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Case study: the resilience of the nature-based tourism system on Australia's Great Barrier Reef

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Cover image

Diving on the Great Barrier Reef, QLD
Photo by Paradise Ink & DSEWPaC

Preface

This report was commissioned by the Department of Sustainability, Environment, Water, Population and Communities to help inform the Australia State of the Environment (SoE) 2011 report. As part of ensuring its scientific credibility, this report has been independently peer reviewed.

The Minister for Environment is required, under the *Environment Protection and Biodiversity Conservation Act 1999*, to table a report in Parliament every five years on the State of the Environment.

The Australia State of the Environment (SoE) 2011 report is a substantive, hardcopy report compiled by an independent committee appointed by the Minister for Environment. The report is an assessment of the current condition of the Australian environment, the pressures on it and the drivers of those pressures. It details management initiatives in place to address environmental concerns and the effectiveness of those initiatives.

The main purpose of SoE 2011 is to provide relevant and useful information on environmental issues to the public and decision-makers, in order to raise awareness and support more informed environmental management decisions that lead to more sustainable use and effective conservation of environmental assets.

The 2011 SoE report, commissioned technical reports and other supplementary products are available online at www.environment.gov.au/soe

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Executive Summary

The Great Barrier Reef (GBR) is one of Australia's most spectacular natural assets and is an area of global significance for marine biodiversity. Tourism to the GBR contributes nearly $5 Billion to the Australian economy per annum. Tourists from all over the world, who travel to the GBR to experience and enjoy its magnificent coral reefs are the key drivers of this nature-based tourism system.

The GBR is however under threat from climate change and the sediments, nutrients, and pesticides from agriculture and coastal development. In addition, climate change may result in an increase in flooding, more intense tropical cyclones, and more damaging storm surges, all of which affect the coastal infrastructure tourism relies on. However, reef tourism on the GBR is not only affected by the health of coral reefs and damage to coastal infrastructure, it is also impacted by a range of national and international socio-economic and political drivers. Therefore, there is concern over the future of reef tourism on the GBR.

As the reefs of the GBR lie 20km or more from the coast, the reef tourism enterprises that take visitors on boats to visit and enjoy reefs are key players in tourism on the GBR. This case study shows that the lifestyle values of enterprise owners and staff, and enterprises' human capital are statistically significant predictors of enterprise resilience to crises and change. Higher lifestyle values are also associated with a higher level of enterprise support for reef conservation, and a greater level of participation in reef conservation activities.

Enhancing the resilience of the GBR's nature-based tourism system therefore requires the consideration of a wide range of factors and the involvement of a broad group of stakeholders. A process in which stakeholders collectively envision and agree to work towards a resilient future for reef tourism in the face of alternative plausible scenarios is a sound way to strengthen the resilience of the GBR's iconic reef tourism system.

1. Introduction

The Great Barrier Reef (GBR) is one of Australia's greatest natural assets. The GBR is the world's premier reef tourism destination (Seven Natural Wonders 2008) and is also an area of global significance for marine biodiversity (McCook et al. 2010). The GBR is made up of 2900 individual reefs, approximately 900 islands, and extends for more than 2300km. The Great Barrier Reef Marine Park (GBRMP) was created in 1975 to conserve the reef ecosystem and is 344 400 km^2 in extent. The GBRMP extends from just north of Bundaberg to the tip of Cape York in Queensland (Figure 1). The GBR was declared a World Heritage Area in 1981 in recognition of its outstanding universal value (GBRMPA 1981).

The economic contribution of the GBR to adjacent communities, the state of Queensland, and to Australia is substantial. The most in-depth assessment of the economic contribution of tourism and other commercial activities in the GBRMP is by Access Economics. The most recent report was for the 2006-2007 financial year (Access Economics 2008). According to this report there are approximately 1.9 million visits to the reefs on the GBR each year. The GBRMP contributes $5.4 Billion to the Australian economy per annum and sustains 54 000 jobs. Over 90% of this economic activity and employment is in the tourism sector. The GBR's tourism sector sustains 37 000 full time positions within the Great Barrier Reef catchment (Access Economics 2008).

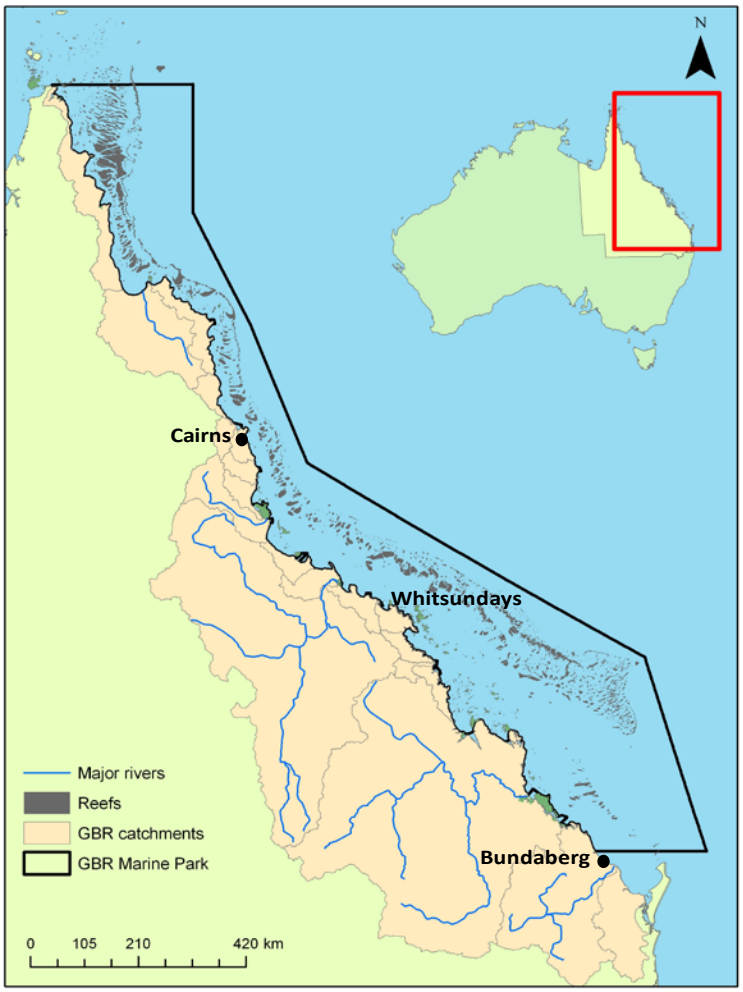


Figure 1. Map of the Great Barrier Reef Marine Park. The Cairns and Whitsundays regions attract 88% of all visitors.

However, the GBR, like many marine ecosystems around the world is under serious threat from a range of human activities. Climate change, and the resultant coral bleaching and ocean acidification is the foremost of these threats (McCook et al. 2010, Hughes et al. 2003). Coral bleaching occurs when corals lose their symbiotic zooxanthellae due to thermal or other stress. The impacts from climate change are exacerbated by the interacting effects of fishing pressure and added nutrients from land-based activities such as farming (Hughes et al. 2010). Therefore, there is concern over the continued impact of reef degradation and how this may impact on reef tourism (Coghlan and Prideaux 2009, Kragt et al. 2009). For example, Kragt et al. (2009) show that reef trips by divers and snorkellers could decline by up to 80 per cent in response to a hypothetical decrease in coral and fish biodiversity. This corresponds to a reduction in

tourism expenditure by divers and snorkellers on full-day reef trips in the Cairns area of about $103 million per year.

The health of the GBR's reef tourism sector is however not only dependent on the condition of coral reefs. A range of socio-political, economic, international security and health concerns, as well as local level issues such as the regulatory environment (Biggs 2011a, Hall 2010) also affect reef tourism. For example, outbound travel from the USA declined sharply following the attacks on the World Trade Centre and the Pentagon in September 2001 (Hall et al. 2003). The number of international travellers to Australia decreased by 12% in the December quarter of 2001 as a result of the September 11 attacks (Dwyer et al. 2006).

Resilience is a useful concept to understand reef tourism on the GBR because it acknowledges the socio-economic and ecological complexities that determine system outcomes. This case study explores the resilience of nature-based tourism on Australia's GBR. A resilient nature-based tourism system on the GBR is defined as a system that is able to uphold its identity as a region with a healthy and diverse reef system that maintains or grows an extensive coral reef tourism industry through crises and change. Identity is defined in the Oxford dictionary as, 'the quality or condition of being the same in substance, composition, nature, properties, or in particular qualities under consideration'. The Oxford dictionary definition aligns with the definition of resilience scientists, for e.g. Cumming et al. (2005) define identity as, 'the property of key components and relationships and their continuity through space and time'. The definition of a resilient nature-based tourism system used in this case study aligns with more widely accepted definitions of resilience that emphasise the ability of a system to adapt to change, whilst maintaining their key characteristics and identity in the face of disturbances (Gunderson and Holling 2002, Cumming et al. 2005).

2. Overview of the Great Barrier Reef's nature-based tourism system

A number of socio-economic and environmental drivers, from the local to the global scale affect the resilience of the reef tourism system on the GBR (Figure 2).

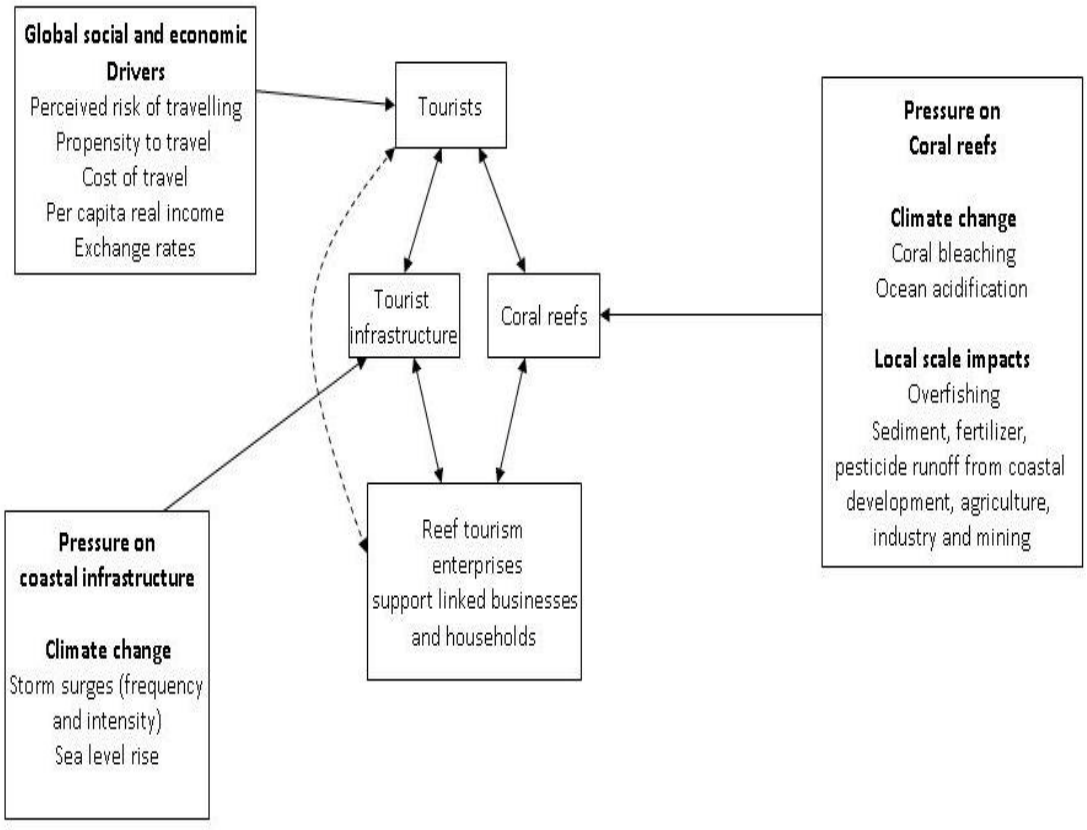


Figure 2. Conceptual diagram of the complexity of linkages and relationships within the nature-based tourism system on the Great Barrier Reef that will be explored in this report. Tourists, tourist infrastructure, and reef tourism enterprises are central to the reef-based tourism system.

Coral reefs and the associated marine life and reef tourism enterprises that give tourists access to reefs enable the existence of linked businesses that include tourist accommodation and restaurants. Pressures on coastal infrastructure and on coral reefs impact on the reef-based tourism system. There is also a direct link between tourists and reef tourism enterprises represented through marketing and web-based client contact. Reef-based tourism enterprises therefore mediate the perception and interaction of tourists with coral reefs and to some extent with tourist infrastructure. Tourist demand and the reef-based tourism system also depends on global social and economic drivers.

The coral reefs of the GBR are the natural attraction at the centre of the reef-based tourism system. The coral reefs of the GBR are under threat from a range of local, regional and global scale factors (Figure 2). At the local level and regional level land-based impacts from the run-off of agricultural, industrial, and urban pollutants from coastal development, negatively affect reefs (Haynes et al. 2007). In addition, climate change, a global scale phenomenon, also affects reefs deleteriously as a result of coral bleaching due to high water temperatures, and ocean acidification (McCook et al 2010). Although the GBR does not suffer from the same levels of over-fishing as on coral reefs in other countries, some aspects of fishing still exacerbate and interact with impacts of pollutants and climate change. These impacts are detailed in section 3.

The international, inter-state, and intra-state tourists that take trips to visit and enjoy the GBRMP are the consumers of the services and products that the tourism system provides (Figure 2). This case study focuses on tourists defined as people who access the GBRMP as part of a commercial tour operation, as opposed to independent recreational users who access the GBRMP with a private vessel or directly off the beach (GBRMPA 2011). Throughout this report, the words tourist and visitor are used synonymously. Over 70% of visitors indicate that a trip to experience the reefs of the GBR is a primary reason for their visit to the region (Saltzer 2002, Coghlan and Prideaux 2009, Mcnamara and Prideaux 2009). Results from surveys of tourists on live-aboard dive boats suggests that sightings of sharks, rays, large fish, turtles, and a wide variety of wildlife are the natural attractions that are the most valued (Stoeckl et al. 2010). Since 1994, an average of 88% of tourists who visit the Great Barrier Reef do so in the Whitsundays and Cairns regions (GBRMPA 2009a, Figure 1).

International visitors represent around 60% of the tourists that visit the GBRMP. Inter-state visitors represent a further 26% of the tourists who take a trip out to experience the GBRMP. The average length of stay is seven nights in the Cairns region (McNamara and Prideaux 2009) and 4.5 in the Whitsundays region (Tourism Queensland 2011). During the course of their stay, visitors spend money on accommodation, food, shopping and other services. Average expenditure per international visitor is $1300 in the Cairns region, and $600 in the Whitsundays that serves the youth and backpacker market to a greater extent (Tourism Queensland 2011). This expenditure ultimately supports the individuals and households that directly provide services to tourists (e.g. hotels and restaurants), or support reef tourism enterprises and other tourist businesses (e.g. wholesalers and suppliers).

The visitors to the GBR region depend on infrastructure that enables their visitation. The infrastructure includes roads, airports, marinas, accommodation facilities, and the infrastructure for the provision of essential services such as water and electricity. This infrastructure is primarily coastal and is potentially at risk due to sea level rise and

increasing storm surges as a result of climate change (CSIRO 2007). The threat that the risk to coastal infrastructure from climate change poses to the GBRs reef tourism system is discussed in more detail in section 4.

The reef tourism enterprises, that operate with well-equipped boats to visit offshore reefs, are key to the functioning of the GBR's tourism system as they enable visitors to access and enjoy reefs. As of April 2009, there were 958 active permits for conducting tourism operations in the GBRMP (GBRMPA 2009b). However, 50 enterprises are responsible for almost three-quarters of the tourist visitor days. Enterprises varied from one to 500 employees in size (mean = 32.7) and less than one year old to 35 years in age (mean = 13.2). Because of their key role in the GBR's nature-based tourism system, the resilience of reef tourism enterprises is the focus of section 5 of this case study.

Reef tourism has a small and concentrated impact on the health of the coral reefs on the GBR (GBRMPA 2009b). Visiting and exploring coral reefs can result in damage to the coral substrate through anchoring, snorkeling and diving. However, the severity of these impacts is much reduced through reef protection infrastructure (such as moorings and markers) and the adoption of best tourism practices (GBRMPA 2009b). Moreover, reef tourism enterprises also play an active role in the conservation of the GBR and in raising awareness among the broader public. The relationship between the resilience of reef tourism enterprises and their contribution to reef conservation is discussed in more detail in section 5.

3. Impacts on the Great Barrier Reef

The four primary threats to the GBR are: runoff from catchments that stem primarily from agriculture and coastal development, climate change, and interactive effects with certain fishing impacts (GBRMPA 2009b). Run-off that contains increased concentration of sediment, nutrients, and pesticides from land-based human activities has a significant influence on water quality and on the ecological health of GBR (De'ath and Fabircius 2010). Haynes and others (2007) compiled a detailed review of pollutants, water quality and ecosystem health on the GBR. This section of the case study draws from this review and the summary on the effects of coastal development and fishing in GBRMPA's 2009 Outlook Report (GBRMPA 2009b).

3.1. Run-off from catchments

3.1.1. Sources of pollutants from catchments

Agriculture

Evidence from the relatively undisturbed catchments of far-northern Cape York shows that the exports of sediments and nutrients from more southern catchments has increased dramatically since the 1850s (Furnas 2003, cited in Haynes et al. 2007). The degradation of inshore reefs has been linked to increased pollutants in terrestrial run-off between Port Douglas and the Whitsundays. In addition, research suggests that mass mortality of corals on inshore and outer shelf reefs on the central GBR from crown of thorns starfish (*Acanthaster planci*) outbreaks are a result of increased terrestrial nutrient run-off (Brodie et al. 2005).

The coastal region adjoining the GBR is divided into 40 river catchments that drain directly into the reef lagoon (Gilbert and Brodie 2001). Human activities in these catchments is the main reason for altered water quality that is ultimately transmitted to the GBR. Extensive land clearing has occurred in the GBR catchments during the last 200 years and approximately 80% of the land area of the catchments that drain into the GBR lagoon support a form of agricultural production (Gilbert and Brodie 2001). Grazing of beef cattle is the dominant form of agricultural production and has resulted in the large scale clearing of forests and woodlands for conversion to pasture. Intensive cropping, mainly of sugarcane, but also horticulture and cotton, are significant industries between Bundaberg and Port Douglas.

Coastal development

In addition to agricultural activities, coastal development that includes mining and industry, and urban infrastructure and port development are also a source of pollutants (GBRMPA 2009b). The rates of population growth in the GBR catchment exceed the Australian average and the human population in the GBR catchment is projected to increase by 40% by 2026 (Office of Economic and Statistical Research 2008, GBRMPA 2009b). Furthermore, during the 20th century there was extensive expansion of ports and shipping activity in the GBR (GBRMPA 2009b). There are proposals for significant expansion of seven of the ten major trading ports on the GBR. Population growth and urban development in coastal areas requires the development of infrastructure such as roads, water, sewage and power. If poorly planned and implemented, these constructions can further degrade the coastal environment and reduce the quality of water flowing into the GBR lagoon (GBRMPA 2009b).

Both urban expansion and agriculture, have resulted in loss of substantial areas of coastal wetlands and adjacent dune systems in particular in the past 50 years (Haynes et al. 2007, GBRMPA 2009b). This has led to the loss of feeding and breeding habitats for marine species and had significant ramifications for water quality due to loss of the wetland mechanisms of nutrient removal, sediment and pollutant, retention, and the disruption of the groundwater discharge and recharge (Lukacs 1998, cited in Haynes et al. 2007, GBRMPA 2009b). In addition, dams, weirs, and drainage infrastructure have altered the timing and extent of major flows and restricted connectivity between marine and freshwater habitats (GBRPMPA 2009b). What is more, urban runoff contains litter that is transported to the ocean. Litter in the ocean may be ingested by seabirds, marine turtles or other wildlife or cause entanglement (GBRMPA 2009b). Ingestion of litter may interfere with feeding, lead to poisoning, negatively affect breeding, and may result in death.

Although there are few reports on the impacts of mining on the GBR, there is evidence of poor mining practices that lead to the release of high volumes of sediment that result in poor water quality (Brodie et al. 2009). Some mining operations have released toxins such as arsenic which can lead to severe local impacts. Rehabilitation **of mining sites,** and the management of the quality of water coming from mines is now part of the management responsibility of the mining industry (GBRMPA 2009b).

3.1.2. Transport of pollutants from catchments

The land-based pollutants described above are transported to the waterways by surface run-off and sub-surface water flows. The majority of this transport occurs during high intensity rainfall events that result in major flow events (Mitchell et al. 1997, Mitchell et al. 2005). The water discharged from flooding rivers forms plumes that extend into the near-shore marine environment of the GBR (Devlin et al. 2001). Major floodwaters and

their associated pollutants from large rivers like the Burdekin may extend northwards for up to 450km (Haynes et al. 2007). The concentration of nutrients in major flood plumes can be up to 100 times higher than seawater concentrations during non-flood periods (Devlin et al. 2001). The inshore marine ecosystems may be exposed to plume waters and their pollutants for periods of days to weeks during the wet season (Devlin and Brodie 2005, Haynes et al. 2007).

3.1.3. Types of pollutants and their impacts

The three main types of pollutants that affect water quality in the GBR catchments are sediments, nutrients, and pesticides.

Sediments

Land clearing for grazing greatly increased soil erosion and sediment loss to water courses. The loss of sediments is exacerbated during drought periods by chronic overgrazing (McIvor et al. 1995, cited in Haynes et al. 2007). Sugarcane also used to be a major source of eroded sediments. However, recent management improvements in the sugarcane industry such as trash blanketing, minimum tillage, and green cane harvesting have reduced soil losses by around 80% (Rayment 2003 cited in Haynes et al. 2007).

High, chronic inputs of terrestrial sediments result in a range of impacts on corals through shading, smothering, and the disruption of recruitment (Haynes et al. 2007). High sediment loads decrease the availability of light, and consequently reduce coral photosynthesis and growth. The early life stages of coral are the most at risk from sediments through the prevention of larval settlement or the burial of juvenile recruits.

Nutrients

Sugarcane cultivation requires substantial use of nitrogen, an inorganic fertilizer (Haynes et al. 2007). Researchers estimate that only 35% of the fertilizer applied to sugarcane is used by the crop in the year of cultivation (Reghenzani et al 1996, cited in Haynes et al. 2007). The remainder of the fertilizer is lost to groundwater and runoff, stored in the soil, or absorbed by the atmosphere.

Sewage flows from urban areas also contribute to the nutrients flowing into the GBR lagoon. An increasing proportion of sewage is tertiary treated or recycled, partly to reduce the direct impacts on the Great Barrier Reef (GBRMPA 2009b). Sewage discharge

contributes only between three and four per cent of the total nitrogen load and less than one per cent of the total phosphorus load discharged annually into the Great Barrier Reef. However, as populations grow, it will be necessary to address increases in sewage outputs (GBRMPA 2009b).

The algal blooms that are produced by higher concentrations of nitrogen and other nutrients may overgrow coral structures, outcompete coral polyps for space, and shade coral colonies to critical levels (Fabricius 2005). In addition, chronic exposure to increased concentrations of dissolved inorganic nutrients can interfere with the symbiotic relationship between corals and their zooxanthellae and weaken coral skeletons (Fabricius 2005, Haynes et al. 2007). Weakened skeletons make corals more susceptible to physical damage from disturbances such as storms. Furthermore, coral reproduction and recruitment are highly sensitive to increased nutrient concentrations (Fabricius 2005).

Pesticides, toxins and poisons

The use of insecticides, herbicides, and fungicides have increased progressively in areas under cultivation (Hamilton and Haydon 1996, cited in Haynes et al. 2007). The main types of compounds used today include triazine, organophosphate, and urea—based pesticides. As a result of extensive use, organochlorins such as DDT, and more modern pesticides are widely distributed in Queensland's catchment soils, in river sediments, and in the near-shore marine environment adjacent to human activity (Haynes et al. 2007).

Many of the commonly used herbicides such as diuron lead to a decrease in photosynthetic activity (Jones 2005). Because of the reliance of adult corals on their symbiotic zooxanthellae to provide additional energy to coral colonies, the presence of herbicides may result in decreased coral fitness (Jones et al. 2003, cited in Haynes 2005). High concentrations of herbicide or long periods of exposure will expel the zooxanthellea resulting in coral bleaching, and potential death.

3.3. The effects of fishing

Although the impacts and pressure of fishing pressure on ecosystems on the GBR is significantly lower than other parts of the world, aspects of the fishing industry still impact on reef ecosystems. The Great Barrier Reef Marine Park Zoning Plan of 2003 designated 33% of the GBRMP as 'no-take' green zones where fishing is not permitted (GBRMPA 2009b, McCook et al. 2010). Various types of fishing is thus permitted in 67% of the GBRMP. Herbivorous fish are not targeted by the majority of commercial and recreational fishers on the GBR (GBRMPA 2009b). Therefore, populations of herbivorous

fish are sufficient to control algal growth on most offshore reefs (GBMPRA2009b). Herbivorous fish play an important role in enabling the recovery of reefs after a bleaching event (Hughes et al. 2010).

Fishing on the GBR is however not without impact, and there is limited information and uncertainty about some of these impacts. Assessments of major fisheries indicate that the populations of some species (e.g. grey mackerel and snapper) are under pressure. Information is lacking on the Inshore Finfish Fishery and the shark fisheries among others (GBRMPA 2009b). Moreover, there are uncertainties about the broader scale and cumulative effects of fishing. For example, there are fewer outbreaks of crown-of-thorns starfish on mid-shelf reefs that are closed to fishing, in comparison to reefs that are fished (Sweatman 2008).

3.2. Exacerbating effects of climate change

The effect of land-based pollutants and fishing on the reefs of the GBR will be exacerbated by the threats that stem from climate change. The main affects of climate change on reefs stem from increased seawater temperatures and changes in ocean chemistry. Increased seawater temperatures will increase the incidence of coral disease and the frequency and intensity of coral bleaching (Hughes et al. 2003, Haynes et al. 2007). Increased carbon dioxide concentrations in seawater that result from climate change may decrease the calcification rates in coral species and negatively impact their ability to build skeletons. Climate change is also predicted to lead to an increase in the intensity of tropical cyclones (CSIRO 2007, Henessey et al. 2007) with a resultant increase in the intensity of the effects of flooding. These threats will interact with each other and the effects of the pollutants described above. For example, a coral reef that is subject to bleaching is more likely to recover to a healthy state if the water quality does not have high concentrations of sediment, nutrients, or pesticides, and has healthy populations of herbivorous fish (Hughes et al. 2010).

4. Climate change, cyclones, storm surges and tourism infrastructure

Sea levels are predicted to rise by between 18cm and 59cm by 2100 relative to the 1990 level. Sea level rise will take place gradually through this century and urban planners need to take the impacts of sea level rise into account because the effects will manifest during the typical 70 year replacement time of urban infrastructure (Walsh et al. 2004).

In addition, relatively small increases in mean sea level can lead to substantial increases in extreme events.

Thus, climate change is also predicted to increase the exposure of low-lying coastal urban infrastructure and resorts to higher flood and storm surge levels in north Queensland (CSIRO 2007). A storm surge is a region of elevated sea level at the coast caused by the combined effect of falling atmospheric pressure and intense winds associated with severe weather events such as tropical cyclones. Tropical cyclones are predicted to become more intense (CSIRO 2007). The combination of rising sea level, more intensive cyclones and floods, and more severe storm surges, has significant implications for the urban and coastal infrastructure that reef tourism depends on. Storm surges and floods that affect low-lying coastal areas will be significantly worsened by sea level rise of only 10cm to 40cm (Henessey et al. 2007). As a result, Cairns, a key city for reef tourism on the GBR, will be at significantly higher risk of inundation by a 1-in-100 hundred storm surge by 2050 (CSIRO 2007). Thus, it is the impact of floods and storm surges, exacerbated by the gradual, underlying sea level rise that is of concern to the tourism industry.

More intense flooding and storm surges will also affect the transport and other infrastructure that tourism depends on (Forsyth et al. 2007). The impacts from the inaccessibility of tourist destinations, and the lack of availability of the services tourism depends on, will in most cases be temporary. However, more frequent flooding, may ultimately lead to the necessity to rebuild infrastructure on higher ground (Walsh et al. 2004). This will have substantial cost implications for local councils and communities and the relocation and rebuilding of infrastructure will need to proceed in a fashion that minimises environmental impacts.

Moreover, the media often exacerbate the negative effects of natural disasters by portraying areas as disaster zones and that a particular crisis is of ongoing concern (Hall 2010). Therefore, the media plays a critical role in informing the decisions of prospective travellers to destinations when there may be concerns over security, or over conditions following a disaster (Hall et al. 2004, Baker and Coulter 2007). However, the effects of the media on tourism following a disaster can be mitigated to some extent through the coordinated efforts of a tourism marketing body that has pro-active relationships with the media (Henderson 2003, de Sousmarez 2007).

Cyclones Larry and Yasi – omens for the future

Flooding and cyclonic events over the past decade in the regions that serve the GBR's tourism system provide an example of the types of disturbances that may become more frequent in a future of accelerating climate change.

Cyclone Larry, a category 4 cyclone made landfall near Innisfail on 20 March 2006. Cyclone Larry was dubbed the worst cyclone to hit Queensland in a century (Cairns Bulletin 2006). Cairns airport and harbour were closed, and all flights were suspended. Major roads were made impassable due to fallen trees and debris which impacted on the ability of tourists to get to their destination (Oloruntoba 2010). The total damage cost of cyclone Larry was estimated at up to $1.5 Billion (ABC news 2006). In addition, because tourism is an important source of income in the region, the most-affected households faced an aggravated income shortage due to commercial and retail supply chains being out of action. The Queensland government made funding available to strengthen the marketing capacity of tourism enterprises to counter the negative perception potential visitors had of the region following the media's coverage of cyclone Larry (Queensland Tourism Industry Council 2007).

Cyclone Yasi, a category five cyclone made landfall near Mission Beach on 3 February 2011. Cyclone Yasi was an even more intensive cyclone that affected a larger area than cyclone Larry. The worst affected areas were Tully, Mission Beach, Innisfail, and Cardwell (ABC news 2011a). Total damage from the storm was estimated at $3.5 billion and losses to the tourism industry were estimated to reach $1 Billion (ABC news 2011b). Electricity services in the tourist town of Cardwell were cut for over a week. By mid-April 2011, tourism operations on Dunk and Hayman islands were still closed following cyclone Yasi. Grants of up to $25 000 were made available to small businesses that suffered direct damage from cyclone Yasi. In addition, the federal and state governments made $10 million available to counter the negative publicity generated internationally through the press on Cyclone Yasi (the Australian 2011).

5. Resilience of reef tourism enterprises

As explained above, because most of the reefs visited by tourists in the GBRMP are more than 20km offshore, tourists require the use of well-equipped boats to get to and enjoy the reefs. In fact, the vast majority (90%) of tourists who visit the GBR to dive or snorkel do so with reef tourism companies who either run guided trips or provide ferry services (Saltzer 2002). The ability of these reef tourism enterprises to adapt to and survive crises and change is therefore important in the resilience of the broader reef-based tourism on the GBR.

5.1. Factors that strengthen enterprise resilience

Biggs (2011a) provides a detailed review and empirical analysis of the factors that strengthen the resilience of reef tourism enterprises to crises and change. A resilient reef tourism enterprise is defined as one that is able to maintain or grow its existing level of employment and income and stay operating in reef tourism in the face of a large disturbance or ongoing change (Biggs 2011a). The literature review in Biggs (2011a)

suggests that the lifestyle values of enterprise owners and staff associated with their participation in reef tourism is an important determinant of enterprise resilience (Table 1). In addition, enterprise age and experience, social capital, human capital, coral reef condition, are determinants of enterprise resilience. Table 1 provides a definition of each of these variables.

Table 1: Factors that strengthen the resilience of reef tourism enterprises. Factors in italics are statistically significant ($p<0.05$) predictors of enterprise resilience in a binary logistic regression analysis (see Biggs 2011a for more details).

Factor/Variable	Definition
Lifestyle values $p = 0.02$	The extent to which the participation of the owners, managers, and staff in an enterprise in reef tourism is motivated by an active lifestyle choice.
Human capital $p = 0.02$	The skills-set, experience, and confidence of owners, managers and key staff in an enterprise.
Enterprise age and experience	The number of years an enterprise has been in operation for, and whether or not it has lived through a crisis in the tourism market (a 25% or greater decline in tourist income for 3 months or more) in the past.
Financial capital	An enterprise's profit, revenue, and debt levels, and ability to access to additional finance.
Social capital	The support to an enterprise from government, family and friends, and the level of increased collaboration with competing enterprises during a crisis.
Reef condition	The condition of the coral reefs an enterprise visits with its clients.

Biggs (2011a) measured enterprise resilience through a five item composite scale. Each item on the composite scale captures a component of enterprise resilience and together the items produce one measure of a more complex issue (Bernard 2002).

Of the factors identified in the literature review (Biggs 2011a), human capital, and lifestyle values emerged as statistically significant ($p<0.05$) predictors of enterprise resilience, as measured by the composite scale of enterprise resilience, in a binary logistic regression analysis. In addition, the results in Biggs (2011a) show that many reef tourism enterprises, particularly the smaller ones, are concerned about the growing

burden of state and federal regulations. Small enterprises typically have a small staff contingent, sometimes only the owner and casual staff. Growing regulatory burdens place both a financial burden, and a significant burden on staff time for these enterprises.

The influence of human capital on the resilience of reef tourism enterprises aligns with the broader tourism literature. Reef tourism is a specialised service-oriented industry, and high levels of human capital are considered essential in providing a quality product and experience to visitors (Burns 1997). In addition, tourism enterprise's with flexible and adaptive staff are more likely to be able to anticipate and respond to crises (Irvine and Anderson 2004).

The importance of lifestyle values in enhancing the resilience of tourism enterprises to crises and change is supported in the broader literature on small tourism firms, particularly in attractive, rural areas (Ateljevic and Doorne 2000, Shaw and Williams 2004). Entrepreneurs not solely driven by profit are willing to tolerate poor financial performance and accept a greater degree of risk (Hall and Rusher 2004, Biggs 2011a). Some lifestyle-motivated entrepreneurs operate on the verge of bankruptcy content with the income their enterprise provides for living a chosen lifestyle (Ateljevic 2007). The owners and staff of lifestyle-driven tourism enterprises can develop emotional attachments to their local environment and community (Cooke 2007), creating commitment to a location, and a reluctance to abandon the enterprise and area during difficult times. Lifestyle-driven entrepreneurs are therefore likely to stay in a nature-tourism sector for longer, and under more trying circumstances, than businesses solely driven by profit (Getz et al. 2004; Biggs 2011a).

It is interesting that coral reef condition did not emerge as a significant predictor of enterprise resilience in Biggs's (2011) paper. In addition, the scientific literature on the importance of reef condition on tourist demand is suggests the relationship is not yet that well understood (Biggs 2011a). Although the majority of studies show decreased willingness to visit, and decreased revenue from tourism following reef degradation e.g. Uyarra et al. (2005), Kragt et al. (2009), tourists are nonetheless willing to visit degraded reefs in some cases (Andersson 2007). In addition, a study from the Caribbean showed that tourists perceive only certain aspects of changes in the biological and ecological condition of coral reefs (Uyarra et al. 2009), Biggs 2011a). More research is needed on the relationship between perceived reef condition and tourist demand. In addition, the relationship between the ecological metrics of reef condition, and visitor's perception of reef condition, and the intermediary role of marketing and interpretation in this relationship requires further investigation.

5.2. Reef tourism enterprise resilience and contribution to conservation

The lifestyle values of reef tourism enterprise' owners and staff are associated with an attachment to the GBR and the marine environment (Biggs 2011b). Associated with this attachment to the local environment is a commitment to contributing to its conservation and sustainable use (Carlsen et al. 2001). Nature-based tourism enterprises can contribute to the conservation of an ecosystem in three different ways (Biggs 2011b).

Agglomerations of nature-based tourism enterprises can make a substantive regional economic contribution leading to policy support for conservation initiatives. The reef water quality protection plan is an example of such a policy on the GBR established in 2003 (Haynes et al. 2007).

Nature-based tourism enterprises can take direct action to improve their local environments and generate environmental awareness (Carlsen et al. 2001, Russel et al. 2008).

Tourists may improve their environmental behaviours once back home as a results of a positive experience (e.g. by reducing household carbon emissions) and become ambassadors for conservation (Powell et al. 2008).

Findings of an empirical study on the GBR

Biggs (2011b) conducted empirical research with reef tourism enterprises on the GBR to explore the relationship between the lifestyle values of enterprise' owners and staff, enterprise resilience, and enterprise contribution to conservation. Biggs (2011b) collected data on the conservation ethic of enterprises, the extent to which enterprises participate in a range of conservation actions, and related these measures to the resilience of enterprise to crises and change. Data was collected on the extent to which: 1) enterprises recycle materials from their boats and offices, 2) participate in crown-of-thorns-starfish eradication 3) are members of, and actively donate money to reef conservation agencies, 4) mitigate and offset enterprise' carbon emissions and 5) actively contribute to education of the public about the GBR.

To understand the structure of the relationship between enterprise resilience, enterprise lack of resilience, and conservation ethic, participation in conservation actions, and lifestyle values, Biggs (2011b) used a Categorical Principal Components Analysis. The bi-plot produced by the Categorical Principal Components Analysis is shown in Figure 3. The bi-plot is interpreted by looking at which variables cluster together. Variables that cluster together are associated with each other. Dimension one in the bi-plot accounted for 38% of the variance (Figure 3). The axis of dimension one can be interpreted as a gradient of enterprise resilience from non-resilient (the variables 'exit now' and 'exit in shock') to resilient measured by the composite variable 'resilient

scale'. The Cronbach's alpha score was 0.82 for dimension one, indicating that it is a reliable scale (Nunnaly 1978). The results of the bi-plot show that a high conservation ethic is associated with high enterprise lifestyle values and high scores on the composite scale for enterprise resilience (Figure 3). Enterprise contribution to the eradication of crown-of-thorns starfish clustered most closely with conservation ethics and lifestyle values. Enterprise contribution to public education on coral reefs and to recycling also clustered in the same direction as conservation ethic and lifestyle values but to a lesser extent (Figure 3). Enterprise donation to reef conservation agencies and reduction and offset of carbon emissions, and recycling clustered furthest away from lifestyle values, enterprise resilience and conservation ethic which indicates a lower of level association. This lower association may be because the reduction of carbon emissions and donation to conservation agencies requires higher level of additional expenditure by enterprises (Biggs 2011b).

In addition, enterprises reported a range of barriers to their participation in conservation. Eight out of 38 enterprises (21%) mentioned regulatory and institutional barriers to taking pro-conservation steps, including the lack of recycling facilities in the marinas in Cairns and the Whitsundays. These regulatory and institutional barriers reduce the surplus resources and time enterprise' staff can dedicate to conservation actions and the ease with which enterprises can participate in conservation actions.

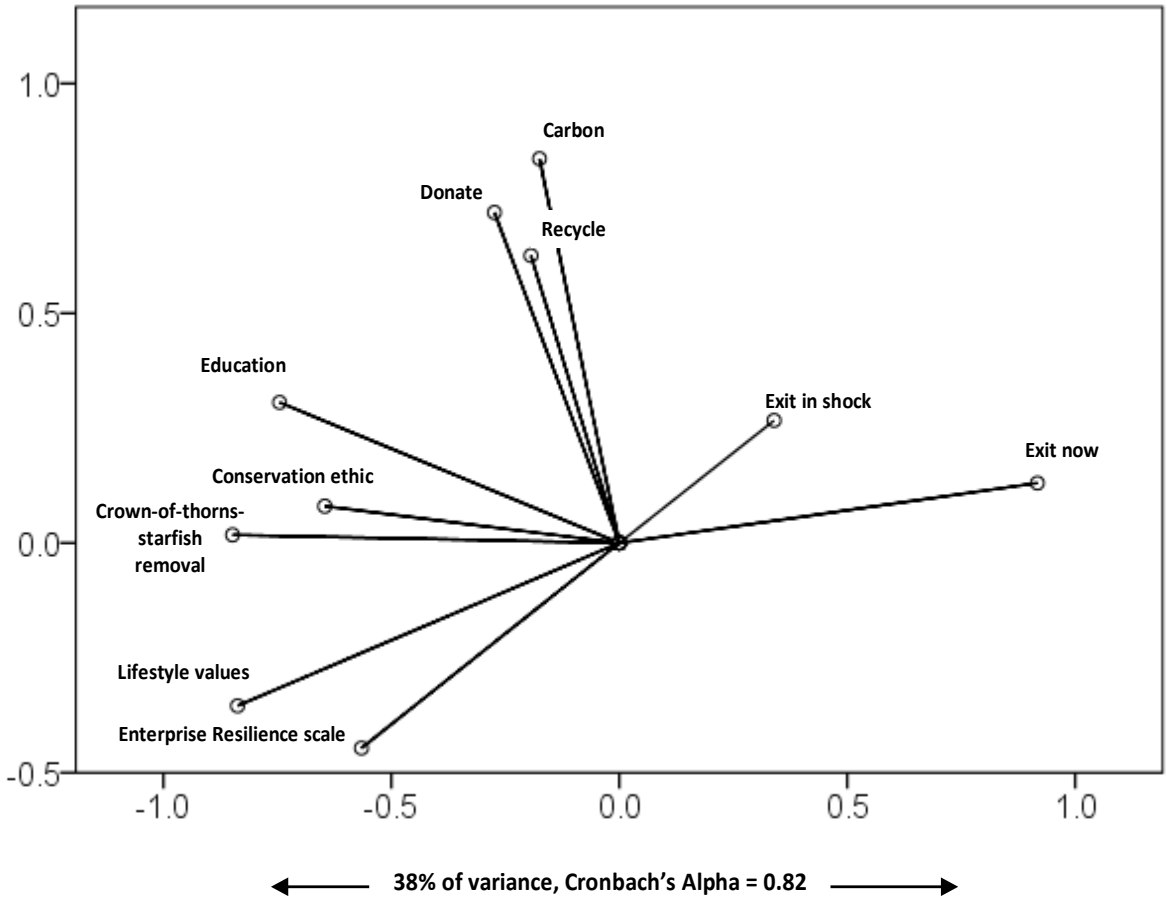


Figure 3. Categorical Principal Components Analysis of the structure of the relationships among enterprise resilience, measured by a composite scale of resilience, and enterprises' conservation ethic, participation in conservation actions, and the lifestyle values of enterprise' owners and staff. A lack of enterprise resilience is measured by the variables 'exit now' and 'exit shock'. 'Exit now = the extent to which enterprises are currently looking to exit reef tourism. Exit shock = enterprises who indicated they would exit in the face of a 50% collapse in tourism demand for 12 months. High levels of enterprise resilience are associated with a strong conservation ethic and high levels of participation in crown-of-thorns-starfish removal and support of reef education.

6. Conclusions and Synthesis

6.1. Conclusions: the resilience of the reef tourism system to crises and change

This case study has presented an overview of the factors that affect the resilience of the nature-based tourism system on Australia's GBR to crises and change (Figure 2). Section 3 discussed the impacts on the health of the GBR's coral reefs. Section 4 provided an overview of how climate change, sea level rise and more intense storms and storm surges may affect the coastal infrastructure that reef tourism depends on. Section 5 provided a summary of recent research on the resilience of reef tourism enterprises to crises, and their contribution to conservation.

The impacts on the GBR's reefs are due to the sediments, nutrients, and pesticides that originate primarily from farming activities in the river catchments, and subsequently flow into the GBR lagoon. The Reef Water Quality Protection Plan, instituted in 2003, has aimed to monitor and improve the water quality flowing out of the regions catchments to improve the health of the coral reefs (Reef Water Quality Protection Plan 2007). However, the benefits to reef health of plans such as the water quality protection plan will not be immediate and may take more than a decade to become apparent. Water quality will therefore remain an important issue for the health of reefs on the GBR, particularly as the harmful climate change-related effects of coral bleaching and ocean acidification worsen into the future. The extent to which the water quality flowing into the GBR lagoon can be improved will be an important determinant of how well the reefs may be able to cope with the effects of climate change with subsequent impacts on reef tourism. Although fishing pressure is more limited on the GBR than in other parts of the world, certain vulnerable species may be under threat and there is a need for more in-depth understanding of the broader ecosystem-level impacts of fishing. Despite some ambiguity in the scientific literature, the balance of evidence suggests that healthy reefs with a diversity of marine life, and in particular larger species play an important role in driving tourist demand for reef experiences. The maintenance of healthy reef ecosystems is therefore important for the resilience of the reef tourism industry.

Rising sea levels accompanied by more intensive tropical cyclones, storm surges, and flooding events will affect the coastal infrastructure that tourism depends on (CSIRO 2007). Events over the past decade in Queensland, such as cyclones Larry and Yasi, led to the closure of airports and major roads, affecting the ability of tourists to get to the GBR region. In addition, the negative national and international media coverage exacerbates the physical impacts of natural disasters such as cyclones and floods, and has a detrimental effect on visitor numbers and the reef tourism sector. Tourism marketing bodies can play a critical role in countering the impacts of negative coverage following natural disasters.

The extent to which the owners and staff of reef tourism enterprises are motivated by lifestyle values and the levels of human capital in an enterprise are predictors of enterprise resilience to crises (Biggs 2011a). The lifestyles values of individuals are associated with their attachment to a particular environment and community and enable individuals to tolerate difficulties in that environment. Human capital represents the skills, experience, and attitudes of the key staff in an enterprise and is a determinant of an enterprise's ability to adapt to, and survive, disturbance and change. Increasing regulation is placing a growing burden particularly on the smaller reef tourism enterprises on the GBR thus undermining their resilience.

Reef tourism enterprises whose owners and staff have higher lifestyle values also have higher conservation ethic scores than enterprises whose owners and staff have lower lifestyle values. The attachment to the reefs and the marine life associated with enterprise staff with higher lifestyle values means that they are more supportive of conservation. The contribution of reef tourism enterprises to the local eradication of crown-of-thorns starfish is an example of the reef tourism sector's contribution to conservation. The growing regulatory burden in the reef tourism sector reduces the resources and capacity, particularly small enterprises, have at their disposal to participate in conservation actions. GBRMPA can play an important role in extending the conservation actions of reef tourism enterprises. For example, the Great Barrier Reef Tourism Climate Change Action Strategy (GBRMPA 2009c) outlines how reef tourism enterprises can work together with GBRMPA and other reef tourism stakeholders to support reef conservation and respond to climate change.

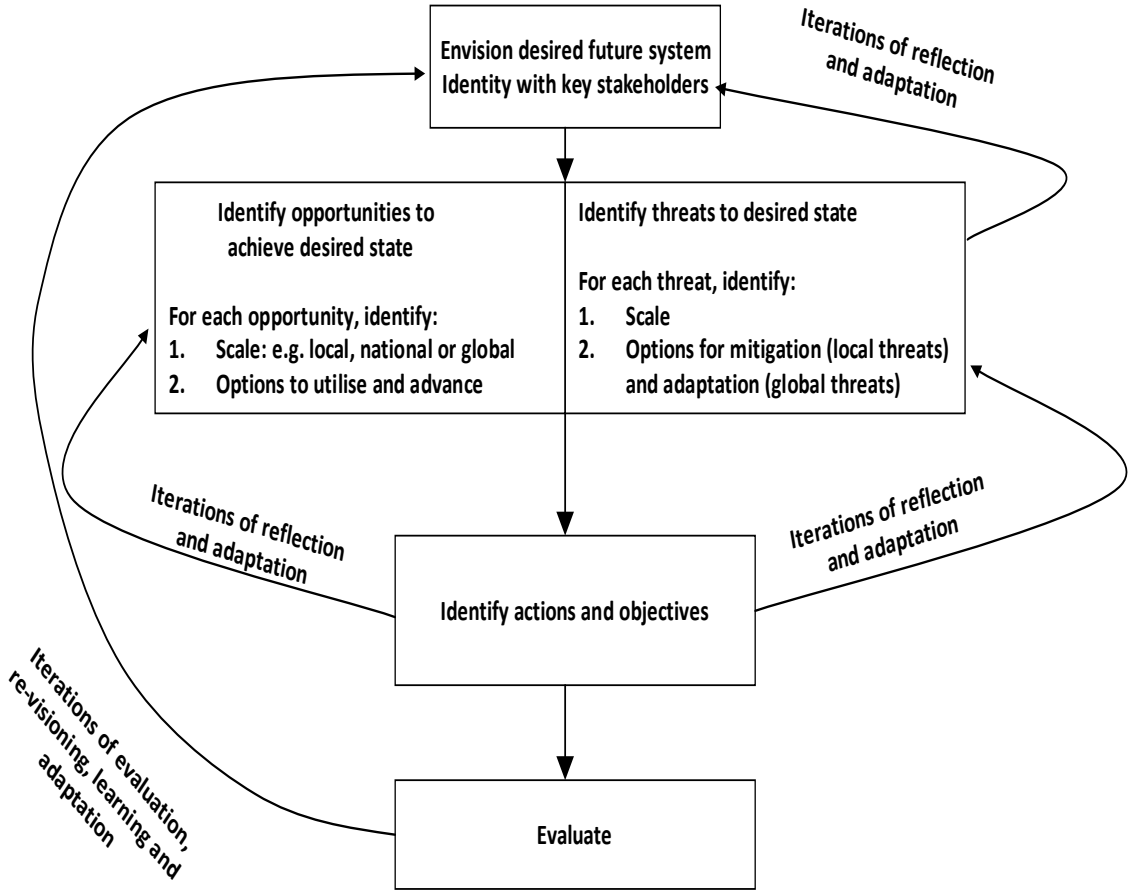
Reef tourism enterprises, and the broader reef tourism system function within a larger socio-economic and political environment determined at the scale of local, state, and federal government as well as internationally. Changes at these levels will influence the functioning and resilience of reef tourism enterprises, the reef tourism sector, and how enterprises relate to the environment. For example, incentives and enabling legislation to support the Australian economy and society to transition towards lower carbon emissions can facilitate innovations and change towards a more carbon neutral reef tourism sector. The policy objectives within the GBR's Tourism Climate Change Action Strategy is an example of the type of actions that can lead to policy and institutional changes that can benefit reef tourism and reef conservation (GBRMPA 2009c).

6.2. A process for enhancing the resilience of the Great Barrier Reef's nature-based tourism system

Enhancing the resilience of the GBR's nature-based tourism system to crises and change will require the consideration of a wide range of factors that operate from the local to the global scale. Necessarily, it also demands the involvement of a wide range of stakeholders that are actors in (e.g. reef tourism enterprises), or that affect the reef tourism system (e.g. fishers and farmers). A process in which these different stakeholders collectively envision and agree to work together towards a resilient reef tourism system in the face of a range of plausible future scenarios is an excellent way to enhance the capacity of the reef tourism sector on the GBR to cope with and adapt to crises and change. The core components of a resilience-oriented stakeholder process for the GBR's reef tourism system that draws on Walker et al. (2002), Cumming et al. (2005) and Resilience Alliance (2010) is shown in Figure 3 and described briefly below.

A stakeholder-led process for envisioning and managing for resilience

The agreement on a shared vision for the future of reef tourism on the GBR among the key stakeholders is the first step in the process. The shared vision of the identity of the reef tourism system provides the basis for identifying the threats and opportunities and the resultant objectives and actions in the later stages of the process. In the introduction to this case study, a resilient reef tourism system was defined as a system which is able to uphold its identity as a region with a healthy and diverse reef system that maintains and grows an extensive coral reef tourism industry. Assuming that is the vision that the stakeholders agree on, the threats to maintaining this identity, and the opportunities for maintaining it are explored (Figure 3).



Throughout consider: multiple stable states, social-ecological interactions, feedbacks, thresholds, multiple stable states and governance

Figure 3: An outline of a stakeholder process for envisioning and managing the resilience of the GBR's reef tourism system to crises and change. Local scale threats such as poor water quality can be mitigated by local action whereas global scale threats such as climate change require adaptation. The process emphasises that on-going reflection, learning, re-evaluation and adaptation is the best way to deal with a complex reality characterised by uncertainty, surprise, and continual change. Compiled from Walker et al. (2002), Cumming et al. (2005), Resilience Alliance (2010).

The red text at the bottom of figure 3 emphasises additional key components of resilience thinking, often ignored in traditional planning models, that should be explicitly considered throughout the process. Social-ecological interactions refer to the inherent linkages between the social system and the ecological system. Feedbacks are connections within a system that can either amplify (positive feedbacks) or dampen (negative feedbacks) the impact of a particular change. An example of a positive feedback is that climate change is shrinking the earth's ice-caps (Resilience Alliance 2010). This reduces the amount of heat and sunlight reflected, leading to faster global warming and more rapid loss of the ice-caps. Thresholds refer to the non-linear tipping points between two or more stable states. For example, marine ecosystems may shift from a coral-dominated state to an algae-dominated state (Hughes 1994). Similarly, a region dependent on nature-based tourism may shift to a mining-based economy due to resource-degradation or other changes.

At first glance, Figure 3 may seem similar to a traditional planning and management process. It differs however in a number of ways. Resilience thinking embraces uncertainty and the need for continued learning and adaptation, rather than the management for stability at a particular optimal state (Walker and Salt 2006). Therefore, multiple, and on-going iterations of evaluation, reflection, learning, re-visioning and adaptation are emphasised in Figure 3. The process in Figure 3 need not be followed in a sequential or linear fashion. Learning, adaptation and change often take place unexpectedly and a process of managing for resilience should enable this.

The process described here (Figure 3) is a stakeholder-led approach to the ongoing management for the resilience of the GBR's nature-based tourism system to crises and change. The Resilience Alliance's workbook for practitioners (Resilience Alliance 2010) covers a stakeholder process for resilience assessment and management in greater detail. Unfortunately, space constraints in this case study, has meant that the stakeholder-led process of managing for resilience has been discussed in a cursory fashion only. The stakeholder process followed by the Tourism Climate Action Group, a joint initiative between GBRMPA and key private sector and government stakeholders in reef tourism, to develop an action plan for climate change and tourism, is a good example of such a stakeholder-led process that is already underway. The explicit consideration and discussion resilience concepts in deliberations over the future of the GBR's reef tourism system in the face of uncertainty and crises can strengthen existing and future stakeholder processes.

Managing for the resilience of nature-based tourism beyond the GBR

The GBR's nature-based tourism system is by no means the only system in Australia confronted by the challenges of accelerating climate and global change and the

associated crises, uncertainties, and surprises. Other nature-based systems in Australia face similar challenges. Tourism to the Australian Alps, Queensland's Tropics, and elsewhere are also impacted by a range of environmental, socio-economic, and political drivers from the local to the international scale. The stakeholder-led process described briefly above to envision and manage for resilience in the GBR's nature-based tourism system would be of value in other nature-based systems, and human-environment systems more broadly.

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