taken by the most appropriate level of government) and has worked successfully in other jurisdictions. The principle has now become statute in New South Wales through recent amendments to the *Heritage Act 1977* (NSW).

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**Box 9.21 Yongala shipwreck site—protection under the *Historic Shipwrecks Act 1976***

The *Yongala* was an early 20th century interstate coastal steamer that sank during cyclonic weather in March 1911 near Townsville, Queensland. It provides a snapshot of Edwardian life in Australia and is now one of Australia’s most highly regarded and popular wreck dives. The site was protected under the *Historic Shipwrecks Act 1976* in 1981 and has been actively managed since 1983 with a declared protected zone around the site and entry only by permit. The wreck remains the final resting place of the 122 passengers and crew who were aboard the *Yongala* on her 99th and final journey.
4.2.3 Statutory protection

Heritage statutes and regulations are effectively planning controls with additional management provisions. Many heritage decisions are made in the context of applications for development consent. However, the planning system does not serve historic cultural heritage well in three areas, thereby increasing pressure on the resource:

- The notions of inheritance and public good could be better integrated within strategic planning frameworks and processes. Historic sites are typically managed as a constraint to be overcome, or a restriction on orderly land use, rather than as a community asset to be understood, cherished and celebrated.

- The planning systems in all jurisdictions are perceived as reactive and incorporating a principle that heritage can be negotiable or expendable if a sufficient case can be made.

- The systems do not offer adequate incentives to the thousands of private owners who are responsible for the care, control and conservation of the overwhelming majority of historic buildings in Australia. These owners deliver the public good but are expected to accept the implications (such as cost or restricted development opportunities).

Conflicts and poor heritage outcomes are often linked to misconceptions about the implications of heritage listing and lack of clear heritage policies and guidelines to assist owners, developers and decision-makers. When appropriate statutes, policies and guidelines are integrated with incentives and are well communicated, the system is far more robust (see Box 9.22).

The linear nature of our development assessment and consent processes places great reliance on existing reserved lands and statutory heritage lists. In Australia, the majority of cultural heritage places are only protected if they are formally identified and listed, whether at local, state or national level. (Exceptions include Aboriginal objects and rare and endangered species habitat in some jurisdictions.) However, many heritage lists have grown through inconsistent and sporadic processes, leading to significant gaps and implicit threats to unlisted places or unreserved significant lands. The National Reserve System contains significant gaps itself, but is also lacking in other important areas, such as landscape connectivity, adequacy of reserve sizes and configuration, the quality of reserved habitat and the complementarity of surrounding land uses.18

In its submission to the 2009 Hawke review of the EPBC Act, Australia ICOMOS identified the need for a strategic overview of heritage listing activity in Australia:

An expert review of all heritage registers in Australia should be undertaken, including the Register of the National Estate, with a view to developing a strategic view about the future of listing activities. The review should consider statutory and non-statutory lists. This review should be completed well before the statutory decline of the Register of the National Estate. Australia ICOMOS and Australian Council of National Trusts Workshop81

No such review has taken place, despite the pending demise of the Register of the National Estate.
4.2.4 More flexible approaches

A perverse pressure on historic heritage arises from the interest of many Australians in conserving these places. Although the overwhelming majority of listed historic heritage places are intact buildings that remain in use, there are also vacant buildings in remote areas, remnants of former mining and other defunct industrial activity scattered across the landscape, and large industrial structures that are beyond practical physical conservation. However, there is a widely held perception that the only way to conserve historic heritage is to restore or reconstruct it to an intact state. This attitude militates against more innovative (and often more realistic) outcomes, such as allowing places to become ruins within the landscape, or recording them in archives before they are demolished.

The pressures of inflexible approaches are nowhere more evident than in the features of the Line of Lode mine at Broken Hill, where a century of mining provides an evocative reminder of our heritage, but which is largely beyond physical conservation.

This issue has been addressed for at least two Australian World Heritage areas. In Kakadu National Park:

The level of available resources and practicalities imposed by the location and condition of many historic sites means that all cannot be conserved and interpreted to a high standard; nor indeed is this necessarily desirable. However, it is considered essential that places relating to the major themes of the park are retained and managed so that they survive in a meaningful way in the long term and are accessible to and understood by visitors. Mackay,21 p. 32

The statutory management plan for Heard Island goes even further, providing an overt management policy where 'the reserve’s cultural heritage is conserved through a process of managed decay’.83 However, in both these cases, the specific heritage places proposed for management in this way are not part of the outstanding universal values that support the World Heritage listing.

Heritage as ruins is a topical and contested issue that Australian heritage managers are only now beginning to grapple with.8 The ruins approach is only one possible solution and needs to be considered carefully; there is a potential danger in creating the perception that it is desirable to allow places to become ruins. This approach may work where heritage places are redundant and in remote areas, or where they are ruinous already (Box 9.23). There is also an important difference between active management as a ruin (which might involve, for example, clearing of invasive vegetation) and complete abandonment. For some places, changed circumstances (such as a new owner) may lead to unforeseen conservation opportunities.

Similarly, understanding how modern needs and statutory guidelines can interact with heritage places can foster creative solutions to protect heritage values (Box 9.24).

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Note: Challenges presented by heritage-listed dilapidated structures and ruins; Heritage Chairs and Officials of Australia and New Zealand workshop, April 2011
Box 9.23 Rural ruins—Mount Perry Powder Magazine

The Mount Perry Powder Magazine, built by the Queensland Government in 1874, is an important reminder of the first copper mining boom period at Mount Perry during the 1870s, and is also the oldest known surviving government powder magazine in Queensland. The brick and stone magazine is located in a paddock approximately 3.5 kilometres north of the town. The solidly constructed walls of the Mount Perry Powder Magazine, its narrow windows and remnant copper fittings are all standard features of Queensland Government powder magazines of the 19th century, and its isolated location demonstrates the practice of locating gunpowder at a safe distance from population centres.

However, by virtue of its location and condition, this building does not lend itself to traditional restoration or reconstruction, which would be likely to obscure its significance and integrity and prove uneconomical. As a managed ruin in the rural landscape, the former Mount Perry Powder Magazine is an evocative structure, standing alone in a grassy field; the peace and solitude of the site provide a contrast with the hectic activity that would have accompanied copper mining at Mount Perry.


Box 9.24 Sustainability vs cultural heritage

In Tasmania, increasing interest in sustainability has resulted in a growing number of applications for the installation of solar panels and heat pumps in heritage-listed properties. To address the issue, the Tasmanian Heritage Council has released guidelines on the installation of services such as solar panels, water tanks and heat pumps. The aim is to encourage owners to think about balancing new technologies with heritage values and features, with the full knowledge that any modern services have the potential to be intrusive on heritage places. It is hoped that these guidelines, the first of their kind in Australia, will help generate greater discussion among the community, architects and planners, so that good community outcomes can be achieved.

Source: Heritage Tasmania
4.3 Inputs

Inputs to heritage management can be assessed by considering the financial, human and other resources that are available for management programs to address pressures and risks to heritage values.

4.3.1 Financial resources

Sound management practices in the heritage system are ultimately determined by available resources, especially funding. It is appropriate that resources are allocated by government because heritage is a public good.

Heritage Victoria has considered the basis for heritage valuation from a cost–benefit perspective:

The economic case for government intervention in heritage lies in the communitywide nature of many of these benefits. The aesthetic quality of a building’s heritage facade, for example, will be of value to passers-by as well as to the building’s owner. Gard’ner,\textsuperscript{84} p. 2

The intangible nature of many of the benefits associated with heritage means they cannot be captured by the market. As a result they cannot be valued using normal market valuation (pricing) techniques. Gard’ner,\textsuperscript{84} p. 3

The issues of who pays for heritage conservation and who is responsible (the owner, community or government) is contentious. Many heritage places are privately owned, and their cultural benefits are shared by their owners and the community, so it is reasonable that the owners contribute some resources and the government contributes other resources, either directly with funding or indirectly through incentives. However, in reality, public funding for heritage in Australia is very low. Comparison with international data suggests that the low level of funding allocated for Australian heritage may be compounded by the extent of the heritage resource and by the relative ability of owners and governments to provide resources for its conservation (Box 9.25).

Heritage is available to all, but funded by some. The Productivity Commission made an important distinction between the respective roles and responsibilities of government and private sector owners of heritage places:

Governments are the custodians of the vast majority of the most significant or ‘iconic’ heritage places. They also own a very large number of less significant places.

There is significant scope for governments to improve how they identify and fund the conservation of government-owned places.

For many private owners, the current use and enjoyment of their property are consistent with, indeed require, maintaining its heritage attributes.

... the wider cultural benefits of the place are provided to their community with little added costs, apart from the extra administrative cost involved with government identification, assessment and listing. Productivity Commission,\textsuperscript{90} p. xxviii

Although many of the Productivity Commission’s findings and recommendations have been disputed, the above citations highlight the important role of government in providing the resource capacity for heritage conservation and the major contribution already made by private owners—a contribution that deserves greater support and improved incentives (Boxes 9.26 and 9.27).

In 2011, federal funding for heritage at the national level was dramatically cut from $34 242 000 in 2010–11 to $26 675 000 in 2011–12: a reduction of more than 22%. The heritage budget for DSEWPaC will be reduced by more than 31%, limiting the extent and effectiveness of current programs and leading inevitably to lack of federal leadership in managing Australian heritage. These cuts require downscaling of fundamental elements of the EPBC Act model for heritage management, such as National Heritage List assessments, and leave little or no ability to instigate effective monitoring or evaluation. The resulting reduction in staff support and other resources will also reduce the effectiveness of groups that rely on federal support, such as the Australian Heritage Council, the Heritage Chairs and Officials of Australia and New Zealand, and the Australian World Heritage Advisory Committee.
An emerging issue for Australia is an apparent disparity between the extent of our rich heritage and the financial resources available for its conservation and management. One way to consider this pressure is by benchmarking against other countries; however, this is challenging because of a lack of readily available and comparable data.

Figures A to D show heritage listing data for several countries. Figure A shows that the number of listed places in Australia is comparable to England and China, but far below the United States. However, when measured relative to country area, the picture is different; Figure B shows that Australia’s listed historic sites are highly dispersed. Figure C suggests that Australia lists more sites per person than the other selected nations. This may be a reflection of the underlying resource, or simply a byproduct of multiple jurisdictions and inconsistent approaches to listing. Figure D shows the gross domestic product of each nation per listed site as a measure of ability to pay.

This information is partial and arbitrary, but it does suggest that Australia needs to consider more ways to resource heritage conservation, perhaps by offering incentives for private heritage owners or allowing greater flexibility for change and adaptation.

Source: Central Intelligence Agency; English Heritage; United States National Parks Service; China Ministry of Culture; Department of Antiquities of Jordan
Box 9.26 Braidwood—economic impact of heritage listing

Braidwood in New South Wales is an excellent example of a surviving planned town from the Georgian period. The layout of Braidwood dates to the 1830s and reflects Governor Darling’s desire for planned towns and the imposition of the English county system in the colony of New South Wales. The town of Braidwood and its immediate surrounds were listed on the New South Wales Heritage Register in April 2006 to preserve its character and setting and to boost tourism and jobs in the area. The listing of a town as a whole was unprecedented on the east coast of Australia. Of the town residents, 50% believed that the listing had a positive influence on the town, and 31% believed that the listing was detrimental to the future of Braidwood. Despite these perceptions, the overall economic impact of the heritage listing on Braidwood was neutral.

In 2007, Heritage Victoria commissioned a useful review of the Victorian heritage grants scheme. The review report notes that the grant allocation criteria accept that appropriately recognised heritage places are equally valuable and deserve to be protected, so there is no prioritisation of grant applications based on subjective assessment of comparative heritage value. As a result, the growing demand and reducing pool of funding has tended to reduce the amount provided by individual grants. While understandable, this has arguably resulted in larger and more iconic places not receiving funding, or not having optimal works programs.

There is a stark contrast between the funding provided by governments in Australia for the conservation of natural and historic heritage. For example, the $2.7 billion Natural Heritage Trust (NHT) represents the biggest financial commitment to environmental action by any Australian government. Yet the Act which established the Trust in 1997 specifically excluded historic heritage from being considered ... Lennon, p. 25

In 2001 and 2006 SoE reports included a series of financial and human input measures. Unfortunately, comparable trend data for financial and human inputs are not easily gathered because the relevant information is often amalgamated within larger agency figures or affected by administrative changes. For some jurisdictions, only partial information is available.
Box 9.27 New South Wales National Trust Heritage Awards

The New South Wales National Trust Heritage Awards illustrate the benefits of incentive programs and recognition for the owners and managers of heritage places. The awards have been running for around 20 years. In 2011, 49 entries were received, representing a total project value of more than $70 million; the majority of entries were building works. Approximately 50% of the entries were from regional New South Wales, and many had a strong educational component, including supporting heritage trades training and educating heritage property owners. Community development and tourism benefits were also demonstrated in the award-winning projects.

The award entries came from projects supported by government, business and the community and demonstrate that heritage is a significant industry that affects all levels of the community.

The National Trust is planning to extend this award program across Australia, giving the whole country the opportunity to celebrate the value and benefits of heritage.

Protecting Australia’s heritage is part of the character and identity of this country, and it’s outstanding to see the level of commitment to protecting and conserving heritage in this state by large corporations, small companies, government bodies and individuals. William Holmes á Court, CEO of the National Trust of Australia (NSW)

Exeter Farm comprises a pair of rare, substantially intact mid-19th century vernacular timber-slab cottage buildings set within the remains of their original rural context. The structures were conserved and repaired as part of the NSW Historic Houses Trust Endangered Houses scheme. The project demonstrates how good conservation outcomes can be achieved through public open days and trades training workshops for heritage and trade professionals (photo by Alan Croker, Design 5 Architects).

A group of winners from the New South Wales National Trust Heritage Awards (photo courtesy of Daniel Griffiths Photography)

Natural and cultural heritage indicator 9 considers funding provided to heritage and other agencies for natural heritage places

Funding for survey and assessment of natural values appears to be declining. Reservation of lands with conservation value continues to depend on public sector budget allocations and opportunistic acquisition. However, additional land continues to be reserved without proportional increases in public sector resourcing. The sparse, partial figures available indicate that operational funding for Australian reserved land management may have increased in amount between 2006 and 2011 but may have declined relative to the dollar value and extent of managed lands. The majority of Australian parks appear to lack adequate resources to address major emerging pressures, and conservation programs are constrained by available resources. These limitations affect the values of cultural places within reserved lands, as well as natural values.

DSEWPAC summary analysis of natural and cultural heritage indicator data, July 2011
Table 9.2 World Heritage area funding ($) from the Natural Heritage Trust (NHT) and Caring for our Country, 2006–07 to 2010–11

Figures are based on approvals per financial year and include funding delivered through regional natural resource management bodies and, in some cases, funding for cultural heritage. No funding to Australian Government–managed World Heritage areas is included (i.e. Great Barrier Reef Marine Park, Kakadu National Park, Uluru-Kata Tjuta National Park).

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<td>3 663 139</td>
<td>3 350 232</td>
<td>2 924 000</td>
<td>5 496 810</td>
<td>2 458 600</td>
<td>17 892 781</td>
</tr>
<tr>
<td>New South Wales</td>
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<td>796 875</td>
<td>1 153 397</td>
<td>2 055 451</td>
<td>2 182 200</td>
<td>6 897 091</td>
</tr>
<tr>
<td>Tasmania</td>
<td>3 469 500</td>
<td>5 015 500</td>
<td>5 170 000</td>
<td>8 329 855</td>
<td>4 003 982</td>
<td>25 988 837</td>
</tr>
<tr>
<td>South Australia</td>
<td>110 000</td>
<td>74 250</td>
<td>–</td>
<td>–</td>
<td>135 000</td>
<td>319 250</td>
</tr>
<tr>
<td>Western Australia</td>
<td>283 503</td>
<td>465 230</td>
<td>425 346</td>
<td>299 700</td>
<td>822 530</td>
<td>2 296 309</td>
</tr>
<tr>
<td>Commonwealth</td>
<td>1 200 000</td>
<td>500 000</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1 700 000</td>
</tr>
<tr>
<td>Total</td>
<td>9 435 310</td>
<td>10 202 087</td>
<td>9 672 743</td>
<td>16 181 816</td>
<td>9 602 312</td>
<td>55 094 268</td>
</tr>
</tbody>
</table>

= no data available
Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities, 2011

Nevertheless, some specific public sector funding programs such as Natural Heritage Trust 2, Caring for our Country and the Jobs Fund initiative have made major positive contributions to particular natural heritage programs (see Table 9.2). However, there are currently no similar forward commitments for ongoing public sector funding of heritage conservation at this scale.

Natural and cultural heritage indicator 10 considers funding provided to heritage and other agencies for historic heritage places

Funding for surveying and assessing historic values is difficult to measure on a national basis, but is declining for the National Heritage List. Although the dollar amount has increased, when adjusted for inflation and the number of listed places, the available funding for historic heritage decreased between 2006 and 2011.

Many Australian historic sites in public ownership lack adequate resources to address major conservation priorities. Private owners of historic sites do not receive incentives that are proportional to the public value of the places they own and manage. Grant funding, though substantial during the Jobs Fund initiative, is now in decline.

Natural and cultural heritage indicator 11 considers funding provided to heritage and other agencies for Indigenous heritage places

Resources for listing and protecting Indigenous heritage places are inadequate, and their allocation is often a post-event reaction to adverse impacts. Insufficient attention is paid to intangible values and effective means of protection other than listing or reservation.

Australia’s listed Indigenous sites do not allocate adequate resources to address major conservation priorities, nor do land-management programs such as Caring for our Country. Conservation programs for intangible heritage are severely constrained by limits on available resources.

Funding for heritage: Jobs Fund (heritage projects)

In April 2009, the Prime Minister announced a $650-million economic stimulus package (the Jobs Fund), to support local jobs, build skills and improve facilities in local communities. This included $60 million for heritage projects. The Jobs Fund program is by far the largest public sector funding initiative for heritage during the SoE 2011 reporting period. Funding of $58.2 million across 2008–09 and 2009–10 was approved for 191 projects (Figures 9.16 and 9.17).
An assessment process identified which projects met Jobs Fund ‘gateway’ and heritage criteria, and independent expert assessment review was provided by the Australian Heritage Council and the minister’s Heritage Working Group. Approximately 180 further projects (with a value of $173 million) were assessed as suitable, but were not funded.
Brennan and Geraghty’s Store in Maryborough, Queensland, is a rare and extremely significant example of a late-19th century store, which still contains an in situ collection of merchandise and records dating from the early 1900s.

The store was constructed in 1871 by Irish immigrants and brothers-in-law Patrick Brennan and Martin Geraghty, adapting a cottage they had built in 1861. The 1880s saw the peak of Brennan and Geraghty’s business empire in a boom period for Maryborough and Queensland. The store was operated for 100 years by descendants of the Geraghty family, closing in 1971. It was purchased by the National Trust of Queensland in 1975 and opened to the public in 1990.

Funding of $250,000 was made available to the National Trust to replace guttering; investigate the downpipe and stormwater system for blockages; replace the rear stairs, three panels of pine awning and rotted cladding on the outhouse, front fences and gates; repair loose mouldings; and repaint the awning, main building, outhouse and stables.

The project employed local consultants, builders and tradespeople because heritage skills and materials were readily available locally. The project made a valuable contribution to sustaining heritage skills in a regional centre that prides itself on being a heritage tourism destination.

In addition to achieving some outstanding heritage outcomes (Box 9.28), the heritage component of the Jobs Fund created 2423 jobs, 231 work-experience positions and 116 traineeships. Thirteen projects were located in Indigenous communities or had particular focus on Indigenous employment, contributing to Closing the Gap targets through economic stimulus.

Like previous major funding programs (such as the Bicentennial and Centenary of Federation funding programs leading up to 1988 and 2001), the Jobs Fund represents a ‘spike’ in funding levels for heritage conservation. Such spikes are typically interspaced with lean periods. This funding pattern may contribute to cyclical patterns observed in the condition and integrity of our heritage (see Section 2.2.7).

4.3.2 Human resources

Human resource inputs for heritage include the knowledge and skills of staff employed in reserves and cultural sites; heritage advisers and regulators; and private sector owners, managers and volunteers.

Conservation of the vast array of culturally significant buildings and places in Australia and New Zealand relies on a body of heritage professionals and tradespeople with relevant specialist skills. These skills are acquired through both formal and ‘on the job’ training. The number
of practitioners with these skills has declined in recent years and the population of appropriately skilled practitioners is ageing—leading to a looming crisis in cultural heritage conservation.\footnote{Godden Mackay Logan,\textsuperscript{21} p. 131}

There was a net increase in the number of professional heritage-related courses between 2006 and 2011. However, available courses are concentrated in eastern Australia and major cities. The focus for courses is on general professional heritage management, whereas opportunities for more specific training in heritage trades have declined (Table 9.3).\footnote{Godden Mackay Logan,\textsuperscript{21}}

Practice standards in heritage professional practice and trades practice rely on skilled practitioners. A particularly challenging problem for practice standards in historic heritage is an apparent skills erosion (Box 9.29).

\textbf{Natural and cultural heritage indicator 18 considers membership of selected peak professional heritage associations}

Comprehensive, reliable longitudinal data are not available for peak professional heritage associations across the heritage sector. Surrogate data (such as membership of Australia ICOMOS) suggest a substantial increase in membership of professional heritage associations of around 20\% between 2006 and 2011 (Figure 9.18).

\textbf{Natural and cultural heritage indicator 19 considers the number of volunteers trained by heritage organisations and institutions}

Comprehensive, reliable longitudinal data are not available for the heritage volunteer sector. Surrogate data indicate that volunteer participation has declined. For example, information provided by the Australian Council of National Trusts shows some variation from state to state, but overall a general decrease of 2.7\% over 2006–2011 and a decrease of 14.1\% since 1998. Actual membership numbers and participation in heritage training or conservation activities may vary depending on state-specific processes for managing membership records, particular advocacy campaigns or membership drives. While National Trust membership can be regarded as indicative only, the figures suggest that, despite some growth in numbers between 2006 and 2008, volunteerism in the heritage sector may generally be declining (Figure 9.19).

However, there are many positive stories about contributions made to heritage conservation by volunteers (Box 9.30).

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\begin{table}[h]
  \centering
  \begin{tabular}{|l|c|c|c|c|c|c|c|c|}
    \hline
    \textbf{State} & \textbf{Physical conservation} & \textbf{Recording} & \textbf{Management} & \textbf{Consultation} & \textbf{Interpretation} & \textbf{Archaeology} & \textbf{Historic landscape management} & \textbf{Legislation and policy} & \textbf{Total} \\
    \hline
    ACT & 4 & 6 & 11 & 1 & 6 & 8 & 7 & 8 & 51 \\
    NSW & 3 & 9 & 4 & 1 & 2 & 5 & 24 \\
    NT & & & & & & & & & 1 \\
    Qld & & 3 & 4 & 2 & 9 \\
    SA & 10 & 12 & 8 & 15 & 12 & 57 \\
    Tas & & & & 1 & 1 \\
    Vic & 10 & 8 & 10 & 4 & 5 & 1 & 2 & 8 & 48 \\
    WA & & 4 & 5 & 3 & 4 & 16 \\
    \hline
    \textbf{Total} & 17 & 33 & 44 & 5 & 27 & 33 & 9 & 39 & 207 \\
  \end{tabular}
  \caption{Professional historic heritage training courses offered in Australia (degree, diploma, certificate and short courses), 2010}
  \label{tab:9.3}
\end{table}

\textsuperscript{17} ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

\textsuperscript{21} Note: Empty cells are where no courses have been identified.

\textsuperscript{21} Source: Godden Mackay Logan
Box 9.29 Loss of traditional heritage trade skills

During 2009 and 2010, the Heritage Chairs and Officials of Australia and New Zealand commissioned a study of heritage trades and professional training in Australia and New Zealand. The project report assessed demand for a variety of heritage professional and trade skills and considered this need in relation to available training and expertise.

The study highlighted the ageing population of specialist tradespeople, a declining skills and knowledge base and, particularly, an emerging generation of practitioners who had completed general rather than specialist training but still considered that they could undertake specialist trades work—they ‘did not know what they did not know’. The report identifies that the amount of specialist heritage trade work available in Australia and New Zealand is barely adequate for existing (generally older) specialist practitioners, which means that there are limited opportunities for new apprentices as funding levels confine the available specialist work to the small number of longstanding, well-established practitioners. However, the situation is fast approaching a precipice, beyond which current experts will have retired without a new generation to take their place. This emerging skills shortage poses a potentially major risk for historic heritage conservation.

Photos by Godden Mackay Logan
Natural and cultural heritage indicator 20 considers the number of people working in Indigenous organisations, number of Indigenous enrolments in university heritage courses, number of Indigenous people employed by agencies involved in Indigenous programs and management of Indigenous heritage.

Insufficient data are available to provide an accurate assessment of this indicator.

Natural and cultural heritage indicator 21 considers the number of local government heritage advisers.

Insufficient data are available to provide an accurate assessment of this indicator.
Effectiveness of management | Heritage

Box 9.30 Heritagecare

Heritage Victoria supported the Heritagecare program between 2006 and 2010. The program was delivered by a nongovernment organisation through an annual grant of $385 000. The grant provided funding for:

- Hands on Heritage, which facilitated short-term volunteering. This program was required to deliver a minimum of twenty 5-day projects (i.e. a total of 100 project-days) per year, with five volunteers per project.
- Community Stewardship, which comprised six-month projects that were required to deliver a minimum of fifteen 26-week projects per year (i.e. 390 volunteer-days per year).

Over the four years, 167 Community Stewardship projects were undertaken, with a total of 17 329 volunteer-days; and 62 Hands on Heritage project sites (including multiple projects at the same site) were delivered, with a total of 2934 volunteer-days.96

Natural and cultural heritage indicator 22 considers the number of professional heritage employees in government agencies

Anecdotal evidence suggests that national parks in Australia suffer from a systemic lack of direct resourcing. Budgets and grant programs are never regarded as sufficient to achieve basic values management and respond to emerging issues. The implications include loss of skilled staff, and management having to omit some activities and programs, leading to further pressures and impacts.

At the national level, Australian Government departmental funding was reduced from $15 million to $13 million between 2006–07 and 2011–12.97 This reduction is even greater when adjusted to reflect actual employment costs, and has resulted in a drop in heritage staffing levels. The reduction adversely affects listing programs, and reduces capacity for delivery of advice, proactive planning and reactive monitoring of heritage places.68

At the state level, comparable trend data for staffing levels within heritage agencies are not available: the relevant information is subsumed within summary figures for larger agencies, or compromised by changes to government structures or differences between jurisdictions. However, a snapshot view as at June 2011 (Table 9.4) shows significant variation in staffing levels between jurisdictions, even taking anomalies into account and adjusting for population or numbers of places listed on state heritage registers. There is an obvious correlation between higher staffing levels and a greater number of listed places; it is not clear whether this correlation occurs because greater staff resourcing enables more places to be assessed, or because greater numbers of listed places require more regulators, or both.

Along with national and state heritage staff, local heritage advisers are highly valued (Box 9.31).
Table 9.4 State and territory heritage office full-time equivalent (FTE) staff numbers, June 2011

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>FTEs internal</th>
<th>FTEs external</th>
<th>FTEs total</th>
<th>Population (million)</th>
<th>FTE/million people</th>
<th>Number of places on state register</th>
<th>Number of places on state register/FTE</th>
<th>Notes</th>
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</thead>
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<tr>
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<td>12.0</td>
<td>0.0</td>
<td>12.0</td>
<td>0.36</td>
<td>33.3</td>
<td>470</td>
<td>39.2</td>
<td>Includes Indigenous heritage</td>
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<td>7.24</td>
<td>5.1</td>
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<td>30.4</td>
<td>250</td>
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<td>36.6</td>
<td>4.52</td>
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<td>1 670</td>
<td>45.6</td>
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<td>16.9</td>
<td>1.64</td>
<td>10.3</td>
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<td>130.8</td>
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<td>Tas</td>
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<td>16.5</td>
<td>0.51</td>
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<td>5 520</td>
<td>334.6</td>
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<td>Vic</td>
<td>42.2</td>
<td>0.0</td>
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<td>7.6</td>
<td>2 240</td>
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<td>WA</td>
<td>28.3</td>
<td>0.0</td>
<td>28.3</td>
<td>2.30</td>
<td>12.3</td>
<td>1 300</td>
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<td><strong>Total</strong></td>
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<td><strong>13.6</strong></td>
<td><strong>196.5</strong></td>
<td><strong>22.35</strong></td>
<td></td>
<td><strong>21 160</strong></td>
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</tr>
</tbody>
</table>

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia; Tas = Tasmania; Vic = Victoria; WA = Western Australia

Source: Heritage Victoria, gathered on behalf of Heritage Chairs and Officials of Australia and New Zealand, unpublished

Box 9.31 Local heritage—the difference made by local heritage advisers

Local heritage advisers are invaluable in providing targeted and specialist advice to home and business owners to help them manage their heritage properties. Through local councils, heritage advisers provide advice to residents and property owners who want to alter, extend or demolish privately owned buildings.

For example, positive and proactive heritage management improved the facade of a commercial building in Geelong, Victoria. The local heritage adviser assisted the owner in reaching a cost-effective solution that improved the appearance and amenity of the building. The heritage adviser used the Geelong Verandah Study to suggest a design that would have a positive effect on the heritage values of the building.98

![231 Moorabool St, Geelong, before verandah reconstruction (photo by Michael Bell, Manifest Architects, Geelong)](image1)

![231 Moorabool St, Geelong, after verandah reconstruction (photo by David Rowe, Authentic Heritage Services Pty Ltd, Heritage Adviser, City of Geelong)](image2)
4.4 Processes

Heritage management processes are assessed by considering the governance systems in place that provide appropriate statutory responses, and adaptive management practices based on effective monitoring systems and adequate resources.

4.4.1 Statutory responses

The overwhelming majority of heritage listing processes and impact assessments occur at the state or local level, often as a reactive response to threats. In many cases, the multilevel and cross-jurisdictional rules cause duplication and inconsistent (sometimes contradictory) outcomes. This is especially the case in jurisdictions where political intervention overrides heritage controls and values-based heritage decision-making. Particular current challenges arise from land zoning, building regulations and development standards that place major pressure on heritage places. Inappropriate zonings and regulations may lead to unrealistic expectations of development potential. Development standards can create a perception that every site should be developed to its maximum potential, irrespective of the effect on heritage items on the site or nearby. Local regulations and guidelines can be extremely influential in this regard because they represent the interface between the place, its owners or developers, and the authorities. These regulations and guidelines need to align with heritage values.

Unexpected adverse pressure on historic buildings has come from growing interest in sustainability and the green building agenda (Box 9.32). Balancing heritage conservation and sustainable development can be challenging, particularly in commercial contexts. Wasted embodied energy (i.e. the energy used to produce the building, including all materials) is an emerging issue. While a whole-of-lifecycle assessment would seem to be an obvious and appropriate approach, current standards and rules almost totally neglect embodied energy and focus on operational energy performance.

The sustainability agenda may also promote inappropriate changes that have adverse effects on individual heritage places if they are not sensitively handled. For example, prioritising native vegetation over exotic species can cause adverse outcomes for significant cultural plantings and gardens.

4.4.2 Adaptive management

Adaptive management is an important technique for effective heritage conservation. Developed for natural areas, adaptive management can be applied to both natural and cultural heritage places. It involves a continuous cycle of improvement based on setting goals and priorities, developing strategies, taking action and measuring results, then feeding the results of monitoring back into new goals, priorities, strategies and actions.\(^{103-104}\)

One well-known adaptive management methodology is the conservation action planning approach of The Nature Conservancy. This process assesses context (values and threats) and outcomes (conservation status), then integrates this into development and implementation of conservation strategies that can be applied to any conservation site.\(^{104}\) Other approaches include the Australian Natural Heritage Charter processes, including the cycle of monitoring and review in preparing a conservation plan.\(^{59}\)

Some Australian national parks already embrace adaptive management.\(^{105}\) Management systems in most national parks go some way towards this aim by identifying conservation needs and making well-informed decisions about management goals, resource allocation and impact assessment. However, formal monitoring and evaluation occurs in relatively few jurisdictions. Australia provides periodic reporting to UNESCO on its World Heritage properties (see Section 2.2.1), and both New South Wales and Victoria prepare reports on the state of their parks. Good systems are generally in place for assessing specific development-driven impacts on other off-park natural heritage places, but there are relatively few proactive and comprehensive conservation management programs.

Indigenous heritage places within reserved lands usually have management systems that identify conservation needs, involve traditional owners and make well-informed decisions about impact assessment and resource allocation. However, outside the reserved lands system, Indigenous heritage decisions are typically reactive and not always well informed, particularly development-driven impact assessment, which may occur without knowledge of the total resource. Little formal monitoring and evaluation or adaptive management of Indigenous heritage occurs.
Box 9.32 The green building agenda

The green building agenda being embraced and promoted by many agencies is refocusing attention on responsible building and development, and directing resources to general upgrading of the built environment. This was thought to have benefits for heritage conservation, but instead the green building agenda is placing significant pressure on heritage buildings. The threats can be grouped into two categories: the impact of sustainability legislation, and the characteristics of heritage buildings themselves.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has determined that the energy embodied in existing buildings in Australia is equivalent to 10 years of the total energy consumption of the entire nation. However, sustainability legislation measures only the operational efficiencies of buildings, with the aim of achieving immediate greenhouse gas savings by increasing efficiencies in heating, cooling and ventilation, saving water and minimising waste. Rating tools generally do not provide any recognition of the sustainability benefits of conserving existing buildings, and do not acknowledge the embodied energy inherent in these structures. They also do not consider the contribution that the inherent quality of materials makes to the lifecycle of a structure, nor the cultural value of the building to the community.

Wasted embodied energy is a growing issue, and a lifecycle assessment approach is appropriate. Better recognition could be paid to the potential for improvement of the environmental performance of existing buildings.

The risk is that, rather than being conserved and refurbished, historic buildings will be demolished because they do not meet the contemporary green standards sought by industry and consumers. This risk will continue while the Green Star rating categories do not award points for heritage and do not adequately recognise the value in retaining existing materials. Points are awarded for replacing existing fabric with recycled material, even if the removed fabric is trucked off to landfill. Few, if any, points may be earned for retaining existing fabric; none for ensuring the ‘integrity’ of the original is maintained. Yet if the full lifecycle is considered, ‘upgrading and maintaining an existing building to a 4.5 Green Star rating is 2.5 times more efficient than demolishing to build an equivalent 5 Green Star building measured at year 30 in the building cycle’. However, ‘a refurbished building will not have new concrete poured and therefore cannot achieve the credit for use of recycled content in structural concrete’.

The requirement for commercial building disclosure now ensures that the National Australian Built Environment Rating System (NABERS) energy ratings are available for large commercial buildings (soon to be extended to residential buildings). As the NABERS rating tool only rates energy efficiency, there is a great danger that heritage buildings will become even less desirable to owners and tenants who seek higher energy ratings. This pressure is already well demonstrated by government policies that require government business to be done from buildings with high NABERS ratings (e.g. the John Gorton Building that houses the Canberra offices of the Australian Government Department of Sustainability, Environment, Water, Population and Communities).

The physical characteristics of a heritage building may also pose difficulties for achieving high energy ratings. Higher star ratings under the current rating tools require significant investment in innovative technologies, and significant additional plant area for capturing water, recycling greywater and installing cogeneration or trigeneration plans. Heritage buildings often have smaller floorplates, sit on smaller sites and may be constrained by the inability to excavate for additional plant area, or to add this to the roof area. These characteristics affect the ability of heritage structures to compete in the current rating system.

Several organisations are working to redress the imbalance of the current rating tools in a number of different spheres. Organisations include the Green Building Council of Australia, which is developing a rating tool for existing buildings; the Australian Tax Office, which is proposing a green investment tax incentive for retrofitting; and RMIT University and Heritage Victoria, which are researching the embodied energy of various heritage building typologies. The CSIRO is developing the Australian Life Cycle Inventory materials database for eventual incorporation into the Nationwide House Energy Rating Scheme, and organisations such as the Property Council of Australia run seminars on retrofitting existing buildings.

The Cleland Bond is a historic warehouse in Sydney’s Rocks district that has recently been adapted for commercial use, with a new lift, stairs, lighting and services, all of which improve energy efficiency and are clearly differentiated from the historic fabric. The adaptation makes use of the thermal properties and embodied energy of the existing structure (owned by Sydney Harbour Foreshore Authority, architect Tanner Architects; photo by Tyrone Branigan, courtesy Tanner Architects).
Management systems at all levels of government generally facilitate well-informed decisions about resource allocation and impact assessment for historic heritage. There are some excellent examples of innovative, values-based decisions leading to good outcomes (Box 9.33). However, formal monitoring and evaluation rarely occurs. Management systems for listed historic places in public ownership identify conservation needs and generally adopt the methodology advocated in Kerr106 and the Burra Charter,46 an approach that includes setting goals, determining priorities, developing strategies and taking action, but places less emphasis on feeding the results of evaluation and monitoring back into management. For privately owned, listed historic places, the systems for impact assessment and resource allocation vary greatly across jurisdictions, owners and site types.

4.5 Outcomes

Assessing heritage management outcomes requires informed evaluation of the way in which current pressures and emerging risks to heritage values are being reduced and the resilience of heritage is being improved to retain values. In short, this is an assessment of whether management objectives are being met.

A nationwide lack of monitoring and evaluation programs makes these assessments challenging and highly reliant on individual examples, anecdotal evidence and phenomenological data. Therefore, the judgements presented in this section are based on opinions expressed during the workshops held as part of the SoE 2011 reporting process (as outlined in Chapter 1).
4.5.1 Natural heritage

Australian national parks and other recognised natural heritage places are accessible to the community, strongly promoted both within Australia and overseas, presented to visitors in engaging ways, and often important elements in community identity and sense of place.

Each Australian jurisdiction has a separate statutory basis and different structures and processes for natural heritage place management. At a national level, there is a strong focus on the National Reserve System, whose targets provide one way to assess the outcome for Australia’s reserved lands. Judged in this way, our reserved lands include a sample of more than 10% of 51 of the nation’s 85 bioregions. However, taking other factors into account, such as subregions determined by vegetation communities, habitat and whole-of-landscape connectivity, reserved lands possibly cover as little as one-third of an adequate selection.18

Limited information is available on the conservation outcomes for natural heritage in Australian national parks, as only New South Wales and Victoria undertake...
Magamarra is a marine sacred site within the estuarine waters of the Blyth River on the Northern Territory Arnhem Land coast. The site is within the custodial waters of the Guwowura and Mareang A-Jirra groups, upstream from the Blyth River mouth, between the townships of Maningrida and Ramingining.

Magamarra is a significant site to the Guwowura and Mareang A-Jirra people of northern Arnhem Land, and is used mainly for cultural burial ceremonies related to commemorating the dead. It is a place for renewal, reflection and commemoration. It is the final resting place for all Guwowura and Mareang A-Jirra people and where the spirits of their ancestors chose to base themselves for eternity.

When we die, our spirits come here to rest in the mermaids' castle. Our spirits join those of our ancestors. This is where we are reincarnated in the waters. Traditional custodian

Magamarra encompasses objects within the Blyth River waters such as the Barala (sand sculpture), stone statues and other objects that embody ancestral spiritual beings. The site was created by ancestral beings in the dreaming. The physical condition and integrity of this site are vital to the cultural wellbeing of the Guwowura and Mareang A-Jirra people. Magamarra is also part of daily life for approximately 40 people living at remote outstations or on country. The Magamarra site is in the custodial waters of the Guwowura and Mareang A-Jirra clans, but may be used by other groups with shared boundaries. The site is also intrinsically linked to the surrounding cultural landscape that incorporates many other marine and terrestrial sacred sites.

Magamarra is a registered sacred site under the Northern Territory Aboriginal Sacred Sites Act 1989, and access to the site is restricted. The mouth of the Blyth River is registered as a sacred site and is demarcated by signage and a closing line, which is designed to prevent people (especially fishermen) from entering the sacred site. The traditional custodians of Magamarra have unrestricted access to the site as it is situated on Aboriginal land.

In 2009, after many years of consultation and negotiation, the lands around Magamarra were declared Australia’s 33rd Indigenous protected area (IPA). The Djelk IPA is managed by the Bawinanga Aboriginal Corporation, based in Maningrida, and is serviced by a large team of rangers known as the Djelk Men’s and Women’s Rangers.

Magamarra has a high level of protection compared with other Indigenous heritage sites—it is located on Aboriginal lands within an IPA managed by Aboriginal rangers and is registered as a sacred site. Unlike traditional custodians of sacred sites in other parts of Australia, traditional custodians of Magamarra have the legal right to control access to the site and to enforce customary laws associated with the site through offences such as trespass and desecration of sacred sites. Nevertheless, the effectiveness of Magamarra’s legal protection is questioned by traditional custodians who have customary responsibility for its protection.

The Blyth River is also a well-known place for recreational and commercial barramundi fishers. Traditional custodians perceive illegal fishing activities at Magamarra as the most significant threat to the site’s condition and integrity. Traditional custodians report ongoing problems with commercial fishers not respecting Aboriginal law or culture and entering the site at night.

The Djelk rangers who manage the whole protected area support the traditional custodians. The rangers mainly deal with environmental issues relating to the area, but are also called in when people are destroying or desecrating sites. However, the long distances from fisheries enforcement officers often mean that offenders cannot be apprehended and prosecuted. There would be merit in exploring the possibility of Indigenous rangers becoming fully-fledged fisheries officers with enforcement powers.

Source: Schnierer et al. 12
substantive formal monitoring and evaluation of the state of parks (Box 9.34). Australia’s Strategy for the National Reserve System 2009–2030 proposes that the states and territories standardise approaches to data collection and evaluation of management effectiveness. The sparse data that are available suggest that heritage values are generally being retained, although some decline in habitat and species loss is evident. Virtually no reliable national data are available to make objective judgements about natural heritage outside the parks system. The data we have relate primarily to inputs—many natural heritage areas have management measures in place to address threats within the bounds of available resources.

4.5.2 Indigenous heritage

There is no cohesive national picture for Indigenous heritage and no adequate action by government agencies to coordinate management of Indigenous heritage resources and share information. Assessing outcomes for Australia’s Indigenous heritage is therefore severely hampered by lack of comparable data and the absence of formal monitoring and evaluation programs.

Differences between jurisdictional systems prevent reliable conclusions being drawn about the coverage of listed and protected Indigenous heritage places. However, the heritage values of Indigenous places in reserved lands or under Indigenous management are being retained. Little information is available on the effects of management action on the values of other parts of Australia’s Indigenous heritage. Incomplete understanding of the resource, the current processes used to respond to development pressures and the tendency of consent agencies to permit site destruction continue to place Indigenous heritage sites at risk.

Despite these shortcomings, Australia’s Indigenous heritage is celebrated by Indigenous people, often accessible to the wider community, strongly promoted within Australia and overseas, and increasingly presented by Indigenous people in accordance with relevant cultural practices (Box 9.35).

4.5.3 Historic heritage

Historic heritage places are usually accessible, often cherished, increasingly presented to visitors in engaging ways and recognised as important elements in community identity and sense of place.

Through the Historic Heritage Chairs and Officials of Australia and New Zealand, there is some national coordination of the management of Australia’s historic heritage resources, despite the separate statutes and different government structures in each jurisdiction.

Australia’s listed historic sites are numerous, but have been assessed, listed and protected in an ad hoc manner. Although the Australian heritage database offers a convenient portal to information about more than 20 000 natural, historic and Indigenous heritage places, it does not include all the statutory heritage lists and is difficult to use. There are no readily available national data that allow assessment of the representativeness of the national set of listed historic places. Limited information is available on the effectiveness of historic heritage management, as very little monitoring and evaluation takes place. However, select sampling of a small set of historic places suggests that the heritage values of our listed historic sites are generally being retained.11

### 9.3 Assessment summary

## Effectiveness of heritage management

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<tr>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
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<tr>
<td></td>
<td>Ineffective</td>
<td>Partially effective</td>
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### Natural heritage

#### Identification

**Context:** Australian park managers have a good understanding of Australia’s bioregions and subregions. The specific heritage values of most reserved lands are understood. Discussion and debate continue on matters such as what constitutes an adequate sample, how to create landscape connectivity, the size and configuration of reserves, and how to account for habitat, resilience and recovery.

**Planning:** There is a clear aim to include 10% of each of Australia’s bioregions within the National Reserve System.

**Inputs:** Funding for survey and assessment of natural values is declining. Reservation of additional lands of conservation value continues to be substantially dependent on public sector budget allocations and opportunistic acquisition.

**Processes:** The National Reserve System provides an overall framework for assessments, which generally take place at the state or local level.

**Outcomes:** Australia’s reserved lands include a sample of more than 10% for 51 of the nation’s 85 bioregions; however, taking other factors like habitat and connectivity into account, the reserved lands may only cover one-third of an adequate selection.

### Management

#### Context:
Management needs and processes are well understood by Australian park managers.

#### Planning:
Many, but not all, major national parks and reserved lands have management plans, with well-resolved provisions and appropriate regulatory controls. Responses to pressures and management responsibilities are clearly identified.

#### Inputs:
The majority of Australian parks are understaffed and lack adequate resources to address major conservation priorities, including emerging urgent pressures. Conservation programs are constrained by available resources.

#### Processes:
Management systems in parks identify conservation needs and make well-informed decisions about impact assessment and resource allocation. However, formal monitoring and evaluation occurs in few jurisdictions.

#### Outcomes:
Limited information is available on the state of parks, as only New South Wales and Victoria undertake substantive monitoring and evaluation of outcomes. Available data suggest that heritage values are generally being retained, with some decline evident.
Summary Assessment grade Confidence

<table>
<thead>
<tr>
<th>Ineffective</th>
<th>Partially effective</th>
<th>Effective</th>
<th>Very effective</th>
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**Protection**

**Context:** Statutory controls for listed natural heritage places and the reservation system are well understood by park and place managers.

**Planning:** The National Reserve System program is seeking to include bioregions that are poorly represented in reserved lands. However, additional work on related factors such as habitat and connectivity is needed to understand what constitutes an adequate sample of reserved lands.

**Inputs:** Additional land reservation occurs without proportional increases in public sector resourcing. Resourcing for survey and assessment is modest compared with the size and significance of the resource, and is declining.

**Processes:** The National Reserve System offers a coordinated response to the need for a nationwide reserve system. Listing processes for other aspects of natural heritage are less well coordinated and transparent. Federal, state and local protective measures and controls are less well understood by the general community.

**Outcomes:** Natural heritage areas have management measures in place to address threats within the bounds of available resources. Natural heritage values of parks and listed natural heritage sites are generally being retained.

**Leadership**

At a national level, there is a strong focus on the National Reserve System and a structure is in place to facilitate information sharing. However, each jurisdiction has a separate statutory basis, and different structures and processes for natural heritage management.

**Celebration**

Australian national parks and other recognised natural heritage places are accessible to the community, strongly promoted within Australia and overseas, presented to visitors in engaging ways, and often important elements in community identity and sense of place.

Continued next page
Effectiveness of heritage management continued

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<tr>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
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<tbody>
<tr>
<td>Indigenous heritage</td>
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<tr>
<td>Identification</td>
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<tr>
<td>Context: Understanding of the nature and extent of Australia’s Indigenous heritage, both tangible and intangible, is inadequate. Indigenous places are also typically seen as individual physical sites rather than part of the rich cultural landscape that is country</td>
<td>Partially effective</td>
<td>● ●</td>
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<tr>
<td>Planning: There is a clear need for nationally coordinated policies and programs that proactively document and assess Indigenous heritage, rather than reactively responding to threats</td>
<td>Partially effective</td>
<td>● ●</td>
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<tr>
<td>Inputs: Funding for survey and assessment of Indigenous heritage values is usually directly proportional to the threat posed by a particular development. Resources available for documenting intangible heritage and country are inadequate</td>
<td>Partially effective</td>
<td>● ●</td>
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<tr>
<td>Processes: The Australian Government provides little leadership or coordination in Indigenous heritage assessment. Most assessments occur at the state level in response to threats. Some state jurisdictions are significantly improving assessment processes</td>
<td>Effective</td>
<td>● ●</td>
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<tr>
<td>Outcomes: It is not possible to ascertain whether identified, listed and protected Indigenous heritage places provide a representative or adequate sample</td>
<td>Ineffective</td>
<td>● ●</td>
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Management

| Context: Managers and decision-makers do not always fully understand the needs and processes that apply to Indigenous heritage, especially the role of traditional land and sea management. However, there has been significant recent improvement, including an increasing role for Indigenous people | Ineffective | ● ● |
| Planning: Management plans for reserved lands usually include provisions for Indigenous heritage management, with well-resolved provisions that have been prepared in consultation with traditional owners. Stand-alone Indigenous land and sea management plans are also being prepared. Unlisted Indigenous heritage places suffer from lack of planning processes | Effective | ● ● |
| Inputs: Australia’s listed Indigenous sites (and even land-management programs such as Caring for our Country) do not allocate adequate resources to address major conservation priorities. Conservation programs for intangible heritage are severely constrained by limits on available resources | Partially effective | ● ● |
| Processes: Management systems for Indigenous heritage do not always make well-informed decisions about impact assessment and resource allocation, especially in the case of development-driven impact assessment in the absence of knowledge of the total resource Little if any formal monitoring and evaluation occurs | Partially effective | ● ● |
Management continued

Outcomes: Very limited, partial information is available on the effects of management action on the values of Australia’s Indigenous heritage. There is no evidence of formal evaluation of outcomes.

Protection

Context: Statutory controls for Indigenous heritage places are generally understood, despite jurisdictional inconsistencies.

Planning: Indigenous heritage is under-represented on statutory heritage lists and registers and is not effectively supported by statutes that claim to provide blanket protection, but also allow progressive site destruction.

Inputs: Resources allocated for listing and protection of Indigenous heritage places are inadequate and often a post-event reaction to adverse impacts. Insufficient attention is paid to intangible values and places, and to effective means of providing protection in ways other than listing or reservation.

Processes: Management systems for Indigenous heritage places within reserved lands identify conservation needs, involve traditional owners and make generally well-informed decisions about impact assessment and resource allocation. However, outside the reserved lands system, Indigenous heritage decisions are less consultative and often reactive to threats.

Outcomes: The heritage values of Indigenous places in reserved lands or under Indigenous management are being retained. However, our incomplete understanding of the resource and the current processes used to respond to development pressures mean that other Indigenous heritage sites continue to be at risk.

Leadership

There is no cohesive national picture for Indigenous heritage, and no adequate action by government agencies to coordinate management of Indigenous heritage resources and share information. Each jurisdiction has a separate statutory basis and different structures and processes for Indigenous heritage management.

Celebration

Australia’s Indigenous heritage is celebrated by Indigenous people, often accessible to the wider community, strongly promoted within Australia and overseas, and increasingly presented by Indigenous people in accordance with relevant cultural practices.
## Effectiveness of heritage management

### Historic heritage

#### Identification

**Context:** Statutory lists and registers have grown in an ad hoc manner and provide a partial understanding of the extent of Australia’s historic heritage. In some areas, systematic thematic survey and assessment provides more thorough coverage, but this is the exception. Historic places are also typically seen as individual sites rather than part of a cultural landscape.

**Planning:** While the assessment and listing process might be improved, most Australian jurisdictions include identification and listing of historic heritage items at all levels of government.

**Inputs:** Funding for surveying and assessing historic values is difficult to measure on a national basis, but is declining for the National Heritage List.

**Processes:** The Australian Government provides leadership in historic heritage assessment through the Heritage Chairs and Officials of Australia and New Zealand, which has identified a range of relevant standards and consistent assessment criteria.

Most assessments take place at the state or local level.

**Outcomes:** Australia’s listed historic sites are numerous, but are protected in an ad hoc manner that does not facilitate judgement of total adequacy or representativeness.

### Management

#### Context:

Management needs and processes are well understood by Australian historic heritage managers.

#### Planning:

Many, but not all, major listed historic sites have conservation management plans with well-resolved provisions and appropriate regulatory controls. However, other significant sites lack such plans, or their plans are outdated or have inappropriate content.

#### Inputs:

Many Australian historic sites in public ownership are understaffed and lack adequate resources to address major conservation priorities, including emerging urgent pressures.

Private owners of historic sites do not receive incentives that are proportional to the public value of the places they own and manage. Grant funding, though substantial during the Jobs Fund initiative, is now in decline.

#### Processes:

Management systems at all levels of government generally facilitate well-informed decisions about impact assessment and resource allocation for historic heritage; however, formal monitoring and evaluation occurs in few jurisdictions.

#### Outcomes:

Limited information is available on the effectiveness of historic heritage management, as there is only partial monitoring and evaluation of outcomes.

Available data suggest that heritage values are generally being retained.

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<th>Summary</th>
<th>Assessment grade</th>
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<td>Identification</td>
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<td>Planning</td>
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<td>Management</td>
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<td>Context</td>
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<td>Outcomes</td>
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**Summary**

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<tr>
<th>Protection</th>
<th>Assessment grade</th>
<th>Confidence</th>
<th>Policy area</th>
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<tbody>
<tr>
<td><strong>Context:</strong> Statutory controls for historic heritage places are generally understood, despite inconsistencies and overlap both within and between jurisdictions</td>
<td><strong>Ineffective</strong></td>
<td></td>
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<tr>
<td><strong>Planning:</strong> Historic sites receive a high degree of statutory protection once they are identified and included in statutory heritage lists</td>
<td><strong>Partially effective</strong></td>
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<tr>
<td><strong>Inputs:</strong> Some historic heritage places are allocated resources for conservation, but rarely at a level that will ensure heritage values are retained across the nation. Private owners in particular could be better supported, especially through indirect means (such as tax or rates relief)</td>
<td><strong>Ineffective</strong></td>
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<tr>
<td><strong>Processes:</strong> Management systems for listed historic places in public ownership identify conservation needs and generally make well-informed decisions about impact assessment and resource allocation; however, formal monitoring and evaluation occurs in few jurisdictions</td>
<td><strong>Partially effective</strong></td>
<td></td>
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<tr>
<td>For privately owned, listed historic places, the systems for assessing impact and resource allocation vary across jurisdictions but usually consider heritage value and stakeholder opinion</td>
<td><strong>Ineffective</strong></td>
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<tr>
<td><strong>Outcomes:</strong> Many historic heritage places, especially those in public ownership, have management measures in place to address threats within the bounds of available resources. The values of listed historic heritage sites are generally being retained</td>
<td><strong>Partially effective</strong></td>
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<table>
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<tr>
<th>Leadership</th>
<th>Assessment grade</th>
<th>Confidence</th>
<th>Policy area</th>
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<tbody>
<tr>
<td>Through the Historic Heritage Chairs and Officials of Australia and New Zealand, a structure is in place to coordinate management of historic heritage resources and share information, despite the separate statutory basis and different structures in each jurisdiction. However, recent funding cuts at the national level pose a direct threat to the Australian Government’s important leadership role</td>
<td><strong>Ineffective</strong></td>
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<thead>
<tr>
<th>Celebration</th>
<th>Assessment grade</th>
<th>Confidence</th>
<th>Policy area</th>
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<tr>
<td>Historic heritage places are usually accessible, often cherished, increasingly presented to visitors in engaging ways, and recognised as important elements in community identity and sense of place</td>
<td><strong>Partially effective</strong></td>
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<td>Very effective</td>
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<tr>
<td>Deteriorating</td>
<td>Partially effective</td>
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<tr>
<td>Stable</td>
<td>Effective</td>
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<tr>
<td>Unclear</td>
<td>Ineffective</td>
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<table>
<thead>
<tr>
<th>Confidence</th>
<th>Policy area</th>
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<tbody>
<tr>
<td>Adequate high-quality evidence and high level of consensus</td>
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<tr>
<td>Limited evidence or limited consensus</td>
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<tr>
<td>Evidence and consensus too low to make an assessment</td>
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Resilience of heritage

Resilience is defined in this report as:

... the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, integrity, and feedbacks. Walker et al.,107 p. 1

In the case of heritage, attributes such as function, structure and integrity are fundamental to the identified values of the place that give rise to its designation as a heritage item. Therefore, with respect to heritage, resilience may be understood as the ability to experience shocks while retaining heritage values.

Resilience is partly an aspect of the nature of the place itself, partly an aspect of the nature of its value, and partly a function of the manner in which it is managed. For example, the resilience of a large natural landscape will be vastly different from the resilience of a small archaeological deposit. In addition, physical change will affect heritage values in some places, while intangible qualities such as use or beliefs are more important in other places. Loss of knowledge may therefore have a greater adverse effect on heritage values than changes to the physical aspects of a place. The resilience of Australian heritage, while influenced by drivers such as climate change, population growth and economic development, is also strongly affected by governance arrangements, resources and community attitudes.

Heritage resilience may be considered and managed at different levels. For example, individual heritage places may be very susceptible to shocks such as fire, flood, demolition or loss of traditional knowledge, but the total natural or cultural resource base may be sufficiently robust to withstand the loss of individual places without substantive overall loss of value.

5.1 Approaches to resilience

Resilience is a concept that is yet to be widely applied in Australian heritage management. However, a range of approaches to both natural and cultural heritage do consider the notion of managing change. In national park and reserved land management, the ‘limits of acceptable change’ model108 recognises that places are inevitably altered by both natural and human pressures, and seeks to align management practice with a level of change that does not alter the fundamental integrity of the place. Lennon has suggested useful indicators for this approach and has illustrated practical application of a values-based management approach in the Tasmanian Wilderness World Heritage Area.53 Environmental impact assessments also try to quantify the impact of specific development proposals and imply that there is an acceptable level of impact. Neither of these models relates specifically to shocks, but they both establish a framework for judging the impact of particular changes.

In the cultural environment, assessing impacts on heritage has become a common technique for evaluating and managing change—the test usually being whether a proposal fundamentally affects identified heritage values.109 This process also recognises that heritage is dynamic and that the primary issue is how much change can reasonably occur. In recent times, this concept has been
extended through a ‘tolerance for change’ model, which analyses heritage significance according to specific attributes: form, fabric, function, location and intangible values. This framework encourages proponents and consent agencies to consider the differential ability of each component to be altered without affecting heritage values. This is an important distinction between heritage places and other parts of the environment—the resilience of a heritage place or resource is directly tied to its specific heritage attributes and their robustness in the face of change.

5.2 Evidence of past resilience

The resilience of heritage places depends on the nature of their values and the extent of the total resource. Australian bioregions that are well represented in the reserved lands system are much more resilient as a whole than under-represented bioregions. Ecosystems and species that are fire dependent will be more resilient to an increase in fire frequency brought about by climate change; conversely, species that are highly dependent on ecological niches will be at risk and susceptible.

Indigenous places may be both fragile and resilient, depending on the circumstance. Tangible Indigenous heritage has been incrementally eroded since 1788 through a repetitive process of one-off decisions that allow individual sites to be destroyed (with or without investigation or recording). Sites whose value is in physical form are not resilient to damage or destruction. However, some Indigenous places with intangible value have demonstrated an ability to recover through re-engagement of traditional owners, transmission of stories and re-establishment of traditions (Box 9.36).

At the 2010 National Indigenous Land and Sea Management Conference in Broken Hill, delegates were told of the return of Aboriginal elders to the Bunya Mountains, north of Brisbane, to revitalise their continuous cultural and spiritual connection to country. The area, which is home to the nut-bearing bunya pines, used to be the focus for gatherings to share stories, song, dance, knowledge and law, but is no longer owned by Aboriginal people. The Bunya Mountains Elders Council has developed a long-term strategy for developing a Bunya Caring for Country Trust, which will help address the issues that arise for Aboriginal communities without tenure, thereby reasserting their rights and obligations to country, re-establishing traditional practices and recovering some of the lost heritage value of the country.
The values of individual historic sites are usually part of the fabric of the place, which, if damaged or destroyed, may be gone forever. Individual historic sites may be made more resilient through protection from external shocks (through maintenance, repairs, archival recording or other management techniques), but have less intrinsic ability to recover. Examples of recovery of heritage value following major damage or physical destruction are very rare, but do exist. In such cases, the intangible associative value of the heritage item is its resilient attribute.

The resilience of Australia’s historic heritage may also usefully be considered in relation to the total of listed historic places and whether a sufficiently representative set of site types has been identified and protected. Although such an approach can never replace the specific characteristics or value of an individual site that is damaged or destroyed, there is a strong case to be made that multiple listings of similar sites are a prudent and desirable measure. For example, the loss arising from destruction of huts by bushfires in Kosciuszko National Park in 2003 was tempered by the continuing presence of the huts that were not burnt. This loss was also mitigated by select reconstruction.

The Broken Dam Hut re-opening, December 2007, Kosciuszko National Park, New South Wales
Photo by Geoff Ashley

5.3 Preparedness for future pressures

The drivers and pressures that threaten Australia’s heritage do so in different ways, leading to different opportunities to prepare for future pressures or shocks.

Natural heritage is most susceptible to the pressures that arise from climate change, including altered fire regimes, shifting ecosystems and traumatic natural disasters. Development pressures arising from population growth and changing land use also pose risks to natural areas and resources. In the case of natural heritage, preparedness at the national scale involves statutory or voluntary protection for individual natural heritage sites and a truly representative reserved lands system. For individual places or resources, local management responses are determinative. These include research to facilitate understanding of potential adaptive responses to threats and more specific management actions directly targeted at avoiding or minimising risk.

Maintenance has a critical role in building resilience in individual cultural heritage places, both Indigenous and historic. Access to, and ongoing use of, Indigenous heritage places by Indigenous communities are also important resilience-building factors.

Development activity and land use place major pressures on Indigenous heritage. These threaten physical sites and traditional practice. Therefore, a key to preparedness is knowledge—both the identification of significant Indigenous places and management of the traditional knowledge that is part of their heritage value.

The preparedness of historic places for pressures and shocks is also largely a matter of management arrangements and risk preparedness, rather than the innate qualities of the places themselves. Australia ICOMOS, in responding to the pressure of climate change on Australian cultural places, has recognised the need for action to:

- identify the cultural heritage places and landscapes at greatest risk
- monitor and collect data
- establish standards of conservation planning and practice
- improve risk preparedness and disaster planning
- underscore the indivisible relationship between tangible and intangible cultural heritage and between communities and their heritage places in planning processes
- engage communities in these processes so they are prepared and able to respond.

Although these actions were prepared in response to climate change, they have a general applicability for a broad range of external pressures.
Historic sites are also particularly at risk from economic impacts, especially resource extraction and other intensive forms of development. There is a trend in Australia to regard impact assessment processes as a step on an inevitable journey towards project approval, rather than a true evaluation of the project impact and a decision as to whether or not it should proceed. As with natural and Indigenous heritage, proactive identification is critical to resilience, so that heritage is seen as a genuine existing constraint, rather than as a problem requiring a reactive response.

5.4 Factors affecting resilience capacity

A major systemic threat to Australia’s heritage is its relative priority in planning, land-use and development decision-making. Heritage is often determined to be expendable in the name of a greater community or economic good. To this end, the place of our heritage in our national psyche—the narratives, community understanding and affection for our heritage—affects its perceived value and therefore the priority it is afforded and the resources it attracts (see Section 3.2.1).

The resilience of Australia’s natural heritage is particularly a function of the underlying spectrum of geodiversity and biodiversity represented in heritage lists and reserved lands. Management activities ranging from fire reduction to control of invasive species also contribute to natural area resilience.

Understanding and identifying the physical extent and tangible and intangible values of our Indigenous heritage is a critical component of its resilience; the more we know, the more we can manage. Involvement of associated communities on country also increases resilience capacity—for both the place itself and the Indigenous community, as cultural safekeeping of traditional knowledge and intergenerational story telling can have direct benefits for Indigenous people’s sense of wellness.114

Historic places too are highly susceptible to shocks, but can be better prepared by ensuring that they have an ongoing, relevant and viable use, and by proactive management, including data collection, good conservation standards, regular maintenance and basic disaster planning (Box 9.37).

Box 9.37 Resilience based on understanding values

The Tharwa Bridge across the Murrumbidgee River in the Australian Capital Territory (ACT) remains in functional public use after major conservation works were undertaken between 2005 and 2011. Built in 1895 using an Allan truss, Tharwa Bridge is highly valued by the local community and is associated with 19th century European settlement and development of the region. It is also the oldest standing bridge in the ACT.115 The bridge had suffered extensive termite damage and was determined to be unsuitable for public use. It was scheduled to be replaced by a new concrete bridge. However, in light of community representations, a major reconstruction and repair project was undertaken and the conserved Tharwa Bridge reopened to the public in June 2011. This case study highlights that the heritage value of historic structures may attach to intangible attributes (such as local community esteem), as well as to historic fabric (such as the old bridge timbers). The bridge also demonstrates that innovative approaches based on a thorough understanding of heritage values can make heritage places more resilient and give them ongoing contemporary roles.

Tharwa Bridge, 30 April 2011
(photo by Lynette Sebo, Australian Government Department of Sustainability, Environment, Water, Population and Communities)
Risks to heritage

Australia’s heritage is a complex network of interrelated places with both tangible and intangible values. This complexity creates a mosaic of different risks. Some types of place and some values are well represented in reserved lands and statutory lists; they are generally more resilient to major pressures. Other places may be unique and irreplaceable. Sometimes it is the setting or context of the place or the fundamental associated knowledge (as well as the place itself) that may be at risk. The risk of irreversible harm occurring to a heritage place is therefore a function of the nature of the place itself and its particular heritage values.

Risks to Australia’s heritage are assessed here in terms of incidents, rather than effects. The pressures identified in Section 3 may lead to incidents, but not all pressures do so. Some risks arise from a combination of more than one pressure. In a management context, while the relationship between pressures, resilience and risk is relevant, questions of likelihood (taking into account management actions taken to address those pressures, and the resilience of the particular heritage resource), impact on values and consequent priority are arguably more important. The evaluation therefore considers risks according to severity rather than according to the underlying pressure or the nature of the heritage resource.

For the purposes of this evaluation, catastrophic risks are regarded as those with the potential to destroy a class or collection of places on a large scale. Risks that would adversely affect the heritage values of a number of places, or destroy individual places of great significance are considered major, whereas more localised risks—typically specific to individual heritage places—are characterised as moderate (in a national context). Only those risks that apply to unidentified places of local significance could be viewed as minor. No risk to Australia’s heritage is insignificant.
## Assessment summary

### Current and emerging risks to heritage

<table>
<thead>
<tr>
<th>Heritage</th>
<th>Risks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Catastrophic</strong></td>
<td>Inadequate resources for physical conservation</td>
</tr>
<tr>
<td><strong>Almost certain</strong></td>
<td>Destruction of heritage places to facilitate new development</td>
</tr>
<tr>
<td><strong>Likely</strong></td>
<td>Loss of rare species habitat</td>
</tr>
<tr>
<td><strong>Possible</strong></td>
<td>Invasive species in reserved lands</td>
</tr>
<tr>
<td><strong>Unlikely</strong></td>
<td>Inadequate land-use and planning controls</td>
</tr>
<tr>
<td><strong>Rare</strong></td>
<td>Loss of Indigenous traditional knowledge</td>
</tr>
<tr>
<td><strong>Not considered</strong></td>
<td>Resource extraction, leading to destruction or disturbance of heritage values</td>
</tr>
<tr>
<td><strong>Unlikely</strong></td>
<td>Large-scale resource extraction from reserved lands, with destruction or disturbance of heritage values</td>
</tr>
</tbody>
</table>
But of the Hut I builded
There are no traces now,
And many rains have levelled
The furrows of my plough.

Henry Lawson,
Reedy river, 1896
Outlook for heritage

This section focuses on the pressures, threats and risks arising from Australia’s major environmental drivers—climate change, population growth and economic growth. Observations on these are followed by more specific consideration of the key factors that may influence outcomes and outlooks for natural, Indigenous and historic heritage.

At a glance

Our heritage includes places that we have inherited and want to pass on to future generations, so the notion of outlook is a fundamental concept for heritage. Heritage provides an important context for our perception of ourselves as Australians, and is part of the ‘social glue’ that binds communities together and expresses identity. Heritage provides the distinct character that underpins the economic future of regional Australia. Australians see natural and cultural heritage as important and vulnerable, but these sentiments are not reflected in the resources devoted to heritage assessment and conservation.

The systems we use to manage our heritage are cumbersome: land reserves, inventories and statutes. These structures do not adequately identify, protect, manage, resource or celebrate the integrated nature of our nation’s cultural landscape. Consequently, our heritage is at great risk from the impacts of climate change, the threats arising from development, and the resource implications of population growth. The outlook for Australia’s heritage will depend on government leadership in two key areas: undertaking thorough assessments that lead to comprehensive natural and cultural heritage inventories and truly representative areas of protected land; and changing management paradigms and resource allocation in response to emerging threats, and responding strategically, based on integrated use of traditional and scientific knowledge.

Neither private nor public natural heritage places are adequately protected. The National Reserve System continues to improve, but statutory listing of natural heritage places and reservation of a truly representative set of landholdings are hampered by factors such as perceived economic values. Climate change poses massive risks to natural heritage, and this heritage is also threatened by inappropriate land use, development pressures, loss of habitat and invasive species. The ultimate impact of these will depend on the ability of scientists and managers to work proactively together, and on the commitment of government to well-resourced, proactive management rather than belated reaction to crises. Adverse effects can be minimised through thorough understanding of the natural heritage resources, recognition of the benefits of public–private partnerships and a whole-of-landscape approach to conservation and management.

There is increasing recognition of the importance of Australia’s Indigenous heritage by all Australians. However, Indigenous heritage in Australia is inadequately documented and protected, and incremental destruction continues. The inclusion of Indigenous heritage places within protected reserved lands is therefore particularly important. Closing the Gap is a welcome initiative, as is the increasing involvement of Indigenous people in sustainable land and sea management. However, loss of language, knowledge and traditional practices, and informed destruction all continue to erode Indigenous cultural traditions and connections to country.

There are many well-managed Australian historic heritage places that remain in good condition. However, statutory lists and registers are inconsistent and incomplete. Historic heritage conservation is not well supported by planning and assessment systems and is directly threatened by development, often because heritage is identified only after a project is proposed and is therefore perceived as a problem. Population shift and inadequate incentives for private owners also threaten historic heritage. A wider range of management approaches would improve the place of historic heritage in the community and facilitate effective conservation.

Wallace’s Hut, Falls Creek, Victoria
Photo by Michael Boniwell
7.1 Likely trends in key factors

Australia’s heritage includes a diverse array of places with a wide spectrum of natural and cultural heritage values. Different types of place and different heritage values will vary in their resilience and response to current and future pressures, giving rise to a range of potential outlooks. Although some factors, such as existing land clearance, species extinction and climate change, are beyond the scope of management responses, leadership in two key areas will ultimately determine the future condition and integrity of Australia’s heritage:

- the willingness of governments to undertake thorough and comprehensive assessments that lead to truly representative areas of protected land and comprehensive heritage inventories
- the ability of governments, heritage place owners and communities to adaptively manage our extensive heritage places with limited resources and in response to continuing pressures and emerging threats by adopting a strategic response based on integrated use of both traditional and scientific knowledge.

7.1.1 Climate change

The impacts of climate change will be an important issue to be addressed as part of any future heritage management plan or national heritage strategy—present, heritage is almost invisible in the climate change debate.

Climate change is causing rising temperatures, alteration to rainfall patterns (with more rainfall in the north of the country and less in the south), and greater frequency and intensity of storms, wind, run-off, floods, droughts, fires and heatwaves. These changes directly affect many biological processes, increasing the risk from invasive species and loss of habitat. It is inevitable that natural heritage areas will be affected by these processes. The ability of natural heritage places to retain their key values will depend on adaptive responses by species and appropriate management responses that prevent, minimise or repair environmental damage, assist in habitat migration, or manage or prevent the arrival of new species that may have negative effects.

Altered rainfall, higher sea and land surface temperatures, more severe storm events, altered fire regimes, ocean acidification and rising sea levels are all likely to significantly affect the values of both natural and cultural heritage places. The effect on natural values is largely self-evident, but cultural sites such as Indigenous middens, sea-cave deposits, archaeological sites and rock art are also highly dependent on the maintenance and protection of their underlying landforms from climate change impacts. Other cultural values, such as architectural heritage, may also be affected by climate change but to a lesser extent, at least in the short term. Without management intervention, altered fire regimes are likely to lead to additional impacts on biodiversity and Indigenous cultural values.

7.1.2 Population growth

Pressure on natural and cultural heritage arises from population growth and the uneven distribution of people around the country.

In rural centres, for example, population decline arising from new land uses and technology has a compounding negative effect. The demand for services decreases, and historic assets can become redundant; at the same time, the community has fewer resources to conserve heritage places. One potential approach to this dilemma (apart from funding subsidies) is to adopt a more flexible approach to conservation by encouraging greater change and adaptation, or accepting that some places may be managed as ruins.

In contrast, in urban areas and parts of the coast that are experiencing residential and commercial intensification, heritage is under pressure from associated development that seeks land uses with higher economic return. In this context, while available community resources are greater (and flexible approaches to adaptation and change are to be encouraged), good conservation outcomes are more likely to depend on early identification of natural and cultural heritage resources so that the expectations of owners and potential developers can be reasonably managed.

Knowledge of the heritage resource through systematic and comprehensive survey and assessment is an essential precursor to values-based heritage conservation and management. At present, although there is a large number of entries and registers spread across multiple jurisdictions, there is no longer a national picture (as was previously provided by the Register of the National Estate). The absence of comprehensive heritage data continually gives rise to conflict with development.
Public sector resourcing for heritage or any other environmental consideration is often a question of community perception. The outlook for the nation’s heritage may therefore rely on the ability of community groups and advocates to communicate their message effectively. Heritage is clearly perceived as a public good, yet this value is not reflected in public sector support. Indeed, in 2011, core funding for heritage management by the Australian Government was reduced by 30%, yet:

The majority of the community believes that inadequate support is provided to heritage conservation. In essence, the majority of the community believes that there are benefits from additional government commitment to heritage conservation. The Allen Consulting Group, p. viii

Community perception is also manifest in the way we treat our heritage places. In remote and rural areas particularly, historic sites may be damaged through vandalism or neglect. Indigenous places may be affected by deliberate acts of damage or culturally inappropriate behaviour. Natural areas can be degraded through community actions, such as dumping of invasive weeds, inappropriate use of vehicles, shooting and resource extraction. Management of these community impacts will depend on a combination of regulation, enforcement and effective communication about heritage values.

7.1.3 Economic growth

Economic growth has multiple environmental effects, particularly arising from increased consumption and waste generation. For heritage, economic growth increases the threat posed by new development and resource extraction. To a lesser extent, economic growth may also lead to impacts from changing land use, or increased activity in heritage places from tourism.

Development is a major threat to all aspects of heritage. This is particularly so because of the reactive nature of the heritage and environmental impact assessment system in most Australian jurisdictions. All too often, significant heritage assets are identified late in the planning and assessment process, with the inevitable result that heritage is damaged or destroyed, although usually accompanied by some form of mitigating action. However, this need not always be the case. Initiatives such as the Australian Regional Forest Assessments clearly demonstrate the benefits of proactive survey and identification of both heritage places and available resources. The main obstacle to such a rational and proactive process is government (and to a lesser extent industry) reluctance to allocate substantial up-front resources for surveys.

For example, the Kimberley is known as a place of outstanding natural and cultural value, but it also contains vast bauxite deposits. How will this intersection of potentially conflicting economic and heritage values be addressed in the future? Early proactive assessment of all resources—including natural and cultural heritage—maximises the chance of well-informed decision-making and appropriate conservation outcomes. Reactive approaches that pitch natural and cultural resources head-on against potential economic benefits are likely to spiral downward into conflict and adverse impact.

Parallel issues arise in urban areas where underlying land values and development potential collide with history and heritage; but this also need not necessarily be the case. Early consideration of all types of heritage place within land-zoning, planning and development processes has potential to reduce conflict and increase both heritage and economic value. Whether or not this can become standard practice on a national scale depends on leadership and coordination at a national level.

7.2 Natural heritage

Australia’s natural heritage includes lands that are reserved in parks and other places, both listed and unlisted. Although the ongoing addition of examples of the full range of ecosystems within each of the 85 bioregions to the National Reserve System is important, broader considerations such as conservation of geological sites, ecosystems and habitats and a national whole-of-landscape approach to natural heritage protection will foster values-based management and build resilience. Environmental conditions across the continent are highly variable, so selection of places for listing or reservation should consider individual place values as well as wider landscapes and ecosystems. Major barriers to a genuinely representative reserve system include scarce remnants of some ecosystems, the economic value of land that can be used for other purposes and political will. The current National Reserve System target of 10% is commendable (but yet to be achieved), but there are strong arguments that a greater sample of the natural environment should fall within reserved protected lands or be recognised as heritage, irrespective of tenure.
Habitat loss and invasive species represent major and continuing threats to natural heritage values. The outlook for habitats will depend on a combination of natural adaptive management and thoughtful intervention—the latter is highly dependent on proactive research and cooperation between scientists and managers. The situation is mixed in relation to invasive species. Some, like mimosa and cane toads, are well beyond eradication and can only be continually managed. Others, like myrtle rust and Phytophthora, could respond to well-resourced eradication programs.

Natural heritage resources are also subject to continuing threats from a variety of external factors. These include inappropriate development on adjacent lands, impacts from over-visitation or inappropriate visitor behaviour, inadequate expertise and technical skills, and the perpetual problem of insufficient resources relative to expectations for managing land with natural heritage values. One potentially useful approach to this resourcing question is to place greater value on the ecosystem services of reserved lands and their role in carbon sequestration, water catchments and benefits to society (see Chapter 8: Biodiversity).

### 7.3 Indigenous heritage

The connection between people and country is a fundamental aspect of Indigenous cultural heritage. Understanding that there is no conceptual divide between nature and culture is a precursor to any informed appreciation of the requirements for Indigenous heritage conservation. Adequate knowledge of both the physical manifestation of Indigenous heritage in individual sites and wider landscapes, and its intangible manifestation in traditional knowledge and cultural practices and ongoing use of heritage places by Indigenous people is also critical.

The outlook for Indigenous heritage is therefore highly dependent on the processes that are available to document physical sites, to record and transmit traditional knowledge and to provide access to them for Indigenous communities. Loss of knowledge, including loss of language, erodes and degrades Indigenous cultural heritage, leading to an undesirable combination of social impacts on Indigenous communities and loss of heritage values.

Indigenous heritage is at serious risk from ongoing incremental destruction. This arises in part from a lack of formally protected sites, but also from our linear statutory assessment and development consent systems, and a pattern of conscious destruction arising from informed development consent. If the current practice continues of announcing proposed developments and only then undertaking survey and assessment as part of environmental impact evaluation, Indigenous heritage will continue to be perceived as a problem and will also continue to suffer a gradual process of erosion and destruction without a clear understanding of the extent to which the total resource is being destroyed. Indigenous communities have been vociferous in their expression of concern about this issue generally, and in their opposition to specific development projects.

In other contexts, our nation has a well-developed approach for involving Indigenous people in the management of their heritage. The Ask first guidelines represent best practice for Indigenous heritage, and widespread adoption of these guidelines would represent a major step forward in Indigenous heritage management.

7.4 Historic heritage

There are extensive lists and registers of historic heritage items in all Australian jurisdictions, but the listed places do not present a cohesive, comprehensive or representative selection. Some lists, such as the National Heritage List, are incomplete because they are relatively recent and require additional resources. Other longstanding lists may include more places, but have usually been compiled in an ad hoc manner with particular focus on history and aesthetics, rather than a comprehensive values-based and representative approach. The incomplete list of statutory registers gives rise to a number of anomalies and undesirable outcomes, including a reactive approach when major developments occur, and inconsistency in regulation between local, state and national governments.

Many aspects of our planning system, building codes and standards affect historic heritage management and could be improved. There is a compelling argument to provide substantial resources for sustained and systematic assessment, because in the long term this can lead to better decision-making, incorporation of heritage values into strategic planning processes and improved heritage conservation outcomes.
The outlook for historic heritage is likely to be greatly improved if governments at all levels implement common criteria and consistent development assessment standards. Perhaps the most anomalous contemporary standard relates to sustainability and the notion that Green Star rating points are not awarded for heritage conservation outcomes. The current sustainability guidelines are prejudiced towards removing historic buildings and fabric and replacing them with recycled materials and new energy-efficient structures, rather than retaining significant existing building materials and upgrading existing structures to make them more energy efficient. This ignores both the embodied energy in the existing materials and structures, and the heritage values of the buildings. Greater adaptation and flexibility in guidelines may reduce pressure for demolition and replacement of historic buildings.

In a similar vein, the outlook for historic heritage would improve if governments were to provide better incentives for private owners of historic heritage places. While recognising the value of historic heritage and the fact that most historic places are privately owned, the Productivity Commission took the negative view in its 2006 report that places should not be listed where owners object.90 Alternatively, a positive response that recognises the contribution made by private owners and seeks to increase available incentives, such as advisory services, development concessions, tax relief or advantageous land valuations, would reinforce the community value of heritage and might stimulate even greater private sector conservation efforts.

Better outcomes require some fundamental rethinking and recognition that our nation has a vast historic heritage that cannot all be retained and maintained in pristine condition. Perhaps if major physical changes or even regression to ruins were recognised as part of normal historic processes for some places, there may be a more positive outlook.

Historic heritage in Australia faces resourcing challenges because the number of listed and unlisted places is high relative to our land area, our population and the purchasing power available to fund heritage conservation. There is also a marked and accelerating downward trend in the skills base and specialist expertise available in historic heritage.

However, many of the human threats to historic heritage are matters of perception. Changing perception will change outlook. Where places are valued for their non-economic contribution as well as financial performance, the value of heritage will be more highly regarded.
References


66 McDonald J, Veth P. Dampier Archipelago petroglyphs: archaeology, scientific values and national heritage listing. Archaeology in Oceania 2009,44(suppl.):49–69.


73 Worboys G, Good R. Caring for our Australian Alps catchments: summary report for policy makers. Summary of a 2011 technical report prepared for the Alps Liaison Committee and the Department of Climate Change and Energy Efficiency: Caring for our Australian Alps catchments—a climate change action strategy for the Australian Alps to conserve the natural condition of the catchments and to help minimise threats to high quality water yields. Canberra: Department of Climate Change and Energy Efficiency, 2011.

75 Chairman and Congress Committee of the Healthy Parks Healthy People International Congress. Melbourne communiqué. International Healthy Parks Healthy People Congress, Melbourne, 2010.


101 Faddy J. Sustainable heritage ... as ratings tools improve, the case for conservation could outweigh demolition. Architecture Bulletin 2011;March–April:13–4.


Brisbane at dawn, Queensland
Photo by Nick Rains
Built environment

10
Australia’s built environment faces many pressures and is only in a fair shape. Australia’s built environment is diverse. There are significant pressures on this environment driven by population and economic growth, and climate change. An increasing need for space and buildings (our urban footprint), increasing traffic congestion and increasing consumption are affecting the livability and environmental efficiency of the built environment. Traffic congestion, in particular, is of growing concern. However, growth in traffic may be levelling, and use of public transport is increasing. Residents are also concerned about the look and design of their cities; in the biggest cities, there are concerns about whether the cities are clean, well maintained and unpolluted. Climate change is creating new risks by increasing the likelihood of weather-related events such as mega-storms.

The Australian built environment consumes significant natural resources, although this may be improving. The residents and industries of the built environment consume natural resources, including water, energy and land. Waste generation within the built environment also has an impact on the natural environment. However, emerging evidence suggests that increases in the use of energy and water may be slowing due to improved technology, and better understanding and recognition of the need to reduce human environmental impact.

Recent government initiatives aim to improve the uncoordinated management of the built environment. Management of the built environment is characterised by complex arrangements involving all levels of government, as well as the private sector, and these arrangements lack effective coordination. Recent initiatives of the Council of Australian Governments to reform capital city planning, as well as the recently released National Urban Policy, seek to address this issue. There are also concerns that insufficient investment has been made in infrastructure.

The outlook for the built environment is mixed. The expected increase in the physical size of cities and increased traffic congestion will have negative impacts, but these may be offset by improved management and more efficient use of natural resources.
Contents

1 Introduction 803

2 State and trends of the built environment 805
  2.1 Livability 805
    2.1.1 Urban amenity 806
    2.1.2 Housing 807
    2.1.3 Transport 809
    2.1.4 Air quality 814
    2.1.5 Water quality 814
    2.1.6 Noise 815
    2.1.7 Natural environment 815
  2.2 Urban environmental efficiency 816
    2.2.1 Land use 816
    2.2.2 Energy efficiency 816
    2.2.3 Water efficiency 817
    2.2.4 Waste generation and recovery 818
    Assessment summary 10.1—state and trends of the built environment 821

3 Pressures affecting the built environment 823
  3.1 Increased urban footprint 823
  3.2 Increased traffic 823
  3.3 Increased pollution 824
  3.4 Increased consumption 824
  3.5 Increased extreme weather events 824

4 Effectiveness of built environment management 827
    Assessment summary 10.2—pressures affecting the built environment 826

5 Resilience of the built environment 834
    Assessment summary 10.3—effectiveness of management of the built environment 833

6 Risks to the built environment 835
    Assessment summary 10.4—current and emerging risks to the built environment 837

7 Outlook for the built environment 838

References 840
... in a modern society it’s not much good just fighting for wages and conditions if we live in polluted cities, devoid of parks, denuded of trees.

Jack Mundey, From ratbags to heroes: creating social movements and making the world a better place, address to the Communities in Control Conference, 4 June 2007

Aerial view of the eastern suburbs of Melbourne, Victoria
Photo by Andrew Griffiths
Introduction

The built environment is the human-made surroundings where people gather to live, work and play. It encompasses both the physical structures where people do these activities and the supporting infrastructures, such as transport, water and energy networks. The built environment is a material, spatial and cultural product of human labour and imagination.

The built environment has an impact on human wellbeing. Its structure, form and function, as well as the quality of its natural environmental assets, determine its suitability for living in. The built environment also puts pressure on natural resources, mainly through the use of land, water and energy resources, as well as through the waste that is generated from activities taking place within it.

Australia’s built environment takes many forms. Almost two-thirds (64%) of Australians live in the eight capital cities.1 Large numbers of Australians also live in other cities and towns and in rural and remote areas (Table 10.1). In 2006, the proportion of Australia’s population living in urban areas was 87%, up from 85% a decade earlier.²

The nature of the built environment in Sydney (major city) is vastly different from that in Cloncurry (remote). However, no matter how big or small, all urban environments place pressure on natural resources and have common characteristics that determine their suitability for living in.

<table>
<thead>
<tr>
<th>Level of remoteness</th>
<th>Number</th>
<th>Percentage of total population</th>
<th>Percentage change from 2009 to 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major cities</td>
<td>15 337 721</td>
<td>68.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Inner regional</td>
<td>4 401 672</td>
<td>19.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Outer regional</td>
<td>2 086 609</td>
<td>9.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Remote</td>
<td>326 643</td>
<td>1.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Very remote</td>
<td>176 202</td>
<td>0.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Total</td>
<td>22 328 847</td>
<td>100.0</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Source: Australian Bureau of Statistics¹

Most Australians live near the coast, and Australia’s highest population densities are found in coastal regions (Figure 10.1). Australia’s seven largest cities are coastal, and only 4 of the 18 cities with populations of more than 100 000 are located inland.
The major challenge facing our built environment is population growth, which can lead to an increase in the physical size of cities, higher population densities, greater demands on natural assets within cities and increased congestion. Related to an increased population is an increased demand for water and energy, and increased waste generation. However, an increasing population does not have to result in a less livable and less efficient built environment. Population growth can be a spur to change and innovation. Other responses, particularly good policy and planning, can also mitigate the effects of population and other pressures, ideally leading to urban areas that are both more livable and more efficient.

Urban policy and planning in Australia have varied with time and in different jurisdictions and institutions. The importance of urban policy to the ongoing prosperity and wellbeing of our communities has been recognised by the Australian Government, which has developed a National Urban Policy to provide national leadership and guidance for the states, territories, local authorities and the private sector in planning, managing and investing in cities.\(^3\)
State and trends of the built environment

This section assesses the built environment according to two main components: livability and urban environmental efficiency.

2.1 Livability

‘Livability’ is a term that can have many meanings, but for the purposes of this chapter it relates to those aspects of the quality of urban life that are determined predominantly by the physical nature of the built environment. Aspects of livability that arise more generally from social and economic conditions, while important, are not assessed. This means, for example, that housing conditions, amenity and access to transport services are included, whereas house prices, access to social services and crime are not. However, the boundary between these aspects is innately grey; for the exclusions just mentioned, the form of the built environment may indeed have some impact, but wider economic and social forces typically have a far greater impact.

Health issues are considered to the extent that they are directly affected by the built environment; for example, the impact of the quality of urban air and water on health, and the contribution that the built environment might make to ‘healthy lifestyles’ by encouraging (or discouraging) exercise through walking and cycling.

By world standards, most Australian cities have relatively low population densities. Sydney is Australia’s most densely populated city, with a population density exceeding 2000 people per square kilometre (Table 10.2). North American cities have population densities similar to Australian cities. In comparison, many cities in Asia have densities more than 10 times this; higher densities than in Australia are typical in cities in Europe, South America and Africa. Population density within a city can also vary significantly—some parts of Australian cities have densities of more than 10 000 people per square kilometre.

### Table 10.2 Population densities for Australian capital cities, 30 June 2006

<table>
<thead>
<tr>
<th>City</th>
<th>People per km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>2058</td>
</tr>
<tr>
<td>Melbourne</td>
<td>1532</td>
</tr>
<tr>
<td>Adelaide</td>
<td>1295</td>
</tr>
<tr>
<td>Perth</td>
<td>1090</td>
</tr>
<tr>
<td>Canberra (includes Queanbeyan)</td>
<td>1005</td>
</tr>
<tr>
<td>Darwin</td>
<td>926</td>
</tr>
<tr>
<td>Brisbane</td>
<td>918</td>
</tr>
<tr>
<td>Hobart</td>
<td>895</td>
</tr>
</tbody>
</table>

km² = square kilometre

Source: Australian Bureau of Statistics

At a glance

Significant parts of Australia’s built environment have aspects that are considered poor. The Australian built environment consumes significant natural resources, including land, water and energy, and there is substantial waste generation.

In the largest cities, traffic congestion is of concern. There are also concerns about whether these cities are clean, well maintained and unpolluted. The attractiveness of Australian cities is considered to be only fair.

In the smaller capital cities and other urban centres with populations of more than 100 000, traffic concerns are far less significant, and the quality of the natural environment is higher. For smaller settlements, waste management is a concern.
Calculation of a city’s population density depends on the land area that is considered to be occupied by the city, which changes over time. For this reason, comparable historical estimates of population densities are difficult to obtain. Also, trends in the average population density of a city might mask trends in particular parts of the city. There is some evidence that the overall population density of Melbourne has fallen since World War 2 (based on Australian census data). However, in recent years, certain parts of inner Melbourne have experienced significant increases in population density, and this trend is also evident in the other large Australian cities (e.g. see Newman & Kenworthy). There are mixed views about the impact of density on the livability and efficiency of urban areas. On the one hand, higher densities might lead to more recreational and employment opportunities and better access to public transport and other services, as well as more ‘vibrant’ cities. Higher densities also make more efficient use of land. On the other hand, higher densities may be associated with a loss of open space (both public and private), more crowded public parks and public transport, and more congested traffic, unless improvements are made to accommodate the growing needs. Also, there is no strong evidence that higher densities lead to more efficient use of resources such as water and electricity. This is a contentious issue; some experts claim that higher densities lead to more efficient use of resources, whereas others hold a different view.

2.1.1 Urban amenity

Access to recreational opportunities and open space is an important aspect of the livability of the built environment. There is a paucity of national datasets relating to these aspects. However, in 2010, the Property Council of Australia commissioned a survey to measure Australians’ attitudes towards their cities, with the focus on capital cities. One of the questions asked was ‘Do residents believe their cities have a wide range of recreational outdoor environments?’ (Figure 10.2). All Australian cities rated well on this measure, with an average score of 79 out of 100. Melbourne rated the highest, with a score of 83, and Hobart and Sydney were equal lowest, with a score of 76.

The look and design of a city is another aspect of its livability. Residents’ views on this were sought in the Property Council of Australia survey. The capital cities rated only moderately well, with an average rating of 52. Melbourne rated the highest, with a score of 64; Darwin rated only 39 (Figure 10.3).
2.1.2 Housing

The structure and condition of housing affect the livability of cities. The vast majority of Australian dwellings are separate houses (77% in 2008). Flats make up 14% of dwelling structures, and semidetached dwellings, 9%. The proportion of separate houses fell slightly (by 1.4%) between 1998 and 2008, offset by a commensurate increase in flats. Australian houses are typically brick—about 69% of houses (78% in capital cities) are brick veneer or double brick. About 13% of houses are timber, and about 8% are fibrocement. The trend over time has been towards greater use of brick veneer. Australian houses are becoming larger on average; the proportion of houses with four or more bedrooms increased from about 23% to about 37% between 1994 and 2008.

For the most part, overcrowding is not an issue in Australian houses. In 2008, only 2.6% of houses were considered to have insufficient bedrooms, as assessed using the Canadian National Occupancy Standard, which is widely used internationally as an indicator of housing use. In contrast, the 2006 census found that 41% of all occupied private dwellings in Australia had two or more bedrooms above minimum household requirements, up from 34% a decade earlier.

The number of people per dwelling has an impact on resource efficiency. In 2006, the number of people per occupied private dwelling was 2.6, down from 2.7 a decade earlier. The size of houses in Australia has increased; a 2005 Australian Bureau of Statistics study found that the average floor area of new residential buildings increased by 37.4% between 1994–95 and 2002–03 (from 149.7 square metres to 205.7 square metres). More recent analysis suggests that the trend is continuing, with an average new house size of 215 square metres in 2008–09, purported to be the biggest in the world. However, block size appears to be falling; the average site area of new houses in Australian capital cities decreased between 1993–94, when it was 802 square metres, and 2003–04, when it was 735 square metres.

Residents of capital cities generally felt that their cities had a good balance of housing types, with an average satisfaction rating of 62%. The spread of responses was not very large, ranging from a rating of 52% in Sydney to 68% in Adelaide (Figure 10.4).

A 2011 Grattan Institute study, *The housing we’d choose*, found that Sydney and Melbourne had a demand for a wide range of housing types, “with shortages of semidetached homes and apartments in the middle and outer areas of both Sydney and Melbourne.”

In some parts of Australia, however, the quality of housing is poor. This is particularly the case in Indigenous communities (see Box 10.1).
The built environment in Indigenous communities differs significantly from other Australian urban environments, with many aspects rating quite poorly.

In 2006, more than 80,000 people lived in 1,112 discrete Aboriginal and Torres Strait Islander communities in remote areas of Australia. This represented about 15% of Australia’s Indigenous population. Fourteen of these communities had more than 1,000 people, accounting for 26% of the population in remote Indigenous communities. A further 41% lived in communities with between 200 and 999 residents, 20% lived in communities with between 50 and 199 residents, and 13% lived in communities with a population of less than 50 people.

Not all people in remote Indigenous communities had a permanent dwelling as a home—3,400 people (4%) lived in temporary dwellings such as sheds and humpies.

A significant number of people living in permanent homes in Indigenous communities experienced problems with the condition of their homes. In 2006, one-third of dwellings needed either major repair (24%) or replacement (9%). This was slightly higher than in 2001, when 31% of homes needed major repair or replacement.

Overcrowding is an issue of concern. In 2006, Indigenous people were 4.8 times more likely than non-Indigenous people to live in overcrowded housing. At the time of the 2006 Australian census, 57% of all Indigenous people in remote areas (including Indigenous communities and other locations) lived in households in need of at least one extra bedroom to adequately accommodate all residents, down slightly on the 2001 result. In the Northern Territory (where the greatest proportion of Indigenous people live in remote communities), 66% of Indigenous people lived in overcrowded housing.

Access to essential services such as water, electricity, sewerage and waste collection is something that most Australians take for granted. However, in remote Indigenous communities, the standard of these services is generally below that enjoyed by Australians in most other locations.

In 2006, only 28% of people living in remote Indigenous communities had access to town water, and the majority (54%) relied on bore water. The proportion of people using town water had increased significantly from 2001, when it was only 12%. In communities with populations of 50 or more, 59% of people in 2006 had experienced interruptions in their water supply in the previous 12 months, with about half of these people experiencing five or more interruptions.

The majority of people (62%) in remote Indigenous communities obtained their electricity from town generators; only 29% obtained power from the state grid. These proportions were similar to those five years earlier. Service interruptions are of concern, with 81% of people in 2006 experiencing at least one interruption in the previous 12 months, and 19% experiencing 20 or more disruptions.

In 2006, waterborne systems were the most prevalent form of sewerage (used by 38% of people) in remote Indigenous communities, followed by town systems (30%) and septic tanks (28%). The proportion of people using town systems had increased significantly from 8% in 2001. In 2006, 40% of people experienced sewerage overflows or leakages.

The livability of the built environment and community viability are affected by access to public facilities and sporting facilities. In remote Indigenous communities with 50 people or more, 95% of people had access to some type of public facility, most typically an administration building, store or hall/meeting area. Only 36% of people had access to a library. Nearly 9 in 10 people had access to some type of sporting facility, with 81% having access to a sporting ground. However, only 21% of people had access to a swimming pool.

Source: Australian Bureau of Statistics

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Yuelamu community, Mount Allan, Northern Territory
Photo by S Sadler
2.1.3 Transport

Transport-related issues are a significant factor in the livability of cities. Relevant aspects include the state of the road network, traffic congestion and access to (and use of) public transport.

Road congestion is seen to be an increasing problem in many of Australia’s urban areas. This is caused by both the growth of the populations of cities and the increasing propensity of people to use private motor vehicles as the dominant mode of motorised transport (although this trend has flattened off in the past few decades). Figure 10.5 shows how the use of motorised transport modes have changed over time, as well as a base-case projection from 2008.

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**Figure 10.5 Use of motorised transport modes in the eight capital cities**

Data after 2008 are from a ‘base-case’ projection.
In 2007, the Bureau of Transport and Regional Economics calculated that the avoidable social cost of congestion in the capital cities was about $9.4 billion in 2005. (Avoidable social cost of congestion includes extra travel time and the accompanying loss of productivity; increased vehicle operating costs; and poorer air quality—because vehicles under congested conditions emit more noxious pollutants—leading to higher health costs.) This was projected to increase to $20.4 billion in 2020. On a unit cost basis (cents per kilometre), the cost in 2005 ranged from less than two cents (in Darwin) to about eight cents (in Sydney), with a metropolitan average of about seven cents (Figure 10.6). \(^{14}\)

The impact of congestion, particularly in Australia’s largest cities, is causing concern. In Sydney, satisfaction with the road network and traffic congestion had a very low rating of 13%, and low ratings were also recorded in Brisbane, Melbourne and Perth (Figure 10.7). Only in Canberra and Darwin were satisfaction ratings of more than 50% recorded.
One way of reducing traffic congestion is to encourage the use of public transport and nonmotorised forms of travel. Public transport can improve urban amenity and reduce the land needed for roads and parking—land that may be put to more attractive uses. Public transport is also more energy efficient than car transport. The Census of Population and Housing, conducted every five years, asks all Australians about their means of travel to work. On census day in 2006, 79% of people travelled to work by motor vehicle, 11% took public transport and 12% rode a bicycle, walked, worked from home or took some other form of transport.\(^2\) The proportion of people travelling by public transport was greatest in Sydney; very few people in smaller cities tended to use public transport (although these cities are less likely to suffer congestion problems). Use of nonmotorised travel to get to work was highest outside the major cities. However, the proportion of travel using public transport is increasing in most capital cities (Table 10.3).

Table 10.3 Percentage of adults using public transport as the main form of transport for usual trip to work or full-time study

<table>
<thead>
<tr>
<th>City</th>
<th>1996</th>
<th>2000</th>
<th>2003</th>
<th>2006</th>
<th>Change between 1996 and 2006(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sydney</td>
<td>23.4</td>
<td>25.0</td>
<td>25.9</td>
<td>26.3</td>
<td>12.4</td>
</tr>
<tr>
<td>Melbourne</td>
<td>13.1</td>
<td>15.9</td>
<td>15.3</td>
<td>17.7</td>
<td>35.1</td>
</tr>
<tr>
<td>Brisbane</td>
<td>14.3</td>
<td>11.6</td>
<td>15.7</td>
<td>17.5</td>
<td>22.4</td>
</tr>
<tr>
<td>Adelaide</td>
<td>12.2</td>
<td>10.6</td>
<td>13.4</td>
<td>14.4</td>
<td>18.0</td>
</tr>
<tr>
<td>Perth</td>
<td>10.5</td>
<td>11.3</td>
<td>10.5</td>
<td>10.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Hobart</td>
<td>12.8</td>
<td>5.2</td>
<td>6.9</td>
<td>10.3</td>
<td>−19.5</td>
</tr>
<tr>
<td>Canberra</td>
<td>11.4</td>
<td>8.2</td>
<td>8.1</td>
<td>7.9</td>
<td>−30.7</td>
</tr>
<tr>
<td>Total capital cities(^b)</td>
<td>16.3</td>
<td>17.2</td>
<td>17.9</td>
<td>19.1</td>
<td>17.2</td>
</tr>
<tr>
<td>Other areas(^c)</td>
<td>2.7</td>
<td>1.9</td>
<td>2.4</td>
<td>1.7</td>
<td>−37.0</td>
</tr>
</tbody>
</table>

**Australia** | **11.9** | **12.2** | **13.0** | **13.5** | **13.4**

\(^a\) Represents the change in the proportion of adults using public transport for their usual trip to work or study
\(^b\) Excludes Darwin
\(^c\) Includes Darwin and all other places outside capital cities

Source: Australian Bureau of Statistics\(^5\)

By March 2009, the proportion of adults using public transport as the main form of transport for their usual trip to work or study had increased to 14.0%. For day-to-day trips other than to work or full-time study, the proportion of adults using public transport was 18.7%, rising to 26.0% in state capital cities. It should be noted that these figures relate to any use of public transport and not whether it was the main form. The main reasons given for not using public transport for usual trips to work or full-time study were lack of availability, and the convenience, comfort and privacy of a private vehicle.\(^6\)

The use of public transport is influenced by both personal preference and the quality of the available public transport service. Australians have a poor view of the quality of public transport in the capital cities, with an average satisfaction rating of 36%. Brisbane is considered the best (with 45%), while Canberra is regarded as the worst (24%). Sydney, which rates very poorly on traffic congestion, also rates relatively low (32%) on the quality of public transport (Figure 10.8).
Despite concerns about traffic congestion, there is emerging evidence that car travel in Australian cities may have levelled off. After growing for many years leading up to 2003–04, total private vehicle passenger travel (measured in kilometres travelled) in the capital cities has since remained stable (Figure 10.9). In terms of kilometres per person, capital city car travel has fallen since 2003–04. Meanwhile, the use of public transport is increasing, albeit from a low base.

Nonmotorised forms of transport, such as walking and cycling, reduce congestion as well as providing health benefits and potentially other benefits, such as increased social interaction. More people in Australia are cycling than ever before, and 2008 saw the largest ever increase in people riding their bikes. Use of cycling for the usual trip to work or full-time study has increased in the past decade, although it is still at very low levels, particularly compared with levels in European cities. In certain areas, considerable investment has been made in cycling networks, but this has not had a major impact on participation, suggesting that infrastructure is necessary but not sufficient. Road safety remains a significant barrier to cycling.

No comprehensive information is available on walking in the Australian built environment, although anecdotal evidence suggests that the design and structure of Australian cities, at least in some areas, has a negative impact on people’s propensity to walk. There have been some initiatives to overcome this, such as improving the accessibility of laneways in Melbourne (see Box 10.3). The level of walking has increased in Perth and Melbourne during recent decades.

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**Box 10.2 Gold Coast light rail**

The council area of Gold Coast City is Queensland’s second most populous and one of the fastest growing regions in Australia, with a population of 528 000 that is increasing by 13 000 each year.

The Australian Government is investing $365 million in the Gold Coast Rapid Transit system. This involves constructing a 13-kilometre light-rail system to link key activity centres from Griffith University (Gold Coast Campus) to Broadbeach via Southport. This is the first stage of a system that will connect Helensvale with Coolangatta. The capital cost to governments of the project is expected to be $949 million; the final cost will be determined through a tender process for the Operator Franchise Public Private Partnership. The Queensland Government and Gold Coast City Council will meet the balance of costs.

The project is expected to reduce greenhouse gas emissions by around 114 000 tonnes (net) over 10 years. In addition, it is expected that the project will significantly reduce the number of daily car trips to key activity centres along the light-rail corridor. As a result of the rapid transit system, the wider public transport network will be improved, with 4 million bus service kilometres to be redirected across the city.

The rapid transit system will support the Gold Coast City Council’s ‘Our Living City’ urban planning scheme through new urban planning opportunities. The council plans to upgrade precincts around key stations and provide for transit-oriented developments along the corridor.

The first section of the Gold Coast Rapid Transit system is expected to be completed in 2014.

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An artist’s impression of the Gold Coast light rail
Source: Gold Coast Rapid Transit
Accessible and active laneways in the Melbourne city centre have increased from 300 metres (1994) to 3.43 kilometres (2004). Of these, 500 metres are completely new lanes or arcades, while the rest are previously inaccessible service laneways that have been opened up with active facades, various functions and art installations. The lanes offer an alternative route through the city centre, with a more human-scale atmosphere. Opening of the lanes, along with other investments in the public realm, have contributed to a remarkable increase in public life in the centre of Melbourne, which is documented in public space – public life surveys in 1994 and 2004.

Source: Institute for Transportation and Development Policy & Gehl Architects

Box 10.3 Opening the laneways, Melbourne

Before

Previously inaccessible laneways, transformed into human-scale, active routes through the city centre

After

Nightlife at Hardware Lane

Lanes used for art installations

Figure 10.9 Passenger kilometres travelled in capital cities
2.1.4 Air quality

The quality of natural assets—such as air, water and biodiversity—in the built environment is an important aspect of livability, for both health and aesthetic reasons. Air quality, in particular, can have significant health implications. Air quality in Australian cities is generally good, but can be variable. In the three largest cities, the annual number of days on which average concentrations of PM10 (particulate matter equal to or less than 10 micrometres in diameter) exceeded the National Environment Protection Measure standard was generally less than 10, although in some years it was significantly higher (Figure 10.10; see also Chapter 3: Atmosphere).

Air quality is affected not only by human-made pollution, but also by natural pollutants, such as dust, and by weather patterns.

2.1.5 Water quality

There is no national information on the quality of natural waterways within the urban environment. Melbourne Water rates urban water quality in Melbourne as poor, particularly with regard to heavy metals and nutrient pollution. Point sources of pollution are considered largely under control; diffuse sources (including nutrients, sediments, toxicants and pathogens) are the largest threat to the health of waterways and bays. Similar findings might be expected in other large Australian cities.

The quality of urban drinking water is, on the other hand, generally considered good. The level of satisfaction with the quality of mains water for drinking has steadily increased across Australia, from 64% in 1994 to 78% in 2010. The level of satisfaction varied between states and territories: the Australian Capital Territory (94%) and the Northern Territory (90%) had the highest rates of satisfaction, and South Australia had the lowest (62%) (Figure 10.11).

Half of those who expressed dissatisfaction with the quality of drinking water nominated taste as the reason. Other common complaints included chlorine, dirty water, odour, colour, and microbial or algal contamination. South Australian households registered the highest level of dissatisfaction (72%) with taste (excluding saltiness).
2.1.6 Noise

Noise pollution is another concern within the built environment. Again, there is a paucity of data, particularly at the national level. The *New South Wales state of the environment 2009* report noted that noise pollution was the third most common type of complaint call received by the Environment Line of the New South Wales Department of Energy, Climate Change and Water, although the number of noise incident calls decreased by 20% between 2004–05 and 2007–08.²⁸ These calls, however, represent only a small proportion of noise complaints, as most complaints are made to local councils and police and there is no centralised collection of information.

2.1.7 Natural environment

What do residents think of the natural environment of their cities? The Property Council of Australia asked capital city residents whether they believed their cities are clean, well maintained and unpolluted (Figure 10.12). Although the question is broader in scope than the quality of natural assets present in the city, it provides some insights. Canberra rated highest, with a satisfaction rating of 72%. Sydney ranked lowest, at 34%.

Residents were also asked if their cities have an attractive natural environment. A similar pattern of rankings emerged: Canberra was ranked equal highest (with Hobart) at 85% satisfaction, and Sydney was lowest with 63%.

**Figure 10.11** Satisfaction with quality of tap water for drinking, 1994–2010

**Figure 10.12** Percentage of residents who believe their cities are clean, well maintained and unpolluted

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; Qld = Queensland; SA = South Australia;
Tas = Tasmania; Vic = Victoria; WA = Western Australia
Source: Australian Bureau of Statistics²⁵⁻²⁷
Little information that is comparable across cities is available on the extent of biodiversity within the built environment. The Australian Conservation Foundation’s 2010 Sustainable Cities Index sought to rank the biodiversity of 20 of Australia’s largest cities according to three factors: habitat connectivity, landscape stress and number of reserves. On this basis, Townsville, Darwin and Wollongong were the top-ranked cities, and Ballarat and Geelong ranked equal last of the cities considered.

Bekessy and Gordon provided examples of biodiversity loss in some major cities in Australia, including declining bushland and mammalian species in Sydney’s Sutherland Shire, a 23% clearing of remnant vegetation on Perth’s Swan Coastal Plain between 1994 and 2003, and a 50% reduction in native grassland in Melbourne between 1985 and 2005.

2.2 Urban environmental efficiency

Urban environmental efficiency relates to how well the built environment encourages the efficient use of natural resources—in particular, land, energy and water—and the implications of the built environment for waste production and minimisation.

2.2.1 Land use

Only limited data exist on the extent of land used by the built environment. The available data show that the built environment occupies only a small proportion of Australia. According to the Australian Collaborative Land Use Mapping Program, 14,031 square kilometres (0.18% of Australia’s total area) were devoted to ‘urban intensive uses’. There are currently no formal methods to detect and report land-use change nationally in Australia. However, it is clear that urban areas in Australia are continuing to grow in size. Land that is taken over for urban development is land that cannot be used for other purposes, and often this land has high environmental value.

2.2.2 Energy efficiency

In 2008–09, Australian households used 998 petajoules of energy—about 12% of Australia’s total national energy use. About three-quarters (74%) of household energy is obtained from secondary sources such as electricity and refined products, with the remaining quarter obtained from primary sources such as natural gas and LPG (liquefied petroleum gas). There has been a trend towards increasing use of primary sources, mainly reflecting growth in household use of natural gas and LPG. Use of solar energy as a primary energy source by households is rather small, at 3.1% in 2008–09 (up from 1.6% in 2001–02).

Household energy use per person increased in the first part of the decade, peaking at 48.0 gigajoules per person in 2005–06. Since then, household energy use per person has fallen by about 5% to 45.5 gigajoules, reflecting more efficient use of energy (Figure 10.13).

![Energy use per person](Figure 10.13 Household energy use)

GJ = gigajoule
Source: Australian Bureau of Statistics
One likely factor contributing to this fall is an increase in the use of insulation. In 2002, 57.5% of Australian dwellings had insulation. By 2008, this had risen to 61.5%. During the same period, the proportion of dwellings with solar hot water rose from 4.3% to 7.1%. The proportion of dwellings with heaters fell from 80.5% to 77.4%. Offsetting these factors was an increase in the proportion of dwellings with coolers, from 48.6% to 66.4%.

Households are tending to give greater consideration to energy efficiency when replacing appliances: in 2008, energy efficiency was the major factor considered when replacing refrigerators, freezers, dishwashers and clothes dryers. (For washing machines, the predominant factor was water efficiency, and for heaters it was cost.)

For other uses of energy (e.g. industry and transport), it is not easy to determine usage in the built environment separately from usage in other areas. However, energy use in manufacturing may provide some information about energy use in the built environment, as manufacturing predominantly occurs within the built environment. In 2008–09, manufacturing was responsible for a little over one-third (35%) of Australian national energy use, and almost 80% of this was obtained from primary energy sources (mainly crude oil). Since 2001–02, the intensity of energy use in manufacturing (measured as energy used per dollar of industry value added) has fluctuated; it was lower in 2008–09 than 10 years earlier (Figure 10.14). However, caution should be used in relating this to changes in energy efficiency, as other factors such as changing industry structures may also affect intensity of manufacturing energy use.

Estimates of energy use—either by households or by industry—on a comparable city-by-city or state-by-state basis are not readily available.

### 2.2.3 Water efficiency

In 2008–09, households used 1768 gigalitres of water, which is about 13% of the water consumed in Australia. Of this, 90% was obtained from distributed sources—that is, from centralised water utilities, rather than self-extracted. Household use of distributed water declined 15% between 2004–05 and 2008–09. Per person, the decline was even more significant, at around 20% (Figure 10.15).

Household distributed water use per person in 2008–09 was highest in the Northern Territory (139 kilolitres) and lowest in Victoria (60 kilolitres). However, care should be used in making comparisons, as different parts of Australia have very different climates, which can affect the availability of, and the demand for, water. Between 2004–05 and 2008–09, per person consumption fell in all states and territories except Tasmania and the Northern Territory, with the most significant falls in Queensland (44%) and Victoria (21%). This undoubtedly reflected the drought conditions in these states during the period and the resulting water restrictions.
In 2008–09, the manufacturing industry used 677 gigalitres of water, which is about 5% of the water consumed in Australia. Half of the water used in manufacturing was obtained from distributed sources. Very little change occurred between 2004–05 and 2008–09 in distributed water use in manufacturing, in terms of either total water use or water used per unit of output. In 2008–09, the highest level of distributed water use in manufacturing occurred in Victoria (110 gigalitres, or about one-third of Australian distributed water use in manufacturing), and the highest use of distributed water per unit of output was in Queensland. However, care should be taken in comparing water intensity across states due to significantly different industry structures.

2.2.4 Waste generation and recovery

It is difficult to obtain comparable information on waste in Australia, both across time and across different states and territories. Waste collection systems are fragmented, and there is currently no national approach to the collection of information.

To overcome this problem, the Australian Government Department of Sustainability, Environment, Water, Population and Communities engaged a consultant to develop a methodology for consistent interpretation of state and territory datasets and to produce a report, *Waste and recycling in Australia 2011*, based on this methodology. Methods of compiling and standardising data on waste and recycling, including some scope and definitional aspects, have changed from 2006–07 to 2008–09, so comparisons should be made with caution.

The report found that waste generation per person in Australia was 2139 kilograms, ranging from 1057 kilograms per person in Tasmania to 2665 kilograms per person in Western Australia. The waste recovery rate for Australia was 52%; the Northern Territory had the lowest recovery rate (5%) and the Australian Capital Territory had the highest (76%).

Between 2006–07 (the previous period for which data for Australia are available) and 2008–09, there appears to have been a 6% increase in waste generation and a 7% increase in recovery, suggesting that, at least for this period, growth in waste generation and waste recovery is proceeding at almost twice the rate of population growth. Despite the data limitations, the available evidence suggests that, for earlier periods, the growth in waste generation also significantly exceeded growth in population.

The 2011 report provided estimates of waste generation and recovery by source sector (municipal, commercial and industrial, construction and demolition) for all states and territories (Figures 10.16 and 10.17).
The fact that waste and recycling data are generated in variable ways by a range of agencies inevitably means that there are wide disparities in the detail, geographic coverage, scale, timeframes and scope of the data. Within those limitations, effort has been made to ensure the accuracy of the information presented. Comprehensive data were not always available, and readers should use a degree of caution when using this information.

Recycling rates for each waste stream within and between jurisdictions can differ markedly from each other, and from the national average. (The major waste streams in Australia are: 1, municipal solid waste (mainly from households); 2, commercial and industrial waste; and 3, construction and demolition waste.) These differences are the product of many factors, including the presence or absence of recycling infrastructure, the viability of end markets for recovered resources (which exert a ‘pull’ on recycling), transport distances, information and awareness, social or cultural factors (such as contamination of recyclables with landfill waste, or vice versa) and policy settings. Differences in jurisdictional definitions and methods for measuring and/or calculating recycling can also be significant, so caution should be applied if making comparisons.
In 2009, the Australian Bureau of Statistics Waste Management Survey of households found that 99% of Australian households participated in some form of recycling and/or reuse of waste. Of these households, 98% had recycled and 86% had reused waste. All states and territories had a household recycling rate of more than 95%. Paper, cardboard, newspapers, plastic bottles, glass and plastic bags were the most recycled materials in Australia. These materials are often recycled through municipal kerbside recycling services, which were used by 91% of Australian households.

Municipal waste, which approximates household waste, accounts for about one-third of waste generation. Queensland has the highest municipal waste generated per person (914 kilograms) and Victoria the lowest (441 kilograms).

Municipal recovery rates were highest in the Australian Capital Territory (59%) and lowest in the Northern Territory (15%).

In 2009, Australian households were recycling the majority of surveyed items at a greater rate than in past survey years. The greatest increase was for steel cans, with 80% of households recycling and/or reusing these in 2009, compared with 70% in 2006.

Waste recycling behaviours embraced by the community tend to be those that are:
- affordable
- easily accessible
- easily linked to environmental benefit.

Although there is a lack of statistical information, there is a prevailing view that because of a less sophisticated infrastructure due to their small size, waste management and recycling are relatively of greater concern in smaller communities.
## 10.1 Assessment summary

### State and trends of the built environment

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban centres with populations greater than 1,000,000</strong></td>
<td>Traffic congestion creates significant problems, and there are concerns about the level of pollution and maintenance of major cities. There are good ranges of recreational activities. The use of natural resources such as land, water and energy is high.</td>
<td>Poor</td>
<td>Adequate high-quality evidence and high level of consensus</td>
</tr>
<tr>
<td><strong>Urban centres with populations between 100,000 and 1,000,000</strong></td>
<td>These cities have lower traffic densities and are generally considered to be less polluted and better maintained. There are good ranges of recreational activities. The use of natural resources such as water and energy is high.</td>
<td>Poor</td>
<td>Limited evidence or limited consensus</td>
</tr>
<tr>
<td><strong>Urban centres with populations between 10,000 and 99,999</strong></td>
<td>Because a larger number of centres fall within this category, there is a diversity of issues and less rigorous evidence about these issues, however, there is a consensus that, on balance, the state of the built environment in these urban centres is good.</td>
<td>Poor</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
<tr>
<td><strong>Smaller places</strong></td>
<td>In spite of a lack of evidence and a diversity of issues, the consensus is that the state of the built environment in these places is good. Because of their small size, these places put less pressure on the natural environment; however, they lack scale in the use of water and energy, and waste management can be of concern.</td>
<td>Poor</td>
<td>Evidence and consensus too low to make an assessment</td>
</tr>
</tbody>
</table>

### Recent trends

- **Improving**: Adequate high-quality evidence and high level of consensus
- **Stable**: Limited evidence or limited consensus
- **Deteriorating**: Evidence and consensus too low to make an assessment
- **Unclear**: Evidence and consensus too low to make an assessment

### Grades

- **Very good**: Almost all dimensions contribute positively to the livability and environmental efficiency of the built environment, with no significant areas of concern
- **Good**: Many dimensions contribute positively to the livability and environmental efficiency of the built environment, with only limited significant areas of concern
- **Poor**: Limited dimensions contribute positively to the livability and environmental efficiency of the built environment, and there are significant areas of concern
- **Very poor**: Few dimensions contribute positively to the livability and environmental efficiency of the built environment, and there are many significant areas of concern
Pressures affecting the built environment

The main drivers identified in Chapter 2 of this report—population growth, economic growth and climate change—lead to a number of pressures on the built environment:

- Population growth leads to
  - increased urban footprint
  - increased traffic
  - increased pollution
  - increased consumption.

- Economic growth leads to
  - increased traffic
  - increased pollution
  - increased consumption.

- Climate change leads to
  - increased extreme weather events
  - increased sea levels.

3.1 Increased urban footprint

As the urban population of Australia continues to grow, additional urban land is required to house the population, or existing urban land has to be used more intensely—together, these changes are known as an increased urban footprint. Although the latter does not lead to a growth in the physical size of cities, it does place pressure on the availability of open space for recreational purposes and the quality of the natural environment within the built environment.

Metropolitan plans in each capital city aim to strike a balance between housing development in new ‘greenfield’ locations (previously undeveloped land used for parks or agriculture) and in existing urban areas. However, given the projections that most of Australia’s population growth will occur in the larger cities, it can be expected that, under current trends, our cities will increase in physical size over the years and decades ahead. Many of Australia’s largest cities are located in areas of high-quality agricultural land or near areas of environmental significance, and expanding urban areas place significant pressures on these scarce or precious assets. For example, there are pressures to subdivide bushland near cities. Coastal landscapes are particularly prized, and most urban growth in Australia is occurring in coastal areas.

3.2 Increased traffic

Both population and economic growth typically cause increased traffic, which can increase traffic congestion. Unless mitigated, traffic congestion tends to increase more quickly than the growth rates in the underlying drivers, because of the compounding effect that additional traffic has on traffic congestion. Although estimating future traffic congestion can be difficult and complex because of the assumptions that need to be made, in 2009, the Bureau of Transport and Regional Economics projected a baseline increase in the avoidable social cost of congestion (see Section 2.1.3) of 117% between 2005 and 2020, compared with a projected increase of 37% in total annual kilometres travelled in passenger-car equivalent units. In comparison, the mid-range population projections in the 2010 intergenerational...
mub of the Australian Government Treasury are for a population increase of 26% between 2005 and 2020. Using that report’s projected economic growth rate (an average annual increase of 2.7% in gross domestic product [GDP]), GDP would increase by 49% over the same period. However, as noted in Section 2, traffic has recently levelled off in major Australian cities (associated with reduced private vehicle kilometres travelled per person); if it continues, this trend would reduce future growth in congestion.

3.3 Increased pollution

Increased traffic, unmitigated, will lead to increased air pollution (see Chapter 3: Atmosphere, Section 3.3.2). As well, higher household demand for energy due to population growth, and higher industrial consumption of energy associated with increased economic growth drives increased use of fossil fuel energy. This can also lead to increases in pollution unless mitigated in some way, such as by reducing the level of harmful particles emitted from particular energy sources through scrubbing, improving energy efficiency or switching to energy sources that are ‘cleaner’. Some renewable energy sources such as solar are nonpolluting. Within nonrenewable sources, the use of natural gas generates less harmful pollutants than the equivalent use of coal or oil.

Although national trends are difficult to establish because of limited comparable data across cities over time, it appears that there has been a slight increase in air pollution in Australia in recent years, as measured by the number of days in which average PM$_{10}$ concentration exceeded the National Environment Protection Measure standard (see Section 2.1.4). This suggests that recent mitigation measures have not been sufficient to fully offset the pressures from increased vehicular use associated with increasing population and economic growth.

3.4 Increased consumption

Both increased population and increased economic growth tend to lead to increased consumption. This, in turn, can increase the use of scarce natural resources such as water and energy, unless the rate of growth is offset by increases in the efficiency with which these resources are used. There is evidence of recent significant increases in the efficiency of urban use of water, particularly by households, where total water use has fallen even though the population has been growing strongly. However, it is not known how much of this is due to temporary factors, such as the recent prolonged drought across significant parts of Australia and consequent water restrictions, and how much relates to more permanent changes in the efficiency of water use. Energy intensity also appears to be falling, at least in recent times, in terms of both household and manufacturing energy use; however, for households, the decrease in intensity has tended to only just offset the increase in population growth (see Section 2.2.2).

Increased population can also lead to increased waste, as a result of increased consumption associated with greater numbers of people and increased affluence due to higher incomes. Waste generation has typically grown more quickly than the population, and this trend remains evident in the most recent data. Recycling and energy recovery can mitigate the environmental impact of growth in waste generation. It appears that the tendency to recycle over time has been increasing, but the recovery rate has recently stabilised (see Section 2.2.4).

3.5 Increased extreme weather events

The built environment is vulnerable to weather events such as storms—particularly cyclones and hailstorms—and weather-related events such as bushfires. Although it is difficult to identify precise relationships between climate change and particular weather events, research by the Commonwealth Scientific and Industrial Research Organisation and the Bureau of Meteorology in 2007 suggests that climate change will lead to increases in:

- the proportion of tropical cyclones in the more intense category, potentially affecting the built environment in coastal northern Australia
- hail risk over the south-east coast of Australia—the 1999 Sydney hailstorm is generally considered to be the most costly natural disaster in Australia’s history, in terms of private property damage
- fire weather risk—likely at most sites in south-eastern Australia.
3.6 Increased sea levels

Climate change is expected to lead to increases in sea level, with projections of a sea level rise of up to 1.1 metres by 2100. (This is the ‘high’ scenario. The ‘low’ scenario is for a rise of 0.5 metres, and the ‘medium’ scenario is for a rise of 0.8 metres.) Such a sea level rise, with an allowance included for a modelled high tide event, could potentially expose 157,000–247,600 existing residential buildings to inundation; the 2008 replacement value of these buildings is estimated at $41–63 billion.37
### 10.2 Assessment summary

**Pressures affecting the built environment**

<table>
<thead>
<tr>
<th>Component</th>
<th>Summary</th>
<th>Assessment grade</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Urban footprint</strong></td>
<td>Increasing population is placing significant pressures on the land required for Australian cities, including agricultural land and other land of significant environmental value</td>
<td>Very high impact</td>
<td>High impact</td>
</tr>
<tr>
<td><strong>Traffic</strong></td>
<td>Traffic congestion will continue to increase in major cities as a result of population and economic growth, unless recent trends of reduced car use continue</td>
<td>Very high impact</td>
<td>High impact</td>
</tr>
<tr>
<td><strong>Pollution</strong></td>
<td>Although pollution levels in Australia’s cities are generally satisfactory, measures may not be in place to mitigate increased emissions resulting from population and economic growth</td>
<td>Very high impact</td>
<td>High impact</td>
</tr>
<tr>
<td><strong>Consumption</strong></td>
<td>Increasing consumption continues to place pressure on environmental resources, although there is some evidence that increases in the use of water and energy may be slowing. Waste generation, however, is continuing to grow faster than population</td>
<td>Very high impact</td>
<td>High impact</td>
</tr>
<tr>
<td><strong>Extreme climate events</strong></td>
<td>Climate change is likely to lead to an increasing frequency of extreme weather events that affect the built environment</td>
<td>Very high impact</td>
<td>High impact</td>
</tr>
<tr>
<td><strong>Changes in sea levels</strong></td>
<td>Climate change is likely to lead to higher sea levels, leading to increased inundation of coastal areas in the built environment</td>
<td>Very high impact</td>
<td>High impact</td>
</tr>
</tbody>
</table>
Effectiveness of management of the built environment

The arrangements for the management of Australia’s built environment are complex. The states and territories, together with local governments, have the primary responsibility to plan for urban growth and change. As well as urban planning, these governments invest in infrastructure such as roads and railways. They also invest in, or regulate, utilities such as power and water. The Australian Government has no direct planning responsibilities, but its policies in areas such as housing, environment, infrastructure, immigration and economic policy, as well as its regulatory functions, have an impact on the livability and environmental efficiency of the built environment. Industry and community actions are also important shapers of the built environment. Increasingly, the private sector is providing critical infrastructure, and individuals and households participate in voluntary programs that can affect the use of environmental resources such as water and energy.

Given the range of mechanisms for managing the built environment and the breadth and complexity of issues that need to be managed, assessing the effectiveness of the management processes is a challenging task. In this report, management effectiveness is addressed only at a broad level. It is beyond the scope of this report to specifically look at each of the mechanisms and make a formal assessment of their effectiveness. Unlike in other environmental domains, there is usually no direct relationship between a management mechanism and a particular environmental issue in the built environment. The most important management approaches tend to be multifaceted, and aim to address social and economic issues as well as environmental ones. The task is complicated by the variability of specific characteristics across the full range of communities, meaning that generalisation is needed to derive conclusions at the national level. Nonetheless, using informed opinion and input from experts, it is possible to make relevant statements about management effectiveness—even if only general ones. This is the approach that has been taken in this section, including in the assessment summary at the end of the section.

Overall, current management for the built environment is considered to be only partly effective. This rating is heavily influenced by disparate management arrangements, which often lack coordination. Although there is often a good understanding of context leading to the development of plans—at least for particular aspects of the built environment—the follow-through in terms of inputs and processes is weaker, leading to outputs and outcomes that are less than effective.

A 2010 ADC Forum cities report, Enhancing liveability, observed that:

These factors [congestion and housing affordability], together with real concerns about the long-term sustainability of suburban development, have fostered significant levels of community unease, and shone a spotlight on the current mechanisms to address the key issues facing our cities. The general view appears to be that these mechanisms are not producing the outcomes we need.
The forum identified six governance issues requiring attention:

- lack of community support for urban planning principles
- lack of integration in planning
- a poor relationship between planning and budgets
- lack of policy alignment between levels of government
- lack of land-use planning systems to address the need for increased density and co-location of housing, and other infrastructure and services
- lack of research to assist policy making.

These challenges have been recognised at the political level. In a speech in August 2009, the Minister for Infrastructure, Transport, Regional Development and Local Government, the Hon. Anthony Albanese MP, stated that ‘the need to pay attention to our cities is more urgent than ever’. He observed that ‘disparate decision-making processes are producing suboptimal planning, land use and settlement patterns’. He foreshadowed a National Urban Policy to ‘articulate the challenges facing our cities’ and ‘highlight how a systems approach to thinking, policy decisions and allocation of resources can achieve greater benefits’.

In December 2009, the Council of Australian Governments (COAG) agreed to reforms to ensure that capital cities are better placed to meet the challenges of the future. It established nine criteria for capital city strategic planning systems, a number of which are directly relevant to the livability and environmental efficiency of the built environment. COAG agreed that, by 1 January 2012, all states will have in place plans that meet the criteria, and these plans will be independently reviewed by the COAG Reform Council.

In 2011, the Property Council of Australia asked residents to rate their state or territory government’s performance in planning and managing urban growth (Figure 10.18). A large majority of residents in all capital cities rated the performance as fair or worse, with Sydney and Darwin having the lowest ratings.
Another perspective is provided by a KPMG assessment of city planning systems, which was commissioned by Built Environment Meets Parliament in 2010.39 (Built Environment Meets Parliament comprises the Property Council of Australia, the Australian Institute of Architects, the Planning Institute of Australia, Consult Australia and the Green Building Council of Australia. It holds an annual summit between parliamentarians and the property and building industry to discuss opportunities to improve life in Australia through the built environment.) Desktop research assessing each capital city’s planning against the nine COAG criteria produced an average score of 54% (Table 10.4). Melbourne rated the highest and Hobart the lowest. The report’s authors noted that the COAG criteria had only been recently adopted and that different jurisdictions are at different stages of the reform process.

Table 10.4 Assessment of city planning systems

The assessment was based on evidence of a framework and practical delivery of the framework. The performance of each capital city system was rated out of 10 and then converted to a percentage.

<table>
<thead>
<tr>
<th>City</th>
<th>Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melbourne</td>
<td>69</td>
</tr>
<tr>
<td>Brisbane</td>
<td>64</td>
</tr>
<tr>
<td>Adelaide</td>
<td>61</td>
</tr>
<tr>
<td>Perth</td>
<td>56</td>
</tr>
<tr>
<td>Canberra</td>
<td>54</td>
</tr>
<tr>
<td>Sydney</td>
<td>47</td>
</tr>
<tr>
<td>Darwin</td>
<td>44</td>
</tr>
<tr>
<td>Hobart</td>
<td>38</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>54</strong></td>
</tr>
</tbody>
</table>

Source: KPMG39

Governments at all levels use regulatory and other instruments that can affect the form and structure of the built environment, as well as the use of resources and the generation of waste within the built environment. These include mandatory standards, fees and charges, licences, or other restrictions on activities or operations. Suasive approaches, which encourage changes in behaviour through the provision of information, are also used.

These types of approaches, particularly mandatory ones, can often be effective in achieving policy outcomes. This is most likely when the policy outcome is defined in specific terms, such as achieving a particular standard (e.g. a building code), meeting a predetermined target in reducing the use of a resource (e.g. energy efficiency standards) or reducing an activity that is considered undesirable (e.g. air pollution or waste generation). The adoption of emission standards for Australian motor vehicles has, for example, had a direct and significant impact on the quality of air in Australian cities. However, organisations such as the Productivity Commission have raised concerns that such approaches, unless properly designed, can have unintended consequences or may not be the most cost-effective way of achieving outcomes, particularly when the approach entails significant indirect costs. There are also concerns that regulatory processes are too fragmentary and suffer from inconsistent objectives, or that they move the focus from managing risks to gaining an ‘approval’ tick. (See, for example, Section 4.4—Environmental and building regulations in Rethinking regulation: report of the Taskforce on Reducing Regulatory Burdens on Business.40)

In some cases, it is argued that a desired outcome, while ‘reasonable’ from an environmental perspective, may impose considerable social or economic costs that were not properly considered in the setting of policy (see Productivity Commission42). This view inevitably creates a tension between those who view environmental issues as important issues in their own right, and those who see environmental issues within a broader socioeconomic context. Whatever the ‘right’ view, it is important that those responsible for designing regulatory approaches fully consider all costs and impacts of the proposed regulation so that properly considered decisions can be made about the appropriate approach.
Approaches that ‘internalise’ externalities through appropriate pricing regimes, where appropriate, tend to lead to more flexible and less prescriptive approaches for dealing with environmental issues; however, this is at the expense of a direct link between the policy approach and the desired environmental outcome. Mandatory labelling to inform consumers in a way that provides an incentive to use an environmental resource more efficiently can also be effective in changing behaviours. In general, the more information that is available to inform decisions, the more likely it is that the right decisions will be made. However, voluntary schemes that rely on the goodwill of people to modify their behaviour often have limited effect and run the risk of being tokenistic.

A particular area of concern for the built environment is traffic congestion. An important mechanism for dealing with traffic congestion is improving public transport. In 2009, the Senate Standing Committee on Rural and Regional Affairs and Transport undertook an inquiry into the investment by the Australian Government and the states in infrastructure and services for public passenger transport. The committee identified a number of concerns relating to the management effectiveness of public transport, including the need for better institutional arrangements; for more strategic, long-term planning; for better integration between transport planning and urban planning; and for more complete networks. Most submissions argued for a significant investment in public transport infrastructure, including cost–benefit analysis. The committee found that ‘significant catch-up investment in public transport is needed, particularly in light of the current strong growth in patronage, and the inevitability that congestion-free public transport will be more important in future as our cities become bigger and more congested’. The committee also considered that improvements in passenger public transport could be complemented by congestion charging, to help reduce congestion by discouraging motorists from travelling when congestion is likely, while recognising that such charges are difficult politically. Congestion charging could also improve fuel efficiency. A 2008 Bureau of Infrastructure, Transport and Regional Economics working paper found that ‘congestion charging is gaining favour as an enduring solution that directly targets congestion, has strong theoretical foundations, has worked well in key cities and provides an innovative source of finance’.43

A number of approaches have been adopted by governments to improve the efficiency of energy use in the built environment, including provision of information by governments, a requirement for disclosure of information by sellers and producers, mandated energy efficiency standards in the Building Code of Australia, mandated investment in more energy-efficient equipment and technologies, and subsidies and other financial investments. These are supported by nongovernment initiatives such as Green Star certification by the Green Building Council of Australia. Readily available, comprehensive evaluations of the effectiveness of these policies and programs are lacking. Undoubtedly, they have led to improvements in energy efficiency, but the efficacy of the various approaches, particularly relative to each other, and their cost-effectiveness do not seem to have been systematically evaluated. The National Framework for Energy Efficiency, which has been established by the Ministerial Council on Energy, aims to improve the coordination of energy efficiency programs across governments. An energy efficiency data gathering and analysis project has been established to improve the development and evaluation of energy efficiency policies.

Urban water supply has also been a focus for governments in recent years. Governments are responding in a number of ways, including by investing in new water supplies, improving the management and delivery of urban water services, and allowing for greater innovation and more efficient water use. In doing so, they have been confronted by issues relating to planning, regulation, pricing, market and institutional reforms, and public confidence. The National Water Commission’s second biennial assessment of progress in implementation of the National Water Initiative in 200944 found that much more work is required to fully implement the urban water reform actions agreed under the 2008 COAG Work Program on Water—in particular, to establish transparent urban water supply security standards, and to develop strategies for urban water security that are flexible and robust.
Box 10.4 Zero Waste SA

Zero Waste SA was established when the South Australian Government realised that a new strategy was needed to increase waste avoidance and recycling. It was recognised that waste management in South Australia was still fundamentally reliant on landfill, despite efforts to change this.

Through collaboration, education, advocacy and financial incentives, Zero Waste SA aims to stimulate innovations in resource efficiency and help South Australians meet the strategic plan target to ‘reduce waste to landfill by 25% by 2014’.

Between 2002 and 2009, South Australia reduced waste to landfill by 17%—more than 200 000 tonnes—despite the state’s increasing population and continued economic growth. South Australia now recycles more than 70% of its waste, and new systems are in place to help reduce waste to landfill even more.

South Australian householders recycling food waste

South Australian councils are increasingly offering a food-waste recycling service to householders, following the successful completion of a pilot project in 2010, involving 17 000 households across 10 councils. The project was the largest pilot of its type in Australia.

In the pilot, householders placed all kitchen scraps, including dairy and meat scraps, in benchtop containers, which were then placed in the garden organics bin for fortnightly collection.

Household satisfaction surveys showed strong support for food-waste recycling using a benchtop container system and/or home composting. Results from the pilot have informed the development of a financial incentives program to assist councils to introduce food-waste collection in households.

In addition to working with local government, Zero Waste SA has several programs that address the generation of food waste in manufacturing, commercial and industrial settings.

The two food-waste recycling systems piloted: the kitchen caddy and the bio basket, with a roll of compostable bags

Recycling at work

Zero Waste SA has developed the Recycle Right at Work grants program, which encourages waste and recycling companies to offer improved recycling collection services for Adelaide’s small to medium businesses.

The commercial and industrial sector generates about 250 000 tonnes of resources—such as paper, cardboard, plastic, food waste and metal—that is still dumped in landfill.

Under the program, the purchase of recycling bins is subsidised, and financial incentives are provided to waste collection companies based on the audited volumes of recycled materials collected.

Zero Waste SA provides funding assistance for collection companies to introduce new services for:

- paper and cardboard recycling
- source-separated, commingled dry recycling
- source-separated organics recycling.

Under the Recycle Right at Work program, the purchase of recycling bins is subsidised

Resource Efficiency Assistance Program (REAP)

TAFE SA Regency International Centre is working to keep food waste out of landfill; a three-bin recycling system has increased recycling rates from 11% to 20%

REAP helps companies take a more sustainable approach to their waste management and resource use to improve results on their triple bottom line of financial, environmental and social returns.

Some of South Australia’s best known organisations work collaboratively with Zero Waste SA and the Business Sustainability Alliance to reduce their costs and environmental impacts. Case studies documenting their achievements are published on the Zero Waste SA website (www.zerowaste.sa.gov.au).

Source: Zero Waste SA
### Assessment summary

#### Effectiveness of management of the built environment

**Summary**

**Understanding:** There is generally a good understanding by the various management entities of issues affecting the built environment. This understanding is improving through initiatives such as the *State of Australian cities* report and the National Urban Policy; however, understanding is adversely affected by the complexity and interrelationships of a wide range of issues.

**Planning:** Planning is hampered by the diverse range of entities involved and a lack of coordination among them. This lack of coordination has been recognised, and steps are being taken to rectify it. Information deficiencies and conflicting or unclear objectives are also hampering planning.

**Inputs:** Inputs are applied in a piecemeal fashion and not always in a manner consistent with plans. There is a poor relationship between planning and budgets. Budgets are not always adequate, and there is underinvestment in infrastructure, particularly that relating to public transport. Improved planning should lead to more effective use of resources.

**Processes:** The lack of coordination across various entities significantly hampers effective processes. Under the Council of Australian Governments initiatives and the National Urban Policy, there is potential for improved alignment between levels of government.

**Outputs and outcomes:** Partially effective inputs and processes are leading to partially effective outputs and outcomes in terms of the livability and urban environmental efficiency of the built environment, as assessed in Section 2. Although expected improvements in planning and processes should have a positive impact on outputs and outcomes, this may be counteracted by increasing pressures on the built environment, as identified in Section 3.

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**Recent trends**

- Improving
- Deteriorating
- Stable
- Unclear

**Confidence**

- Adequate high-quality evidence and high level of consensus
- Limited evidence or limited consensus
- Evidence and consensus too low to make an assessment

**Grades**

- Very effective
- Effective
- Partially effective
- Ineffective

---

Australia State of the Environment 2011 833
Resilience of the built environment

The approach to assessing resilience in this section is the same as that used in the rest of the report. Resilience for the purposes of State of the Environment reporting is defined as ‘the capacity of a system to experience shocks while essentially retaining the same function, structure and feedback and therefore identity’. For natural systems, this approach works well. For human systems, such as the built environment, functionality, structure and identity are constantly changing, so describing and gauging resilience is difficult. Some shocks may alter the structure and identity of the built environment, but some may consider that responses to these changes, while not restoring the original structure and identity, may not always be undesirable and in some cases may increase livability.

An increase in the urban footprint brought about by population growth fundamentally alters the structure of a city and can have significant impacts on its identity, many of which would be seen as negative. Urban sprawl can reduce livability and environmental efficiency, and can have an irreversible impact on the natural environment (e.g. due to land clearing). However, if population growth occurs in areas that are in decline or where land is underutilised, and the development is done in a way that preserves quality green spaces, the impact of the growth is much less significant.

Increased traffic congestion arising from population and economic growth can significantly affect the function of a city. Some of the ways in which this might be mitigated (e.g. building additional roads) impact on the structure and possibly the identity of the built environment. On the other hand, growth in traffic congestion can be mitigated through increased use of public transport, which has a much smaller impact on the structure and identity of the built environment.

Pollution may lead to an increase in episodes of poor air quality. The frequency, duration and severity of these episodes are influenced by short-term meteorological conditions and local topography, and air quality is usually restored to acceptable levels once the immediate conditions change. However, human resilience in the face of prolonged or recurring exposure to air pollutants is limited.

The resilience of the built environment in the face of increased consumption depends on the extent to which the built environment system itself leads to increases in efficiency. There are mixed views on whether urban systems create efficiencies in the use of environmental resources; many improvements in environmental efficiency tend to result from factors ‘outside’ the system, such as changed behaviours and technological improvements. In this regard, the built environment itself could not be considered resilient to increased consumption. However, where development and redevelopment activities in urban areas use ‘green’ building techniques and are associated with better infrastructure and services, the environmental impact of increased consumption can be significantly reduced.

Generally, the built environment is quite resilient to extreme weather events. Cities have a very good capacity to ‘bounce back’ from these shocks, particularly following rebuilding and other recovery activities. However, in some extreme cases, the structure and identity of the built environment might alter as a result of an extreme weather event, and there may be long-lasting effects on urban amenity. Higher sea levels would have a more lasting impact on affected built environments, particularly if there is a structural response in areas at risk of inundation.
Risks to the built environment

The most significant risks to the built environment are shown in the assessment summary at the end of this section. The risks examined in this section are incidents occurring at one point in time, rather than the impacts of pressures that may occur over longer periods. The assessment was made using qualitative analysis based on expert opinion. In analysing risk, the effectiveness of management responses and the resilience of the system are taken into account. Only risks that are considered the most significant (in terms of the combination of likelihood and consequence) are shown in the assessment summary; risks that are assessed as falling within the shaded cells of the summary table are not shown.

Many of the risks to the built environment result from extreme natural events. Although the previous section concluded that the built environment is generally quite resilient to such events, the immediate consequences of these events in terms of property damage, human casualties and loss of amenity can be quite significant. Mega-storms, such as Cyclone Tracy, which devastated Darwin in 1974, or the hailstorm that hit Sydney in 2000, are considered to be the most significant risk to the built environment. Storms of this nature are rare events for any particular urban area at any particular time, but over a long period there is a strong likelihood that some major urban area will experience such a storm. Since climate change is expected to increase the frequency of such storms, this likelihood is expected to increase.

Mega-fires, of the type that struck Victoria in February 2009, are considered the next most significant risk. These are also likely to affect urban areas at some time in the future, although their consequences for the built environment are rated a little lower than the consequences of mega-storms.

Floods, localised storms and extreme heat events that impact on the built environment are considered almost certain to occur in the future, on the basis of historical evidence. Climate change is likely to increase their prevalence. The urban heat-island effect in cities (which causes a metropolitan area to be significantly warmer than its surrounding rural areas) means that increases in temperature from climate change are particularly problematic. However, the impacts of these are assessed as being moderate, rather than major or catastrophic.

The risk of weather-related events is difficult to manage, since they cannot be prevented (although measures that mitigate climate change would reduce their likelihood). Appropriate building codes can reduce the consequences, as can appropriate emergency responses; however, the ‘power of nature’ is such that, even if these things are done well, very significant impacts could still occur in extreme situations.

The increased urban footprint arising from population growth poses a significant risk to the built environment. Growth in the physical size of cities is almost certain to occur, with major implications for the livability of the built environment. Increased traffic congestion is another risk that could be expected to have major consequences for the built environment. This risk is considered likely rather than almost certain. Although congestion in Australian cities has been increasing over many years, there is some recent evidence that growth in motor vehicle use may be levelling off; if this continues, the likelihood of increased congestion will be reduced.

A rise in sea levels is considered almost certain. Based on projections of the extent of sea level rise in 2100, this would have a very significant impact on certain parts of coastal cities in Australia. However, since most parts of the built environment in Australia—
even in coastal cities—would not be directly affected by a sea level rise, the overall impact of this risk is rated as only moderate.

Contamination of a major water supply is considered to pose a high degree of risk to the built environment. It could result from population growth placing pressure on critical infrastructure, leading to the breakdown of quality control. Such an incident is rated as possible; however, if it occurred in a major urban area, there would be major consequences, particularly for human health. Good management can minimise the likelihood of such incidents, and Australia generally has a very strong track record of managing the quality of urban water. However, increasing pressure on critical infrastructure means that there is a need to continually improve the quality of management of this infrastructure.
### 10.4 Assessment summary

#### Current and emerging risks to the built environment

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Catastrophic</th>
<th>Major</th>
<th>Moderate</th>
<th>Minor</th>
<th>Insignificant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Almost certain</td>
<td>- Increased urban footprint, leading to increased pressure on the natural and built environments</td>
<td>- Extreme heat events, with impacts on health</td>
<td>- Sea level rise, leading to disturbance or destruction of the built environment</td>
<td>- Bushfires, leading to disturbance or destruction of the built environment</td>
<td></td>
</tr>
<tr>
<td>Likely</td>
<td>- Mega-storms, leading to disturbance or destruction of the built environment</td>
<td>- Increased traffic congestion, with impacts on livability and health</td>
<td>- Mega-fires, leading to disturbance or destruction of the built environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possible</td>
<td>- Major contamination of water supply, with impacts on health</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unlikely</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rare</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Not considered
Outlook for the built environment

Australia’s built environment faces a mixed future. As our population grows, the physical size of our cities—particularly the major cities—will continue to increase. Although this can be mitigated by urban infill, this also poses challenges for the built environment through increased demands on infrastructure, particularly roads, and urban amenity. Traffic congestion has two possible outlooks: a continuation of long-term trends towards significant increases in the social costs of congestion, or a continuation of more positive trends in motor vehicle use observed in recent years, including through the provision of better public transport. Maintaining the quality of urban environmental assets—such as parks, waterways and urban air—will require continued investment in urban infrastructure and other actions by governments; otherwise, the pressure of extra people and additional economic activity will be too great.

Climate change will also pose significant challenges for our cities through the increased potential for property damage and loss of amenity caused by increased extreme weather events and rising sea levels, and through increased risks to human health within the built environment.

An increasing population and economic growth lead to increased consumption, which can lead to a greater demand for scarce natural resources and energy, as well as greater waste generation. However, these impacts can be mitigated through technological improvements that lead to more efficient use of resources, as well as changes in behaviours through pricing and other mechanisms. There is emerging evidence that the rate of growth in the use of natural resources has slowed and, in some cases, there appears to be falling per capita use of certain resources. It remains to be seen whether these recent trends, which could be influenced by specific events such as the recent drought, can be sustained over time. However, waste generation continues to grow.

At a glance

The outlook for the built environment is mixed. On the one hand, the increasing pressures on the built environment resulting from population and economic growth and climate change pose significant challenges. Increasing urban land use and traffic congestion are two areas of concern; however, congestion will be less of an issue if the recent levelling off of motor vehicle travel continues and if there is growth in public transport. Waste generation continues to grow. On the other hand, there is emerging evidence of more efficient consumption of water and energy. Furthermore, recent initiatives to improve urban planning should lead to greater capability to deal with emerging challenges.

The management of the built environment, particularly in regard to urban planning, has been only partially effective for many years, primarily due to a lack of coordination across disparate planning mechanisms. However, recent COAG initiatives and the recent development of a National Urban Policy are hopeful signs that there may be substantial improvements in the coordination and effectiveness of management in the near future.
References


Point Lonsdale, Victoria
Photo by Michael Boniwell
Key findings

Variations in climate, and changes in the size and composition of the population around Australia’s coasts, have been major drivers of pressure on the coasts—for both the natural and the built environment—over the past decade.

Concerns about how to deal with the pressures caused by these drivers and how to prepare for future climate change have been the catalysts for adaptation responses.

The major pressures on natural and cultural heritage, marine and terrestrial biodiversity, and ecosystem processes along Australian coasts are similar to those in previous reports on the state of the environment.

They include urban expansion in capital cities and major regional coastal cities; modification of coastal habitats by urban and commercial developments, and nearshore mining and dredging; changed flows of rivers into estuaries and coastal environments; disturbance of acid sulfate soils; loss and fragmentation of native vegetation; increasing use of coastal areas for food production (aquaculture); fishing and intertidal harvesting; rapidly growing numbers of invasive species and pathogens; tension between the potential economic value of land, including areas that are suitable for intensive agriculture, and its conservation; modest budgets for management of reserved lands; degrading conditions that affect buildings (e.g. wind, salt, inundation); low levels of recognition and understanding of what is culturally significant; and decline in connections between Indigenous people and coastal places.

Some trends in land use and management practices have reduced some pressures.

These include expansion of conservation and Indigenous areas, decline in the extent of native forest managed for wood production and a corresponding increase in the extent managed for conservation, and improvements in land-management practices that have reduced the flows of sediments and chemicals to the coast during major rainfall events.

The greatest reductions in native vegetation extent have been in eastern, south-eastern and south-western Australia.

Impacts on the coastal strip are highly variable around Australia’s coastline. The extent of native vegetation ranges from very heavily cleared, with less than 10% remaining, in parts of Victoria and South Australia, through 31–50% remaining in large parts of the south-western and north-eastern coastal areas, to 71–100% remaining for most of northern Australia. Many species of plants and animals are threatened by activities associated with Australia’s coast-based population.

All chapters of this report cite examples of promising responses to coastal challenges by governments, working individually and together, but outcomes for some major issues are still far from ideal.

There is significant uncertainty about how species and ecological systems will be affected by climate change. Local governments are expressing concern about the lack of guidelines, standards and national strategic approaches to address coastal development, growing populations and environmental impacts. The recent Hawke report, reviewing the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act),
Debate about coastal governance and management took an important step forward with a 2009 report from the House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts. The report, *Managing our coastal zone in a changing climate: the time to act is now*, noted that there is limited national collaboration and cooperation to achieve consistencies, efficiencies and agreements on issues such as variation in planning laws, capacities of local councils, monitoring coastal habitat change and legal liabilities. The report made 47 recommendations to address these issues. Most of these recommendations have been noted or accepted in principle by the Australian Government. As with the responses to the review of the EPBC Act, the quality and timeliness of actions will be critical if existing challenges to coastal sustainability are to be addressed and looming ones prepared for.

Recent research comparing Australian coastal governance with examples elsewhere in the world concluded that the ability to adapt to emerging pressures, especially climate change, is low and declining in many parts of Australia. Recommended remedies include allocating authority and resources between levels of governance according to their effectiveness at each level (rather than trying to manage everything centrally);

You can tell all you need to about a society from how it treats animals and beaches.

Frank Deford (1938–)

strengthening development rules and incentives to encourage relocation before irreversible problems arise; allowing for uncertainties by building flexibility into rules and incentives so that they can be adjusted when knowledge and circumstances change; transferring public and private benefits, costs, risks, uncertainties and responsibilities from governments to beneficiaries of development; and viewing catastrophes as opportunities for learning and change, not signals to automatically rebuild. There is potential for these issues to be addressed in the responses to the key reports mentioned above, but this will require strong leadership from both government and other sectors.

The major emerging risks that remain incompletely addressed for Australia’s coasts are those relating to climate change, especially sea level rise, and demographic change. The future of coastal Australia will depend largely on how rapidly these changes occur, how extreme they are, and how Australians prepare for and respond to them.

Although coastal environments are facing major pressures, awareness is growing that ecological, social, economic and cultural issues are interlinked and cannot be addressed separately. The future of our coasts depends on whether government and governance arrangements can be developed that allow a much more strategic approach to managing coastal resources, over spatial scales that match the scale of the challenges. Desirable futures are most likely if major reform of coastal governance is achieved in the next decade or sooner, which is possible, but not guaranteed.
## Contents

1. Introduction 849
  1.1 Coastal features and issues 849
  1.2 In this chapter 850

2. Major issues for coastal environments 851
  2.1 Atmosphere (including climate change) 852
    2.1.1 Air quality 852
    2.1.2 Climate change and variability 852
    2.1.3 Responses 852
  2.2 Inland water flows and use 854
    2.2.1 Coastal river and estuary pollution 854
    2.2.2 Desalination 854
    2.2.3 Seawater intrusion 854
    2.2.4 Impacts of water abstraction on flora and fauna 854
    2.2.5 Responses 855
  2.3 Coastal land 857
    2.3.1 Major trends 857
    2.3.2 Factors affecting coastal land-use change 857
    2.3.3 Acid sulfate soils 857
    2.3.4 Changes in native vegetation and habitat 858
    2.3.5 Invasive species 861
  2.4 Coastal marine waters 861
    2.4.1 Fishing and aquaculture 861
    2.4.2 Impacts of rising sea temperatures 862
    2.4.3 Invasive species 862
  2.5 Biodiversity 862
    2.5.1 Threatened species 862
    2.5.2 Concerns from previous State of the Environment reports 862
    2.5.3 Impacts of climate change 863
  2.6 Coastal heritage 864
    2.6.1 The nature of coastal heritage 864
    2.6.2 Pressures 864
    2.6.3 Risks and responses 864
  2.7 Population growth and urban development 866
    2.7.1 Population growth 866
    2.7.2 Coastal population growth 867
    2.7.3 Environmental impacts 868
    2.7.4 Tourism and recreation 869

3. Governance of the coast 870
  3.1 Assessment by previous State of the Environment reports 870
  3.2 Emergence of the governance debate 871
  3.3 Recent developments 873
Risks to and resilience of coastal communities and environments 877

4.1 General risks to our coasts 877
4.2 Future risks associated with climate change 878
4.3 Sea level rise 878
4.4 Resilience and adaptive capacity 883
4.5 Hopeful signs 883

Outlook for coastal environments 885

5.1 Undesirable futures 885
5.2 Desirable futures 885

References 887
There is something about coastal management which is quite paradoxical: on the one hand it is central to the well-being, the livelihoods and the lifestyles of so many Australians; on the other hand it appears marginal to the central interests of natural resource management, to planning, to public policy, and even to R&D.

Bruce Thom, The Australian coast: images, problems and solutions, keynote address to Coast to Coast Conference, 2004
Introduction

Australia is a land of diverse geographical and biological features. The natural features of our coasts are some of the most iconic in Australia—many of the ‘jewels in the crown’ of Australia’s World Heritage properties are in the coastal zone. ‘Coastal zone’ has been defined in various ways in the past. In this chapter, coasts are considered loosely to be the zone of interface between terrestrial, aquatic and marine environments. The size of that interface is different for different issues and processes.

1.1 Coastal features and issues

Biologically, coasts are an interface between the biota of the oceans and the land, including biota of freshwater systems that mingle with salt water in estuaries. The transition between terrestrial and marine environments represents one of the sharpest changes in habitat for living organisms found on Earth. It produces unique flora and fauna adapted to deal with unique environmental challenges. One of those challenges is that the border between terrestrial and marine systems is constantly changing; it is set to become even more variable with the effects of climate change in coming decades. Geomorphology is also unique and dynamic.

Australian coastal environments include a range of ecosystems that contain habitat for a variety of species. Habitats include mangroves, saltmarshes, saltflats, seagrass beds, beaches, dunes, estuaries, intertidal mudflats, gulfs, bays and coastal wetlands. Nearshore and offshore marine habitats are potentially impacted by human coastal settlements and activities. Coasts, especially the mouths of rivers, are where valuable resources such as high-quality soils accumulate, and where people practise agriculture and a range of other resource-based industries, as well as enjoying the amenity of these places.

Australia’s population is focused strongly around its coastline, especially around the estuaries of major river systems. These areas include good shipping and boating facilities, as well as prime agricultural land. Australians have been concentrated on the coast since the beginning of European settlement. Before then, coastal Aboriginal people had lifestyles that differed from those of Aboriginal people living inland, although goods, stories and practices were exchanged between coastal and inland people.

Concentration of people around the coasts puts pressure on coastal ecosystems. It also complicates the management of these systems because several major demands on the land come into potential conflict with each other: demand for urban development at the waterline; demand for agricultural production on fertile floodplains; increasing demand for inshore areas for food production (aquaculture); increasing recreational use, including fishing and boating; and demand for conservation of nature for both its intrinsic values and the benefits it provides for humans through water filtration, regulation of river flows, provision of food and provision of cultural values. Coastal ports are also prime sites for entry of invasive pests and diseases.
Governance issues are highly complex in coastal areas. The importance of coastal assets means that many interest groups place demands on local, state and national governments. The responsibilities and authorities of these three levels of government overlap at times, which can lead to conflict if objectives differ between levels of government. Issues can be inadequately addressed if it is unclear where responsibilities lie, with one level of government expecting another to take responsibility and action. Resourcing can often be a major issue at all levels, especially when the desires of coastal residents outstrip funding, including land rates.

Coastal environments are where the dynamics of future change will be writ large on the landscape and ecosystems. Many aspects of climate change will directly affect the coast: sea level rise; changing wind patterns; changes in the frequency and magnitude of cyclones, storms, tidal surges and rainfall events; changes in erosion and sediment transport; and changes in nearshore ocean currents. The effects of changes in the nature and amount of trade with other countries will be felt in coastal ports, with flow-on effects on local economies and lifestyles. All these will drive change in ecosystems and human values at the waterline, where even small changes in sea level and the quality of water can have major effects on the species that live where the sea and the land overlap.

1.2 In this chapter

Many state of the environment reports around Australia and the world do not include a chapter on coasts, considering them under the topics of land, water and the marine environment. The State of the Environment Committee preparing this report considered that the unique characteristics of coastal environments, the strong focus on coasts in Australian culture and settlement patterns, and the growing concern about the convergence of social, economic and environmental issues around our coasts warranted a chapter discussing the key issues.

Like other chapters in this report, this chapter is structured loosely around a framework of drivers, pressures, state, impact and response (DPSIR). However, the committee considered that there are insufficient data specifically relating to coasts to support the detailed assessment used in other chapters. Conclusions about the condition of coastal environments, factors affecting condition and the effectiveness of management responses are therefore drawn primarily from other chapters of the report. We have considered ongoing risks, resilience and outlook together in a general discussion section, drawing on both insights from other chapters and additional information that is specific to coasts.

Tacking Point Lighthouse, Port Macquarie, New South Wales
Photo by Matt Lauder
Major issues for coastal environments

At a glance

The three drivers of environmental change—climate change, population growth and economic growth—result in a range of pressures on our coastal environment. Events associated with variations in climate have been major pressures on Australian coasts over the past decade, and concern about preparing for possible future impacts of climate change and variability has been a strong driver of adaptation responses. Concern about changes in the size and composition of coastal populations has also been growing for several decades. Urbanisation and coastal development for farming and industry are a major pressure on terrestrial and marine biodiversity and environmental quality, water resources, air quality, and cultural and natural heritage. The 2006 State of the Environment report concluded that ‘most, if not all, of the issues identified and assessed in both the 1996 and the 2001 national state of the environment reports still remain to be resolved’.

Our coastal regions bring together many of the issues identified for other environmental themes.

For inland waters, issues relevant to coasts include coastal river and estuary pollution, desalination, seawater intrusion, and impacts of water abstraction (removal) on flora and fauna. Overall, the management of coastal waters has improved greatly in Australia in the past decade, including some high-profile programs to ensure river and estuary health in metropolitan areas (e.g. Hobart and Brisbane). Widespread drought has increased tensions over water use, including in coastal areas, and this is likely to be an important consideration for coastal management in the future.

For land, major trends in land use that have both negative and positive impacts on coastal Australia include urban expansion in capital cities and major regional coastal cities, changed flow in rivers that influences freshwater and nutrient flows to estuaries and coastal environments, expansion of conservation and Indigenous areas, declines in the extent of native forest managed for wood production and increases in the extent managed for conservation, and improvements in land-management practices that have reduced the flows of sediments and chemicals to the coast during major rainfall events. Disturbance of acid sulfate soils remains a major consequence of coastal development, with significant environmental, economic and social costs to coastal communities.

For vegetation, impacts on the coastal strip are highly variable around Australia’s coastline. Native vegetation ranges from very heavily cleared, with less than 10% remaining, in parts of Victoria and South Australia, through 31–50% remaining in large parts of the south-western and north-eastern coastal areas, to 71–100% remaining for most of northern Australia. The greatest reductions in native vegetation extent have been in eastern, south-eastern and south-western Australia.

For biodiversity in general, many species of plants and animals are threatened by activities associated with Australia’s coast-based population. The introduction of weeds and pest species to our coasts has also contributed to national reductions in biodiversity, and to marine, estuarine and coastal productivity.

For the marine environment, issues relevant to coasts include modification of coastal habitats by processes such as coastal urban development, catchment development, marinas, breakwaters, island reclamation projects, coastal and nearshore mining and dredging, harbours and shipping channels; and a continued increase in impacts of invasive species, including threats from pathogens and viruses. A particular concern is the incremental nature of coastal development, which reduces the abundance of native vegetation and breaks down connectivity among remnant habitat patches. The cumulative effects of coastal development are rarely considered.

For natural and cultural heritage, our coastal areas include many important wetlands, places of importance in the traditional culture and practices of Indigenous people, buildings associated with areas of early European colonisation, historically important shipwrecks, threatened species and communities, and other places of natural heritage significance. Issues relevant to coasts include degrading conditions (e.g. wind, salt, inundation), low levels of recognition and understanding of what is significant, a decline in connections between Indigenous people and coastal places, the rapidly increasing number of invasive species and pathogens, progressive loss of habitat, tension between the potential economic value of land and its dedication for conservation purposes, and modest budgets for the management of reserved lands.
In this section, we draw on the other chapters of this report, as well as some key literature specific to coasts, to consider in an integrated way the major drivers and pressures affecting Australia’s coasts, the impacts of these drivers and pressures on the state of coastal environments, and the responses that have been made to manage coasts as a national asset.

2.1 Atmosphere (including climate change)

For further information, see Chapter 3: Atmosphere.

2.1.1 Air quality

Australia’s coasts are where most of the nation’s people live, where the major cities and urban areas exist and, therefore, where the effects of human activities on local air quality are most felt.

Air quality in Australia’s major urban centres is generally good. This is due to the progressive tightening of national vehicle emission and fuel standards over the past 20 years and actions by state and territory environment protection agencies to substantially control industrial, commercial and domestic sources of air pollution. Maintenance of past gains in air quality, especially with respect to peak levels of particles and ozone, will be influenced by technological advances (such as improvements in propulsion systems for motor vehicles and clean forms of production), changes in climate and planning issues (such as transport and urban sprawl). Coastal councils around Australia are concerned about how they can manage these issues when demands on their land-rates base are rising but per capita rates are falling.

National health-based standards are rarely exceeded for prolonged periods, and very high levels of pollution are usually associated with short-lived extreme events such as bushfires and dust storms that generate very high levels of particle pollution.

2.1.2 Climate change and variability

Climate change is emerging as a major driver of change for Australian coasts and marine areas in the next few decades and beyond (see also Section 4 of this chapter and Chapter 6: Marine environment).

Although the extent to which long-term climate change has driven pressures on coasts over the past decade is still being debated, the variability of climate (whatever its cause) has led to many incidents of inundation, erosion of coastline and damage to human lives and property. Of particular significance are sea temperature increases in the south-west, east and south-east regions, which are among the largest in the world (see Section 2.4.2). This is likely to affect commercial and recreational fishing and aquaculture, and could potentially have wider impacts on a range of coastal activities that are part of the social and economic fabric of coastal communities.

Sea level rise is emerging as a major future impact of climate change (see Section 4), but the processes affecting it have been active for some time (Figure 11.1). Over the past 25 years, the rate of sea level rise has been an order of magnitude greater than the average for several previous decades—an average rise of 3.1 millimetres per year occurred between 1993 and 2003, compared with 1.8 millimetres per year between 1961 and 2003, and 1.2 millimetres per year during the 20th century as a whole.1

Future direct and indirect impacts of climatic events and climate variability on Australia’s coasts are discussed in Section 4.

Many of the management responses to pressures on Australian coasts, especially in the past six years, have been in response to concerns about future impacts of climate in combination with other drivers and pressures (see Section 3).

2.1.3 Responses

Roles for governments in adapting to climate change include:

- supporting scientific studies that are unlikely to be undertaken by the private sector (particularly relevant at the national government level) and providing information to the private sector and the community to encourage and assist adaptation (relevant to all tiers of government, but especially state and local governments)
- adopting policies that facilitate adaptation and a regulatory framework that supports, rather than distorts, effective market signals (a critical role for the national government, but one that state governments can significantly reinforce)
using policy mechanisms such as land-use planning, building codes and product standards to deal with situations where short-term market responses may act to restrict longer term adaptive action (mainly relevant to state governments, but local government also plays an important role in on-ground implementation)

- fully factoring climate change into planning, resourcing and managing the provision of public goods and services, such as public health and safety; emergency services; flood and coastal protection; water supply, drainage and sewerage services; protection of public lands, parks and reserves; fisheries; and other natural resources (relevant to all tiers of government, but especially state and local governments).

The role of governments is particularly challenging for coastal communities and environments because of the complex interactions and divided responsibilities between the different levels of government and the currently limited mechanisms for coordinated and strategic action (see Section 3).

Source: National Tidal Centre, reported in Australian Government Department of Climate Change and Energy Efficiency
2.2 Inland water flows and use

For further information, see Chapter 4: Inland water.

2.2.1 Coastal river and estuary pollution

River pollution often arises from upstream development and land use. However, it has particular impacts on the environment where it enters estuaries and the nearshore coastal environment. Some of the most significant of these estuaries and coastal lagoons are near our major cities (Sydney, Melbourne, Brisbane, Adelaide, Perth) or significant environmental assets (the Great Barrier Reef).

The land is a major source of coastal and marine pollution. Considerable progress has been made in addressing point-source pollution, although some problems still arise from these sources. Current diffuse pollution to catchments often results from historical land clearing and land-use changes. Urban stormwater is a major non–point source. Although extensive land clearing for agriculture has been considerably reduced in Australia, the legacy of sedimentation and salinisation of rivers continues. The millennium drought (lasting from 2000 to 2010 throughout southern Australia, but starting in 1997 in some areas) slowed some of these degrading processes in places, but it is likely that subsequent flooding will bring these issues back to the fore among environmental concerns.

Chapter 4: Inland water gives examples of major short-term increases in sedimentation after bushfires in south-eastern Australia (due to reduced vegetation cover and exposure of soil) and major longer term (25–30 years post-fire) reductions in water yield (due to regrowth of vegetation).

2.2.2 Desalination

Most Australians live in metropolitan areas, most of which are located on the coast. Although many of these cities draw water from inland areas, pressure is increasing for them to be able to replace or supplement these inputs by collecting the water that falls as rain in their metropolitan areas and/or by desalinating sea water, as a hedge against climate change. This would reduce further pressure on local freshwater resources. However, it entails a potential risk to coastal waters if salt is disposed of into these waters, and will increase the overall energy use in our cities.

The amount of desalination undertaken by Australian cities increased sharply during 2005–10, largely in response to drought, climate uncertainty, population increase and a new understanding of the need to provide water flows to the environment. Desalination plants were commissioned in Sydney and at Tugun in south-east Queensland in 2010; others are under construction in Melbourne (completion 2011), Perth (completion 2011) and Adelaide (completion 2013). However, desalination is not a universal strategy, as many local governments have sought to manage demand for water and improve water saving at municipal and household levels, often avoiding the need for major new water infrastructure.

2.2.3 Seawater intrusion

Development of groundwater resources to meet growing demands at the coast can put local aquifers at risk of seawater intrusion. Before development, groundwater gradients are naturally towards the sea and maintain an interface between fresh and salt water. If aquifers are exploited too heavily, this gradient can reverse and draw sea water into previously fresh aquifers. Rising sea levels also have the potential to reverse this gradient.

A number of locations around Australia have already been identified where seawater intrusion is a concern, including coastal locations in Queensland (Lower Burdekin, Bribie Island and the Pioneer Valley), South Australia (Eyre Peninsula, Port McDonnell and metropolitan Adelaide), Victoria (Port Phillip, Westernport and Werribee) and Western Australia (Swan Coastal Plain, Carnarvon, Esperance, Cottesloe and Cape Range).

Coastal development leading to increased groundwater use, potentially exacerbated by sea level rise, poses a risk to fresh groundwater resources and the people and natural environments they support.

2.2.4 Impacts of water abstraction on flora and fauna

Coastal environments and the species that inhabit them are particularly vulnerable to the effects of drought, because the impacts of drought are exacerbated by withdrawal (abstraction) of water for human use along rivers before they reach the coast. Impacts on waterbird and shorebird populations due to abstractions and extended drought were evident
by 2008. The annual survey of waterbird communities at the Living Murray icon sites found a 48% decrease in bird numbers from the previous year. No waterbird breeding was recorded at the Lower Lakes, Coorong and Murray mouth, and only minimal breeding of white ibis and black swans was recorded at Chowilla Floodplain and Lindsay–Wallpolla islands. The decline of inland wetlands was identified as a significant contributor to the drastic decline in shorebirds (73% and 81% declines for migratory and resident shorebirds, respectively) between 1983 and 2006.

2.2.5 Responses

Management of coastal waters has improved greatly in Australia during the past decade, including some high-profile programs to ensure river and estuary health in metropolitan areas (e.g. Hobart and Brisbane). These programs have developed and tested cost-effective approaches to monitoring, modelling, reporting, innovation, communication, strategic interventions and effective partnerships between researchers and managers. Another successful approach to the management of coastal waters is described in Box 11.1.

Box 11.1 The Lower Lakes, Coorong and Murray mouth—Ngarrindjeri ruwe

The Lower Lakes, Coorong and Murray mouth in South Australia extend over approximately 140 000 hectares, covering 23 different wetland types, from very fresh to saltier than the sea. This area, where the Murray River meets the sea, is one of 10 major havens for large concentrations of wading birds in Australia, and is recognised internationally as a breeding ground for many species of waterbirds and native fish. The area was designated as a Ramsar Wetland of International Importance in recognition of its diverse range of wetland ecosystems, habitats and species of birds, fish and plants (more than 30% of the migratory wading birds that fly to Australia spend summer there). It is also of high cultural, economic, spiritual and social value to the Ngarrindjeri people, the traditional owners of the region, who maintain a continuous, strong relationship with their land and waters (ruwe).

Cultural flows are essential for the continued breeding and health of Ngarrindjeri ngartjis (totems), which determine the health of the Ngarrindjeri nation. Cultural flows are also essential to maintain the health of Ngarrindjeri cultural heritage sites. Some of these are areas of high cultural significance but have not been identified as being environmentally significant.

Years of water overallocation and the severe drought of 2001–10 led to significant impacts on the Coorong, Lower Lakes and Murray mouth. Due to the barrages holding back sea water, water levels in the lakes dropped to unprecedented lows—more than one metre below sea level in Lake Alexandrina in April 2009. As the water levels fell, serious land and water management issues emerged, with the drying of wetlands, exposure of previously submerged sulfidic soils and disconnection of different elements of the system. The water quality of the system declined markedly due to insufficient freshwater flows through the barrages.

The Lower Lakes, Coorong and Murray mouth icon site environmental management plan commits to protect and restore natural habitats, restore viable populations of native species, improve water quality and increase flows through the wetlands, as well as recognising the Ngarrindjeri association with the area. The short-term emergency response included the pumping of water from Lake Alexandrina to Lake Albert to prevent acidification; preparatory work towards the ponding of fresh water within the Finnis River and Currency Creek area to help manage acidification, as well as trials to assess the effectiveness of revegetation and bioremediation techniques to manage acid sulfate soils; and the purchase of water on the temporary water market to provide flows to the lakes.

Throughout the crisis, Ngarrindjeri elders worked closely with the South Australian Department of Environment and Natural Resources to put in place the emergency works and plan for the future of the Coorong, Lower Lakes and Murray mouth, and actively participated in the bioremediation and revegetation around the Lower Lakes. In recognition of their contributions, the Ngarrindjeri elders were awarded the 2010 South Australian Environment Award.
2.3 Coastal land

For further information, see Chapter 5: Land.

Urban settlements and our population are concentrated along the eastern, south-eastern and south-western coastal fringes of Australia. This area overlaps, and sometimes conflicts, with the areas most suitable for intensive agriculture (i.e. higher rainfall zones within 200 kilometres of the coast and where the floodplains of major rivers provide the most fertile soil). Land managed for nature conservation is located primarily in central and northern Australia, and in the forested ranges of the east and south-west of both mainland Australia and Tasmania.

2.3.1 Major trends

Some major trends in land use that are relevant to coastal Australia include:

- continuing urban expansion in both capital cities and major regional coastal cities (see also Chapter 10: Built environment)
- continuing expansion of the conservation and Indigenous estates (see also Chapter 6: Marine environment, and Chapter 8: Biodiversity)
- continuing decline in the area of native forest managed for wood production and a corresponding increase in the extent of native forest managed for conservation, much of which is found in coastal ranges (see Chapter 5: Land)
- changes in flows from rivers into estuaries and coastal environments, due to increased extraction of water for agricultural and urban use, and to drought over the past decade in many areas (see Chapter 4: Inland water)
- growth of mining developments in the north-west of Australia (see Chapter 6: Marine environment), which is increasing the number of people accessing coastal environments for recreation, warranting monitoring of its impacts
- improvements in land-management practices in many (but not all) areas, which have reduced the flows of sediments and chemicals to the coast that were characteristic of major rainfall events in the past (see Chapter 4: Inland water).

2.3.2 Factors affecting coastal land-use change

Growing Australian and global populations will demand more food and fibre, and expanding settlements and infrastructure will continue to impact on the environment. Economic growth places more demands on natural resources, as well as generating financial resources and new technologies for environmental management. The changed climate regimes and sea level rise associated with global warming are expected to place new pressures on both the natural environment and primary production systems. All of these factors will affect coastal ecosystems, but particular pressure will come from the interaction between sea level rise and human settlements.

2.3.3 Acid sulfate soils

Acid sulfate soils occur naturally in both coastal (tidal) and inland or upland (freshwater) settings. When disturbed, sulfides within the soil react with oxygen in the air, forming sulfuric acid. Coastal development for tourism, towns and agriculture has disturbed large areas of acid sulfate soils, with significant environmental, economic and social costs to coastal communities. Adverse impacts of acid sulfate soils in coastal lowlands include:

- poor water quality (e.g. dissolved metal contaminants, low pH, reduced oxygen levels)
- direct killing of fish, or fish becoming more vulnerable to pathogens
- loss of critical habitat areas, aquaculture production, fish stocks, wetland biodiversity and amenity
- acid erosion of infrastructure
- the need for rehabilitation of disturbed areas.

The public health implications of disturbing acid sulfate soils are not well understood. However, acidified coastal wetlands may provide predator-free habitat for species of mosquito that transmit arboviruses (e.g. Ross River virus). Acid dust mobilised during ploughing and construction activities may cause dermatitis and eye irritation.

Risk mapping in various locations around Australia has lacked consistency and contained many large gaps. In collaboration with the National Committee for Acid Sulfate Soils, the Commonwealth Scientific
and Industrial Research Organisation (CSIRO) developed the Atlas of Australian Acid Sulfate Soils, which has now been incorporated into the Australian Soil Resource Information System.a

Local and state governments around Australia have produced policies, plans and guidelines for managing the risks of acid sulfate soils. At a national scale, the National Water Quality Management Strategy4 provides guidelines on water management, including management of acid sulfate soils; the National Strategy for the Management of Coastal Acid Sulfate Soils5 assists in coordinated management; and the handbook Managing acid and metalliferous drainage6 provides guidance on best-practice management for an Australian context.

2.3.4 Changes in native vegetation and habitat

Chapter 5: Land, and Chapter 8: Biodiversity discuss data on declines in native vegetation around Australia and its significance for biodiversity conservation. The greatest reductions in native vegetation extent have been in eastern, south-eastern and south-western Australia (Figure 11.2). Impacts on the coastal strip are highly variable around Australia’s coastline, ranging from very heavily cleared, with less than 10% remaining, in parts of Victoria and South Australia, through 31–50% remaining in large parts of the south-western and north-eastern coastal areas, to 71–100% remaining for most of northern Australia.

Natural coastal habitat systems, including the coastal swamp systems (such as those dominated by Melaleuca, Casuarina, saltmarsh and mangrove species) and the submerged wetlands (such as mudflats, seagrasses and algal beds), play a major ecological role in the lives of marine fish and invertebrates. These habitat systems provide breeding, feeding and nursery grounds for many species of fish and invertebrates, as well as rich feeding grounds for migratory waders and other shorebirds.7

Coastal urban development (especially canals), catchment development, marinas, breakwaters, island reclamation projects, coastal and nearshore mining and dredging, harbours and shipping channels all have impacts on the ecology of coastal habitats. For example, coastal dune vegetation and natural beaches may be replaced by housing, hard surfaces and beach groynes. In places, entirely new forms of habitat may be created, such as low-energy harbours with surrounding rock walls, which attract a different suite of marine species.

Coastal development happens in an incremental way, making it difficult for local or state planning authorities to assess the cumulative impact of specific development proposals. One consequence of coastal development is a reduction in the abundance of native vegetation and the breakdown of connectivity among remnant habitat patches.

To obtain a coarse assessment of changes in vegetation, the Environmental Resources Information Network unit in the Australian Government Department of Sustainability, Environment, Water, Population and Communities compared the current mapped extent of major (native) vegetation groups (MVGs) around Australia’s mainland coast with their modelled extent before European settlement (i.e. pre-1750) (Figure 11.3). In this analysis, the ‘coastal strip’ was defined in three different ways: 10 kilometres, 50 kilometres or 100 kilometres inland from the high water line. To examine impacts on lowland vegetation separately from impacts on mountains, separate analyses were run for map components lying below 20 metres above sea level, components below 50 metres above sea level and components regardless of elevation. Figure 11.3 shows the data for vegetation below 50 metres elevation and for two widths of coastal strip. The broad conclusions hold for the other combinations, which are available on the State of the Environment website.b

In the 10-kilometre coastal strip (where most coastal settlements fall), most MVGs, apart from Acacia shrublands and Callitrus open woodlands, occur at more than 50% of their pre-1750 extent; several are above 80% (Figure 11.3). This conclusion should be regarded with caution as MVGs are very broad groupings and may include ecosystems that are far more reduced than the average for the MVG. Furthermore, these figures are for the nation’s coastline overall, much of which (especially in northern Australia) has not been affected by urban development. Therefore, the decline of two MVGs to less than 50% of their pre-1750 level and of five MVGs to below 60% suggests that major clearing has occurred around coastal settlements. This is supported by the state of the environment reports by the states and territories.

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a  www.asris.csiro.au
b  www.environment.gov.au/soe
The extents of reservation for 9 of the 23 MVGs are below 10% of pre-1750 extent, and a further 4 are at or below 15% (see Chapter 8: Biodiversity for a discussion of targets for the National Reserve System). This represents a large risk to the ecosystems within these MVGs, given the pressure on Australia’s coasts.

For several MVGs, a greater proportion of pre-1750 extent remains in the 100-kilometre coastal strip than in the 10-kilometre strip (Figure 11.3). This indicates that clearing of these MVGs (e.g. *Acacia* open woodlands) has been more intense near the coast than further inland. For most other MVGs,
Figure 11.3  Proportion of major vegetation groups (MVGs) below 50 metres altitude remaining around Australia’s coasts showing (a) data from a 10-kilometre strip inland from the high tide line, (b) data for a 100-kilometre strip and (c) the difference in percentage of MVGs remaining between the 100-kilometre strip and the 10-kilometre strip.

In a and b, the darker parts of the columns are the percentage of pre-1750 vegetation remaining, and the lighter parts of the columns are the percentage of pre-1750 vegetation currently in International Union for Conservation of Nature reserve categories I–IV (i.e. strict nature reserves and wilderness areas, national parks, natural monuments or features, or habitat/species management areas). A positive value suggests that there has been selective clearing in the 10-kilometre strip, and a negative value suggests that clearing has been proportionally greater outside the 10-kilometre strip.
the differences are small; for three, there is 5–10% less remaining in the 100-kilometre strip, suggesting that a little more clearing has occurred inland.

Although many mangrove swamps have been lost to coastal development, particularly as a result of land reclamation near urban areas and estuarine flood mitigation programs, at the national level we still retain around 96% of mangrove area. Most of this is in pristine areas of the Northern Territory, Cape York and the Kimberley. However, even though large coherent areas of such ecosystems remain and are highly valued, many small areas of fringing mangroves have been lost from estuaries (particularly on the east coast). This will have significant ecological impacts on locally dependent species and ecological functions, such as connectivity, that contribute strongly to the resilience of coastal ecosystems. Some loss of fringing mangroves occurs across all regions. For example, substantial areas of mangroves fringing the water’s edge have declined along the Pilbara coast of Western Australia, probably as a result of local developments, changes in hydrodynamics and climate change impacts. These losses are hard to detect—trends in area coverage shown in the coarse-scale national statistics may significantly underestimate the extent of the ecological impact from the loss of fringing mangroves.

Change in area of vegetation is only one type of measure; more information is needed on how ecological processes have changed and little such information is currently available.

2.3.5 Invasive species

We deal with invasive species only briefly here, as most of the invasive species associated with coasts have invaded marine environments and are discussed in detail in Chapter 6: Marine environment (see also Section 2.4.3).

Introduced weeds and pest species have contributed to national reductions in biodiversity and marine, estuarine and coastal productivity. Many of the weeds that threaten native species and ecosystems across Australia have impacts on coastal areas. Two weeds that have particular impacts on coastal dune systems are bitou bush (Chrysanthemoides monilifera ssp. rotundata) and boneseed (C. monilifera ssp. monilifera). These species displace native vegetation, are highly invasive and have potentially high economic and environmental impacts. Weeds are a particular problem in peri-urban areas (between the outer fringes of urban centres and rural areas) as they are easily transported by high rates of traffic and people who are unaware of necessary precautions; as well, some inexperienced or temporary residents in coastal areas may practise poor weed control (see Section 2.7.3). Feral animals like foxes and cats are particularly active around human settlements because of the ready abundance of food.

Native species can have similar effects to invasive species when they move rapidly outside their usual range, threatening species that normally live in a particular environment. Such movements occur when native species are spread by birds, other animals or people, all of which are very active along Australia’s coastal strip, both on the land and in the water. Unusual movements of native species also occur as habitat changes (e.g. with increasing sea temperature). An example in south-east Australia is the expansion of the range of the sea urchin Centrostephanus, which is denuding coastal reefs in Victoria and Tasmania with subsequent impacts on biodiversity and recreational and commercial fishing.

2.4 Coastal marine waters

For further information, see Chapter 6: Marine environment.

2.4.1 Fishing and aquaculture

Pressures from commercial and recreational fishing are important outcomes of coastal urban development, growth in the Australian and global populations, and a range of economic drivers. Aquaculture in coastal waters is one of the fastest growing commercial sectors in Australia.

Pressures from fishing are decreasing overall. However, in some areas of the south-east, east and south-west regions, pressures are widespread and causing serious degradation. Pressures from the development of aquaculture continue to increase in the south-east region, where the worst areas are already suffering serious degradation.
2.4.2 Impacts of rising sea temperatures

Sea surface temperatures have increased since the early 20th century—by 0.7 °C from 1910–29 to 1989–2008. As mentioned in Section 2.1.2, increases in sea surface temperature, which are particularly marked in the south-west, east and south-east regions, are likely to affect commercial and recreational fishing, aquaculture and a wide range of coastal activities that are part of the social and economic fabric of coastal communities.

Changing ocean temperature directly affects the distribution and abundance of many species and habitats, including seagrasses, macroalgae, phytoplankton, coral reefs, tropical and temperate fish, pelagic fish, marine reptiles and seabirds. The general trend is that habitats and distributions of species are moving southward. Further declines in seagrass meadows and algal beds, due to storms, turbidity and warmer water, are expected in the future. A loss of diversity in coral fish and other coral-dependent organisms is also expected.

For species that require shallow and cool coastal waters, such as for breeding or nursery grounds, this southward forcing by the changing temperature will eventually result in major population reductions as habitats become less available, and finally become unavailable south of the mainland and Tasmania. Changing temperature is likely to create the greatest set of ecological changes in shallow-water marine ecosystems in the coming decades.

2.4.3 Invasive species

An emerging concern in the marine environment is the threat from pathogens and viruses, which are spread by people, cargo, fishing gear and boats, and are difficult to detect. Introduced marine pests can enter Australia by a variety of routes, including ships’ ballast water, biofouling on ships’ hulls and equipment, and the aquarium trade and aquaculture. Around 97% of the volume of Australia’s trade is moved through the network of ports. In 2008–09, approximately 800 million tonnes of cargo were moved through Australian wharves by 4200 vessels that made 26 700 port calls. Further introductions of marine pests in coastal waters represent a significant economic and environmental threat.

Translocation of introduced marine pests within Australian waters occurs through the same means, as well as through natural processes. More than 100 introduced species and marine pests have been identified in Australian coastal waters.

Governments are working together to develop and implement a national system to prevent and manage marine pest incursions.

2.5 Biodiversity

For further information, see Chapter 8: Biodiversity.

2.5.1 Threatened species

Australia’s population is heavily concentrated in coastal regions, and so are impacts on our biodiversity. Figure 11.4 shows a coarse assessment of the location of threatened species listed under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) in a 100-kilometre band around Australia. Such data are difficult to interpret. For example, the concentration of threatened species around the northern coast contradicts other data in this report showing that these coastlines are relatively undisturbed. This could partly reflect the larger number of species in tropical parts of Australia. As well, a range of small mammals, birds and reptiles, whose ranges include coastal areas, are currently of concern in the north. Events outside Australia potentially affect migratory species like birds. More consistent with expectations is the high concentration of threatened species around the areas of high population growth in south-east Queensland and northern and central New South Wales (Figure 11.4).

2.5.2 Concerns from previous State of the Environment reports

The past three national State of the Environment reports have expressed concern about impacts on most coastal habitats or about lack of information on which to base assessments of impacts. They noted that, while there are continued efforts to improve coastal management responses, coastal zone condition is not significantly improving and continues to decline against a number of criteria. Pressures on coastal resources are increasing at a rate that exceeds the ability of damaged environments to stabilise and be repaired.

www.environment.gov.au/coasts/imps
The increasing cost of addressing these issues as coastal populations grow and the need for specialised knowledge are major challenges for coastal management.¹²

### 2.5.3 Impacts of climate change

Potential impacts of climate change on terrestrial and marine biodiversity are dealt with in detail in Chapter 8: Biodiversity and Chapter 6: Marine environment, respectively. There is significant uncertainty about how species and ecological systems will be affected by climate change. Current regional climate models suggest that impacts will be widespread and that a ‘business as usual’ greenhouse gas emissions scenario over the next few decades will result in global mass extinctions on a scale previously unseen in human history.¹³ Evidence is mounting that, even with a concerted mitigation effort, it may not be possible to avoid impacts such as the loss of large components of biodiversity, including freshwater systems, coral reefs and coastal mangroves.¹⁴ Northern Australian wetlands and the Great Barrier Reef are among the threatened assets.

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**Figure 11.4** Threatened species that occur within 100 kilometres of the coast

This map uses the 1698 threatened (critically endangered, endangered or vulnerable) species listed as at June 2011 under the Environment Protection and Biodiversity Conservation Act 1999. Each species distribution was intersected with a 5-kilometre grid of the coastal region (100 kilometres inland), and a count for each grid cell was calculated.
2.6 Coastal heritage

For further information, see Chapter 9: Heritage.

2.6.1 The nature of coastal heritage

Many Australian natural heritage places are in coastal areas. Many important wetlands, for example, occur on coastal plains, which are especially vulnerable to degradation both because they are often accessible and close to population centres and because they are at the end of river systems that have had water extracted for various uses before it reaches the coast (see also Chapter 4: Inland water).

Because Australia was initially settled around its coasts, coastal areas have many buildings of heritage significance and historically important shipwrecks. Conditions that degrade buildings and natural structures (e.g. wind, salt, inundation) are often more extreme in coastal areas, requiring particular attention to the preservation of heritage assets.

Indigenous places of cultural significance in the coastal zone are potentially under threat from the same forces that affect natural heritage. As well, many Australians lack recognition and understanding of what is significant, and connections between Indigenous people and coastal places have declined. In Chapter 9: Heritage, the Tjilbruke dreaming trails are described. This dreaming links features of coastal environments together in an explanation of the creation of seven freshwater springs along the coast of the Fleurieu Peninsula, between Crystal Brook in the north, through the Adelaide Plains, to Parewarangga (Cape Jervis) in the south. This example illustrates the challenges for managing such heritage values, since the dreaming trails spread across large areas of public and private land and require management by several local councils.

2.6.2 Pressures

Pressures specific to natural heritage include rapid increases in the number of invasive species and pathogens; progressive loss of habitat; conflict in land use, including tension between the potential economic value of land and its dedication for conservation purposes; and the relatively modest budgets made available to those charged with the care, control and management of reserved lands.

Coastal Indigenous heritage in Australia faces pressures in two major areas. Firstly, knowledge and tradition have been lost, particularly in areas of early European colonisation. However, there are also positive factors, such as increasing involvement of Indigenous people in traditional sea and land management in coastal areas. Secondly, Indigenous sites are subject to an ongoing process of incremental destruction, usually associated with urban development, farming and mining. The obligation for identification and assessment of impact rests with the proponent of the development, and Indigenous heritage is often seen as being ‘in the way’ of progress. In many cases, consent for destruction of specific sites is issued in the absence of a comprehensive understanding of the nature and extent of the overall Indigenous resource.

Historical cultural heritage is also particularly threatened by pressures for redevelopment, on both a large and a small scale. The impacts range from complete destruction to inappropriate change, and may affect associated attributes, such as visual setting. Planning systems, land zonings and related regulations, although often well intentioned, do not necessarily assist in achieving conservation outcomes. Some building codes and standards (including, surprisingly, the green building agenda) also create pressure for demolition or inappropriate change. Inflexible paradigms may require building conservation, rather than allowing natural processes and evolution to ruins.

2.6.3 Risks and responses

In coastal and urban areas, population increase leads to more immediate and direct incidents that threaten heritage, such as demolition to make way for new development, damage from the introduction of new infrastructure, and adverse impacts on the setting of significant natural and cultural places. As noted above, climate change will bring about sea level rise, with the risk of inundation of coastal heritage areas.

Dealing with the pressures on natural and cultural heritage around Australia’s coasts is hindered by inadequate survey, assessment and listing of Indigenous places; past ad hoc practices for listing of historic places on statutory registers (although this is now improving); and resource limitations that often restrict activities at the national level to reactive processes for dealing with threats to natural heritage, especially from invasive species.
2.7 Population growth and urban development

For further information, see Chapter 10: Built environment.

2.7.1 Population growth

Concern about changes in the size and composition of the population along Australia’s coasts has been growing for several decades. In 2004, coastal councils from around Australia established the National Sea Change Taskforce to document and promote their concerns. This led to two major pieces of research on demographic change and ways to address it. Smith and Doherty review a number of other contributions to this dialogue.

Australia’s population has grown by about 18.1 million since federation and is currently around 22 million. The most recent intergenerational report projected a population of around 36 million by 2050. About 81% of the population lives within 50 kilometres of the coast.

Population growth in Australia is expected to occur mainly around:

- the big cities (through natural increase, internal migration, international migration and tourism)
- high-amenity coastal regions (especially those located within, or close to, the metropolitan areas of the capital cities)
- the larger regional centres (both coastal and inland).

Source: Australian Government Department of Sustainability, Environment, Water, Population and Communities

Figure 11.5 Population change in Australia, 2001–10
2.7.2 Coastal population growth

Australia’s coastal population has been growing faster than the population of the rest of the country for some time (Figures 11.5 and 11.6) and is expected to increase by another one million people over the next 15 years.23

Increasingly, coastal councils around Australia are expressing concern about population growth in small settlements outside large centres. This growth is occurring faster than many local councils can manage and is associated with expectations for the provision of services that often cannot be supported by the rates base.23-24

Gurran et al.17 made the following observations about the types of people who are moving to coastal communities (although this report is six years old, the main points still apply):

- Although retirees contribute to the sea-change phenomenon, they are no longer the major drivers of coastal population growth.
- New residents of high-growth coastal regions are of a younger age profile than Australia as a whole and significantly younger than the existing profile of communities affected by sea change. However, this is not likely to affect the high median age of sea-change areas in the immediate future because the newcomers represent only a small proportion of the total population.
- As the ‘baby-boomer’ generation has started to retire, the number of retirees moving to the coast, including ‘hill-change’ areas immediately inland (such as the hinterland to the Gold Coast...

![Population increase (%)](chart.jpg)

Source: Australian Bureau of Statistics25

**Figure 11.6** Change in estimated resident population of New South Wales ‘sea-change’ local government areas, 2001–10
and northern New South Wales coasts, which also offer high amenity and access to coastal population centres) is likely to rise again, contributing to an overall increase in the rate of population growth in these places.

The challenges associated with the sea-change phenomenon are not the same everywhere, since different coastal communities are growing for different reasons and in different ways. The drivers for nonmetropolitan coastal development include:

- the attractions of high environmental amenity and space associated with beach and bush—the attraction for some is being able to live near the coast as well as having access to cities for work and visiting relatives, while for others the attraction is getting away from population centres
- employment—many people move to the coast with the hope of finding employment (but unemployment rates in coastal areas are generally much higher than the national average)
- housing choices and affordability—housing affordability has been a major factor drawing people to nonmetropolitan coastal areas, although the difference is decreasing for the most desirable coastal destinations, which might slow migration to these places; changing lifestyle choices are also leading to demand for types of housing that are not available or affordable in metropolitan areas.

2.7.3 Environmental impacts

Urbanisation has been identified as a major pressure on biodiversity, water resources, cultural and natural heritage, marine environments and atmosphere in other chapters of this report. Growing coastal populations require houses, wastewater treatment, roads and other facilities. Environmental controls on urban development and the need for onsite containment of wastes are of vital concern in coastal areas, and adequate development and implementation of these can be a major challenge for resource-limited coastal councils. As noted in Chapter 8: Biodiversity, the impacts of urbanisation are not just direct (e.g. removal or modification of ecosystems) but also indirect (e.g. the consumption of natural resources as an indirect result of consumption of goods by people living in urban areas).

Differences in motivation for moving to coastal areas affect the ways in which people interact with the environment. For example, recent studies of the
impacts of peri-urban development suggest that many people who move to coastal and hinterland areas for lifestyle reasons have little understanding of environmental management, especially how to control weeds and other pests. Furthermore, when high-income, second-home owners become part-time residents in peri-urban areas, especially coastal ones, they tend to drive prices up and force those who provide labour locally to move further away, increasing their travel costs and impacts. Part-time residents also reduce per-household inputs to local economies and to the development of community ethics about environmental management.

2.7.4 Tourism and recreation

Two other major impacts of population increase on coastal areas are tourism and recreation. Nature-based tourism is the reason for more than 3 million international tourist visits to Australia, nearly 13 million domestic overnight trips and more than 12 million domestic day trips annually (Table 11.1). Marine tourism and recreation, including recreational fishing, were estimated to contribute $18.7 billion to the Australian economy in 2007–08, and recreational fishing is now considered to be the nation’s largest participatory recreational activity (see Chapter 6: Marine environment for further details). As well, many of the most attractive bushwalking opportunities and national parks occur in the coastal zone.

Interactions between coastal development and tourism can be complex. For example, tourism has the potential to support good management of coastal areas if incentives and regulations are adequate to encourage reinvestment of some revenue in the environment. On the other hand, there can be conflict between tourism development and residential development in coastal areas—residential and retirement development sometimes undermine tourism appeal or values.

Addressing population pressures on coasts requires cooperation and strategic decision-making across several levels of government—this has been slow to emerge in Australia. One major factor holding back progress is that managing population pressure is not only an environmental issue. It also requires coordinated management of a range of social issues including health, transport, energy and housing infrastructure (see Section 3).

### Table 11.1 Proportion of visitors by type of nature activity, 2008

<table>
<thead>
<tr>
<th>Nature activity</th>
<th>Visitor (%)</th>
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<tbody>
<tr>
<td></td>
<td>International</td>
</tr>
<tr>
<td>Bushwalking or rainforest walks</td>
<td>37</td>
</tr>
<tr>
<td>Visiting national parks or state parks</td>
<td>66</td>
</tr>
<tr>
<td>Visiting botanical or other public gardens</td>
<td>56</td>
</tr>
<tr>
<td>Visiting wildlife parks, zoos or aquariums</td>
<td>58</td>
</tr>
<tr>
<td>Whale or dolphin watching</td>
<td>13</td>
</tr>
<tr>
<td>Snorkelling</td>
<td>18</td>
</tr>
<tr>
<td>Scuba diving</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total nature visitors (million)</strong></td>
<td><strong>3.36</strong></td>
</tr>
</tbody>
</table>

Source: Tourism Research Australia
Governance of the coast

For two decades, government and governance have been a major focus of the debate about the management of Australia’s coasts. More recently, this debate has focused on what government and governance mean for the resilience of coastal ecosystems and the communities whose futures are linked to the environment. These topics are the focus of this section—we suggest that they are the overarching factor that will determine how Australian coastal environments cope with the dual drivers of population growth and climate change.

3.1 Assessment by previous State of the Environment reports

In all previous State of the Environment reports, the overriding concern expressed about Australia’s coasts has been that development has proceeded in a piecemeal, uncoordinated way. Along with cumulative impacts, this presents a risk that coastal assets may be degraded before they are fully assessed and before the objectives for their management and conservation have been set.

All chapters of this report provide examples of promising responses to coastal challenges by governments, working individually and together. However, outcomes in relation to a number of major issues are still far from ideal.

There is significant uncertainty about how climate change will affect species and ecological systems. Local governments are expressing concern about the lack of guidelines, standards and national strategic approaches to addressing coastal development, growing populations and environmental impacts. A major debate about coastal governance has been running for nearly two decades in Australia. The concern among many stakeholders, including those charged with managing coastal settlements and environments, is that development of Australia’s coasts has proceeded in a piecemeal, uncoordinated way. There is a risk that coastal assets could be degraded before they are fully assessed or objectives have been set for their management by Australia as a nation.

So concerned were coastal councils around Australia that, in 2004, they formed the National Sea Change Taskforce. The taskforce has been very active in developing and promoting solutions to state and Australian governments.

This debate took an important step forward in 2009, when the House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts handed down its report, *Managing our coastal zone in a changing climate: the time to act is now*. The report noted that there is limited national collaboration and cooperation to achieve consistencies, efficiencies and agreements on issues such as variation in planning laws, capacities of local councils, monitoring coastal habitat change and legal liabilities. The report made 47 recommendations to address these issues. Most of these recommendations have been noted or accepted in principle by the Australian Government. The quality and timeliness of actions will be critical if existing challenges to coastal sustainability are to be addressed and looming ones prepared for.

In addition, the recent Hawke report, which provided an independent review of the *Environment Protection and Biodiversity Conservation Act 1999*, recommended a range of changes to the Act that would allow it to be applied more strategically and at ecosystem and landscape scales. Many of these recommendations have been accepted by the Australian Government. It remains to be seen whether action is sufficient and soon enough to allow assessment and successful management of the cumulative effects of small developments along the coastal strip. How the three levels of government work together to address these cumulative impacts will be key in determining the future of Australia’s coasts.
The 2001 national report made the following observations:29

There is clearly still a need for a nationally applicable Coastal Zone Policy to be developed to further assist in reducing the fragmentation of effort to manage the coastal zone and associated coastal waters. This issue was highlighted by a House of Representatives report in 1991, which said: ‘The absence of a national perspective towards the entire Australian coastline could lead to national interests being undervalued or even lost for future generations, as the existing ad hoc, hodge-podge pattern of development slowly nibbles away at a precious and beautiful resource, the natural coastline.’

The 2006 report concluded:30

The most all-pervading systemic problem that underpins almost all the issues of managing Australia’s coasts and oceans is the lack of any systematic and strategic policy or operational framework that provides for the national-level monitoring and assessment of the condition of the ocean features, biodiversity or key resources.

In Chapter 6: Marine environment, we conclude:

‘Creeping degradation’ can be effectively prevented by the establishment of absolute standards for the environment. Important calls have been made for environmental benchmarks to be set for use in environmental accounts,31 but a set of standards based on equivalent metrics is equally important. The lack of a set of standards for the Australian marine environment that are based on measurable and ecologically sound metrics means that acceptability on social and economic grounds can, and often does, result in greater pressures being applied to the Australian environment.

In marine systems, there are very few defendable metrics that can be used within management frameworks for this purpose.

3.2 Emergence of the governance debate

Experts who have been involved with coastal issues for decades have emphasised the growing need for a more strategic approach to planning how coasts are managed. Such an approach should take account of the spatial and temporal scales at which pressures on coasts operate, and consider cumulative impacts of small pressures over time. Opinions differ about how a strategic approach could or should be developed, but there is little doubt that current approaches are too fragmented and at too limited a spatial scale.

Following the report of the coastal zone inquiry by the Resource Assessment Commission in 1993,32 Australian, state, territory and local governments developed legislative, policy and program responses to meet the management challenges associated with increasing pressures in the coastal zone. Governments are continuing to improve these responses. At a national scale, the Australian Government released its report, Climate change risks to Australia’s coasts, in 2009.1

Initiatives by state governments during the past decade include:

- the South East Queensland Healthy Waterways Strategyd
- the Victorian Coastal Spaces projecte and the 2008 revision of the Victorian Coastal Strategy,f which has been developing as a partnership between the Victorian Government, the Victorian Coastal Council and Victoria’s regional coastal boards since 1995
- several interlinked initiatives in New South Wales, including the development of an approach to comprehensive coastal assessment as a key component of the New South Wales Government’s Coastal Protection Package (introduced in 2001); the New South Wales inquiry into infrastructure provision in coastal growth areas,g which recommended improvements to the New South Wales Government’s regional strategiesh to increase scrutiny, reporting and enforcement of compliance; and the 2009 NSW Sea Level Rise Policy Statement,i which specifies sea level planning benchmarks for the coastline

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d www.healthywaterways.org/Home.aspx

• the Tasmanian Climate Change and Coastal Risk Assessment Project, including a report on indicative mapping of the Tasmanian coast’s vulnerability to climate change and sea level rise
• the Adelaide Coastal Waters Study and the Living Coast Strategy for South Australia
• the Pilbara Coastal Water Quality Project.

The Framework for a National Cooperative Approach to Integrated Coastal Zone Management was endorsed by the Australian, state and territory governments in October 2003. It encourages complementary arrangements that build on the successes and momentum established through ongoing state and territory coastal management initiatives. This was a formalisation of cooperative processes that had been evolving for some time. Other mechanisms included the Intergovernmental Coastal Advisory Group, which reported to the Marine and Coastal Committee.

Following from the framework, the National cooperative approach to integrated coastal zone management: framework and implementation plan was released in 2006, with six priority areas:

• integration across the catchment–coast–ocean continuum
• management of land-based and marine-based sources of pollution
• planning for climate change and its impacts
• management of pest plants and animals
• planning for population change
• capacity building (the range of activities by which individuals, groups and organisations improve their capacity to achieve sustainability).

Coastal issues were also addressed under the Natural Heritage Trust I and II. Other Australian Government initiatives have included the Coastal Catchments Initiative and the Sustainable Cities Initiative. It appears that most of these initiatives have been absorbed into the Caring for our Country program, which aims, by 2013, to:

• reduce the discharge of dissolved nutrients and chemicals from agricultural lands to the Great Barrier Reef lagoon by 25%
• reduce the discharge of sediment and nutrients from agricultural lands to the Great Barrier Reef lagoon by 10%
• deliver actions that sustain the environmental values of
  – priority sites in the Ramsar estate, particularly sites in northern and remote Australia
  – an additional 25% of (non-Ramsar) priority coastal and inland aquatic ecosystems of high conservation value, including, as a priority, sites in the Murray–Darling Basin
• improve water quality management in the Gippsland Lakes in Victoria, the Tuggerah Lakes Estuary in New South Wales and all priority coastal hot spots
• increase the community’s participation in protecting and rehabilitating coastal environments and critical aquatic habitats.

In 2005–06, the then Minister for the Environment, the Hon. Ian Campbell MP, briefly explored the possibility of developing a 30-year strategic plan for Australia’s coastal zone, but this initiative was abandoned. However, strategic application of the EPBC Act in coastal areas and elsewhere is being investigated; this has received impetus from the recent Hawke review, which examined the performance and future of the EPBC Act. That review recommended a range of changes to the Act that would allow it to be applied more strategically and at ecosystem and landscape scales. Many of these recommendations have been accepted by the Australian Government.

Local government has responded to the challenges of coastal management in several ways across jurisdictional boundaries, including:

• formation of the National Sea Change Taskforce in 2004—that this initially comprised 70 coastal municipalities around Australia (the number varies) that have combined their efforts to examine strategies for a response to population pressures (see also Box 11.2)
• coalitions between other coastal councils, including the Sydney Coastal Councils Group, the Geelong Regional Alliance, the Far North Queensland Regional Organisation of Councils, the Victorian Coastal Council and the South West Catchments Council (in Western Australia)

• increased attention to planning—for example, an Australian Local Government Association survey found that two-thirds of municipalities had altered their town planning schemes and activities in the past three years in response to increased pressure of development, with a key focus on town boundaries and identification of green space between towns that requires protection; Gurran et al. and the National Sea Change Taskforce are among numerous expert groups that have proposed best-practice approaches to dealing with the challenges of coastal population growth and its environmental impacts.

3.3 Recent developments

In 2009, the House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts handed down its report to the Australian Government: Managing our coastal zone in a changing climate: the time to act is now. This report was based on an 18-month inquiry, which received 100 written submissions and 180 exhibits, and held 28 public hearings around Australia. The report noted that there is limited national collaboration and cooperation to achieve consistencies, efficiencies and agreements on issues such as variation in planning laws, capacities of local councils, monitoring coastal habitat change and legal liabilities. It made 47 recommendations, including:

• improving research, and the use of research, on climate change and its impacts in the coastal zone (including sea level rise, extreme sea level events and ocean acidification)

• improving mechanisms for considering adaptation strategies and practices to promote resilience to climate change (including better risk and vulnerability assessment, building adaptation skills for professionals and communities, improving information accessibility and sharing, building professional and community networks, meeting human resource needs, and improving disease mitigation)

• addressing the many uncertainties around insurance, planning and legal matters relating to the coastal zone—these are sources of much conflict between developers, local councils and advocates of better environmental management

• improving governance arrangements (including improving collection and use of information; encouraging research on alternative approaches to governance; raising community awareness of the issues facing the coastal zone; developing an intergovernmental agreement on the coastal zone, to be endorsed by the Council of Australian Governments; improving longer term strategic planning; and developing a national coastal zone policy and strategy, a national catchment–coast–marine management program and a national coastal council)

• improving mechanisms for achieving sustainable coastal communities and managing environmental impacts (including establishing a set of national coastal zone environment accounts; collecting better information on demographic trends and visitation rates; focusing on climate change impacts on biodiversity in Caring for our Country; focusing the National Reserve System on high-biodiversity coastal habitat, and expanding reserves to include better buffer zones and habitat connections; applying the EPBC Act to address cumulative effects of coastal development; using the management of the Great Barrier Reef and Victoria’s coasts as case studies for integrated coastal zone management; ensuring that Ramsar wetlands—and Kakadu National Park, in particular—have effective plans to deal with climate change impacts; developing a national shorebird protection strategy; ensuring that natural resource management bodies include coastal and marine priorities in their planning; and ensuring that there are mechanisms to identify, register and manage Indigenous and non-Indigenous cultural heritage in vulnerable areas).

The Australian Government has noted, accepted or accepted in principle most of these recommendations. The quality and timeliness of actions will be critical if existing challenges to coastal sustainability are to be addressed and looming ones prepared for.
Following this inquiry, a Coasts and Climate Change Council was established in late 2009 to engage with communities and stakeholders and to advise the Australian Government on key issues. The council provided a report to the Minister for Sustainability, Environment, Water, Population and Communities in December 2010, with the recommendations that the Australian Government:

- As a matter of urgency define and progress a 10-year national agenda to ensure that Australia is positioned to address the significant near, medium and long term risks facing the well being of our coastal regions from the impacts of climate change.

- Take a leadership role in driving the science and information base for decision-support tools; developing national standards for risk assessment; tackling legal reform to enhance national consistency and to reduce liability risks; and in the provision of technical support for local governments who are at the cutting edge of impacts on communities, property owners and businesses.

- Recognise the need to improve collaboration and delivery of outcomes across a range of federal, state and local government agencies and in doing so, align adaptation to climate change in coastal regions with national micro-economic reform, social equity, regional development and population sustainability agendas.

- Continue the appointment of the Coasts and Climate Change Council for at least 12 months to assist in communicating the issues facing Australia from the impacts of climate change on the coast, engaging with a wide range of stakeholders and community groups on their issues and needs, and providing advice to the Minister for Climate Change and Energy Efficiency on ways to improve coastal adaptation to climate change.

As a result of this report, the term of the council has been extended to December 2011. Its focus will be on advising the government on how to prepare coastal communities for the impacts of climate change.

Building on the reports by the House of Representatives Standing Committee, and the Coasts and Climate Change Council, the National Sea Change Taskforce published a 10-point plan for coastal Australia in 2010 (Box 11.2). Although this plan focuses on governance issues and management of infrastructure, the same principles are relevant to environmental governance and management of environmental assets. Furthermore, social and economic problems are likely to reduce the ability of local governments to manage the natural environment strategically. This illustrates a key observation about coastal governance: that environmental, social and economic management cannot be considered independently of one another (see also Section 4 on resilience).

We are not in a position to provide detailed comments on the effectiveness of these approaches. The recommendations of the various inquiries discussed above are based on a much more rigorous and detailed process than we could carry out. We note, however, that the overpowering weight of opinion and evidence is that major steps need to be taken very soon to address governance arrangements for Australia’s coasts. Without these reforms, there are high risks that uncoordinated and nonstrategic development will lead to continued degradation of environmental, social, economic and cultural assets of the coasts. This is likely to make coastal communities and ecosystems vulnerable to shocks and surprises that may be both highly undesirable and irreversible.

Box 11.2 Abbreviated version of the National Sea Change Taskforce’s 10-point plan for coastal Australia23

1. Adopt and implement the recommendations of the coastal inquiry conducted by the bipartisan House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts.
2. Introduce a new funding formula to enable coastal councils to respond effectively to the social and economic needs of coastal communities and to provide regional facilities and services.
3. Provide funding for coastal councils to undertake natural resource management activities in coastal areas.
4. Develop a national growth management policy to better coordinate the planning and provision of infrastructure in regional and rural areas, including rapidly expanding coastal communities.
5. Ensure that the Australian Bureau of Statistics collects accurate and consistent data on nonresident populations in coastal areas, to enable more effective allocation of resources to meet demand associated with tourists, nonresident workers and part-time residents.
6. Assist coastal councils to address the social and economic needs of ageing populations and to meet the shortfall in aged-care accommodation and services in these areas.
7. Introduce a consistent national response to the legal and insurance risks associated with coastal planning and the impact of climate change, to assist coastal councils to implement plans for adaptation and coastal infrastructure protection in response to rising sea levels.
8. Declare 2012 as the Year of the Coast.
9. Initiate a collaborative national approach to address the shortage of affordable housing in coastal communities.
10. Review current governance and institutional arrangements for the coastal zone.
Risks to and resilience of coastal communities and environments

In the context of this chapter, resilience is the ability of coupled coastal communities and ecosystems to recover from shocks without moving to a new way of functioning that delivers different, and probably lower, values and benefits to humans and other species. The resilience of coastal environments is coupled with the social, economic and cultural systems that support Australian people living or depending on the coasts. Conversely, factors that affect the resilience of human communities are likely to affect their relationships with ecological communities. This is a broader approach to assessing the state of the environment than has been used previously, but we argue that a strong body of evidence indicates that it is now important to take this broader system view.

4.1 General risks to our coasts

Many of the pressures that affect our coasts are detailed in Section 2. Climate change is already having impacts on many aspects of the coastal environment, and these impacts will increase.

The future risks to coasts are the combination of risks to marine environments, and risks to estuaries and the terrestrial environments that stretch to the sea. Along the coasts, these risks are likely to be additive and sometimes interactive (e.g. pollution coming to the coast via rivers can interact with oceanic weather events). These risks are dealt with in detail in other chapters and are not repeated here. In summary, they include:

- risks associated with atmospheric processes, especially climate change
- risks associated with the expansion and future management of the built environment and related infrastructure

The resilience of, and future prospects for, coastal natural environments are inextricably coupled with the social, economic and cultural systems that lead to Australian people living on, depending on or influencing the coasts.

Globally, the threat of rising sea levels as a result of climate change is one of the most concerning pressures on coastal communities. It brings into focus all other aspects of the resilience of coasts, because it potentially affects their economic, social, cultural and environmental assets and processes. In Australia, a sea level rise of a metre or more during this century is plausible, and several hundred thousand homes are potentially at risk of inundation. Rising sea levels will also result in greater wave action on the shore, leading to increased rates of coastal erosion, particularly during extreme weather events, which are increasing in frequency. The capacity for coastal habitats and species to migrate inland to higher ground is limited in many parts of Australia by both the natural limits to the coastal plains and human-built structures such as seawalls, beach groynes and offshore reefs. Direct impacts on certain types of cultural sites, including many of significance to Indigenous people, are also possible. One of the major determinants of the future of Australia's coasts is how extreme and rapid the effects of climate change will be on coastal Australia.

The emerging risks from climate change remain incompletely addressed for Australia's coasts. Recent research comparing Australian coastal governance with examples elsewhere in the world has concluded that the ability to adapt to emerging pressures, especially climate change, is low and declining in many parts of Australia. Recommended remedies include allocating authority and resources between levels of governance according to their effectiveness at each level (rather than trying to manage everything centrally); strengthening development rules and incentives to encourage relocation before irreversible problems arise; allowing for uncertainties by building flexibility into rules and incentives so that they can be adjusted when knowledge and circumstances change; transferring public and private benefits, costs, risks, uncertainties and responsibilities from governments to beneficiaries of development; and viewing catastrophes as opportunities for learning and change, not signals to automatically rebuild.
• risks associated with inland waters as they flow to the coast, which themselves are affected by changes in land use and management
• risks to terrestrial and marine biodiversity
• risks to coastal cultural heritage.

4.2 Future risks associated with climate change

Climate change is a major driver of change for Australia. Commenting on Australia's vulnerability, the Intergovernmental Panel on Climate Change (IPCC) noted in 2007:41

Even if adaptive capacity is realized, vulnerability becomes significant for 1–2 °C of global warming. Energy security, health (heat-related deaths), agriculture and tourism have larger coping ranges and adaptive capacity, but they may become vulnerable if global warming exceeded 3 °C.

Since then, further studies suggest that the risks may be more immediate than indicated by the IPCC.41-42

The indirect effects of climate change are likely to be particularly important for coastal environments and settlements. They include:

• decreased water availability and water security due to reduced rainfall and increased evaporation, reducing run-off to streams and recharge of groundwater systems
• impacts on the coastal zone, such as inundation from sea level rise (see Section 4.3) and changes in the frequency and severity of tidal and storm surges
• damage to energy, water, communications and built infrastructure
• a decline in agricultural and aquacultural productivity due to increased drought, fire and water temperatures
• damage to iconic natural ecosystems, such as the Great Barrier Reef and Kakadu National Park
• a decline in biodiversity.

Climate change could also act in combination with other pressures to challenge the resilience of coastal communities and environments. For example, if commercial fishing, recreational fishing (tourism) or aquaculture were negatively impacted by climate change, a town may be less resilient to other pressures (e.g. a decline in forestry or agricultural activity). The decline in the Western Australian rock lobster fishery, for example, is affecting small coastal communities, and the decrease in economic activity in these communities is being felt in many sectors.

Drawing on information from the IPCC, the CSIRO concluded that the three sectors in the Australian and New Zealand region that are most vulnerable to climate change are coastal communities, water security and natural ecosystems.43

More subtle effects on cultural heritage places may result from changes in atmospheric moisture, wind effects, and climate and pollution acting together.44 Increases in the frequency of heatwaves could see people moving temporarily to coastal areas to take advantage of sea breezes, which would exacerbate the existing population pressures. Extension in the range of various disease vectors (notably mosquitoes) is a direct threat to coastal settlements and could lead to major habitat modification and/or use of chemicals for vector control. In some areas, climate change is expected to have the positive effect of reducing cold weather, which could also add to coastal population pressures.

Chapter 3: Atmosphere discusses the potentially adverse effects of climate change, via extreme events such as bushfires and dust storms, on respiratory and cardiovascular health, both acute and chronic. Coastal areas already struggle to maintain adequate health facilities for their growing populations.

4.3 Sea level rise

The impact of sea level rise will be felt most strongly in our coastal regions. Sea level rise is a result of expansion of the oceans as they warm; addition of water to the ocean from melting glaciers, ice caps, and the ice sheets of Greenland and Antarctica; and changes in the relative level of seabeds and the land (see Chapter 6: Marine environment and Chapter 7: Antarctic environment for further discussion). Sea level is now rising globally, and the rate of rise increased from the 19th to the 20th century and during the 20th century (Figure 11.7). Since the early 1990s, the rate of rise has been almost double the average for the 20th century.
Sea level is forecast to continue to rise during the 21st century and beyond, in response to increasing concentrations of greenhouse gases in the atmosphere. Including an allowance for the melting of ice sheets, IPCC projections are for a rise of 18–79 centimetres by 2095 compared with 1990.

However, our current understanding of the response of ice sheets to global warming is inadequate, and a larger rise is possible. The rate of sea level rise is currently near the upper end of current projections—observations indicate that global sea level is currently rising (since 1993) at around 3 millimetres per year.\(^{45}\)

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**Figure 11.7** Global mean sea level (GMSL) changes between 1860 and 2009, compared with the 1990 average sea level

The blue solid line is sea level estimated from coastal and island sea level data. The one standard deviation uncertainty estimates are indicated by the shading. The Church and White\(^ {47}\) estimates for 1870–2001 are shown by the red solid line and dashed red lines indicate the one standard deviation errors. The series are set to have the same average value over 1960–90 and the new reconstruction is set to zero in 1990. The average rate of rise from 1900 to 2000 was around 1.7 millimetres per year. The rate of rise measured by satellite altimeters since 1993 has been around 3.2 millimetres per year, and from tide gauges around 3.0 millimetres per year.
Risks and resilience | Coasts

Sea levels are rising around Australia. A sea level rise of a metre or more during this century is plausible. It could be less or much more. Between 160,000 and 250,000 individual homes are potentially at risk of inundation from a 1.1-metre rise in sea level (Figure 11.8).

Rising sea levels will result in inundation of low-lying coastal regions, and increased access of higher water levels and greater wave action to the shore. This will increase the rate of coastal erosion, particularly during extreme weather events, which are increasing in frequency. Expansion of mangroves into newly flooded coastal lands is also likely, where the topography is suitable. The capacity for coastal habitats (such as beaches, dunes and wetlands) to migrate inland to higher ground is limited in many parts of Australia by both the natural limits to the coastal plains (where steep hills approach the coast) and the human structures (such as seawalls, beach groynes and offshore reefs) built to defend against extreme weather events. The progressive effect is a reduction in natural habitats at the shoreline (particularly low-slope, soft-sediment habitats) and an increase in human structures that provide habitat of a different type (mainly hard structures, such as rock walls). The ecological impacts of these changes are currently gradual, but could become sudden and unexpected. They are likely to be profound.

Direct impacts on certain types of cultural sites are possible. Aboriginal middens, for example, are invariably located close to foreshores and are particularly prone to erosion. Historical sites associated with defence, coastal trade or transport—such as gun emplacements, docks, wharves, shipyards, fishing ports and whaling stations—are also at direct risk from rising sea levels.

Potential impacts of sea level rise around Australia are summarised in Box 11.3.

**Box 11.3 Potential impacts of sea level rise around Australia**

Global sea levels increased by 1.7 millimetres per year during the 20th century. Over the past 15 years, this trend has increased to approximately 3.2 millimetres per year. The rate varies significantly around Australia.

**New South Wales**

A sea level rise of 1.1 metres will put at risk between 43,900 and 65,300 residential buildings, with a current value of between $14 billion and $20 billion, and up to 4,800 kilometres of roads, 320 kilometres of railways and 1,200 commercial buildings, with an estimated value of up to $10.4 billion, $1.3 billion and $9 billion, respectively.

Local government areas of Lake Macquarie, Wyong, Gosford, Wollongong, Shoalhaven and Rockdale contain more than 50% of the residential buildings at risk in New South Wales.

Since the early 1990s, New South Wales has experienced a sea level rise of approximately 2.1 millimetres per year.
Northern Territory
A sea level rise of 1.1 metres will put at risk between 260 and 370 residential buildings, with a current value of between $100 million and $134 million, and up to 2045 kilometres of roads, 32 kilometres of railways and 24 commercial buildings, with an estimated value of up to $1.8 billion, $100 million and $500 million, respectively.

Darwin is particularly vulnerable to riverine flooding and more intense cyclonic activity. Impacts on infrastructure are expected to be extreme under a ‘business as usual’ climate scenario, including major threats to vital port infrastructure on the Northern Territory coast.

Since the early 1990s, northern Australia has experienced sea level rises of up to 7.1 millimetres per year.

Queensland
Queensland’s highly developed and populated coastal communities are likely to be significantly affected by the impacts of climate change. A sea level rise of 1.1 metres will put at risk between 48 300 and 67 700 residential buildings, with a current value of between $15.4 billion and $20 billion, and up to 4700 kilometres of roads, 570 kilometres of railways and 1440 commercial buildings, with an estimated value of up to $12.9 billion, $2.3 billion and $15 billion, respectively.

Since the early 1990s, northern Australia has experienced sea level rises of around 7.1 millimetres per year, while eastern Australia has experienced increases of around 2.0–3.3 millimetres per year.

South Australia
A sea level rise of 1.1 metres will put at risk between 25 200 and 43 000 residential buildings, with a current value of between $4.4 billion and $7.4 billion.

Nearly half (47%) of the South Australian coastline is sandy beaches, and more than half of these sandy beaches are backed by soft-sediment plains. Rising sea levels will make these coastlines significantly more vulnerable to shoreline recession and foredune destabilisation.

Since the early 1990s, southern Australia has experienced sea level rises of 2–7 millimetres per year.

Tasmania
A sea level rise of 1.1 metres will put at risk between 12 000 and 15 000 residential buildings, with a current value of $4 billion, and up to 2000 kilometres of roads, 160 kilometres of railways and 300 commercial buildings, with an estimated value of up to $4.5 billion, $700 million and $1 billion, respectively.

Since the early 1990s, Tasmania has experienced sea level rises of 2.6–3.4 millimetres per year.

Victoria
A sea level rise of 1.1 metres will put at risk between 31 000 and 48 000 residential buildings, with a current value of between $8 billion and $11 billion, and up to 3500 kilometres of roads, 125 kilometres of railways and 2000 commercial buildings, with an estimated value of up to $9.8 billion, $500 million and $12 billion, respectively.

Since the early 1990s, south-eastern Australia has experienced sea level rises of 1.3–2.8 millimetres per year.

Western Australia
Western Australia has the longest coastline of any Australian state or territory. A sea level rise of 1.1 metres will put at risk between 20 000 and 30 000 residential buildings, with a current value of between $5 billion and $8 billion, and up to 9000 kilometres of roads, 114 kilometres of railways and 2100 commercial buildings, with an estimated value of up to $11.3 billion, $500 million and $17 billion, respectively.

Since the early 1990s, the southern coast of Western Australia has experienced sea level rises of up to 4.6 millimetres per year, while the western coast has experienced increases of up to 7.4 millimetres per year.

Source: Australian Government Department of Climate Change and Energy Efficiency\(^2\)
4.4 Resilience and adaptive capacity

Many small island states, including Australia’s external territories and nations with which Australia interacts in relation to environmental issues in the region, are highly sensitive to sea level rise resulting from climate change and have limited scope for adaptation (i.e. the ability to change to remain resilient). Australian mainland coastal communities have considerably more scope and resources to plan for, and adapt to, climatic and other change. That capacity to adapt will only be realised, however, if planning and action are effectively coordinated at the national, state and local levels.

Abel et al.40 reviewed the literature on how high-income countries are approaching the challenges of climate change around their coasts. They found common themes:

- The origins of, and potential solutions to, problems of development and sea level rise are at different scales of space and time. Issues include lack of feedback from local to higher levels of governance, lack of capacity to initiate and implement local change, and defensive structures at one location causing erosion at others.
- Stakeholders are in conflict about the distribution of public and private benefits and costs in relation to climate change responses. Criteria for evaluating policy outcomes are unclear, and the rights of future generations are largely neglected (i.e. conserving assets and resources for the future is given little weight compared with values for current generations).
- Stakeholders’ decisions are influenced strongly by rules, norms and incentives, particularly property rights, compensation, liabilities and development controls.
- Where development is already intense, property rights, costs sunk in structures and lobbying by those affected work against policies for moving coastal settlements away from advancing water levels. (This situation is being experienced by many coastal councils in Australia. An example is the opposition to a planned retreat strategy proposed by Byron Shire Council, which is still in dispute.53)
- Arguments for action are weakened by large uncertainties about rates and magnitudes of sea level rise and future actions of governments.

In the literature dealing with the United States, New Zealand and Australia, the role of Indigenous people in adaptation to sea level rise was discussed frequently.

Abel et al.40 noted that:

Coastal development is spreading along the World’s coasts. Sea levels are rising, so major future asset losses are expected. Planned retreat from the sea behind natural ecological defences is one adaptation option. To maintain it, land could be set aside for colonisation by coastal ecosystems, or buildings constructed on condition they are removed when sea level reaches a specified distance from the building.

A study of south-east Queensland concluded that the option of ‘planned retreat’, and hence a major opportunity to maintain the resilience of this area, is disappearing (Box 11.4).

The issues identified for south-east Queensland are very similar to those identified consistently over the past two decades by a range of experts in coastal management and governance and, more recently, by the coalition of coastal councils that forms the National Sea Change Taskforce (see Section 3.2).

If the limits of the resilience of coastal settlements and ecosystems are exceeded, adaptive strategies framed around incremental change are unlikely to be adequate to prevent major harmful impacts on key sectors. Instead, the functioning and management of coastal communities and ecosystems might have to change fundamentally to cope with changing circumstances.

4.5 Hopeful signs

Although the above assessments are somewhat critical of current arrangements with regard to resilience, some very hopeful trends are emerging that will potentially build greater resilience of coastal social–ecological systems. In Section 3.2, we reported on a range of cooperative initiatives being taken by coastal councils to address many of the deficiencies discussed above. One of these, the South East Queensland Healthy Waterways Partnership, is cooperating with the CSIRO to use management strategy evaluation to address some of the environmental, economic and social impacts of coastal urban areas.54
In Section 3.3, we reported on the 2009 report to the Australian Government by the House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts, and the subsequent establishment of the Coasts and Climate Change Council and its recommendations to government. Both sets of recommendations go to the heart of the issues about resilience and adaptive governance raised in this section. Coastal management might move in these directions in the coming decade, resulting in improvements in coastal resilience and the state of coastal environments.

**Box 11.4 A study of the coastal resilience of south-east Queensland**

Based on an examination of plans, records, policies and development approvals, combined with interviews and workshops with a range of stakeholders, Abel et al. concluded that the option of planned retreat (movement of buildings and other infrastructure away from areas likely to be inundated as sea level rises in the future) is disappearing because:

- the state government promotes population increase
- the need to protect coastal ecosystems does not seem urgent, so houses are built on the coast
- liability laws favour development
- planning ignores cumulative impacts and the chance that these impacts could eventually cause major irreversible changes in coastal communities and ecosystems
- political pressure to build defences (e.g. seawalls) grows as the value of built assets increases.

To implement planned retreat, changes to coastal governance would be needed, for which the authors proposed five guiding principles:

- Allocate authority and resources between levels of governance according to their effectiveness at each level (rather than trying to manage everything centrally).
- Strengthen development rules and incentives to encourage relocation before irreversible problems arise.
- Allow for uncertainties by building flexibility into rules and incentives so that they can be adjusted when knowledge and circumstances change.
- Transfer public and private benefits, costs, risks, uncertainties and responsibilities from governments to beneficiaries of development.
- View catastrophes as opportunities for learning and change, not signals to automatically rebuild.
Outlook for coasts

Although coastal environments are facing major pressures, including the direct impacts of expanded human settlements and a range of indirect impacts of human activities (such as impacts from tourism, recreation, invasive species and acid sulfate soils), awareness is growing of the interlinking of ecological, social, economic and cultural issues. Few people with a stake in Australia’s coasts want to see environmental and other assets decline. Based on the issues raised in Sections 3, 4.1 and 4.2 of this chapter, two major uncertainties that are likely to determine the future of Australia’s coasts are:

• how government and governance arrangements develop (especially whether cooperative and strategic approaches to managing coastal resources can be developed that are effective over the same spatial scales as the challenges)

• how extreme and rapid the effects of climate change are on coastal Australia.

5.1 Undesirable futures

‘Business as usual’ is likely to lead to undesirable outcomes for coastal Australia. There are already signs that it is becoming difficult to manage the combined pressure of permanent and temporary populations. Coastal communities that face social and economic problems are unlikely to be conducive to good environmental management, regardless of the levels and types of regulations and sanctions imposed. Local councils in many areas already struggle to maintain infrastructure; if current pressures are not addressed, pollution events and other forms of environmental destruction are likely to become more frequent.

Although there is a relatively high level of protection of major vegetation groups along most of Australia’s coasts, data on how well ecosystems are protected appears to be inadequate (partly because there is no nationally agreed classification of ecosystems—see Chapter 8: Biodiversity). Increasing population pressure is highly likely to have deleterious impacts on coastal ecosystems, which will be hard to manage if good information on what is there, both inside and outside reserves, is not available.

5.2 Desirable futures

Desirable futures—that is, futures in which harmony exists between the demands that humans place on coastal environments and the sustainability of coastal ecosystems—are most likely if major reform of coastal governance is achieved in the next decade or sooner, so that strategic action can be taken to identify and prepare for risks from sea level rise. Whether through incentives, regulation or both, coastal communities will need to balance infrastructure and services against population size and make-up. This will require dialogue about such issues as where and how people live, and how the facilities and services offered by coastal centres compare with those offered in larger centres.

Coastal communities might improve their financial base by playing a role in emerging carbon economies. The concept of ‘blue carbon’—carbon sequestration by healthy coasts and oceans—is gaining considerable currency in international discussions.55

These changes will be important first steps in addressing pollution, waste management, recreation, tourism, invasive species and other pressures on coastal environments. Another requirement will be improved information on which species and ecosystems are being affected, and are likely to be affected, by human activities on coasts. The advanced level of dialogue and tangible plans for action that have been put forward by a range of stakeholders—culminating in the recommendations of the 2009 report by the House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts, Managing our coastal zone in a changing climate: the time to act is now56—are a good start towards desirable coastal futures. However, whether action is taken quickly enough will depend partly on political will and partly on the magnitude and speed of climate change in coming decades.
References


Red or spider mangrove (Rhizophora stylosa)
Low Isles, Great Barrier Reef Marine Park, Queensland
Photo by Reg Morrison
References


Tree fern, Russell Falls, Tasmania
Photo by Ken Duncan
Future reporting
One touch of nature makes the whole world kin.

William Shakespeare, *Troilus and Cressida*, 1602
Future reporting

*Australia state of the environment 2011* presents an assessment of the state of the Australian environment, and the risks and future it faces. We hope that our ambitions and innovations in grading and projecting outlooks for the environment offer a clear perspective and a new model for subsequent reports. Feedback to the State of the Environment (SoE) 2011 Committee is appreciated in this regard, and will be preserved and available to those charged with producing SoE 2016.

Australia is positioned for a revolution in environmental monitoring and reporting. Researchers are adding to the amount of environmental information at an accelerating pace. Decision-makers are increasingly expected to bring that information to bear upon policy development, management practices and resource allocation. Improved national data collection and use of alternative data sources are vital for understanding and effectively managing important aspects of Australia’s environmental and cultural systems.

As well as the data collected by government for reporting and management purposes, a substantial amount of environmental data is collected by the private sector for a variety of purposes. However, little of this information makes its way into consolidated national systems. A significant exception is the private–public partnership that operates in the geosciences, where exploration data have to be lodged with government, and eventually become publicly available. Of particular value would be partnerships with the resources sector, which collects rich datasets on our coastal and marine environments (where publicly available data are particularly scarce) as part of its environmental approvals and compliance processes; and the agricultural sector, where industry consultants collect a wide variety of environmental datasets on soil, water and pests.

However, collecting information is not enough. Creating and using systems that allow efficient access to environmental information are great national-scale challenges. Such systems would allow scientists and managers to analyse and make connections in the data, so that they can begin to understand the links among various aspects of ecological processes. It is also important that socioeconomic data relevant to environmental issues are available, so that connections between the environment and society can be understood. Finally, the usefulness of environmental and related data will be magnified if it can be effectively transformed into information products that are meaningful to a broad audience and relevant to the issues of today and tomorrow.

Innovations are being developed that focus on these environmental information challenges. Many of these are technical in nature: more intelligent and powerful monitoring, increased standardisation of measurement and reporting systems, and better data management and environmental modelling platforms. Other innovations will be in the policy domain, where national commitments to standardise and share environmental data between jurisdictions and industry offer significant value to environmental management. Some of the most significant innovations will be in how changes in environmental conditions are
tracked—for example, through community-based environmental accounting, or through a national commitment to a set of benchmarks and standards for environmental and sustainability indicators. The Australian Government has a vital leadership role in this process.

Better information, combined with evidence-based decision-making, will support better management. The environmental changes and challenges likely in the coming decades bring with them the need not only for wise decision-making but also for humility and acknowledgement of uncertainties. As society’s ability to shape the environment increases, so does the risk of getting it wrong. In the coming decades, robust research and monitoring will help anticipate and deal with challenges and bring about positive outcomes for the Australian environment.

The SoE 2011 Committee encourages this innovation and commitment to increasing the value derived from environmental monitoring and reporting against agreed benchmarks and standards. We are convinced that it is an important key to improving the outlook for the state of the Australian environment.
Mitchell Falls, Western Australia
Photo by Nick Rains
Appendix
Acknowledgements

State of the Environment 2011

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Atmosphere

The Atmosphere chapter benefited greatly from the generous inputs of many people. The committee particularly thanks Peter Marsack and Brad Moore of the DSEWPaC National Environmental Reporting section for their assistance and support. The following individuals provided valuable early advice on a draft outline setting out the overall approach to the chapter: Dr Tom Beer (Commonwealth Scientific and Industrial Research Organisation, CSIRO); Ian Carruthers, Julie Gilfelt and Rob Sturgis (Australian Government Department of Climate Change and Energy Efficiency, DCCEE); Dr Peter Manins; and Professor Michael Manton and Dr Graeme Pearman (Monash University). Comments on a pre-peer review draft of the chapter from the following people highlighted important omissions and corrected errors of fact: Dr Andrew Klekociuk (AAD); Dr Karl Braganza, Kevin Hennessey and Dr Neville Smith (Bureau of Meteorology, BoM); Kushla Munro and Anthony Swirepik (DCCEE); Chris Chambers, James Duggie, Drew Farrar, Arthur Grieco, Sarah McEvoy, Kristie Stevens and Ray Wallis (Department of Environment and Conservation Western Australia, DEC WA); Dr David Robinson, Keryn Oude-Egberink, David Wainwright and Lynn Whitfield (Department of Environment and Resource Management Queensland, DERM Qld); Wendy Spencer and Stephen Waight (Department of Premier and Cabinet Tasmania); Ellis Cox, Bob Hyde and Derrick Walters (Department of Primary Industries, Parks, Water and Environment Tasmania, DPIPWE Tas); Dr David Finlay and Andrew Thiele.
Appendix | Acknowledgements

Australia      State of the Environment 2011

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Inland water

The committee recognises the central role of Lee-Anne Shepherd of the DSEWPaC National Environmental Reporting section in supporting the development of the Inland water chapter and ensuring its accuracy, completeness and quality assurance. The chapter was strengthened by valuable contributions from other DSEWPaC officers, including Kelly West, Matthew Sprott, Belinda Allison, Jennifer Martin, Bruce Gray, Ian Warren and Dr Jin Wang. Further appreciation is expressed for early comments on approaches to the chapter by Dr Bill Young (CSIRO), Professor Peter Davies (University of Western Australia), Peter Cozier (Wentworth Group of Concerned Scientists), Dr Ben Gawne (Murray–Darling Freshwater Research Centre), Dr Arlene Harriss-Buchan (Australian Conservation Foundation) and Warwick McDonald (BoM); for the comments of three anonymous external reviewers; and for input and review on Indigenous issues by Brad Moggridge (CSIRO). This chapter uses data from commissioned reports prepared by Emma Collins and the team at Sinclair Knight Mertz, and Dr Evan Harrison and the team at the Institute for Applied Ecology at the University of Canberra. These reports relied on the generous provision of data, time and advice by state and territory representatives and others, for which we are very grateful, and were improved through independent review by four anonymous reviewers. The support of the National Water Commission and the BoM in providing key documents and data is greatly appreciated.

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Marine environment

The committee thanks Boon Lim of the DSEWPaC National Environmental Reporting section for ensuring the accuracy, completeness and quality assurance of the Marine environment chapter. We also greatly appreciate the contributions from the 40 invited marine experts who freely contributed their time to the National Marine Condition Assessment workshops (these people are listed in the additional material on the SoE website); from Chris Marshall (Marine Division DSEWPaC), who assisted and participated in the workshop process; from Dr Kirstin Dobbs (Great Barrier Reef Marine Park Authority), who provided her experience with the Great Barrier Reef outlook process and contributed to the workshops; from Richard Stoklosa (E-Systems Pty Ltd) for moderating the workshops; and from Ian Warren, Carolyn Armstrong, Sarah Coulson and Jo Allison (ERIN, DSEWPaC), who provided a number of map and data products. The committee is also very grateful for logistics support for the workshops provided by Colleen McRae and Carly Rickerby (DSEWPaC). The input from the authors of the four case studies is also appreciated, especially given the tight timelines imposed by the chapter preparation process. The committee is grateful for the important additional information provided by Dr Craig Syms (University of Technology Sydney), Dr Morgan Pratchett (James Cook University), Dr Roy Melville-Smith (Curtin University of Technology), Duan Biggs (James Cook University), Dr Ken Anthony (Australian Institute of Marine Science, AIMS), Dr Peter Harrison (Southern Cross University), Dr Janice Lough (AIMS), Dr Richard Brinkman (AIMS), Dr Jamie Oliver (AIMS), Dr David Wachenfeld (Great Barrier Reef Marine Park Authority), Dr David Blondeau-Patissier (CSIRO), Dr Arnold Schroeder (CSIRO) and Dr Vittorio Brando (CSIRO). Five anonymous referees provided challenging and constructive comments on the draft, which have greatly improved the final version, and the committee is grateful for their inputs.

Biodiversity

The committee thanks Megan Watson, Peter Marsack, Dr Nancy Dahl-Tacconi, Dayani Gunawardana, Brad Moore, Lee-Anne Shepherd and Yarden Oren of the DSEWPaC National Environmental Reporting section for their input. Although we accessed information from across DSEWPaC, several parts of the department provided particularly key inputs: ERIN, Parks Australia, those responsible for the Australian Natural Heritage Assessment Tool, the Conservation Policy section of the Biodiversity Conservation Branch and the Endangered Species Unit. We acknowledge the key contributions to this chapter from the SoE reports of Australia’s states and territories and from the Assessment of Australia’s terrestrial biodiversity 2008. State and territory representatives generously gave their time to discuss our summaries of their reports. We thank several people who contributed comments and/or material for boxes in the report: Dr Sarah Bekessy (RMIT University); Dr Matt Colloff, Dr Jocelyn Davies, Dr Simon Ferrier and Dr Andy Sheppard (CSIRO); Professor Ted Lefroy (University of Tasmania); Paul Sattler (Paul Sattler Eco-consulting Pty Ltd); and Dr Brendan Wintle (University of Melbourne). We particularly thank Dr Graham Worboys (Jagumba Consulting Pty Ltd) for providing, with Ian Pulsford, a review of connectivity conservation and for giving us his time to discuss the issues. Penelope Figgis and Dr Martin Taylor (WWF Australia and IUCN World Commission on Protected Areas), and Virginia Young (Strategic Interventions) contributed many ideas and viewpoints, and we especially thank Martin for access to WWF’s Building nature’s safety net report before its publication. Finally, we thank the five anonymous reviewers for their detailed, insightful and sometimes tough comments, which improved the chapter immeasurably.
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The committee recognises the central role of Lynette Sebo of the DSEWPaC National Environmental Reporting section in supporting the development of the Heritage chapter and for ensuring its accuracy, completeness and quality assurance. The chapter received strong support from the entire DSEWPaC National Environmental Reporting section but particularly incorporates assistance from Lee-Anne Shepherd, Matthew Sprott and Kelly West. Other DSEWPaC officers who contributed include Jane Ambrose, Rodney Atkins, Veronica Blazely, Doug Brown, Mark Carruthers, Jennifer Carter, Peter Cochrane, David Collett, Peter Graham, Leanne Handreck, Ken Heffernan, Theo Hooy, Rochelle Johnston, Anne Martinello, Dr Leah McKenzie, Paul Murphy, Mark Nizette, Brian Prince, James Shevlin, Megan Smith, Dr Greg Terrill, Elizabeth Wren and Ilse Wurst; as well as Jim Longworth and Thomas Polden from ERIN; the Heritage and Wildlife Division; Indigenous Policy Branch; and Parks Australia. A major contribution to the chapter was generously delivered by more than 50 professional colleagues who participated in meetings and roundtable workshop discussions in 2010 and 2011 with the Australian Heritage Council, the Heritage Chairs and Officials of Australia and New Zealand, the Australian Committee for the International Union for Conservation of Nature (ACIUCN), the Australia International Council on Monuments and Sites (ICOMOS), heads of Australian parks agencies and the DSEWPaC Indigenous Advisory Committee; all of these people are listed in the additional material on the SoE website. The Heritage chapter incorporates data and illustrations supplied by state heritage and parks agencies. Officers who contributed include Cameron White, Stewart Watters, Dianne Bensley, Gail Pini, Ghristine Giovannucci, Lisa Chaston, Vicky Rapley, Nicole Mulholland, Zelja Danilovic, Meredith Evans and Mike Bentham. The chapter is supported by results from expert reports commissioned from Dr Michael Pearson and Duncan Marshall, Environmental Resource Management Australia (David Nicholson), and Watego Legal and Consulting (Eloise Schnierer, Sylvie Ellsmore and Professor Stephan Schnierer). Contributions to specific case studies were provided by Geoff Ashley, Sheridan Burke, Jennifer Faddy and Rachel Jackson (Godden Mackay Logan); Ken Markwell (Markwell Consulting); Andrew Copp (DSEWPaC); and Joy Elley and Harry Webber (Aboriginal Affairs Victoria); Natalie Gross and Maisy Stapleton (National Trust of Australia, NSW); Ester Guerzoni (Heritage Tasmania); Dr Andrew Growcock, Donna Quinn, Jacqueline Reid and Greg Storrier (Parks Service, NSW OEH); Dr Jo McDonald (Jo McDonald Cultural Heritage Management); Dr Martin Taylor (WWF Australia and IUCN World Commission on Protected Areas); Dr Graeme Worboys (ACIUCN); Kaurna Tappa Iri Reconciliation Working Group; Tanner Architects Pty Ltd; Wunambal Gaambera Aboriginal Corporation; and Kado Muir. Throughout the preparation of the report, wise counsel, useful sources and comments were offered by Joan Domicielj, Kristal Buckley, Dr Jane Harrington, Dr Tracy Ireland, Dr Jane Lennon, Peter Phillips and Meredith Walker (ICOMOS); Kate Clark (NSW Historic Houses Trust); Chrissy Grant and Dave Johnson (DSEWPaC Indigenous Advisory Committee); Dr Peter Dowling (Australian Council of National Trusts); Penny Figgis (ACIUCN); Jim Gard’ner (Heritage Victoria); Fiona Gardiner (DERM Qld); and Professor Sharon Sullivan (Australian Heritage Council). Anna Cartwright, Nina Pollock and Julian Siu (Godden Mackay Logan) undertook a range of research and analysis tasks. Four anonymous referees provided constructive comments on the draft and suggestions for additional sources and case studies.

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## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>abstraction</td>
<td>Withdrawal of water from the environment for human use.</td>
</tr>
<tr>
<td>abyssal plain</td>
<td>A flat, relatively featureless bottom of the deep ocean at a depth greater than 2000 metres.</td>
</tr>
<tr>
<td>acidification</td>
<td>The process of becoming more acidic (i.e. lowering the pH). Soils tend to become acidic through natural leaching and weathering, and as a result of agricultural practices such as overuse of nitrogenous fertilisers and practices that lead to loss of organic material. The ocean is becoming more acidic as atmospheric carbon dioxide (CO₂) levels rise and the concentration of dissolved CO₂ in sea water increases, forming carbonic acid.</td>
</tr>
<tr>
<td>adaptation</td>
<td>Shifts (e.g. in behaviour, management practices, biology) in response to change that support survival; responses that decrease the negative effects of change and capitalise on opportunities.</td>
</tr>
<tr>
<td>adaptive management</td>
<td>A systematic process for continually improving policies and practices by learning from the outcome of previously used policies and practices.</td>
</tr>
<tr>
<td>airshed</td>
<td>A body of air, bounded by meteorology and topography, in which substance emissions are contained.</td>
</tr>
<tr>
<td>air toxics</td>
<td>A group of pollutants found in ambient air, usually at relatively low concentrations, including heavy metals and many types of volatile and semivolatile organic compounds. These include known or suspected carcinogens and pollutants linked to other serious health impacts, including birth defects and developmental, respiratory and immune system problems.</td>
</tr>
<tr>
<td>algal bloom</td>
<td>A sudden proliferation of algae (microscopic plants) that occurs near the surface of a body of water. Blooms can occur due to natural nutrient cycles, or can be in response to eutrophication or climate variations. See also eutrophication.</td>
</tr>
<tr>
<td>ambient air</td>
<td>Outdoor air.</td>
</tr>
<tr>
<td>amenity</td>
<td>Features, benefits and advantages of the built environment, including the character and appearance of buildings and works; proximity to shopping facilities; quality of infrastructure; and absence of noise, unsightliness or offensive odours.</td>
</tr>
<tr>
<td>Antarctic Treaty area</td>
<td>The area south of 60°S.</td>
</tr>
<tr>
<td>anthropogenic</td>
<td>Caused by human factors or actions.</td>
</tr>
<tr>
<td>aquaculture</td>
<td>Cultivation of aquatic and marine species such as fish, crustaceans, shellfish and algae, predominantly for use as human or animal food.</td>
</tr>
<tr>
<td>aquifer</td>
<td>An underground layer of water-bearing permeable rock or loose material such as gravel, sand or silt; aquifers may provide well or bore water.</td>
</tr>
<tr>
<td>asset</td>
<td>Parts or features of the natural environment that provide environmental functions or services.</td>
</tr>
<tr>
<td>Australian margin</td>
<td>The Australian continental margin; the submerged zone consisting of the continental shelf, slope and rise that separates the terrestrial portion of a continent from the deep ocean floor.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>benthic</td>
<td>Associated with the sea floor.</td>
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</tbody>
</table>
| biodiversity                  | The variety of all life forms. There are three levels of biodiversity:  
  • genetic diversity—the variety of genetic information contained in individual plants, animals and microorganisms  
  • species diversity—the variety of species  
  • ecosystem diversity—the variety of habitats, ecological communities and ecological processes. |
| biogenic                      | Produced by living organisms or biological processes.                                                                                           |
| biomass                       | The quantity of living biological organisms in a given area or ecosystem at a given time (usually expressed as a weight per unit area or volume). |
| bioregion                     | A large, geographically distinct area that has a similar climate, geology, landform, and vegetation and animal communities.  
  The Australian land mass is divided into 85 bioregions under the Interim Biogeographic Regionalisation of Australia. Australia’s marine area is divided into 41 provincial bioregions under the Interim Marine and Coastal Regionalisation for Australia. |
<p>| biosecurity                   | Processes, programs and structures to prevent entry by, or to protect people and animals from, the adverse impacts of invasive species and pathogens. |
| biota                         | Living organisms in a given area; the combination of flora, fauna, fungi and microorganisms.                                                    |
| The Burra Charter 1999        | The Australia ICOMOS Charter for Places of Cultural Significance, which provides standards and guidelines for cultural heritage management; Australia ICOMOS Inc. is the national chapter of the International Council on Monuments and Sites. |
| bycatch                       | Species taken incidentally in a fishery where other species are the target.                                                                   |
| carbon dioxide equivalent (CO₂-e) | A measure that combines the global warming effect of the six greenhouse gases listed in Annex A of the Kyoto Protocol (carbon dioxide [CO₂], methane [CH₄], nitrous oxide [N₂O], hydrofluorocarbons [HFCs], perfluorocarbons [PFCs] and sulfur hexafluoride [SF₆]) into a single meaningful number. Specifically, CO₂-e represents the carbon dioxide emissions that would cause the same heating of the atmosphere as a particular mass of Annex A greenhouse gases. |
| carbon sequestration           | Processes to remove carbon from the atmosphere, involving capturing and storing carbon in vegetation, soil, oceans or another storage facility. |
| caring for country            | Indigenous land and sea management.                                                                                                             |
| Caring for our Country        | The Australian Government’s central environment program since 2008, which funds environmental management, protection and restoration. |
| catchment                     | An area of land determined by topographic features, within which rainfall will contribute to run-off at a particular point. The catchment for a major river and its tributaries is usually referred to as a river basin. |
| cetaceans                     | Whales, dolphins and porpoises.                                                                                                                 |
| chlorophyll                   | The green pigment in plants that functions in photosynthesis by absorbing light from the sun.                                                  |
| climate change                | A change of climate attributed directly or indirectly to human activity that alters the composition of the global atmosphere and is additional to natural climate variability observed over comparable time periods (under the terms of the United Nations Framework Convention on Climate Change). |</p>
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>community</td>
<td>A naturally occurring group of species inhabiting a particular area and interacting with each other, especially through food relationships, relatively independently of other communities. Also, a group of people associated with a particular place.</td>
</tr>
<tr>
<td>condition</td>
<td>The ‘health’ of a species or community, which includes factors such as the level of disturbance from a natural state, population size, genetic diversity, and interaction with invasive species and diseases.</td>
</tr>
<tr>
<td>connectivity</td>
<td>Linkages between habitat areas; the extent to which particular ecosystems are joined with others; the ease with which organisms can move across the landscape.</td>
</tr>
<tr>
<td>connectivity conservation</td>
<td>Conserving or re-establishing interconnected areas and corridors of vegetation to protect linked ecosystems and the species within them.</td>
</tr>
<tr>
<td>conservation</td>
<td>Protection and management of living species, communities, ecosystems or heritage places; protection of a site to allow ongoing ecosystem function or to retain natural or cultural significance (or both) and to maximise resilience to threatening processes.</td>
</tr>
<tr>
<td>continental shelf</td>
<td>The legal continental shelf is defined under article 76 of the United Nations Convention on the Law of the Sea: ‘where not limited by delimitation with another state (country), it will extend beyond the territorial sea to a minimum of 200 nautical miles from the territorial sea baseline. In some places where certain physical characteristics of the seabed are met it can extend further’. This differs from the geoscientific definition of a continental shelf: the seabed adjacent to a continent (or around an island) extending from the low water line to a depth at which there is usually a marked increase of slope towards oceanic depths. This increase of slope usually occurs at water depths of 200 metres around the Australian continent.</td>
</tr>
<tr>
<td>coral bleaching</td>
<td>When the coral host expels its zooxanthellae (marine algae living in symbiosis with the coral) in response to increased water temperatures, often resulting in the death of the coral.</td>
</tr>
<tr>
<td>corridor</td>
<td>A linear landscape structure that links habitats and helps movement of, and genetic exchange among, organisms between these habitats.</td>
</tr>
<tr>
<td>critically endangered</td>
<td>At extreme risk of extinction in the wild; the highest category for listing of a threatened species or community under the criteria established by the Environment Protection and Biodiversity Conservation Act 1999 (C’wlth).</td>
</tr>
<tr>
<td>(species or community)</td>
<td></td>
</tr>
<tr>
<td>crustaceans</td>
<td>A class of mainly aquatic arthropods including prawns, lobsters and crabs.</td>
</tr>
<tr>
<td>decline</td>
<td>When the condition of an ecosystem, species or community has decreased to a point where its long-term viability is in question. It usually represents more than just a decrease in numbers of individuals, and describes the result of several interacting factors (e.g. reducing numbers, decreasing quality or extent of habitat, increasing pressures). In this report, the use of the term is generally prompted by reports that a substantial number of species within a group or community are classified as threatened and there is a high likelihood that more species are likely to qualify for a threatened classification if trends continue. Where ‘decline’ is applied to elements of environments (e.g. condition of vegetation as habitat), it means that changes have been sufficient to potentially affect the viability of species relying on those elements.</td>
</tr>
<tr>
<td>demersal</td>
<td>Associated with the region just above the sea floor.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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</tr>
<tr>
<td>disturbance</td>
<td>A temporary change in average environmental conditions that disrupts an ecosystem, community or population, causing short-term or long-term effects. Disturbances include naturally occurring events such as fires and floods, as well as anthropogenic disturbances such as land clearing and the introduction of invasive species.</td>
</tr>
<tr>
<td>drainage division</td>
<td>An identified water catchment; Australia has been classified into 12 drainage divisions.</td>
</tr>
<tr>
<td>drivers</td>
<td>Overarching causes that can drive change in the environment; this report identifies climate change, population growth and economic growth as the main drivers of environmental change.</td>
</tr>
<tr>
<td>ecological processes</td>
<td>The interrelationships among organisms, their environment(s) and each other; the ways in which organisms interact and the processes that determine the cycling of energy and nutrients through natural systems.</td>
</tr>
<tr>
<td>ecology</td>
<td>See ecological processes.</td>
</tr>
<tr>
<td>ecosystem</td>
<td>An interrelated biological system comprising living organisms in a particular area, together with physical components of the environment such as air, water and sunlight.</td>
</tr>
<tr>
<td>ecosystem services</td>
<td>Actions or attributes of ecosystems of benefit to humans, including regulation of the atmosphere, maintenance of soil fertility, food production, regulation of water flows, filtration of water, pest control and waste disposal. It also includes social and cultural services, such as the opportunity for people to experience nature.</td>
</tr>
<tr>
<td>El Niño</td>
<td>A periodic extensive warming of the central and eastern Pacific Ocean that leads to a major shift in weather patterns across the Pacific. In Australia (particularly eastern Australia), El Niño events are associated with an increased probability of drier conditions. See also La Niña.</td>
</tr>
<tr>
<td>emission</td>
<td>Output or discharge, as in the introduction of chemicals or particles into the atmosphere.</td>
</tr>
<tr>
<td>emissions trading</td>
<td>A system of market-based economic incentives to reduce the emission of pollutants.</td>
</tr>
<tr>
<td>endangered (species or community)</td>
<td>At very high risk of extinction in the wild; in danger of extinction throughout all or a portion of its range; criteria are established by the Environment Protection and Biodiversity Conservation Act 1999 (C’wlth).</td>
</tr>
<tr>
<td>endemic</td>
<td>Unique to a spatially defined area; in this report, used mainly to refer to large bioregions of the continent and marine environment.</td>
</tr>
<tr>
<td>endemism</td>
<td>The degree to which species and genes are found nowhere else; the number of endemic species in a taxonomic group or bioregion.</td>
</tr>
<tr>
<td>Environment Protection and Biodiversity Conservation Act 1999 (C’wlth) (EPBC Act)</td>
<td>The Australian Government’s main environmental legislation; it provides the legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places.</td>
</tr>
<tr>
<td>environmental flows</td>
<td>Managed freshwater flow to natural water systems, designed to maintain aquatic ecosystems.</td>
</tr>
<tr>
<td>equivalent effective stratospheric chlorine</td>
<td>An estimate of the effective quantity of halogens (chlorine and bromine) in the stratosphere, used to quantify anthropogenic depletion of stratospheric ozone. See also stratospheric ozone.</td>
</tr>
<tr>
<td>eutrophication</td>
<td>Excessive nutrients in a body of water, often leading to algal blooms or other adverse effects. See also algal bloom.</td>
</tr>
<tr>
<td>exclusive economic zone</td>
<td>The marine seabed, subsoil and waters between the 3 nautical-mile boundary and the 200 nautical-mile boundary off the coast of Australia.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
</tr>
<tr>
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</tr>
<tr>
<td>extended continental shelf</td>
<td>An area of continental shelf that extends beyond the Australian exclusive economic zone, the seabed of which forms part of Australia’s marine jurisdiction.</td>
</tr>
<tr>
<td>extent</td>
<td>Areal coverage; for example, of vegetation or sea ice.</td>
</tr>
<tr>
<td>extinct (species)</td>
<td>When there is no reasonable doubt that the last individual has died.</td>
</tr>
<tr>
<td>feedback</td>
<td>Where the outputs of a process affect the process itself.</td>
</tr>
<tr>
<td>fire regime</td>
<td>Frequency, intensity and timing of bushfires.</td>
</tr>
<tr>
<td>fishdown</td>
<td>Where fishing efforts shift from one species to another, or to smaller specimens, as a target species becomes difficult to catch.</td>
</tr>
<tr>
<td>fishing effort</td>
<td>The measure of the amount of specific type of fishing gear used on the fishing grounds over a given unit of time (e.g. the number of hauls of a beach-seine net per day).</td>
</tr>
<tr>
<td>flow regime</td>
<td>The pattern of water flow through a river.</td>
</tr>
<tr>
<td>food web</td>
<td>Interconnected food chains; a system of feeding connections in an ecosystem.</td>
</tr>
<tr>
<td>fragmentation</td>
<td>Isolation and reduction of areas of habitat, and associated ecosystems and species, often due to land clearing.</td>
</tr>
<tr>
<td>general resilience</td>
<td>Resilience to unknown or unidentified pressures, disturbances or shocks.</td>
</tr>
<tr>
<td>geographic range</td>
<td>Geographical area within which a species can be found.</td>
</tr>
<tr>
<td>geomorphology</td>
<td>Scientific study of landforms and the processes that shape them.</td>
</tr>
<tr>
<td>gigalitre</td>
<td>One thousand million litres.</td>
</tr>
<tr>
<td>global warming</td>
<td>See greenhouse effect.</td>
</tr>
<tr>
<td>greenhouse effect</td>
<td>Where thermal energy (infrared radiation) that otherwise would have been radiated into space is partially intercepted and reradiated (some of it downwards) by atmospheric greenhouse gases, resulting in warmer temperatures at the planet’s surface. The greenhouse effect has supported the development of life on Earth; however, strengthening of the greenhouse effect through human activities is leading to climate change (also known as global warming).</td>
</tr>
<tr>
<td>greenhouse gases</td>
<td>Gases that contribute to the greenhouse effect, the most important of which are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), short-lived tropospheric ozone (O₃), water vapour, chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF₆).</td>
</tr>
<tr>
<td>gross domestic product</td>
<td>The total market value of goods and services produced in a country in a given period, after deducting the cost of goods and services used in production but before deducting allowances for the consumption of fixed capital.</td>
</tr>
<tr>
<td>gross value added</td>
<td>The value of output at basic prices minus the value of intermediate consumption at purchasers’ prices. The term is used to describe gross product by industry and sector. Using basic prices to value output removes the distortion caused by variations in the incidence of commodity taxes and subsidies across the output of individual industries.</td>
</tr>
<tr>
<td>habitat</td>
<td>The environment where a plant or animal normally lives and reproduces.</td>
</tr>
<tr>
<td>high seas</td>
<td>All parts of the sea that are not included in the exclusive economic zone, territorial sea or the internal waters of a state.</td>
</tr>
<tr>
<td>hydrology</td>
<td>Related to water quality, movement and distribution.</td>
</tr>
<tr>
<td>Interim Biogeographic Regionalisation of Australia</td>
<td>A set of 85 bioregions within the Australian landmass, used as the basis for the National Reserve System’s planning framework to identify land for conservation.</td>
</tr>
<tr>
<td><strong>invasive species</strong></td>
<td>Non-native plants or animals that have adverse environmental or economic effects on the regions they invade; species that dominate a region due to loss of natural predators or controls.</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>jurisdiction</strong></td>
<td>An Australian state or territory, or under the control of the Australian Government.</td>
</tr>
<tr>
<td><strong>kilolitre</strong></td>
<td>One thousand litres.</td>
</tr>
<tr>
<td><strong>Kyoto Protocol</strong></td>
<td>An international agreement that commits industrialised nations to stabilising the level of greenhouse gas emissions; the agreement is linked to the United Nations Framework Convention on Climate Change.</td>
</tr>
<tr>
<td><strong>lagoon</strong></td>
<td>A shallow body of water, especially one separated from a sea by sandbars or coral reefs.</td>
</tr>
<tr>
<td><strong>landscape</strong></td>
<td>An area of land comprising landforms and interacting ecosystems; an expanse of land, usually extensive, that can be seen from a single viewpoint.</td>
</tr>
<tr>
<td><strong>landscape processes</strong></td>
<td>Processes that affect the physical aspects of the landscape (e.g. weathering of rock formations, erosion, water flow).</td>
</tr>
<tr>
<td><strong>La Niña</strong></td>
<td>A periodic extensive cooling of the central and eastern Pacific Ocean. In Australia (particularly eastern Australia), La Niña events are associated with increased probability of wetter conditions in eastern Australia. See also <em>El Niño</em>.</td>
</tr>
<tr>
<td><strong>major vegetation groups</strong></td>
<td>Aggregation of vegetation into distinct categories; Australia’s native vegetation has been classified into 23 major vegetation groups.</td>
</tr>
<tr>
<td><strong>megalitre</strong></td>
<td>One million litres.</td>
</tr>
<tr>
<td><strong>millennium drought</strong></td>
<td>The recent drought in southern Australian that lasted from 2000 to 2010 (although in some areas it began as early as 1997).</td>
</tr>
<tr>
<td><strong>mitigation</strong></td>
<td>Actions intended to reduce the likelihood of change or to reduce the impacts of change.</td>
</tr>
<tr>
<td><strong>Montreal Protocol</strong></td>
<td>The Montreal Protocol on Substances that Deplete the Ozone Layer aims to reduce or eliminate human use of substances that deplete the atmospheric ozone layer.</td>
</tr>
<tr>
<td><strong>National Reserve System</strong></td>
<td>Australia’s network of protected areas that conserve examples of natural landscapes, and native plants and animals. The system has more than 9300 protected areas, including federal, state and territory reserves, Indigenous lands, and protected areas run by conservation organisations or individuals.</td>
</tr>
<tr>
<td><strong>natural resource management</strong></td>
<td>The management of natural resources such as land, water, soil, plants and animals, with a focus on sustainable practices.</td>
</tr>
<tr>
<td><strong>NOx</strong></td>
<td>A generic term for nitric oxide and nitrogen dioxide.</td>
</tr>
<tr>
<td><strong>nutrient cycling</strong></td>
<td>Movement and exchange of organic and inorganic materials through the production and decomposition of living matter.</td>
</tr>
<tr>
<td><strong>ozone depleting substances</strong></td>
<td>Substances that break down stratospheric ozone, principally chlorofluorocarbons, freons and halons used as refrigerants, industrial solvents, and propellants in aerosol spray cans.</td>
</tr>
<tr>
<td></td>
<td>These substances are stable and long lived in the lower atmosphere, but drift up to the stratosphere where they break down through the action of ultraviolet radiation. This releases highly reactive atoms (chlorine and bromine) that react with ozone molecules and break them apart. See also <em>stratospheric ozone</em>.</td>
</tr>
<tr>
<td><strong>ozone hole</strong></td>
<td>The reduction of the amount of ozone in the lower stratosphere above Antarctica that has occurred each spring since around 1980.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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</tr>
<tr>
<td>ozone layer</td>
<td>See stratospheric ozone.</td>
</tr>
<tr>
<td>pathogen</td>
<td>A microorganism that causes harm to its living host.</td>
</tr>
<tr>
<td>pelagic</td>
<td>Associated with the open ocean or upper waters of the ocean.</td>
</tr>
<tr>
<td>peri-urban</td>
<td>A region between the outer suburbs and the countryside.</td>
</tr>
<tr>
<td>pH</td>
<td>A measure of acidity or alkalinity on a log scale from 0 (extremely acidic) through 7 (neutral) to 14 (extremely alkaline, or basic).</td>
</tr>
<tr>
<td>photochemical</td>
<td>Referring to a chemical reaction that is triggered by the effect of light on molecules.</td>
</tr>
<tr>
<td>pressures</td>
<td>Events, conditions or processes that result in degradation of the environment.</td>
</tr>
<tr>
<td>primary production</td>
<td>The production of organic compounds from atmospheric or aquatic carbon dioxide, principally through photosynthesis.</td>
</tr>
<tr>
<td>radiative forcing</td>
<td>A measure of the influence a factor (such as greenhouse gases) has on altering the balance of incoming and outgoing energy in the Earth–atmosphere system.</td>
</tr>
<tr>
<td></td>
<td>Warming of climate is a response to positive radiative forcing, while cooling is a response to negative radiative forcing.</td>
</tr>
<tr>
<td>recruitment</td>
<td>Influx of new members into a population or habitat by reproduction, immigration or settlement.</td>
</tr>
<tr>
<td></td>
<td>In fisheries management, recruitment represents influx into the fishable part of the stock of a target species.</td>
</tr>
<tr>
<td>resilience</td>
<td>Capacity of a system to experience shocks while retaining essentially the same function, structure and feedbacks, and therefore identity.</td>
</tr>
<tr>
<td>riparian</td>
<td>Related to riverbanks or lake shores.</td>
</tr>
<tr>
<td>run-off</td>
<td>Movement of water from the land into streams.</td>
</tr>
<tr>
<td>salinisation</td>
<td>The process of becoming more salty; the accumulation of soluble salts (e.g. sodium chloride) in soil or water.</td>
</tr>
<tr>
<td></td>
<td>Many Australian soils and landscapes contain naturally high levels of sodium salts held deep in the soil profile.</td>
</tr>
<tr>
<td>salinity</td>
<td>See salinisation.</td>
</tr>
<tr>
<td>seamount</td>
<td>Submerged mountain rising more than 1000 metres from the ocean floor with its summit below the surface of the sea.</td>
</tr>
<tr>
<td>sequestration</td>
<td>See carbon sequestration.</td>
</tr>
<tr>
<td>smog</td>
<td>Fog mixed with smoke (i.e. mixing of particulate pollutants with water droplets).</td>
</tr>
<tr>
<td></td>
<td>Also photochemical smog resulting from the action of sunlight on nitrogen oxides and hydrocarbons present in a polluted atmosphere.</td>
</tr>
<tr>
<td>species</td>
<td>A group of organisms capable of interbreeding and producing fertile offspring.</td>
</tr>
<tr>
<td>specific resilience</td>
<td>Resilience to identified pressures, disturbances or shocks.</td>
</tr>
<tr>
<td>step-change</td>
<td>A sudden or major change.</td>
</tr>
<tr>
<td>stratosphere</td>
<td>A layer of Earth's atmosphere, beginning at an altitude of around 10 kilometres above Earth's surface and extending to approximately 50 kilometres.</td>
</tr>
<tr>
<td>stratospheric ozone</td>
<td>A layer of ozone in the stratosphere that limits the amount of harmful ultraviolet light passing through to lower layers of the atmosphere.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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</tr>
<tr>
<td>subsidiarity, principle of subsidiarity</td>
<td>Where action is taken by the lowest appropriate level of government.</td>
</tr>
<tr>
<td>surface phytoplankton bloom</td>
<td>A sudden bloom of phytoplankton (microscopic plants) that occurs near the surface of a body of water. See also algal bloom.</td>
</tr>
<tr>
<td>sustainability, sustainable</td>
<td>Using ‘natural resources within their capacity to sustain natural processes while maintaining the life-support systems of nature and ensuring that the benefit of the use to the present generation does not diminish the potential to meet the needs and aspirations of future generations’ (Environment Protection and Biodiversity Conservation Act 1999, p. 815). ‘Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (United Nations Brundtland Commission).</td>
</tr>
<tr>
<td>taxa</td>
<td>A group of one or more organisms classified as a unit. Taxonomic categories include class, order, family, genus, species and subspecies.</td>
</tr>
<tr>
<td>taxon</td>
<td>One member of a group; singular of taxa.</td>
</tr>
<tr>
<td>taxonomic</td>
<td>Related to the classification and naming of species (taxonomy).</td>
</tr>
<tr>
<td>threatened (species or community)</td>
<td>Likely to become endangered in the near future.</td>
</tr>
<tr>
<td>threatening process</td>
<td>A process or activity that ‘threatens ... the survival, abundance or evolutionary development of a native species or ecological community’ (Environment Protection and Biodiversity Conservation Act 1999, p. 273) and which also may threaten the sustainability of resource use.</td>
</tr>
<tr>
<td>threshold</td>
<td>A boundary between two relatively stable states; a point where a system can go rapidly into another state, usually because of positive feedback(s).</td>
</tr>
<tr>
<td>trigger values</td>
<td>Criteria levels within guidelines that trigger action; specifically, those that indicate a risk to the environment and a need to investigate or fix the cause.</td>
</tr>
<tr>
<td>trophic</td>
<td>Related to the organism’s place in a food chain. Low trophic levels are at the base of the chain (microorganisms, plankton); high trophic levels are at the top of the chain (dingoes, sharks).</td>
</tr>
<tr>
<td>troposphere</td>
<td>The lowest layer of Earth’s atmosphere. Its depth varies with latitude, averaging around 17 kilometres in the mid-latitudes.</td>
</tr>
<tr>
<td>turbidity</td>
<td>A measure of water clarity or murkiness; an optical property that expresses the degree to which light is scattered and absorbed by molecules and particles in the water. Turbidity results from soluble coloured organic compounds and suspended particulate matter.</td>
</tr>
<tr>
<td>urban footprint</td>
<td>The extent of area taken up by urban buildings and constructions.</td>
</tr>
<tr>
<td>value</td>
<td>The worth of environmental assets. Categories of environmental values include: • direct-use values: goods and services directly consumed by users (e.g. food or medicinal products) • indirect-use values: indirect benefits arising from ecological systems (e.g. climate regulation) • non-use values (e.g. benevolence) • intrinsic value (i.e. environmental assets have a worth of their own regardless of usefulness to humans).</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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</tr>
<tr>
<td>Vegetation Assets, States and Transitions (VAST) framework</td>
<td>A systematic classification of vegetation condition by the degree of anthropogenic modification from a benchmark natural condition.</td>
</tr>
<tr>
<td>volatile organic compounds</td>
<td>Primary pollutants that react with oxides of nitrogen in photochemical processes to generate a range of secondary pollutants (notably ozone).</td>
</tr>
<tr>
<td>vulnerable (species)</td>
<td>At high risk of extinction in the wild; likely to become endangered unless the circumstances threatening its survival and reproduction improve.</td>
</tr>
<tr>
<td>water market</td>
<td>A regulatory and planning-based system of managing surface water and groundwater resources for rural and urban use that aims to optimise economic, social and environmental outcomes.</td>
</tr>
<tr>
<td>watertable</td>
<td>The level below which the ground is saturated with water; the division between the subsurface region in which the pores of soil and rocks are effectively filled only with water and the subsurface region in which the pores are filled with air and usually some water.</td>
</tr>
<tr>
<td>Weeds of National Significance (WoNS)</td>
<td>Weeds identified as a threat to Australian environments based on their invasiveness, potential for spread, and socioeconomic and environmental impacts; 20 plant species are currently listed as WoNS.</td>
</tr>
<tr>
<td>wildfire</td>
<td>An unplanned fire, whether accidentally or deliberately lit (in contrast to a planned or managed fire lit for specific purposes such as fuel reduction).</td>
</tr>
</tbody>
</table>
## Acronyms and abbreviations

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAQ NEPM</td>
<td>National Environment Protection (Ambient Air Quality) Measure</td>
</tr>
<tr>
<td>AAT</td>
<td>Australian Antarctic Territory</td>
</tr>
<tr>
<td>ABARES</td>
<td>Australian Bureau of Agricultural and Resource Economics and Sciences</td>
</tr>
<tr>
<td>ABS</td>
<td>Australian Bureau of Statistics</td>
</tr>
<tr>
<td>ADR</td>
<td>Australian Design Rules</td>
</tr>
<tr>
<td>AFMA</td>
<td>Australian Fisheries Management Authority</td>
</tr>
<tr>
<td>AQI</td>
<td>air quality index</td>
</tr>
<tr>
<td>ASMA</td>
<td>Antarctic Specially Managed Area</td>
</tr>
<tr>
<td>ASPA</td>
<td>Antarctic Specially Protected Area</td>
</tr>
<tr>
<td>CCAMLR</td>
<td>Commission on the Conservation of Antarctic Marine Living Resources</td>
</tr>
<tr>
<td>CFC</td>
<td>chlorofluorocarbon</td>
</tr>
<tr>
<td>CO₂</td>
<td>carbon dioxide</td>
</tr>
<tr>
<td>CO₂-e</td>
<td>carbon dioxide equivalent</td>
</tr>
<tr>
<td>COAG</td>
<td>Council of Australian Governments</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organisation</td>
</tr>
<tr>
<td>DPSIR</td>
<td>drivers–pressures–state–impact–response</td>
</tr>
<tr>
<td>DSEWPaC</td>
<td>Australian Government Department of Sustainability, Environment, Water, Population and Communities</td>
</tr>
<tr>
<td>DSI</td>
<td>dust storm index</td>
</tr>
<tr>
<td>EAIS</td>
<td>East Antarctic Ice Sheet</td>
</tr>
<tr>
<td>ECS</td>
<td>extended continental shelf</td>
</tr>
<tr>
<td>EEZ</td>
<td>exclusive economic zone</td>
</tr>
<tr>
<td>EPBC Act</td>
<td>Environment Protection and Biodiversity Conservation Act 1999</td>
</tr>
<tr>
<td>ETS</td>
<td>emissions trading scheme</td>
</tr>
<tr>
<td>GBRMP</td>
<td>Great Barrier Reef Marine Park</td>
</tr>
<tr>
<td>GDP</td>
<td>gross domestic product</td>
</tr>
<tr>
<td>GHG</td>
<td>greenhouse gas</td>
</tr>
<tr>
<td>GL</td>
<td>gigalitre</td>
</tr>
<tr>
<td>GRACE</td>
<td>Gravity Recovery and Climate Experiment</td>
</tr>
<tr>
<td>HFC</td>
<td>hydrofluorocarbon</td>
</tr>
<tr>
<td>IBRA</td>
<td>Interim Biogeographic Regionalisation of Australia</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
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<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>ICOMOS</td>
<td>International Council on Monuments and Sites</td>
</tr>
<tr>
<td>IGR</td>
<td>intergenerational report</td>
</tr>
<tr>
<td>IPA</td>
<td>Indigenous protected area</td>
</tr>
<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>IUCN</td>
<td>International Union for Conservation of Nature</td>
</tr>
<tr>
<td>IUU (fishing)</td>
<td>illegal, unregulated and unreported</td>
</tr>
<tr>
<td>kl</td>
<td>kilolitre</td>
</tr>
<tr>
<td>km²</td>
<td>square kilometres</td>
</tr>
<tr>
<td>LULUCF</td>
<td>land use, land-use change and forestry</td>
</tr>
<tr>
<td>ML</td>
<td>megalitre</td>
</tr>
<tr>
<td>MPA</td>
<td>marine protected area</td>
</tr>
<tr>
<td>MTCO₂-e</td>
<td>megatonnes of carbon dioxide equivalents</td>
</tr>
<tr>
<td>MVG</td>
<td>major vegetation group</td>
</tr>
<tr>
<td>NEPM</td>
<td>National Environment Protection Measure</td>
</tr>
<tr>
<td>NLWRA</td>
<td>National Land &amp; Water Resources Audit</td>
</tr>
<tr>
<td>NOₓ</td>
<td>nitrogen oxides</td>
</tr>
<tr>
<td>NRM</td>
<td>natural resource management</td>
</tr>
<tr>
<td>NRS</td>
<td>National Reserve System</td>
</tr>
<tr>
<td>NRSMPA</td>
<td>National Representative System of Marine Protected Areas</td>
</tr>
<tr>
<td>NVIS</td>
<td>National Vegetation Information System</td>
</tr>
<tr>
<td>NWI</td>
<td>National Water Initiative</td>
</tr>
<tr>
<td>NWQMS</td>
<td>National Water Quality Management Strategy</td>
</tr>
<tr>
<td>ODS</td>
<td>ozone depleting substance</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Co-operation and Development</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>particulate matter smaller than 10 micrometres</td>
</tr>
<tr>
<td>ppb</td>
<td>parts per billion</td>
</tr>
<tr>
<td>ppm</td>
<td>parts per million</td>
</tr>
<tr>
<td>SAM</td>
<td>southern annular mode</td>
</tr>
<tr>
<td>SoE</td>
<td>state of the environment</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
</tr>
<tr>
<td>UV</td>
<td>ultraviolet</td>
</tr>
<tr>
<td>VAST</td>
<td>Vegetation Assets, States and Transitions</td>
</tr>
<tr>
<td>VOC</td>
<td>volatile organic compound</td>
</tr>
<tr>
<td>WAIS</td>
<td>West Antarctic Ice Sheet</td>
</tr>
<tr>
<td>WMO</td>
<td>World Meteorological Organization</td>
</tr>
</tbody>
</table>
An ‘f’ following a page number indicates a figure; ‘t’ indicates a table

A
abalone (Haliotis spp.), 427–8
abalone viral ganglioneuritis, 427–8
abbreviations, 913–14
Aboriginal and Torres Strait Islander Heritage Protection Act 1984, 750–1
Aboriginal Heritage Act 2006 (Vic.), 715
Acacia salicina (river cooba), 216
acidification
inland water environments, 206
of oceans, 110, 416–17
of soil, 270, 287–93, 356
Southern Ocean, 466, 477, 491–2, 495, 527–30, 533, 550–1, 556
acidity (pH) of fresh water, 208
acid sulfate soils, 287, 851, 857–8
acknowledgements, 898–903
acronyms, 913–14
adaptability, 528–9, 622, 670–2
Eucalyptus spp., 729
adaptive capacity to climate change, 883–4
adaptive management, 2, 768, 770
Adelaide air quality, 136–7
Adelaide Coastal Waters Study, 872
Adelaide Park Lands and City Layout, 744
Adelaide Plains, 203
Adélie penguins, 505
aerosols, 84
Agreement on the Conservation of Albatrosses and Petrels, 543
agriculture, 274
climate change impacts, 94, 318, 321
cultivation, 334–5
grazing, 317, 331–3, 338, 351
greenhouse gas emissions, 90–1
nutrients, 334
soil acidification, 270, 287–93, 356
soil carbon, 277–86
soil compaction, 335
soil erosion, 294–304
water consumption, 198
aircraft operations, Antarctica, 515
air quality, 67, 73, 117
assessing, 134–41
built environment, 814, 824, 826, 834
climate change impacts, 143, 146–7, 169, 171, 175
coasts, 852
dust storms, 295–300
human health, 3, 122–8
management, 150–67
national standards, 152–3
outlook, 174–5
pollutants, 127–41, 145–9
pressures, 143–9
resilience, 168
risks, 170–3
summary, 10–11
see also indoor air quality; particulate pollution
air quality index, 126
airsheds, 128, 168
air toxics, 133
Albany, 390
albatrosses, 506, 543–5
algal blooms, 409–12, 413
alien species see invasive species
alligator weed (Alternanthera philoxeroides), 234
Altona Treatment Plant, 229
Amanda Bay, 525
ambient air quality see air quality
Amundsen Sea, 486
Amundsen Sea Low, 479
Angle Crossing, 210
animal species
Antarctica, 467, 497, 502–7, 548
biodiversity, 599–611
Antarctic bottom water, 491
Antarctic Circumpolar Current, 382, 471, 490
Antarctic climate change and the environment, 555
Antarctic Heritage Register, 523
Antarctic ice sheet, 484–5
Antarctic Heritage Register, 523
Antarctica
biodiversity, 472, 493, 543–5
global importance, 471–2
governance, 472–6
heritage values, 522–6, 538–9
key findings, 466–7
management, 540–7
natural environment, 472, 493–507
outlook, 555–6
physical environment, 477–89
pressures, 4, 527–39
research stations, 508–21
resilience, 548–9
risks, 550–3
Southern Ocean, 490–2
summary, 13
Antarctic bottom water, 491
Antarctic Circumpolar Current, 382, 471, 490
Antarctic climate change and the environment, 555
Antarctic Heritage Register, 523
Antarctic ice sheet, 484–5
Antarctic krill, 474, 495, 532, 550
Antarctic Marine Living Resources Conservation Act 1981, 541
Antarctic ozone hole see ozone hole
Antarctic Peninsula, warming of, 466, 471–2, 478–9, 485, 527
Antarctic Polar Frontal Zone, 471
Antarctic Specially Managed Areas, 522, 523, 524–5, 542
Antarctic Specially Protected Areas, 522, 523, 524–5, 542
Antarctic Treaty Act 1960, 540–1
Antarctic Treaty (Environment Protection) Act 1980, 523, 541
Antarctic Treaty System, 472–4, 523, 540–3
Antarctic vertebrates, 467, 497, 502–7, 548
Apis cerana (Asian honeybee), 634
aquaculture, 372, 383–6, 425–9, 432, 447
pressures on coasts, 861
aquatic ecosystems, 611–12, 616
condition of, 215
aquatic weeds, 234–5, 242
Aquatic Weeds of National Significance, 242
aquifers see groundwater
Archer River, 229
Ardry Island and Odbert Island, 524
area of occupation (of species), 582–3
artesian bores, 203
Ashmore Reef National Nature Reserve, 424
Asian honeybee (Apis cerana), 634
Ask first guidelines, 736, 742, 791
Assessing invasive animals in 2008, 232
Assessment of Australia’s terrestrial biodiversity 2008, 326, 331, 334, 576, 579, 617, 649, 651–2
asthma, 124, 147
athel pine (Tamarix aphylla), 234, 242
Atlas of Australian Acid Sulfate Soils, 858
Australasian Antarctic Expedition, 523
Australian Action Plan for Frogs, 220
Australian Alps, 749
Australian Antarctic Airlink, 515
Australian Antarctic Division, 476
Australian Antarctic program, 476, 509–17, 540
Australian Antarctic Science Strategic Plan 2011–12 to 2020–21, 476
Australian Antarctic Territory, 475–6
Australian Antarctic Territory Act 1954, 540
Australian Capital Territory
air quality, 129, 136–7
Canberra water supply, 229
climate change policies, 104
heritage management, 717, 783
water quality, 210
Australian Climate Change Science Program, 100
Australian Convict Sites, 705
Australian Design Rules, 150, 153, 156
Australian Fisheries Management Authority, 384–6, 532
Australian Heritage Council, 745
Australian Maritime Safety Authority, 541
Australian National Antarctic Research Expedition, 523
Australian National Shipwrecks Database, 698
Australian Natural Heritage Charter, 742, 768
Australian Pest Animal Strategy, 242, 642
Australian Regional Forest Assessments, 789
Australian Renewable Energy Agency, 102
Australian River Assessment System, 214
Australian sea lions, 395, 613
Australian Soil Resource Information System, 277, 858
Australian water quality guidelines for fresh and marine waters, 206
Australian Water Resources 2005, 193, 202
Australian Weeds Strategy, 642
Australia’s Biodiversity Conservation Strategy 2010–2020, consultation draft, 748
Australia’s Oceans Policy, 435, 442
Australia’s Strategy for the National Reserve System 2009–2030, 642, 650, 719, 773
B
bacteria, 493, 591
bandicoots, 637
barramundi, 428
Barrow Island, 423
Basin Salinity Management Strategy, 207
Beale review, 660
Beenyup Wastewater Treatment Plant, 229
Bellingshausen Sea, 485, 486, 527
benthic environment, Antarctica, 495, 529
benzene, 133
benzo(a)pyrene, 133
biodiversity
aquatic ecosystems, 611–12, 616
built environment, 816
climate change impacts, 94
coasts, 858–61
ecosystem services, 576–8
genetic and species diversity, 581–3
importance, 451, 573–5
information availability, 579–81
key findings, 568–9
management, 569, 579–81, 642–67
marine environment, 373, 382–3, 389–403, 452, 613, 616
outlook, 679–81
plants and animals, 592–616
pressures, 4, 568, 617–41, 643–5, 674–5, 679, 851
resilience, 645, 655, 668–73
risks, 643–5, 674–8
summary, 15
terrestrial ecosystems, 584–91, 614
Biodiversity Fund, 102, 647
biodiversity hot spots, 573, 700, 732
biological control, 235, 242
bioregions, 711–14
see also National Reserve System
biosecurity, 659–60
biosequestration, 274
birds, 607–9, 615
   adaptability, 622
   habitat degradation, 629, 638
   levels of endemism, 582
   seabirds, 504–7, 543–5
   threatened status, 600–1, 647
   waterbirds, 216, 217, 219, 388, 611–12
Birds Australia, 643
bitou bush (Chrysanthemoides spp.), 771, 861
blackberry (Rubus fruticosus), 234
   ‘black ooze’, 429
blackwater events, 216
BLANKET (Base-Line Air Network of EPA Tasmania), 162
blue carbon, 885
boarfish, 419
Bolboschoenus spp. (marsh club-rush), 216
boneseed (Chrysanthemoides spp.), 861
bores, 203
Braidwood, 758
Brennan and Geraghty’s Store, 762
Brighton bypass, 736
brane rejection, 491
Brisbane air quality, 136–7
British, Australian and New Zealand Antarctic Research Expedition, 523
BROKE-West (Baseline Research on Oceanography, Krill and the Environment-West), 495
bromine, 118
brown trout, 233
bryophytes, 498–9
buffel grass (Cenchrus ciliaris), 318
Bufo marinus (cane toad), 232, 248
buildings, risk of inundation, 111, 825, 880
built environment
   climate change impacts, 94
   impact on land use, 274
   key findings, 800
   livability, 805–16, 821
   management, 800, 827–33, 838
   outlook, 838
   populations, 5, 800, 823–6
   resilience, 834
   risks, 835–7
   summary, 16
   urban environmental efficiency, 816–21
Built Environment Meets Parliament, 829
Bunbury air quality, 141
Bunya Caring for Country Trust, 781
Burdekin catchment, 215
Burdekin River, 410–11, 431
Bureau of Meteorology, 194, 345
Burra Charter, 742
Burrup Peninsula National Heritage Place, 717, 746
bushfires, 262, 274, 317, 322–3, 330, 348
   water quality impacts, 231, 854
   see also fire regimes
bycatch, 477, 543–5
Byron Shire Council, 883

C
Cabomba caroliniana, 234
cage fish culture, 428
calcification processes, 416–17, 495, 550–1
Cambridge Gulf, 390
Canadian National Occupancy Standard, 807
Canberra
   air quality, 129, 136–7
   water supply, 229
cane toad (Bufo marinus), 232, 248
carbon cycle, 416
carbon dioxide, 47, 48f, 74, 84–92
   atmospheric levels, 491
   and stratospheric ozone, 143–4
   see also vehicle emissions
carbon dioxide, dissolved see ocean acidification
carbon dioxide equivalent, 86
Carbon emission policies in key economies, 115
Carbon Farming Futures program, 102
Carbon Farming Initiative, 98, 102, 278, 327
carbon monoxide, 67, 123t, 124t, 127, 131
Carbon Pollution Reduction Scheme, 100, 105
carbon price, 98, 100, 115, 681
carbon sequestration, 274, 279–80, 656, 885
   see also soil carbon
caring for country, 9, 272, 575, 701, 735, 772
Caring for our Country program
   biodiversity, 642, 645, 647, 649, 655
   coasts, 872
   heritage, 760
   inland water environments, 211
   land environment, 341, 342
   marine environment, 429
carp (Cyprinus carpio), 232, 233
Cartier Island Marine Reserve, 424
Catchment condition report 2007, 243
catchment run-off, 429–32, 432, 447–8
CCP—Integrated Action®, 106
Cenchrus ciliaris (buffel grass), 318
Census of Antarctic Marine Life, 472, 493
Census of Marine Life, 382
Census of Antarctic Marine Life, 472, 493
Census of Marine Life, 382
Centre for Australian Weather and Climate Research, 194
Centrostephanus spp. (sea urchin), 861
Chaetodon lunulatus (redfin butterflyfish), 422
Chamocephalus gunnari (mackerel icefish), 502, 532
chemical processes, marine environment, 404–7, 413
chlorine, stratospheric, 118, 479, 483
chlorofluorocarbons, 67, 84, 86, 117, 118, 144
chlorophyll, 410–11
**Index | Appendix**

*Chrysanthemoides* spp., 861
chytrid fungus, 633
Cities for Climate Protection®, 106
Clark Peninsula, 524
classification systems, 584
Clean Energy Finance Corporation, 102
Clean Machine Program, 159
climate change, 2, 66, 73–4, 82
  - air quality, 143, 146–7, 169, 171, 175
  - connectivity corridors, 357
  - direct effects, 92–3
  - droughts, 225
  - economic impacts, 60
  - environmental impacts, 42, 45–51
  - fire danger days, 322
  - governance, 98–109, 852–3
  - ice sheet records, 471
  - indirect effects, 93–6
  - inland water environments, 188, 236, 245, 249–51
  - management, 98–109
  - marine environment, 373, 415–17, 432, 444, 455, 458–9
  - outlook, 114–16
  - pressures in Antarctica, 477, 527–9, 533–6, 543, 547, 548, 550, 555–6
  - pressures on biodiversity, 617, 622–3, 639, 662, 675, 863
  - pressures on built environment, 824, 826, 835, 838
  - pressures on coasts, 844–5, 850, 852, 878
  - pressures on heritage, 728–9, 738, 782, 787, 788
  - pressures on land environments, 262, 317, 318–21, 348, 356
  - summary, 10–11
  - see also ocean acidification; sea level rise
climate Change Authority, 102
*Climate change risks to Australia’s coasts*, 871
climate change science, 99–100
climate models, 47, 50
climate projections, 47–51
climate research, 82
climate resilience, 110–11
climate trends, 75–82
coal mining, 274
coal-seam gas resources, 254, 274
Coal Seam Gas Water Management Policy, 254
c coal use, 87, 88–9
Coastal Catchments Initiative, 872
coastal development, 430, 432, 444
Coastal Protection Package, 871
Coastal Waters Acts, 437
coasts
  - air quality, 852
  - biodiversity, 862–3
  - climate change, 852–3
  - governance, 850, 870–5
  - heritage places, 864
  - key findings, 844–5
  - land use, 857–61
management, 855
marine environment, 861–2
outlook, 885
population growth, 54, 866–9
pressures, 5, 844–5, 849, 851–69
resilience, 883–4
risks, 877–81
summary, 17
water resources, 854–5
Coasts and Climate Change Council, 874
Cockburn Sound, 390, 437
Cockburn Sound Management Strategy, 436
cod, 395
cogeneration of electricity, 170
commercial fisheries
  - Antarctica, 474, 502, 532–3, 550
  - marine environment, 383–6, 417–22
  - and seabirds, 504, 543–5
Commission for the Conservation of Antarctic Marine Living Resources, 474, 502, 543, 544
Commonwealth Environmental Water Holder, 194
Commonwealth Heritage List, 698, 707–8, 717
community (definition), 584
congestion charging, 831
connectivity conservation, 357–8, 655–6
conservation
  - Antarctica, 523, 543
  - biodiversity, 642–3
  - conservation assessments, 582, 585–6
  - conservation farming, 335
  - connectivity corridors, 357–8
  - management, 350
  - see also National Reserve System
conservation strategies, 584
Convention for the Conservation of Antarctic Seals, 541
Convention for the Safeguarding of the Intangible Cultural Heritage, 750
Convention on Biological Diversity, 576, 651, 713–14
Convention on the Conservation of Antarctic Marine Living Resources, 474, 540, 541, 551
Convention on the Protection of the Underwater Cultural Heritage, 751
Cooper Creek Basin, 229
Coordinated Smoke Management System, 162
Coorong, Lower Lakes and Murray mouth, 287, 405
Copenhagen Accord, 103, 114
coral bleaching, 103, 416
coral trout, 422
cotter Reservoir, 229
cotton industry, 274
*Crassostrea gigas* (Pacific oyster), 409, 427
cropping systems, 278–9
cryosphere, 484–9
CSIRO Sustainable Yields project, 203
cultivation, 263, 294, 317, 334–5
cultural flows, 240, 855
cumbungi (Typha spp.), 216
cycling, 812
Cyclone Tracy, 835
Cyprinus carpio (carp), 232, 233
Cyrtobagous salviniae, 235

D
Dampier, 390, 425
Dampier Archipelago, 746
dangerous climate change, 93, 114
Darwin air quality, 137
Darwin Harbour, 390, 410–11
data collection, 2, 893
Davis Station, 522, 526
Dawesville Channel, 430
Decade of Landcare, 346
decision science, 644
defence operations, 433
deforestation, 326f, 327f
see also land clearing
degraded environments, inland water, 214, 256
Denmark River, 247
Derwent Estuary Program, 436
Derwent River, 405, 410
desalination, 199t, 425, 433, 854
development pressure on heritage, 732–3, 736, 739, 788–9
Dhimurru IPA management plan, 441
diesel vehicles, 153, 157–8, 159
dingoes, 631
Dinosaur Stampede National Monument, 698
Directions for the National Reserve System: a partnership approach, 650
Directory of Important Wetlands in Australia, 195
diseases, 94, 113, 318, 327
marine environment, 409–12, 413, 425, 427–8
Dissostichus eleginoides (Patagonian toothfish), 502, 532
drainage divisions, 194–5
drinking water management plan, 441
drinking water quality, 814–15
drinking water trial, 229
drivers versus pressures, 617–18
see also climate change; economic growth; population growth
droughts, 47, 75, 82
and bushfires, 322
impact on agriculture, 274
inland water environments, 188, 198, 225–7, 236
land environment, 270
pressures on biodiversity, 617, 640
pressures on coasts, 854–5
wind erosion of soil, 295–6
dryland agriculture, 271, 338, 352
dryland salinity, 277, 327, 342
dust storm index, 296–300
dust storms, 295–300, 622

E
East Antarctica, 498–9, 551
climate change impacts, 466, 472, 477, 527–8
East Antarctic Ice Sheet, 466, 484–5, 489
East Australian Current, 77, 381, 405, 415, 458
Eastern Australian Waterbird Survey, 217, 219, 611–12
eastern gemfish, 418
East Marine Region, 390–1, 397, 401, 405, 409
ecological change, 579
ecological footprint, 589, 625–7
see also urban footprint
ecological processes
inland water, 611–12
inland water environments, 201, 214–23
marine environment, 401–3, 413
economic growth
built environment, 823, 834
driver of pressures, 42, 45, 46, 57–60
pressures on biodiversity, 617
pressures on heritage, 731–3, 739, 789
economic values
ecosystems, 591
marine environment, 383–7
ecosystem (definition), 584
ecosystem function, 201
ecosystem health
estuaries, 429–30
marine environment, 388, 404–13
Ecosystem Health Monitoring Program, 243
ecosystem services, 576–8, 589–91, 749
ecotourism, 453
edge effects, 326
electric ants, 733
electricity generation, 92, 170
electricity, water consumption, 1981
Eleocharis obicis (spike rush), 216
El Niño, 81, 87
El Niño Southern Oscillation, 481
embodied energy, 769
emissions trading scheme, 100, 102
employment by industry, 57
endemism, 268, 573, 581–3
energy efficiency
built environment, 831
and heritage management, 755, 768, 769, 792
energy generation, 433
energy sector, 90
energy sources, 88–9, 92
energy use, 45, 58
Antarctic research stations, 511–15, 517
built environment, 816–17, 824
engineering of natural systems, 675
environmental degradation, 52, 627
environmental flows, 238
environmental health
indicators of, 215, 220
inland water, 201
environmental management system, Antarctica, 542
environmental resilience to climate change, 110–11
environmental watering, 243
environmental water requirements, 239
Environment Protection and Biodiversity Conservation Act 1999, 195, 434–6, 523, 541, 625
Environment Protection and Management Ordinance 1987, 541
estuaries, 429–30, 854
Eucalyptus camaldulensis (river red gum), 216
Euphausia superba (Antarctic krill), 474, 495, 532, 550
Exeter Farm, 759
extent of occupation (of species), 582–3
extinctions, 452, 606
extreme weather events, 527, 535
built environment, 824, 826, 834, 835
particulate pollution, 67, 117, 147, 169
pressures on heritage, 729, 738
F
fast ice, 486, 488, 505
fauna, Antarctica, 467, 497, 502–7, 548
feral animals see invasive species
feral pigs, 232
fertilisers, 274, 334, 337
fertility rates, 52–3
Fifth national communication on climate change, 2, 67, 89, 94, 98
Finke River, 242
fire ants, 733
fire regimes
pressures on biodiversity, 606, 617, 619–21, 638, 641
pressures on heritage, 729, 738
traditional cultural practices, 735
see also bushfires
fire risk to built environment, 835
First Peoples’ Water Engagement Council, 240
fisheries
Antarctica, 474, 502, 532–3, 550
environmental impacts, 417–22, 432
management, 434–9, 446, 452–3
pressures on coasts, 861
and seabirds, 504, 543–5
value and volume, 383–6
fish fauna, Antarctica, 502, 506
Fitzroy River, 431
flatback turtles, 423
flathead, 420–1
floodplains, 247
floods, 81, 216, 226, 248
river flood plumes, 431
soil erosion, 295
fluorinated gases, 86
food production constraints, 269
food security, 274
food waste recycling, 832
food web, Antarctica, 477, 493–5, 529
foraminifera, 495
forecasting landscape dynamics, 345
forest fire danger index, 322–3
forestry, 1981, 252, 274, 317, 335–6, 338
climate change impacts, 318
management, 351
formaldehyde, 133
fossil fuels, 47–8, 84, 85, 88–9
fragmentation of habitat, 617, 629–30, 640, 664–5
fragmentation of vegetation, 310, 326
Framework for a National Cooperative Approach to Integrated Coastal Zone Management, 872
Fraser River, 229
Frazier Islands, 525
Freedom Ride, 699
freshwater fish, 221, 609
frogs, 220, 583, 633
Fuel Quality Standards Act 2000, 150, 153
fuel use, Antarctic research stations, 511–15, 516–17
fugitive emissions, 90
funding
biodiversity, 647
heritage management, 742, 756–62, 766, 789
land management, 342
fungi, 327–8, 597–9, 615, 633–4
G
gambusia, 233
garnaut Climate Change Review, 60, 98
Geelong South, air quality, 140
gemfish, 418
general resilience, 672–3
genetic diversity, 581–3
 genetic engineering, 675
Geographe Bay, 410–11
geomorphology of seabed, 380–1
Georgina River, 242
Gippsland Lakes, 342, 405, 872
glaciers, 484–5, 488
Global Earth Observation System of Systems, 345
global financial crisis, 91
Global Footprint Network, 625
global processes, 46
global warming, 2, 66, 82, 108
Antarctica, 498, 527, 528
Antarctic ice sheet, 484
Antarctic Peninsula, 466, 471–2, 478–9, 485
droughts, 226
glossary, 904–12
Gnangara Mound, 251, 252
Gold Coast Rapid Transit system, 812
goldfish, 233
Gondwana Rainforests, 705
Gorgon gas production project, 423
Goulburn–Broken catchment, 668–70
Goulburn River System, 229
governance
air quality standards, 152–3, 169
Antarctica, 472–6, 540–1
biodiversity, 642–67, 673
built environment, 800, 828
climate change, 67, 98–109, 114–15, 852–3
coasts, 845, 850, 870–5, 877, 884
environment, 2
heritage management, 745–8, 768
land environment, 263, 340–54
marine environment, 373, 434–49
Gravity Recovery and Climate Experiment satellites, 484–5
grazing
pressures on biodiversity, 617, 631–3, 641, 666
pressures on land, 317, 331–3, 338, 351
Great Artesian Basin, 195
Great Artesian Basin Sustainability Initiative, 203
Great Barrier Reef
agricultural run-off, 391, 430–1, 872
coral bleaching, 103, 415, 417
water quality, 436
Great Barrier Reef Marine Park, 442, 443
Great Barrier Reef outlook report 2009, 390
Great Eastern Ranges corridor, 656
greenhouse gas emissions, 84–94
and coral bleaching, 103, 417
emissions trading scheme, 100, 102
and global warming, 66, 74
impacts in Antarctica, 479, 481, 482
management, 109
outlook, 114–16
per person, 87
pressures, 97, 143–4
reducing, 2, 46, 84, 98, 103, 106–7
reporting systems, 100
and resource consumption, 58
risks to atmosphere, 169
risks to climate, 42, 47–51, 112–13
greenness fraction, 310
Green Star energy rating, 769, 792
Gregory River, 229
gross domestic product, 57, 60
gross value of fisheries production, 383
gross value of irrigated agriculture, 198
gross value of water, 200
groundwater, 195, 202, 203, 206
climate change projections, 251
origin by state, 199t
salinity, 211, 277
seawater intrusion, 854
water abstraction, 251
Guidelines for the ecologically sustainable management of fisheries, 435
Guide to the proposed Basin Plan, 239
Gulf of Carpentaria drainage division
climate change projections, 250
ecological processes, 222
map, 195
river health, 217
streamflow regimes, 202, 204
water quality, 211
water storage, 202
Gulf St Vincent, 390

H
habitat degradation, 214, 256, 499–500
habitat disturbance, Antarctica, 537
habitat fragmentation, 617, 629–30, 640, 664–5, 858–61
habitat loss
biodiversity, 619–21
pressures on heritage, 734, 739
see also climate change; land clearing
heritage quality, 589, 590
marine environment, 390–4, 413
Haliotis spp. (abalone), 427–8
halons, 117, 118
harvesting species, 624–5
Hawke report, 442–3, 844–5
Hawker Island, 525
hayfever, 124
hazardous air pollutants, 133
health facilities, 878
Healthy Parks Healthy People, 749
Healthy Waterways partnership, 243, 436, 871, 883
Heard Island, 472, 485, 488, 497, 522, 523, 524, 526, 754
historic heritage, 538
Heard Island and McDonald Islands Act 1953, 541
heatwaves, 96
herbicides, 337
heritage
coasts, 864
heritage listings, 697–9
key findings, 692
management, 742–79
outlook, 787–92
pressures, 5, 716, 717, 721, 728–41, 745, 768, 851, 878, 880
resilience, 780–3
risks, 784–5
summary, 15–16
see also historic heritage; Indigenous heritage; natural heritage
heritage associations, membership of, 765
Heritagecare program, 766
heritage listings, 522, 697–9
heritage values, 704, 730, 738, 743–5, 759
Hibernia Reef, 424
Hinchinbrook River, 229
historic heritage, 703, 704, 716, 724–5, 727
Antarctica, 522–6, 539–9, 546
funding, 760
management, 752, 773, 778–9
outlook, 791–2
pressures, 736, 741, 754–5, 787
resilience, 780–3
Historic Shipwrecks Act 1976, 698
Hobart air quality, 129, 137
hole in ozone layer, 119–22, 168, 466, 479–81, 483, 528, 555–6
horticulture, 274
hot spots, 573, 700, 732
household energy use, 816–17
household water use, 198t, 817–18, 824
housing, 807–8
Houtman Abrolhos Islands, 417
human health
  air quality, 68, 117, 122–8, 134, 145–7, 174–5
  climate change impacts, 93–6
  melanoma, 117, 120, 122
see also indoor air quality
human resources
  biodiversity management, 647
  heritage, 762–7
  land environment, 263, 341–2, 343, 346–7
human wellbeing, 576–7
hydro-electric power, 198, 202, 217
hydrofluorocarbons, 84, 86
hydrology changes, 277, 327, 617, 638, 641
Hymenachne amplexicaulis, 234

iceberg grounding, 495
ice sheet, 484–5
icon sites, 855
illegal, unregulated and unreported fishing, 502, 532–3, 543
Indian Ocean Dipole, 82
Indian Ocean drainage division
  ecological processes, 222
  map, 195
  streamflow regimes, 204
  water quality, 212
  water storage, 202
indicators
  Antarctic environmental health, 474
  biodiversity, 576, 581t
  environmental health, 215, 220
  marine species health, 422
  soil condition, 277
Indigenous communities
  built environment, 808
  ecological footprint, 627
  land management, 272, 274, 275, 334, 338, 350, 575
  marine resources use, 433
  resilience to climate change, 111
  water management, 240, 241
Indigenous heritage, 699, 701, 704, 715, 721–4, 726–7, 732, 746, 864
  funding, 760
  management, 750, 768, 772–3, 776–7
  outlook, 791
  pressures, 734–7, 740, 787
  resilience, 780–3
Indigenous land and sea management, 9, 272, 575, 701, 735, 772
Indigenous languages, 723–4
Indigenous protected areas, 341, 440–1, 650, 711, 737, 772
Indonesian Throughflow, 382
indoor air quality, 68, 117, 142, 175
  management, 150, 160, 163, 167
  pressures, 143, 147, 149
  risks, 169, 171
industry, employment by, 57
industry water consumption, 198t
inflows, 226, 228
information availability, 2, 893–4
  biodiversity, 579–81, 618–19, 643–5
  heritage, 703
  land environment, 342–5
information portal for water, 194
infrastructure for water resources, 228–9
inland water
  ecological processes, 214–23, 611–12
  environmental health, 201
  key findings, 188–9
  management, 238–46
  outlook, 256
  pressures, 3, 225–37, 851
  resilience, 247–8
  risks, 249–55
  streamflow regimes, 202–5
  summary, 11
  surface water resources, 194–200
  water policy reforms, 188, 189, 193–4, 239–42
  water quality, 206–13
institutional arrangements, 342–5
integrated marine management, 442
Integrated Marine Observing System, 436
intensive land-use zone, 271
Interdecadal Pacific Oscillation, 82
intergenerational report, 52, 53, 60
Intergovernmental Agreement on Biosecurity, 660
Intergovernmental Agreement on the Environment, 748
Intergovernmental Agreement on World Heritage, 748
Intergovernmental Coastal Advisory Group, 872
Intergovernmental Panel on Climate Change, 42, 47, 82, 878
International Convention for the Prevention of Pollution from Ships, 541
International Convention for the Regulation of Whaling, 541
International Maritime Organization, 541
International Whaling Commission, 541
invasive species
  Antarctica, 467, 477, 493, 499–500, 535–6, 547
  aquatic weeds, 234–5, 242
  coasts, 861
  fungi, 633–4
  inland water environments, 232–3, 237, 242, 246, 248, 254, 256, 634
  invertebrates, 591, 634
jurisdictional summaries, 634–6
land environment, 262, 317, 318, 327–31, 349
managing, 656–60
marine environment, 409–12, 413, 425, 634, 862
pressures on biodiversity, 606, 617, 619–21, 631, 636–8, 641, 666–7
pressures on heritage, 733, 739
terrestrial weeds, 234, 318, 328–30, 631, 633, 636, 771, 861
invertebrates, 583, 611, 615
Antarctica, 472, 497, 497–501, 529
role in soil health, 591
investment see funding
irrigated agriculture, 274, 338, 352
island states, sea level rise, 883

J
Jabiru Shoals, 424
jet stream, 481
Jobs Fund, 760–2
jurisdiction zones for Australia’s marine environment, 377–9

K
Kakadu National Park, 754
Kangaroo Island, 749
Kaurna people, 722–3
Kemble Grange, air quality, 139
Kerguelen Deep Western Boundary Current, 490
key environmental functions, 201
key findings, 2–5
Antarctica, 466–7
atmosphere, 66–8
biodiversity, 568–9
built environment, 800
coasts, 844–5
drivers, 42–3
heritage, 692
inland water environments, 188–9
land environment, 262–3
marine environment, 372–3
Kimberley region, 390, 410–11, 428, 789
king crabs, 493
Kosciuszko National Park, 782
krill, 474, 495, 532, 550
Kyoto Protocol, 86, 89, 100

L
Lake Argyle, 202
Lake Eyre drainage division
ecological processes, 217, 222, 611
map, 195
streamflow regimes, 204
water quality, 212
water storage, 202
weed control, 242
Lake Margaret Power Station, 770
land
history of use, 275
key findings, 262–3
land use, 270–4
management, 263, 272, 340–54, 546
outlook, 362–3
pressures, 3, 317–39, 851
resilience, 355–8
risks, 359–61
soils, 267–8, 274–304
summary, 11–12
vegetation, 268, 305–15
inland water environments, 231
management, 349
native vegetation, 305, 310, 851
pressures on biodiversity, 617, 627–9, 640, 664–5
pressures on heritage, 734, 739
landfill waste, 57
land managers, 272
land resource information, 342–5
Landscape Logic project, 646
land stewardship programs, 655
land use
built environment, 816
coasts, 844
inland water environments, 188, 231, 236, 244–5, 252
pressures on coasts, 857–61
pressures on heritage, 734, 739
La Niña, 75, 80, 82, 87
Lark Quarry Conservation Park, 698
Larsemann Hills, 525, 542
Launceston, particulate pollution, 129, 140, 146, 160
lead, 67, 124t, 127, 132, 154–5
Leeuwin Current, 381
legislation
Antarctica, 540–1
heritage management, 748–53
inland water environments, 197
leopard coral trout (Plectropomus leopardus), 422
life expectancy, 52
light rail, 812
lime in agricultural systems, 287–8
Line of Lode mine, 754
liquid hydrocarbon, 383
liquid natural gas, 254
listed marine species, 435–6
livability of built environment, 805–16, 821
livestock grazing see grazing
livestock production, 631–3, 641, 666
Living Coast Strategy for South Australia, 872
Living Murray icon sites, 216, 855
living standards, 57
lobster fisheries, 428, 878
local government climate change policies, 106
local heritage, 699, 709–11, 719
Lockhart River, 229
M

Macarthur River, 390, 405
mackerel icefish (*Champsocephalus gunnari*), 502, 532
Macquarie Harbour, 414
Macquarie Island, 467, 472, 497, 499, 522–4, 526
management of, 541
Macquarie Island Pest Eradication Project, 500
Macquarie Marshes, 216, 217
macroinvertebrates, 214
Madrid Protocol, 467, 474, 509, 511, 520, 522, 541, 551
Magamarra sacred site, 772
major vegetation groups, 584, 587–9
mammals, 615
levels of endemism, 582
threatened status, 600–6
*Managing acid and metalliferous drainage*, 858
*Managing our coastal zone in a changing climate: the time to act is now*, 845, 870, 873
Mandurah, 430
mangrove swamps, 861
manufacturing
energy use, 817
water use, 198t, 818
maps
Australian Antarctic Territory, 475, 476
Australian National Heritage sites, 706
Australian World Heritage sites, 705
bioregion priorities, 714
cane toad distribution, 232
carp distribution, 233
connectivity corridors, 358
drainage divisions, 195
dust storm index, 298–300
endemism, 582–3
fire frequency, 322
fire regimes, 323
fisheries catch levels, 386
forest cover change, 2002–06, 324
forest cover change, post-2006, 325
freshwater fish, 221
frogs, 220
gemoorphology of seabed, 380
grazing impacts, 332–3
habitat fragmentation, 630
jurisdiction zones for Australia’s marine environment, 379
land use, 273
local heritage sites, 710, 711
marine environment reporting regions, 389
megadiverse countries, 574
National Reserve System, 712, 713
native vegetation extent, 859
native vegetation loss, 311
native vegetation, pre-1750, 308
native vegetation, present, 309
nitrogen levels in fresh water, 209
ocean currents, 381
oil and gas facilities, 384
pH (acidity) of fresh water, 208
phosphorus levels in fresh water, 210
population density, 804
population distribution, 55
population growth, 866
pressures on threatened species, 621, 637
projected vegetation extent in 2070, 320
protection status of wetlands, 197
rainfall, 78–81, 227
rainfall projections, 51
rivers and water bodies, 196
salinity of fresh water, 207
sea ice duration, 487
sea level rise, 853
soil acidification, 289
soil carbon, 281
soil erosion, 301
soil types, 276
temperature projections, 50
temperatures, 76–7
threatened birds, 608
threatened mammals, 604–5
threatened plants, 596–7
threatened species, 593, 863
turbidity of freshwater, 206
VAST classification, 313
vegetation cover, 295
vegetation types, 306
weeds, 234–5
Western Australia river health, 218
marbled rock cod (*Notothenia rossii*), 502
marine debris, 430, 432, 449
marine environment
biodiversity, 382–3, 388–403, 613, 616
ecosystem health, 388, 404–13
fisheries, 383–6, 417–22
jurisdiction zones, 377–9
key findings, 372–3
management, 373, 377–9, 434–49
ocean currents, 381–2
oil and gas industry, 383, 423–4
outlook, 458–9
pollution, 624
pressures, 4, 414–33, 493–5, 528–33, 617, 638, 675, 851
resilience, 451–3
risks, 455–7
seabed geomorphology, 380–1
summary, 12–13
Marine Environment Protection Committee, 541
marine microorganisms, 493–5
Marine Plain, 524
marine protected areas, 439–41
marine species, 395–400, 413, 422, 423
marine trophic index, 421
market failure, environmental information, 343–5
marsh club-rush (Bolboschoenus spp.), 216
Mary River, 228
Mary River Statement, 240
Mawson's Huts, 522, 523, 526
Mawson's Huts Historic Site, 522, 523
Mawson, Sir Douglas, 475
Mawson Station, 522, 526
McDonald Islands, 522, 524, 526, 541
meat production, 631–3
megadiverse countries, 574
melanoma, 117, 120, 122
Melbourne
  air quality, 136–7
town planning, 813
water quality, 814
water supply, 229
Melbourne eddy, 128
Melville Bay, 390
methane, 84–90, 143–4, 169
microbiotic communities, 497
microorganisms, marine, 493–5
micropollutants, 624, 675
migration rates, 53
millennium drought see droughts
Millennium Ecosystem report, 52
*Mimosa pigra*, 234
mining
  pressures on biodiversity, 630–1
  pressures on land, 274, 317, 336, 339, 353
  water consumption, 198t
mining and industry, 433, 448–9
modelling, 644
Moe air quality, 139
monitoring, 893–4
  Antarctic environment, 474, 476, 477
  biodiversity, 644
  environmental information, 342–3, 345
  heritage management, 768, 770
  inland water environments, 188, 214, 243
  land use, 294, 324–5
Monitoring, Evaluation, Reporting and Improvement initiative, 343
Montara oil spill, 424
Montreal Protocol on Substances that Deplete the Ozone Layer, 86, 118, 120, 143–4, 150–2, 168, 174, 479
morbidity, 96
Morning Inlet river, 229
mortality, 52, 96
mosquitoes, 94, 113, 857, 878
*Motor Vehicle Standards Act 1989*, 150, 153
Mount Lofty Ranges, 203
Mount Perry Powder Magazine, 755
Mundaring Weir, 247
Murray–Darling Basin, 194, 226
  birds, 609
environmental watering, 872
freshwater fish, 611
groundwater, 251
land clearing, 629
land use, 275
rainfall, 81, 82
salinity, 207
water regulation, 225
Murray–Darling Basin Authority, 194
Murray–Darling Basin Plan, 194, 211, 239, 243
Murray–Darling drainage division
  climate change projections, 249
  ecological processes, 222
  environmental health, 209, 214–16, 256
  map, 195
  streamflow regimes, 202, 204
  surface water availability, 250
water quality, 212
water storage, 202
Murray Lower Darling Rivers Indigenous Nations, 240
Murrumbidgee River, 210, 247
myrtle rust (*Uredo rangelii*), 328, 633

N
National Action Plan for Salinity and Water Quality, 211, 277
National Adaptation Framework, 105
National Aquatic Weeds Management Group, 242
National Australian Built Environment Rating System, 769
National Biosecurity Committee, 659–60
National Climate Change Adaptation Research Facility, 99–100
National cooperative approach to integrated coastal zone management—framework and implementation plan, 872
National Environmental Biosecurity Response Agreement, 660
National Environmental Research Program, 436
National Environment Protection (Ambient Air Quality) Measure, 124, 126, 150, 152
National Environment Protection (Diesel Vehicle Emissions) Measure, 153
National Framework for Climate Change Science, 100
National Framework for Energy Efficiency, 831
National Framework for the Assessment of River and Wetland Health, 215
National Framework for the Management and Monitoring of Australia's Native Vegetation, 642
National Greenhouse and Energy Reporting Act 2007, 100
National Greenhouse Gas Inventory, 100
National Heritage List, 698, 707, 717, 743–4, 747, 791
National Indigenous Knowledge Centre Project, 734
National Indigenous Languages Survey, 723
National Introduced Marine Pest Information System, 409
National Land & Water Resources Audit, 277, 343, 584
National Plan for Environmental Information, 2, 345, 591, 643
National Representative System of Marine Protected Areas, 439–41
National Reserve System
biodiversity, 576, 583, 650–4
connectivity corridors, 357
heritage, 711–14, 719, 742, 748–9, 753, 771, 789
Indigenous land, 575
inland water environments, 196–7
National Sea Change Taskforce, 866, 872, 875
National Strategy for the Management of Coastal Acid Sulfate Soils, 858
National System for the Prevention and Management of Marine Pest Incursions, 425
National Urban Policy, 804, 828, 829
National Vegetation Information System, 584, 587
National Water Commission biennial assessment, 240–1
National Water Initiative, 188, 193, 238–9
National Water Knowledge and Research Plan, 241
National Water Market System, 238
National Water Quality Management Strategy, 239, 241, 858
National Weed Incursion Plan, 636
native vegetation, 270, 305–15, 586–9, 858–61
climate change impacts, 318, 319, 321
land clearing, 323–7
natural gas, 254, 383
natural heritage, 700, 704, 710–14, 719–21, 726
funding, 759–60
management, 750, 771, 773, 774–5
outlook, 789–91
pressures, 733–4, 739–40, 787
resilience, 780–3
Natural Heritage Trust, 642, 647, 655, 673, 760
natural resource management, 340–2, 647, 672–3
nature conservation reserves see conservation reserves
New South Wales
climate change policies, 104
heritage management, 717, 758, 771
marine legislation, 437–9
sea level rise, 880
New South Wales National Trust Heritage Awards, 759
Ngarrindjeri people, 855
Ningaloo Coast, 705
Ningaloo Reef, 390, 417
nitrogen dioxide, 67, 123t, 124t, 127, 132, 147, 158
unflued gas heaters, 150, 160, 163
nitrogen levels in fresh water, 209
nitrogen oxides, 156
nitrous oxide, 84–9, 143–4, 169
noise pollution, 815
non-native vegetation, 312
North Australian Indigenous Land and Sea Management Alliance, 240
North-East Bailey Peninsula, 524
North-east Coast drainage division
climate change projections, 250
ecological processes, 222
map, 195
river health, 217
streamflow regimes, 202, 203, 204
water quality, 211, 212
water storage, 202
northern Australia
climate change projections, 250
mammal extinctions, 605–6
water abstraction, 251
Northern Basin Aboriginal Nations, 240
northern quolls, 606, 637
Northern Rivers region, 429
Northern Territory
climate change policies, 104
heritage management, 772
sea level rise, 881
North Marine Region, 390, 395–6, 401, 405, 409
North-western Plateau drainage division
ecological processes, 222
map, 195
streamflow regimes, 202, 204
water quality, 212
water storage, 202
North-west Marine Region, 390, 395, 401, 404, 409
North West Shelf, 390
North West Shelf Flatback Turtle Conservation Program, 423
Nototothenia rossii (marbled rock cod), 502
NSW Coastal Protection Package, 871
NSW Sea Level Rise Policy Statement, 871
nutrients, soil, 334
nutrient status of marine waters, 382–3
O
ocean acidification, 110, 416–17
Southern Ocean, 466, 477, 491–2, 495, 527–30, 533, 550–1, 556
ocean circulation, 486–7
ocean currents, 381–2, 471, 490–1, 492
ocean salinity, 492
ocean temperatures see sea temperature rise
OECD environmental assessment, 241–2
Offshore Constitutional Settlement, 378, 427
oil and gas industry, 383, 423–4, 432, 445
oil supply, 674
Onslow, 390
operational indicators, Antarctica, 509–17
Ord River system, 202, 390
organic matter, 277, 334–5
organochlorines, 337
overcrowded housing, 807, 808
overfishing, 417–22, 452
oyster reef beds, 391
oysters, 409, 427, 429
control measures, 150–1
ozone hole, 119–22, 168, 466, 479–81, 483, 528, 555–6
ozone pollution, 123, 124t, 127, 129, 134–6, 139, 146–7, 169
Ozone Protection and Synthetic Greenhouse Gas Management Act 1989, 152

P
Pacific oyster (Crassostrea gigas), 409, 427
pack ice, 486, 488, 505
particulate pollution, 123t, 124t, 126t, 127, 814
extreme weather events, 67, 117, 147, 169
monitoring, 134–5, 137–8, 140–1
outlook, 174–5
planned burning, 146, 160, 162, 166
trends, 129–31
wood smoke, 146, 159–60, 169, 174
Paspalum distichum (water couch), 216
Patagonian toothfish (Dissostichus eleginoides), 502, 532
pathogens, 862
peak phosphorus, 334
pearl farming industry, 429
Peel–Harvey Estuary, 430
pelagic environment, Antarctica, 493–5
penguins, 504–5, 507, 548
perfluorocarbons, 86
peri-urban development, 630
Perkins, Charles, 699
Perth
air quality, 136–7
water supply, 228, 229, 251, 252
pesticides, 337
pests see invasive species
petrels, 507, 543–5
pH (acidity) of fresh water, 208
see also acidification
Phaeocystis antarctica (phytoplankton), 494
phosphorus fertilisers, 334
phosphorus levels in fresh water, 210
photochemical smog, 127, 128, 171
photosynthesis, 118
physical processes, marine environment, 404–7, 413
Phytophthora cinnamomi, 328, 634
phytoplankton, 410–11, 493–5
Pilbara Coastal Water Quality Project, 872
pilchards, 428
Pine Island Glacier, 484
Pioneer catchment, 215
Pioneer River, 431
planned burning, 146, 160, 162, 166
planning
biodiversity, 645–6
built environment, 800, 804, 827–33, 838
heritage management, 745–55
water management, 239–43
plantation forests see forestry
plant diseases, 327–8
plant endemicism, 582
plant species, 594–7, 614
pressures on biodiversity, 638–9
Plectropomus leopardus (leopard coral trout), 422
policies
built environment, 804, 827–9
climate change, 92, 98, 104–7
coastal environments, 870–5
energy efficiency, 45
heritage management, 748–53
Indigenous language, 724
waste management, 57
water management, 188, 189, 193–4, 239–42
pollens, 124
pollination, 591
pollutants, 122–41, 145–9
pollution
Antarctica, 519–21, 536
diffuse sources, 158–60, 165–6, 170
industrial sources, 154–6, 164–5, 170, 174
marine environment, 429–32, 447–8, 531
pressures on biodiversity, 624, 640, 662–3, 675
rivers and estuaries, 854
vehicle emissions, 143, 145–6, 156–8, 165, 169, 170, 174–5
see also air quality; indoor air quality; particulate pollution; water quality
pollution control, 73
polycyclic aromatic hydrocarbons, 133
denmar, 491
pond apple (Annona glabra), 234
population density, 803–6
population distribution, 803
population growth, 804, 823, 834, 838
driver of pressures, 43, 45, 46, 52–5, 555
pressures on biodiversity, 617, 627, 642
pressures on coasts, 844–5, 849, 851, 866–9
pressures on heritage, 729–31, 738, 788–9
pressures on land, 317
and water consumption, 189, 228, 251, 256
Porongurup National Park, 700
Port Hedland, 390
Port Phillip Bay, 410
Port Pirie air quality, 132, 140
ports, 425, 432, 445
Posidonia spp. (seagrasses), 390, 391
pressure interactions, 638–9, 675
Priority Assessment List, 748
private vehicle use, 809, 812
productivity, marine environment, 382–3
Proserpine River, 431
Protocol on Environmental Protection to the Antarctic Treaty (Madrid Protocol), 467, 474, 509, 511, 520, 522, 541, 551
Prydz Bay, 486
public transport, 811–12, 831
Purnululu World Heritage site, 705

Q
Queensland
climate change policies, 104
coastal resilience, 884
floods, 431
Healthy Waterways partnership, 243, 436, 871, 883
heritage management, 698, 716, 717, 755, 762
river health, 217
sea level rise, 881
water supply, 229
Queensland Heritage Strategy, 747
Queensland water quality guidelines, 206
quolls, 606, 637

R
rabbits, 331, 500, 637
radiative forcing, 84, 86
rainbow trout, 233
rainfall, 78–82, 227
rainfall patterns, 50, 51f, 93, 112–13
pressures on heritage, 729, 738
Rainforest Aboriginal people, 732
Ramsar Convention on Wetlands of International Importance, 195, 855, 872
recreational boating, 433
recreational fishing, 386–7, 446
recycled water, 229
Recycle Right at Work, 832
recycling, 57–8, 59t, 819–20, 832
red-eared slider turtles, 232
redfin butterflyfish (Chaetodon lunulatus), 422
redfin perch, 233
reductionist science, 575
Reef Water Quality Protection Plan, 436
reference condition, 201
reforestation, 247
Register of the National Estate, 698, 708, 721, 753
regrowth, 270, 317, 325, 326f, 327f
regulated river systems, 225
regulations, heritage, 753
regulatory processes, built environment, 829
renewable energy
Antarctica, 512–13
and heritage management, 755
Renewable Energy Target, 92, 98, 102
reproductive success, 579
reptiles, 610–11, 615
levels of endemism, 583
threatened status, 600–1
research and development, investment, 342
research, Antarctic environment, 540
research stations, Antarctica, 508–21, 551
resilience
Antarctica, 548–9
Australia’s atmosphere, 168
Australia’s climate, 110
biodiversity, 645, 655, 668–73
built environment, 834
coastal environments, 883
environment and society, 110–11
heritage, 780–3
inland water environments, 188, 247–8
land environment, 355–8
marine environment, 451–3
soil carbon, 278–9
resource consumption, 45, 57
built environment, 800, 824, 826, 834, 838
pressures on biodiversity, 624–7, 640, 663–4
resource demands, 589
resource efficiency, 807
Resource Efficiency Assistance Program, 832
resource extraction, 731–2, 739
Resources Assessment Commission Coastal Zone Inquiry, 435
reuse water, 199
risks
Antarctica, 550–3
Australia’s atmosphere, 169–73
Australia’s climate, 112–13
biodiversity, 643–5, 659–60, 674–8
built environment, 835–7
coastal environments, 877–81
heritage, 784–5
inland water environments, 249–55
land environment, 359–61
marine environment, 455–7
river cooba (Acacia salicina), 216
river flood plumes, 431
river red gum (Eucalyptus camaldulensis), 216
rivers, 195–7, 854
rock art, 746
Roebuck Bay, 390
Rookery Islands, 524
Ross Sea, 485, 486
Rotten Row, 718
Rottnest Island, 417, 442
Rubus fruticosus (blackberry), 234
ruby snapper, 419
ruins, 754–5

S
salinity
dryland salinity, 277, 327, 342
inland water environments, 207–8, 211, 247
of oceans, 492
Salix spp. (willow), 234
salmon, 428
salt interception schemes, 207
Salvinia molesta, 234
Scientific assessment of ozone depletion, 118, 120, 168
Scientific Committee on Antarctic Research, 478, 548, 555
Scott Reef, 417
Scullin and Murray Monoliths, 525
seabed geomorphology, 380–1
seabirds, 504–7, 543–5
sea-change phenomenon, 731, 866–8
seafood production, 383–6
seagrasses (Posidonia spp.), 390, 391
sea ice
  extent, 466, 471, 485–8, 505, 530, 555–6
  formation, 491
  seasonality, 488
  thickness, 531
sea level rise, 94, 111, 825, 826, 835–6
  Antarctica, 485, 492
  coasts, 852–3, 857, 877–81
  pressures on heritage, 729, 738
sealing industry historic sites, 523
sea lions, 395
seals, 503, 506, 541, 548
sea temperature rise, 77, 110, 415–16, 491–2, 530, 852, 862
sea urchin (Centrostephanus spp.), 861
seawater intrusion of groundwater, 854
Securing a Clean Energy Future plan, 84, 92, 97, 98, 102, 114, 115, 342, 647
Securing Our Water Future Together, 243
seed harvesting, 624
Seneca, Lucius, 73
Settlement River, 229
Shark Bay, 390
shipping, 425, 432, 446, 541
shipwrecks, 698, 752
shorebirds, 216, 854–5
skills shortage, heritage management, 764
skin cancer, 117, 120, 122
Snowy Mountains Scheme, 242
Snowy River, 242
social–ecological systems, 655, 668–73
social resilience to climate change, 110–11
soil acidification, 270, 287–93, 356
soil biodiversity, 591
soil carbon, 270, 277–86, 326–7, 356
soil compaction, 335
soil contamination, 337
soil data, 344f
soil degradation, 275
soil erosion, 270, 294–304, 331, 356, 622
  Antarctica, 536
  pressures on heritage, 734, 740
soil formation, 294
soil condition, 277–86
soil nutrients, 334
soils, 262, 267–8, 274–304, 675
  Antarctica, 498
  pressures, 4, 326–7
soils baseline, 275
soil types, 275–7
solar insolation, 87
South Australia
  climate change policies, 104
  heritage management, 718, 722–3, 744, 745
  sea level rise, 881
  waste management, 832
South Australian Gulf drainage division
  ecological processes, 222
  map, 195
  river health, 217
  streamflow regimes, 203, 204
  water quality, 210, 212
  water storage, 202
South-east Coast drainage division
  ecological processes, 222
  map, 195
  river health, 216
  streamflow regimes, 203, 204
  water quality, 210, 212
  water storage, 202
South Eastern Australian Climate Initiative, 82
South-east Marine Region, 391, 397, 401, 405, 409–10
South East Queensland Healthy Waterways partnership, 243, 436, 871, 883
South East Queensland Healthy Waterways Strategy, 871
South-east Tiger Flathead Fishery, 420–1
  southern annular mode, 82, 479, 555
  southern bluefin tuna, 388, 613
Southern Ocean, 490–2
  acidification, 466, 477, 491–2, 495, 527–30, 533, 550–1, 556
  atmospheric driver, 471
  temperature rise, 466
Southern Ocean Continuous Plankton Survey, 495
South West Aboriginal Land and Sea Council, 240
South-west Coast drainage division
  climate change projections, 251
  ecological processes, 222
  environmental health, 256
  land use, 252
  map, 195
  streamflow regimes, 202, 205
  water abstraction, 252
  water quality, 211, 212
  water storage, 202
South-western Plateau drainage division
  ecological processes, 223
  map, 195
  streamflow regimes, 205
  water quality, 212
  water storage, 202
South-west Marine Region, 390, 395, 401, 404, 409
Special report on emissions scenarios, 86
species diversity, 574, 579, 581–3, 592–616
Antarctica, 472, 493–9, 497, 502, 556
species, marine, 395–400, 413, 422, 423
species richness, 452, 582–3, 621
specified resilience, 670–2
spike rush (Eleocharis obicis), 216
Staaten River, 229
stakeholder engagement, 673
standard of living, 57
state and territory heritage, 699, 708–9, 717–18
state government climate change policies, 104–5, 107
State of Australian cities 2010, 829
State of Indigenous cultural heritage report 2011, 721
State of the climate, 92–3, 114
State of the environment report (Victoria), 45
State of the environment report: Western Australia 2007, 243
State Plan 2006, 437
Statewide river water quality assessment for Western Australia, 211
statutes, heritage, 753
Stewart River, 229
Stockholm Convention on Persistent Organic Pollutants, 133, 519
Storm Bay, 410–11
stratospheric ozone, 67, 117–22, 174, 466, 483
management, 150–2, 164
pressures, 144, 148–9
resilience, 168
risks, 169
Stream and Estuary Assessment Program, 217
streamflow regimes, 202–5
subsistence fishing, 386–7
Sugarloaf Pipeline, 229
sulfate aerosols, 87
sulfur dioxide, 67, 1241, 127, 132, 154–5
sulfur hexafluoride, 86
sulfur levels in fuel, 153
surface water resources, 194–200
Sustainable Cities Index, 816
Sustainable Cities Initiative, 872
sustainable development, heritage management, 768, 769, 792
Sustainable development panel report, 251
Sustainable Rivers Audit, 216
Sydney air quality, 136
Sydney Opera House, 705, 729
Sydney rock oyster, 427
Tamarix aphylla (athel pine), 234, 242
Tasmania
climatic change policies, 105
fisheries, 419
heritage management, 718, 736, 755, 770
planned burning, 162
river health, 217
sea level rise, 881
water abstraction, 252
water supply, 229
Tasmania drainage division
climate change projections, 250
ecological processes, 223
map, 195
streamflow regimes, 203, 205
water quality, 211, 213
water storage, 202
Tasmanian Climate Change and Coastal Risk Assessment Project, 872
Tasmanian Heritage Register, 752
Taylor Rookery, 524
temperature rise, 66, 74, 76–7, 82, 86–7, 93, 112–14
Antarctica, 478–9, 482, 485, 527
heatwaves, 96
pressures on heritage, 728–9, 738
projections, 48, 50f
Terrestrial Ecosystem Research Network, 345, 581
terrestrial ecosystems
Antarctica, 495–501, 535–7
biodiversity, 584–91
Teviot Brook, 229
Thala Valley tip, Antarctica, 520
Tharwa Bridge, 783
The critical decade: climate science, risks and responses, 47
The Nature Conservancy, 768
The state of Australia’s birds, 608–9
threat abatement plans, 435
threatened ecological communities, 589
threatened species
adequacy of protection, 651–4
albatrosses, 543
coasts, 862, 863
inland water environments, 220–1
marine environment, 395–400
pressures, 619–21, 636–7
threatened species lists, 592–4
whales, 502–3
threatening processes, 328, 631, 633
tiger flathead, 420–1
tilapia, 232
tillage, 263, 294, 317, 334–5
Timor Sea drainage division
climate change projections, 250
ecological processes, 223
map, 195
streamflow regimes, 202, 205
water quality, 213
water storage, 202
Tjilbruke dreaming trails, 722–3, 864
tobacco smoke, 147, 150, 160
toluene, 133
Torres Strait, sea level rise, 111
tourism, 733, 739, 749, 869
Antarctica, 527
marine environment, 386–7, 433, 448, 453
traditional cultural practices, 701, 735, 740
traditional knowledge, 721, 734–5, 740
traffic congestion, 809–13, 823–4, 826, 831, 834, 835, 838
training courses, heritage management, 763
transport, 809–13
Traveston Crossing, 228
Tree of Knowledge, 717
tropospheric ozone, 84
tooth, 233, 422, 428
Tuggerah Lakes, 429–30, 872
Tugun Desalination Plant, 229
tuna, 388
turbidity, 206–7
turtles, 232, 423
Tweed River, 391
Typha spp. (cumbungi), 216
ultraviolet radiation, 117, 121–2, 151, 528, 530
underwater cultural heritage, 751
unflued gas heaters, 150, 160, 163
United Nations Convention on Biological Diversity, 748
United Nations Declaration on the Rights of Indigenous Peoples, 748
urban amenity, 806, 815–16
urban environmental efficiency, 816–21
urban footprint, 823, 826, 834, 835
see also ecological footprint
urbanisation, 54
coastal environments, 857–61, 866–9
inland water environments, 231
pressures on biodiversity, 629–30
pressures on heritage, 788
pressures on land, 317, 336, 338, 353
urban water consumption, 198–200, 251
urban water supply, 831, 836
Uredo rangelii (myrtle rust), 328, 633
vegetation, 268, 305–15, 356–8, 851
Antarctica, 497–501
Vegetation Assets, States and Transitions framework, 310, 312–14
vegetation communities, 586–9
vegetation type (definition), 584
vehicle emissions, 143, 145–6, 156–8, 165, 169, 170, 174–5
vehicle emission standards, 68, 132, 150, 153
vehicle fuel use, Antarctica, 514–15, 516
Victoria
climate change policies, 105
heritage management, 718, 766, 767
Indigenous heritage, 715
sea level rise, 881
Victorian Coastal Spaces project, 871
Victorian Coastal Strategy, 871
viruses, 428, 862
volatile organic compounds, 132, 170
volunteers, heritage sector, 763, 765–6
W
Wagga Wagga air quality, 140
walking for transport, 812
Waste and recycling in Australia, 818
waste management
Antarctic research stations, 510–11, 516, 519–21
built environment, 818–20, 824, 832
and economic growth, 57–9
land environment, 337, 338, 354
waste sector, 90–1
water abstraction, 198, 251–2
pressures on coasts, 854–5
water accounts, 194
Water Act 2007, 194
waterbirds, 216, 217, 219, 388, 611–12, 854–5
water bodies, map, 196
water buybacks, 243
water consumption, 198–9, 627
water couch (Paspalum distichum), 216
water erosion of soil, 294–5, 622
Water Forever strategic plan, 252
Water for the Future, 194, 243
Water Information Research and Development Alliance, 194
water infrastructure, 228–9
water markets, 189, 238
water policy reforms, 188, 189, 193–4, 239–42
water prices, 189, 199
water quality
built environment, 814
and bushfires, 231
in catchments, 188
estuaries, 429–30
inland water environments, 206–13, 256
management, 244–5
marine environment, 436
National Water Quality Management Strategy, 239, 241
water resource development, 228–31, 236, 244
water security, 3, 94, 238
Water Services Association of Australia report card 2009–2010, 228
water shortages, 188
water storage, 202, 226
water supply, 831, 836
water use, 58
built environment, 817–18, 824
households, 60
water vapour, 84, 144
water yields, 203
weathered landscapes, 355
weather patterns, 75, 82, 93, 112–13
  Antarctica, 477–83, 527, 535
built environment, 824, 826, 834, 835
climate change impacts, 94, 96
pressures on heritage, 729, 738
Weddell Sea, 486, 491
weeds
  aquatic weeds, 234–5, 242
Australian Weeds Strategy, 642
inland water environments, 237, 246, 254, 256
terrestrial weeds, 234, 318, 328–30, 631, 633, 636, 771, 861
Weeds of National Significance, 234, 328–9
Wenlock Basin, 229
West Antarctica, 527
West Antarctic Ice Sheet, 484–5
Western Australia
  climate change policies, 105
  heritage management, 700, 718, 719, 737, 753
marine environmental management, 443
marine legislation, 437
river health, 217, 218
sea level rise, 881
Western Deepwater Trawl Fishery, 419
Western Rock Lobster Fishery, 428, 878
West Mackay air quality, 140
wetlands, 195–7, 216, 217, 219
Wet Tropics World Heritage Area, 732
‘whale highway’, 382, 424
whales, 502–3, 506, 541, 548
whale shark, 613
wildlife reserves, 637
  see also National Reserve System
wildlife trade, 625
Wild Rivers Act 2005 (Qld), 229
Wilko Station, 522
Wilkins review, 105
willow (Salix spp.), 234
wind erosion of soil, 270, 295–6, 331
wind turbines, 512–13
wood smoke pollution, 129–30, 146, 159–60
Woodstock Abydos Protected Area, 737
Working on Country program, 341
World Heritage Convention, 697–8, 705, 716
World Heritage List, 697–8, 743
World Heritage listings, 522
World Heritage sites, 705, 716–17, 754
Wunambal Gaambera Healthy Country Plan 2010–2020, 701
Wungong catchment, 252
WWF-Australia biodiversity assessment, 651–3, 714
Wyaralong Dam, 229

X
  xylene, 133

Y
  Yanga National Park floodplain, 247
  Yarragadee Aquifer, 228
  Yongala shipwreck site, 752
  Yuraygir National Park, 771

Z
  Zero Waste SA, 832
  zooplankton, 493, 495