Limits to Adaptation

Limits to climate change adaptation in the Great Barrier Reef

NCCARF
National Climate Change Adaptation Research Facility

Synthesis and Integrative Research Program
Limits to climate change adaptation in the Great Barrier Reef
Scoping ecological and social limits

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1. **EXTENDED SUMMARY**

The Great Barrier Reef World Heritage Area (GBRWHA) was designated in 1981 in recognition of the high ecological and cultural value of its marine and coastal habitat. Climate change is viewed as the biggest future threat to the area and impacts have already been felt across the region. Mass coral bleaching was experienced in 1998 and 2002, and sea level rise and ocean acidification have also been documented. Ongoing, the GBRWHA will be affected in many ways by air and sea temperature increases, sea level rise, changing rainfall patterns, and increased intensity of storm events. How society and our natural environment respond and adapt, now and in the future, to the risks and opportunities that accompany climate change will determine the overall outcomes for people and the reef.

In this study, we developed a set of four alternative future scenarios to explore different climate change impact and adaptation pathways and their implications for the Great Barrier Reef (GBR) and its fishing and tourism industries. We conducted a rapid literature review and a scientific consultation in order to develop the initial scenarios. We then presented and discussed the scenarios in multi-stakeholder workshops and in interviews with representatives from the tourism and fishing industries, non-governmental organisations, local and state government, and the research community. The workshops and interviews explored a range of issues, including i) the plausibility of the scenarios for different parts of the GBR region, ii) the extent to which different industries or groups were able to adapt in certain ways, iii) the limits and opportunities that characterise adaptation, iv) the trade-offs and synergies that occur between sectors, v) possible conflicts that arise from climate change adaptation in the region, and vi) the overall implications for the industries.

The study scoped potential adaptation options and the myriad of limits that characterise adaptation in the GBR region. Our results highlight some important issues. Desirable outcomes from adaptation for the commercial sectors include long-term sustainability of resources and ecosystems, and long-term viability or profitability of individuals and industries. For the recreational fishing sector, sustainability and hassle-free enjoyment of the resource are desirable. Stewardship and business planning were identified as core adaptation strategies and it was argued by stakeholders that adaptation should be embedded within broader environmental management and industry-enterprise development processes. Further, adaptation and adaptive capacity are viewed as important for climatic, non-climatic, and composite disturbance events. The adaptation strategies discussed and the limits identified are, therefore, not just relevant to the climate change debate. Yet, dialogue around climate change is so far helping to bring stakeholders within the GBR together, thereby strengthening partnerships in the region over the past five years or so.

Through this scoping study we found that often limits to adaptation were identified and discussed as both limits and opportunities, as interchangeable perspectives. We argue that when it comes to economic, institutional, social and political limits, the thresholds or the points at which these factors render adaptation ineffective as a response to risk are socially constructed or subjective, meaning that limits are not insurmountable or absolute, but can just as easily be seen as future opportunities. For instance, high market competition and the lack of market positioning mechanisms are identified as important limits to adaptation through improved business management and product diversification. Yet, marketing and branding GBR industries as sustainable, well-managed, and as local community assets is seen as one of the biggest opportunities to improve sustainability and profitability outcomes, and to reduce the current and future vulnerability of GBR ecosystems and industries.
We also found that distinct adaptation strategies are characterised by a diversity of interacting limits, which are difficult to isolate. We therefore, identify a series of ‘wicked problems’ that represent bundles of limits, which affect different industries and sectors in subtly different ways, but which could provide broad over-arching entry points for action to address limits. These ‘wicked problems’ are introduced below:

1. **A whole industry perspective**: Beneficial outcomes, including sustainability, profitability and lifestyle values for GBR industries and individuals cannot, in many cases, be achieved through individual action but necessitate a ‘whole-of-industry’ or an ‘integrated industry’ approach. With this comes a particular set of limits to adaptation.

2. **Uncertainty and system connectivity**: Uncertainty around how climate change will manifest and the vulnerabilities of individuals and industries to impacts makes it difficult to systematically evaluate the most effective adaptation strategies and limits the potential of forecasting, financial management, stewardship, mobility, diversification and technological investment to consistently deliver benefits and reduce negative outcomes. Further, interactions within the social-ecological system that is the GBR and its industries mean that often, inadvertently, vulnerabilities are simply transferred elsewhere.

3. **Private action for public goods**: Climate change adaptation can deliver important public goods but it often relies on collective and, increasingly, private action. In the GBR region, private property rights are the dominant form of entitlement. There is, therefore, considerable tension in the region between private interests and public goods such as water quality, wetland protection and rehabilitation, and community safety, all of which underlie effective planned adaptation and desirable outcomes for GBR industries. Further, powerful private interests are based on deeply embedded and historical identities and values linked to Australian primary industry (e.g., cattle grazing and sugar cane) and coastal lifestyles.

4. **Perceptions and reputations**: The perceptions, identities and aspirations of people with a direct stake in Australia’s Great Barrier Reef play a role in limiting adaptation within GBR industries, including effort management, diversification and stewardship. The perceptions of consumers of fisheries and tourism products also limit the potential of adaptation to reduce vulnerability. For instance, despite considerable progress in the stewardship of GBR commercial fisheries, there is still a deeply held view of fishers as exploitative opportunists, which limits the market value and product diversification options for fishers. Government perceptions of industry can also drive, block or limit adaptation.

5. **Australia in the globalised world**: The integration of the Australian economy in global markets brings considerable benefits to some sections of Australian society, but also introduces high market competition and intractable limits on adaptation of GBR businesses and industries.

In our research, we were also interested in the utility of a ‘limits’ approach to adaptation planning. To-date, exploring the limits to adaptation, as distinct from barriers, has been a relatively academic endeavour. In practice, we found it difficult to distinguish between barriers, limits and opportunities when talking about real experiences and perspectives on adaptation. We also found it challenging to identify individual limits as multiple limits seemed to act on a single adaptation strategy (which themselves are not pursued in isolation) at any one time. Nonetheless, we highlight some real and complex issues that will limit
adaptation to climate change in the region, now and in the future. Our findings suggest that understanding limits in a practical sense is important for adaptation planning and action. Within the GBR region adaptation planning includes a recent focus on industry-level vulnerability or risk assessment to identify impacts from climate change and potential adaptation strategies. The aim eventually is to use these planning processes to develop tailored adaptation plans. In evaluating which adaptation strategies or combination of strategies would be the most appropriate and viable in the long-term, we suggest including some questions about limits to identify under which conditions particular strategies fail to reduce the vulnerability of ecosystems and industries to climatic change.
2. PROJECT BACKGROUND

The Great Barrier Reef (GBR) is one of the seven natural wonders of the world. It is a national and international icon, with considerable social, cultural and economic value. Ecological and social impacts from climate change are already evident in the GBR region and climate change is viewed as the greatest future threat to the reef. Adaptation to climate change is, therefore, at the forefront of research, policy development and management of the region.

The legitimacy and feasibility of different climate change adaptation pathways are largely determined by how different state, private and civil society stakeholders perceive climate change trends, impacts and adaptation options, and the limits that define their context. Further, the action taken by distinct groups in response to climate change will influence the outcomes for other groups and other sectors. The project objectives were to explore: i) the limits and opportunities that characterise adaptation, ii) the trade-offs and synergies that occur between sectors, and iii) possible conflicts that arise from climate change adaptation in the GBR region.

Adaptation to climate change is adjustment in natural or human systems in response to actual or expected climate change and its impacts, which aims to mediate harm or exploit beneficial opportunities (adapted from IPCC 2007). Limits to adaptation are the conditions or factors that render adaptation ineffective as a response to climate change (Adger et al. 2007). So, adaptation is limited when a particular adaptation strategy does not reduce the vulnerability of an organism, individual, group or society to climate change. Limits also prevent a more appropriate adaptation strategy that would reduce vulnerability from being pursued. Limits are largely insurmountable but are not absolute. In the GBR region, examples of limits might include ecological limits to the physiological acclimation or behavioural adaptation of corals or fish, institutional norms that define the lifestyle values associated with particular employment and livelihood activities, which make it difficult to change, and economic limits to our capacity to fund pre-emptive adaptation action in the face of other pressures and priorities. Underlying limits are social and cultural factors that influence i) how climate change trends and impacts are seen, ii) to what extent adaptation options are viewed as legitimate and feasible, and iii) how desirable and acceptable overall outcomes are.

The project proposed to explore these issues through a set of four alternative future scenarios. Scenarios are “plausible descriptions of how the future may develop” (IPCC, 2000). They do not predict the future but present different choices and explore potential outcomes from these choices. We proposed to use scenarios to contrast two different climate change trends and their potential impacts on the reef and its industries, and to explore possible outcomes from contrasted adaptation responses. We planned to develop the scenarios through a rapid and comprehensive literature review and a process of scientific consultation. We then intended to present and discuss the scenarios in multi-stakeholder workshops and interviews with representatives of local and state government, the tourism and fishing industries, traditional owners, and non-governmental organisations in order to identify critical limits to climate change adaptation. Finally, we aimed to present findings to key GBR policy makers and managers in a dissemination workshop. This would elicit their views on the importance of

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1 In this sense limits and barriers are inter-changed. We did this for the purposes of discussion with stakeholders about their experiences of adaptation. Stakeholders do not distinguish between barriers and limits. We report on the more considerable barriers, which could reflect limits as effectively insurmountable in that they require considerable re-organisation by society to overcome them.
identified limits and identify strategies to address the limits. Initially we had suggested that we would use the final workshop to rank limits, however, given the complexity of the limits we identified, this did not seem that useful. Instead, we used the workshop to explore further the utility of a ‘limits to adaptation’ perspective for understanding vulnerability and opportunities for effective adaptation in the Great Barrier Reef ongoing.
3. PROJECT

3.1 Introduction

3.1.1 Study area

The Great Barrier Reef (GBR) (350,000 km²) and its catchment (425,964 km²) are of significant ecological, social, and economic importance, both nationally and internationally (Figure 1). In recognition of this, the GBR region has been designated as both a Marine Park (1975) and a World Heritage Area (1981) and is managed through a Commonwealth Statutory Authority, the Great Barrier Reef Marine Park Authority (GBRMPA), and the government of Queensland. The GBR catchment supports a population of approximately 850,000, which is expected to rise to one million by 2026 (Commonwealth of Australia, 2006). The total contribution of tourism, commercial fishing, and cultural/recreational activity in the GBR to Australian gross national product was A$ 6.9 billion in 2005-2006 (Access Economics, 2007). Climate change is already evident in the GBR region and is seen as the greatest future threat to both ecological health and human wellbeing (Marshall and Johnson, 2007). Ecological and social adaptation responses to climate change are, therefore, critical to the future of coastal ecosystems and communities in the region.

Figure 1: The Great Barrier Reef catchment and reef (source GBRMPA website accessed 01 June 2010)
3.1.2 Governance of the Great Barrier Reef

The Great Barrier Reef Marine Park Act of 1975 enacted by the Commonwealth government established the Great Barrier Reef Marine Park Authority (GBRMPA). The GBRMPA is mandated to manage the Marine Park for biodiversity conservation and sustainable use and to promote understanding and enjoyment of the reef (Wachenfeld et al., 2007). The GBRMPA essentially oversees marine park policy and planning. The primary objective of the Authority is to enhance the resilience of the reef to existing and future disturbance. The day-to-day running of the marine park is coordinated by the Queensland government, through the Department of Employment, Economic development and Innovation which oversees licensing, permitting and enforcement of regulation in Queensland’s Primary Industries and Fisheries, including commercial and recreational fisheries, and Queensland Tourism; and the Department of Environment and Resource Management which oversees environmental management, environmental protection, water management, and climate change science and management. The GBRMPA and Queensland Government have developed a range of plans for zoning, fisheries management, water quality management, tourism management, and climate change mitigation and adaptation. The GBRMPA also run a number of programmes to promote monitoring, information exchange, education and compliance, such as the Reef Guardian Programmes.

To improve spatial management of the park the GBRMPA undertook an ambitious re-zoning of the marine park in 2003/2004. The re-zoning aimed to incorporate a larger and more representative area of habitat into no-go and no-take areas. Now, 33 percent of the park is protected through no-take zones, representing at least 20 percent of 70 identified bioregions (Wachenfeld et al., 2007). Commercial fisheries management is based around fishery specific planning, for instance the East Coast Trawl Industry Development Plan 2010–13 and the Coral Reef Line Fishery Plan 2010–2013 (draft), and regulation based on licensing, boat size, effort unit quota, total allowable catch, gear restrictions and spawning and/or temporary closures. Management of the recreational fishery primarily revolves around bag limits, fish size restrictions, and temporary closures (Recreational fishing rules and regulations for Queensland, 2010). Tourism management also involves planning, such as the Tourism Action Plan to 2012, and regulation based on environmental impact assessment and operator permits.

The GBRMPA and Queensland Government promote a degree of co-management of the marine park through involvement of community in formal committees, such as Reef Advisory Committees and Local Marine Advisory Committees as well as involvement of Primary Industry and Tourism in key planning and policy processes.

3.1.3 Climate change and the Great Barrier Reef

Climate change is viewed as the biggest future threat to the Great Barrier Reef (Wachenfeld et al., 2007). Climate change is a significant change in average climate and/or its variability so much so that our expectation of weather patterns also changes (Lough, 2007; Australian Academy of Science, 2010). Direct consequences of cumulative post-industrial CO₂ emissions include increasing global air and sea temperatures, perturbed regional weather patterns, changing sea levels, and ocean acidification (Brierley and Kingsford, 2009). Impacts from global climate change are already evident but are location specific, dependent on how global climate change manifests at regional and local scales and on the vulnerability of the local context to these changes (Hoegh-Guldberg and Hoegh-Guldberg 2004).
The GBR region has experienced warming in air and sea surface temperature, increases in sea level, and a reduction in oceanic pH (see Hoegh-Guldberg and Hoegh-Guldberg 2004; Lough, 2007). In general, it is estimated that future trends in air temperature for tropical and coastal Australia will reflect global averages in warming (Lough, 2007). Whereas, sea surface temperature increases in the vicinity of tropical reefs will likely be 80-90% of average global air temperature change (a higher estimate than the 50% of air temperature stated in the IPCC predictions) (Lough, 2007) (Table 1).

Table 1: Projected climate change in the GBR region (Church and White, 2006; Lough, 2007; Whetton et al., 2005)

<table>
<thead>
<tr>
<th></th>
<th>2050 (compared to)</th>
<th>2100 (compared to)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air temperature</strong></td>
<td>+ 0.9 - 2.6°C</td>
<td>+ 2.0 - 5.0°C</td>
</tr>
<tr>
<td></td>
<td>(1960-1990 average)</td>
<td>(1960-1990 average)</td>
</tr>
<tr>
<td><strong>Sea surface temperature</strong></td>
<td>+ 1.1 - 1.2°C</td>
<td>+ 1 - 3°C</td>
</tr>
<tr>
<td></td>
<td>(1960-1990 average)</td>
<td>(present)</td>
</tr>
<tr>
<td><strong>Sea level rise</strong></td>
<td>+ 0.13 - 0.68m</td>
<td>+ 0.1-0.9m</td>
</tr>
<tr>
<td></td>
<td>(1960-1990 average)</td>
<td>(1960-1990 average)</td>
</tr>
<tr>
<td><strong>Acidification</strong></td>
<td>- 0.15 - 0.25</td>
<td>- 0.4 - 0.5</td>
</tr>
<tr>
<td></td>
<td>(1960-1990 average)</td>
<td>(1960-1990 average)</td>
</tr>
<tr>
<td><strong>Rainfall and extreme events</strong></td>
<td>Increased variability in rainfall expected but trends uncertain. Increased intensity of cyclones</td>
<td>Increased variability in rainfall expected but trends uncertain. Increased intensity of cyclones</td>
</tr>
</tbody>
</table>

Ecological impacts are also already evident in the GBR region and include changes in the behaviour, physiology, function, productivity, and mortality of many species, ecological communities and ecosystems (Berkelmens et al. 2004; Done et al. 2003; Hoegh-Guldberg and Hoegh-Guldberg 2004; Marshall and Johnson, 2007; Meehl et al., 2007). Direct impacts on social systems and indirect impacts through effects on ecological systems will have considerable consequences for human livelihoods and values in the region, including agriculture, fisheries, tourism, and biodiversity conservation. These impacts will be more severe as CO₂ emissions continue to rise.

**Fisheries:** The GBR fisheries will be impacted by sea surface temperatures (directly and indirectly through effects on coral reef and coastal habitat), ocean acidification, sea level rise and other disturbances such as rainfall run-off and extreme events. These climate-driven changes can affect the fecundity, dispersal and settlement, behaviour, distribution, productivity, growth and mortality of fishes. Changing abundance and distribution of target species in turn affects the viability, value and enjoyment of different fishery sectors. Climate change and its impacts represent an added disturbance to the fisheries sector. Fisheries resources are already under pressure from run-off, pollution, and in some cases over-fishing, while the stakeholders are affected by volatile economic markets, changes to regulation, and fuel price fluctuations.

**Tourism:** There is considerable uncertainty around the extent to which tourism is affected by reef quality, although evidence suggests that visitor numbers in the GBR region have already decreased due to changes to reef quality associated with coral bleaching, poor water quality,
and crown-of-thorns starfish (Fenton et al., 2007). Research by Tourism Australia shows that visitors from the key markets of the UK, China and Japan rank climate change in their top three issues of concern and importance in holiday planning (2008). Weather, in particular, is a key factor influencing length and quality of the tourist season and visitor satisfaction (Great Barrier Reef Tourism Climate Change Action Strategy 2009-2012). More stormy and wet weather will affect safety of passengers and tourism operators, industry seasonality, tourism infrastructure and associated tourism industry development (Fenton et al. 2007). More severe storms and sea-level rise will also put waterfront and coastal infrastructure, including marinas, roads, restaurants and accommodation, at risk (Great Barrier Reef Tourism Climate Change Action Strategy 2009-2012).

As with fisheries, climate change impacts of relevance to the tourism industry are exacerbated by other stressors, including poor water quality and fishing (Marshall and Johnson, 2007), as well as fluctuations in the economic market. The tourism industry is particularly vulnerable to external disturbances, including political and economic events, real and perceived security issues, weather, and consumer preferences. Climate-driven changes in tourism in particular, are highly subjective and dependent on what happens elsewhere; the GBR may lose or gain a marketing advantage as a reef and/or coastal destination. Indeed, as more than 50 percent of tourists visiting the GBR region are ‘reef-interested’ and represent 70 percent of total tourism expenditure in these regions (Hoegh-Guldberg and Hoegh-Guldberg 2004), the implications of climate change impacts on the GBR for tourism are considerable.

Biodiversity conservation: Marine and coastal habitats, including coral reefs, seagrasses and mangroves, as well as the species that depend on them, (e.g., benthic and sub-tidal organisms, fish, turtles, dugongs, and sea birds) are affected by the full range of climate changes (e.g., air and sea surface temperature increases, sea level rise, changes to rainfall and storms) to a greater or lesser extent (Marshall and Johnson, 2007; Lovelock and Ellison, 2007). Climate change will impact habitat availability and quality, food sources, breeding sites, distribution of other species, and composition of ecological communities. In many cases, the expected trends in climate change in terms of temperature, acidity, sea level and other disturbance (due to changes in rainfall runoff and extreme events) are likely to fall outside the ranges of natural variability or the conditions previously experienced by many coastal and marine ecosystems and species. Broadly, biodiversity will be affected through associated changes in distributions, productivity, and mortality of species.

3.1.4 Governance and climate change in the Great Barrier Reef region

A number of climate change mitigation and adaptation plans have been developed for the Fisheries and Tourism industry of the GBR, as well as for biodiversity conservation. The Great Barrier Reef Climate Change Action Plan 2007-2012 is the overarching plan for the GBR. Central to the Action Plan is the GBRMPA’s broad objective to enhance the resilience of the reef ecosystem, but the plan also addresses adaptation of industries and communities, and climate footprints. Under the adaptation objective, the plan refers to fostering enabling legislation and industry regulation, promoting risk assessment and adaptation planning at the level of individual businesses, and collaborating with local government to build resilience in communities and industry.

More specifically, the National Climate Change Action Plan for Fisheries and Aquaculture (2010) sets out climate risk, mitigation potential and adaptation options for the commercial and recreational wild catch fisheries. Its primary focus is to identify management strategies,
policy opportunities, and operational actions to improve the adaptive capacity of the fisheries sectors in order to ensure sustainability and preserve their competitiveness. The strategies identified generally promote i) understanding and awareness of climate change, ii) improved resilience of fisheries operations, through climate risk assessment in business planning and value chains, and removal of identified barriers to adaptation, including legislative constraints on mobility, diversification and so on; iii) monitoring of impacts and outcomes, and iv) provision of an enabling policy environment.

The Great Barrier Reef Tourism Climate Change Action Strategy (2009-2012) similarly lays out a set of objectives for adapting to climate change and reducing the climate footprint of the Tourism industry. Objectives include broad awareness, understanding and action to enhance resilience of the reef, as well as more strategic action to integrate climate concerns into business planning. A tailored guide on climate mitigation and adaptation for the industry then lays out particular actions that tourism operators can take to respond to climate change (Climate Change Guide: mitigation and adaptation measures for Australian tourism operators, 2009). Importantly, the first module in the guide outlines how an operator can evaluate their business in order to understand the key impacts of their operations. Adaptation strategies outlined in the guide then include improved self-sufficiency and reduced dependence on external supply of inputs such as water and electricity, increased efficiencies through technologies and changed behaviours, diversified product, reduced impact on the natural environment, increased marketing and information provision, improved health and safety, and emergency planning.

Many of these government initiatives are supported and reflected in industry level planning and action on climate change. For instance, the Climate Futures work by Tourism Queensland and CSIRO, and the stewardship, risk assessment and adaptation work emerging in various fisheries in Queensland.

3.2 Methods

3.2.1 Literature review

We conducted an initial rapid literature review to consolidate existing knowledge of climate change trends, impacts, adaptation, and potential limits to adaptation in the Great Barrier Reef region. We undertook three distinct literature searches, using ISI Web of Knowledge, to compile literature related to: i) climate change trends and impacts; ii) adaptation responses; and iii) limits to adaptation. All three searches focused on literature related to the GBR or Queensland, and in the case of limits to adaptation, also to Australia. Additional searches were carried out using the Google Scholar database for subject-specific material, to fill identified gaps in the acquired information. In total 253 articles were fully reviewed and referenced in the background literature review.

3.2.2 Scenario development

We developed a set of four alternative future scenarios to explore different climate change and adaptation outcomes. Scenarios are plausible descriptions of how the future may unfold (IPCC, 2000). They do not predict the future but present different choices and suggest potential outcomes resulting from these choices. While scenarios can over-simplify complexity, they are powerful tools for thinking through and visualising key interactions and
outcomes, thereby facilitating multi-stakeholder engagement in the research process. Scenarios have been used at the global level to model changes to our climate from global carbon emissions (IPCC, 2000), and to investigate the links between ecosystem change and human wellbeing (MA, 2005). They have also been used at the regional level in the GBR to understand the perspectives of stakeholders to climate change (Fenton and Beedon, 2006); to explore potential outcomes for the region based upon two key uncertainties, identified as climate change and governance (Bohnet et al., 2008); and, recently, to outline more specifically the range of futures that could emerge in the region by 2100 from different combinations of global and regional action on climate change and environmental governance (Bohensky et al., 2011).

Our scenarios are framed around two climate change trends: best-case (reflecting a situation where climate change is mitigated) in which instance air temperatures rise by less than 1.5°C above 1990 levels (or 2°C above pre-industrial levels), and; worst-case (reflecting a situation in which climate change is not mitigated) whereby air temperatures rise by more than 2.5°C above 1990 levels (or 3°C above pre-industrial levels); and two adaptation pathways: ideal ecological and social adaptation; and limited ecological and social adaptation (Figure 2). Limited adaptation represents a situation in which adaptation in natural and human systems does not reduce the vulnerability to climate change of marine organisms or the fishing and tourism industries and individuals. Ideal adaptation instead reflects a situation where adaptation is effective in reducing vulnerability to climate change.

**Figure 2:** Four alternative scenarios representing two possible climate change trends and two adaptation pathways

We developed the scenarios through a process of scientific consultation. Scientists working on climate change in Australia, from a range of disciplines, were contacted by email, provided with a project brief (Appendix A), and asked to contribute to the project by completing a scenario response template (Appendix B). This template included information on climate change trends for 2050, under the best-case and worst-case scenario (Table 2). These climate change projections were largely based on the GBRMPA’s vulnerability assessment (Johnson and Marshall 2007) and are within the ranges outlined in the regional climate projections developed by Queensland Climate Change Centre of Excellence (QCCCE, n.d.).
Table 2: Summary of the climate change trends underlying four alternative scenarios of climate change adaptation in the Great Barrier Reef region

<table>
<thead>
<tr>
<th>1. Best case climate scenario for 2050</th>
<th>2. Worst-case climate scenario for 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature + &lt;1.5°C</td>
<td>Air temperature + &gt;2.5°C</td>
</tr>
<tr>
<td>Sea surface temperature +1°C</td>
<td>Sea surface temperature +2°C</td>
</tr>
<tr>
<td>Sea level rise +0.13m</td>
<td>Sea level rise +0.68m</td>
</tr>
<tr>
<td>pH reduced -0.15</td>
<td>pH reduced -0.25</td>
</tr>
<tr>
<td>Rainfall moderately more variable</td>
<td>Rainfall considerably more variable</td>
</tr>
<tr>
<td>Cyclones more intense</td>
<td>Cyclones much more intense</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>a. Limited adaptation</th>
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The scientists we contacted were asked to outline potential ecological and social impacts from these climate change trends and to explore adaptation strategies under a limited and ideal situation. Approximately 200 scientists were contacted and our direct response rate was approximately 13 percent (n = 27). Some of these responses were group responses, compiled following brainstorming meetings on the scenario framework. The response data were coded by three project investigators and the most frequent trends were used to develop the scenarios. Respondents ranged from fish and coral ecologists, mangrove and seagrass specialists, and those working on turtles and sea snakes, to agricultural scientists, environmental engineers, planners, and economists and social scientists working on fishing, tourism, agriculture and coastal development. Other scientists provided information in the form of papers and project briefs which were included in the literature review. Having developed the scenarios, we then selected to focus further activities on the Reef and its fishing and tourism industries in order to achieve some level of depth in our analysis. Agricultural and coastal development issues were included in the scenarios but as relevant to fishing and tourism, rather than in their own right.

The scenarios can be accessed through [URL]:
[http://dl.dropbox.com/u/9744348/Limits%20to%20CCA%20in%20the%20GBR.pdf](http://dl.dropbox.com/u/9744348/Limits%20to%20CCA%20in%20the%20GBR.pdf)

3.2.3 Grounding scenarios and exploring limits

To ground-truth our initial set of alternative scenarios, we then conducted a series of multi-stakeholder workshops and interviews with representatives of the Queensland Government, local government, the fishing and tourism industries, non-government organisations and research institutions. We held a workshop in Townsville on 25th March 2011 (n=9) and a workshop in Cairns on 01 April 2011 (n=10) (Appendix C). Interviews were conducted with stakeholders in Bowen, Mackay, and Townsville (n=7) to reach stakeholders who were unable to attend the workshops (Appendix E). The people who participated in our workshops and interviews (n = 26) were representatives of their agencies rather than individual owner operators, except where individuals had been put forward as representatives. This meant that the pool of contacts was relatively small but every effort was made to include a wide range of organisations. Representatives from Agric-Science Queensland (DEEDI), Cairns and Far
North Environment Centre (CAFNEC), Cairns Marine, Cairns Regional Council, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), EcoFishers Queensland, Mackay Tourism, Ocean Watch, Queensland Parks and Wildlife Service (DERM), Queensland Fisheries (DEEDI), Queensland Seafood Industry Association (QSIA) and independent operators, Queensland Tourism Industry Council (QTIC), SunFish, and Tourism Queensland attended the workshops or agreed to interviews. Several representatives from the GBRMPA, Natural Resource Management bodies, conservation agencies, and traditional owner groups were invited to attend the workshops but did not. A third workshop in Mackay was considered but there were not enough representative contacts to warrant going ahead in that area. Instead, we conducted individual interviews with key stakeholders. With more time, we may have been able to follow up with the agencies which are not represented in the workshops, through interviews, which require less time from busy and over-workshopped staff.

The scenarios represent best available information and scientific opinion on the ecological and social impacts of two sets of climate change trends: best and worst-case. The scenarios then purposefully contrast the limited and ideal adaptation pathways by suggesting adaptation actions which fail to reduce vulnerability to climate change on one hand (limited) and adaptation actions which do effectively reduce vulnerability to climate change on the other (ideal). The adaptation strategies suggested under the ideal and limited situations are taken from the responses to the scientific consultation and also reflect broad consensus in the literature on appropriate adaptation strategies. However, they are used to incite discussion about what is actually effective or limited in the context of the GBR region. Participants in the workshops were asked to critique and contradict the scenarios where they were not appropriate to their knowledge and experience. The scenarios, particularly with regards to adaptation and overall outcomes, therefore, do not intend to reflect the current or projected reality of the GBR. The workshops and interviews explored a range of issues, including i) the plausibility of the scenarios for different parts of the GBR region, ii) whether the adaptation strategies outlined in the scenarios were feasible and to what extent they would reduce the vulnerability of the fishing and tourism industries and individuals to climate change impacts under best-case and worst-case climate scenarios, iii) to what extent different industries or groups within industry were more or less able to adapt in certain ways, iv) what factors prevented groups adapting as they would like to, v) what the overall implications were for the industries and vi) to what extent these implications and outcomes reflect desirable or undesirable futures. Through the discussion we addressed the project objectives outlined above, which were to explore: i) the limits and opportunities that characterise adaptation, ii) the trade-offs and synergies that occur between sectors, and iii) possible conflicts that arise from climate change adaptation in the region. Workshop discussions and interviews were digitally recorded and transcribed and the data were coded by three project investigators in QSR Nvivo V9.

### 3.2.4 Disseminating findings

We presented our research findings to policy makers and managers in a dissemination workshop in Brisbane on 12th August 2011 (n = 7). Representatives from Agric-Science Queensland (DEEDI), Great Barrier Marine Park Authority (GBRMPA), the Great Barrier Reef Foundation, Griffith University, the Queensland Office of Climate Change (DERM), and Queensland Seafood Industry Association (QSIA) attended. Participants discussed the scenarios, the findings, the categorisation of bundles of limits into ‘wicked problems’, and the
potential of a ‘limits to adaptation’ perspective to inform ongoing adaptation planning and action.

In total over 60 people provided input into this scoping study and the findings suggest interesting avenues to pursue further through more comprehensive analyses of adaptation and limits to adaptation in GBR ecosystems and industries.

3.3 Results

The results outline potential ecological and social adaptations and their limits based on information and data from the literature review, scientific consultation, and stakeholder workshops.

3.3.1 Ecological adaptation and its limits

Marine and coastal habitats and associated organisms each have their own unique capacities for climate change adaptation. For instance, under climate change, corals will face two main challenges: rising sea surface temperatures and ocean acidification. In response to increasing temperatures, corals can adapt in three ways. They can acclimatise (a phenotypic change within an individual), adapt (a genetic response at the population level), or shift their geographical distribution (Hoegh-Guldberg et al. 2007; Precht and Aronson, 2004; Walther et al. 2002). Research on the potential for corals to cope with acidifying seas is still in early stages. Nevertheless, it appears that coral species vary in their ability to deal with increased acidity (Manzello 2010); and that they may be able to reduce the effects of acidification through physical or physiological mechanisms (Ries et al. 2009; Ries et al. 2010). Seagrass and mangrove habitat will need to adapt to increased temperatures, increased physical disturbance from sea-level rise and cyclone/storm activity, and potentially increased exposure to run-off and associated impacts from increased siltation and nutrient loads. Seagrasses and mangroves can adapt by altering their physiological capacity, morphological structure, and by shifting vertically and horizontally up slopes (Cahoon et al. 1999; Morris et al. 2002; Waycott et al. 2007). Mangrove response to severe storm/cyclone damage is largely unknown, however there has been some evidence to suggest that trees can recover as long as patches of reproductive individuals remain and hydrology and sediments are not altered to an extent where reestablishment is prevented (Gilman et al. 2008; Sherman et al. 2001; Smith et al. 1994).

Ecological and physical limits to adaptation comprise the natural limitations associated largely with the natural environment, ranging from ecosystem thresholds to geographical and geological limitations (Jones, 2010). There is mixed evidence for adaptation of corals in situ. Overall, corals appear to have already reached their limits for acclimatisation and adaptation, suggested by the increasing mortality rates among coral communities over the past 25 years (GCRMN 2004; Hoegh-Guldberg 1999; Hoegh-Guldberg et al. 2007). With regards to geographical shifts, species distributions of corals are influenced by species-specific physiological thresholds of temperature and precipitation tolerance. Some coral species may be able to respond to warming seas by shifting south along the GBR (poleward in latitude) and upward in elevation, to the extent that dispersal and resource availability allow (Walther et al. 2002). However, such shifts may not occur if distribution shifts are limited by other factors such as light (Walther et al. 2002) and water quality, and even if they do occur, are not expected to be fast enough to compensate for warming-related losses (Precht and
Aronson, 2004). The differing capacities of different species of corals to adapt to climate change are likely to result in changes in coral community composition.

Local declines in existing seagrass populations along the GBR in response to storms and floods suggest that ecological adaptation to these kinds of impacts is limited (Shaffelke et al. 2005). In contrast, the potential rate of vertical growth of most seagrasses will be greater than the predicted rate of sea level rise (Waycott et al. 2007), assuming minimal obstruction from coastal structures and artificial barriers like rock walls and groynes (Orth et al. 2006; Waycott et al. 2007). Yet, evidence suggests that significant seagrass habitat continues to be lost to coastal development (marinas, canal estates, and industry), leading to meadow fragmentation, with unknown consequences for long-term survival (Fonseca et al. 2000). Among the 97 estuaries within the GBR region that have been surveyed, there is a high proportion of salt-marsh/salt-flat to mangrove (Lovelock and Ellison, 2007; Ozcoasts, 2010), and a gently sloping coastal plain that is currently infrequently inundated, which suggests that significant landward expansion of mangroves is possible (Lovelock and Ellison, 2007). However, like with corals and seagrasses, distribution shifts in mangrove habitat are largely dependent on the lack of other physical barriers, so will be heavily influenced by coastal development policy and trends.

The scenarios reflect varied but relatively limited capacity for physiological and morphological adaptation in coastal and marine habitats. In scenario 1b in which climate changes are minimised and adaptation ideal, heat-sensitive corals are able to buffer and recover from disturbances, particularly as impacts under this scenario are localised or patchy, but recovery is inhibited by acidification, which slows growth to some extent. In scenario 2b in which climate changes are not mitigated but adaptation is ideal, the capacity for these types of ecological adaptations is overwhelmed by the rate and extent of climate change, with ocean acidification undermining the coral structure in addition to slowing growth. On the other hand, the capacity of mangroves, seagrass and beaches to buffer impacts from sea-level rise and increased intensity of storms is minimal, even under an ideal adaptation situation. Instead, under ideal adaptation - 1b and 2b - the potential for adaptation through distribution shifts is considered more viable. In general, responses from the scientific consultation suggest that the outcomes for marine and coastal habitat in the different scenarios are determined by the effectiveness of management and social adaptation rather than by the inherent capacity for ecological adaptation of these systems. Where catchment and reef management build resilience and connectivity and where coastal development enables movement of habitat upstream, shoreward and south, habitat loss is minimised. In a best-case climate scenario habitat cover is maintained, though composition and location change (scenario 1b). However, in a worst-case climate scenario even ideal management and adaptation strategies cannot fully buffer the effects of climate change (scenario 2b).

With regards to fisheries resources, it is estimated that up to 75 percent of fish stock abundance is explained by environmental factors and climatic processes (Munday et al., 2008). Fish are, therefore likely, to be sensitive to the full suite of climate changes. Fish can adapt through acclimation, adaptation and range shifting. The extent to which fish adapt will vary greatly among species, depending on their current ranges, habitat requirements, temperature tolerances, genetic connectivity with other populations and generation times (Munday et al. 2008).

Acclimation or adaptation of fish to increased temperature seems possible, especially for species with short generation times. However, there is little prospect of adaptation to
associated habitat degradation (Munday et al. 2008). So, the ecological limits to adaptation in coral, seagrasses, mangroves so on, have high implications for the ecological limits to adaptation of dependent species. Climate change is also predicted to drive fish species ranges toward the poles – south in the context of the GBR (Perry et al. 2005). For some species, like many coral reef species, which are broadly distributed, their geographical ranges might not be significantly affected by climate change in the short-to-medium term (Munday et al. 2008). For other species, particularly pelagic species which respond to temperature on a seasonal or inter-annual time-scale, their distributions are likely to shift and potentially reduce, where southerly migration is limited by thermal or physical thresholds (Hobday 2010). Many of these changes are likely to have negative consequences for abundance and productivity. However, some species may benefit from changes to the East Australian Current and nutrient upwelling (Hobday et al., 2006), and some to changes in habitat (e.g., herbivores). With regards to ocean acidification, internal pH in fish is controlled by the exchange of ions, mostly across the gills, and small changes in internal or external pH can be readily compensated (Claiborne et al. 2002). Although this adaptation mechanism is not detrimental in the short-term, ultimately it might have some physiological costs, especially for species such as pelagic fishes with high metabolic rates (Munday et al. 2008).

In the scenarios, the outcomes for coral reef fish are largely driven by changes to habitat. Only in the scenario where coastal development, and catchment and reef management buffer impacts from minimal climate changes (scenario 1b) are the indirect effects on dependent species nominal. In the remaining scenarios either rapid rates of climate change (scenario 2b) or ineffective social adaptation (scenario 1a and 2a) lead to reduced abundance of coral reef fish. Only a few species benefit from these habitat changes (e.g., Red-throat emperor and herbivores). In relation to direct effects on fish from climate change, responses from the scientific consultation suggested outcomes, including more variability in abundance of species dependent on rainfall or nutrients (e.g., barramundi, prawns, some pelagics), and shifts in almost all species ranges southward and to deeper waters. The assumption is made in the scenarios that species will shift distribution as the primary ecological adaptation strategy before adapting physiologically to climate changes. The trends are the same in both sets of scenarios, but the degree of change is faster and more extreme in the worst-case climate scenarios, with greater implications for the GBR industries.

In general, the ecological limits to adaptation will largely depend on the degree and speed of climate change. While ecological adaptation strategies are available to corals, seagrasses, mangroves and fish, they may be overwhelmed at even moderate levels of climate change. Other factors, including non-climatic stressors and existing use of these ecosystems and resources, which reduce resilience and create physical barriers to re-distribution, to some extent also undermine the full potential for ecological adaptation. In essence, the capacity for social adaptation will largely drive the overall outcomes for the GBR ecosystems and industries.

3.3.2 Social adaptation and its limits

Within human systems, adaptation comprises both individual and collective decisions and action, in this case in response to existing or anticipated climate impacts (Adger et al. 2007). Adaptation can manifest as either building adaptive capacity thereby increasing the ability of an individual or group to implement adaptation actions, or implementing adaptation actions directly (Tompkins et al. 2009; Moser and Ekstrom, 2010). Here, we focus on both adaptive capacity and direct adaptation action within the fisheries and tourism industries of the GBR,
at the sector and individual level. From the literature review, scientific consultation, and stakeholder workshops we have classified adaptation strategies as: i) industry organisation, ii) business planning, iii) stewardship, iv) mobility and migration, v) effort, vi) diversification, vii) technology, viii) infrastructure development and, ix) emergency planning (e.g., Mahon, 2002; Tompkins and Adger, 2004; Brander, 2007; Fenton et al., 2007; Marshall and Marshall, 2007; Nilsson et al., 2007; Daw et al., 2009; Badjeck et al., 2010; Jopp et al., 2010; Hale et al., 2010; Perch-Nielsen, 2010; Tobin et al., 2010; Biggs, 2011).

Importantly, climate adaptation is generally viewed by the GBR stakeholders we spoke to as one component of overall enterprise or ecosystem management, not as an independent agenda. Integration of climate risk or vulnerability assessment and adaptation planning into broader development (industry and coastal development) and environmental management, rather than the other way around, is seen as critical to the success of climate change policy. Many of the experiences and insights discussed by these stakeholders relate to non-climatic events that influence their industries, but with implications for adaptation to climate change. Further, climate change is seen as one driver of change among many. Adaptation is, therefore more beneficial where it addresses more than one potential threat or opportunity.

**Industry organisation:** The scenarios suggest that under a best-case climate change situation, the ecological and social impacts will not trigger re-organisation of the fisheries or tourism industries (scenarios 1a and 1b). Under a worst-case climate change situation, industries will re-organise in two directions. In one instance, the industries aggregate into large international companies in an effort to buffer climate impacts through efficiency (scenario 2a). This is portrayed in the scenarios as a limited adaptation option that will not reduce the vulnerability of those adapting. In the other case (scenario 2b), the industries organise into co-operatives, which aim to buffer climate impacts through collaboration and operator ownership. This is expected to be a more effective adaptation option to reduce vulnerability of industries and individuals and is portrayed as ideal.

Insight into how re-organisation might work as an adaptation strategy can be drawn from the experiences of different commercial fisheries (within and beyond the GBR), which are already organised in a variety of ways in response to non-climatic factors. Some fisheries, such as the inshore fisheries, which are lower profit fisheries, may not be bought up by international interests but remain as independently operated fisheries. In other fisheries, however, commercial development incentives are driving amalgamation into bigger companies. Consolidation of assets in big companies is essentially a strategy for increasing efficiency, which may work to accumulate profit in contexts of stability and predictability. However, in contexts of uncertainty and variability the strategy may increase vulnerability to disturbance events, including climate risks. It was perceived by the workshop participants and industry representatives that while amalgamation strategies may keep big business owners viable, they reduce the adaptive capacity of individual owner/operators who work under this arrangement.

_The big amalgamation that’s occurring over the longer term removes that ability to diversify. If the banana prawns fall over in the gulf next year because of increased acidification, you’ve got a huge industry there which has an extremely small ability to diversify or adapt... I expect that X or Y [names of big conglomerates] is smart enough to have enough money backing them that if the banana prawn fishery falls over tomorrow it’s not going to mean the end of their business. They’ve got investments elsewhere_ (Fishing industry representative, 25 March 2011)
The big conglomerates are a commercially run business, whereas the owner/operators are the ones who are prepared to adapt, who are there for the long term and who are looking at not just how much money they are going to make in this fiscal year, but they’re looking at an industry there for their kids. They’re the ones who want to adapt to climate change (Fishing industry representative, 25 March 2011)

Reducing the adaptive capacity of individual operators, by treating them as company assets and removing them from decision-making roles, has implications for the capacity of these operators to adopt other adaptation strategies, including improved stewardship, reduced effort, and diversification. On the other hand, building a degree of efficiency into industry and business models can lower operating costs and contribute to adaptive capacity. Similarly, improving collaboration and co-operation amongst operators can strengthen collective capacity to address problems and establish codes of conduct thereby also contributing to adaptive capacity. There are other organisational models, which fall along the spectrum of independent operators to large corporations, which facilitate this. For instance, the Northern Prawn Trawl fishery is managed as a proprietary limited company in order to benefit from economies of scale on procurement and marketing as well as to function as a point of contact for government. This and other models reflect co-operative arrangements with buy-in from members and are generally viewed as more effective for reducing vulnerability of owner/operators. However, the capacity of the GBR fisheries to adopt a particular organisational model as an adaptation strategy is dependent on their current context and make-up. The East Coast Trawl Fishery for instance, has more operators than the Northern or Gulf Trawl fisheries and is highly dispersed making it difficult to amalgamate or form a co-operative.

In the commercial fisheries of the GBR, the participants in our research perceive the sectors to comprise of a normal distribution of operators: with some being highly innovative, adaptive and profitable, the bulk being moderately adaptive and profitable (though profitability of fisheries is declining), and a proportion being less adaptive and less profitable or unprofitable. The innovators apparently represent 5 to 15 percent of the industry and are relatively unconcerned by changes affecting the industry, such as market or regulatory change, because they are quick to adapt. They are considered to be entrepreneurs or professionals who are most highly motivated by profit. These operators are not necessarily larger, just “smarter” in terms of their approach to business. Indeed, following cyclone Hamish, many of the bigger operators in the Reef Line Fishery, with big capital investment and who were following rapid growth trajectories, where the ones who were forced to exit the industry, while the smaller operators, without debts, managed to buffer the prolonged declines in stock availability.

The operators at the tail end of the distribution are the most vulnerable to change. They include the operators who are more motivated by the lifestyle values of the industry and may include new or younger entrants with less capital investment. Some of these operators, as new entrants, may be the future innovators and their adaptive capacity needs to be fostered by industry and government. Adaptation at the industry level involves “forewarning” and “forearming” operators, and providing them with the tools they need to understand their own vulnerability to disturbance (biophysical, market, management change) and how to adapt appropriately to perturbation. On the other hand, some of these operators cannot and will not manage to build capacity to adapt (through the improved business planning and other
adaptations). At the industry level, these operators add to pressure on fisheries resources, market share, and profits and may undermine the capacity of the industry as a whole to persist in the long term. As it is, the profitability of commercial fisheries is on a downward trend as prices have stagnated and costs have risen. Adaptation at the industry level may therefore involve facilitating the exit of these operators (thereby reducing capacity of the fleet or re-distributing quota).

There’s always going to be the innovators who will remain profitable. The ones we need to worry about are the ones in the middle and the other end, the lifestyle fishers who will be the first to go (Fishing industry representative, 01 April 2011)

Depending on the particular characteristics of the fishery and the factors driving declining trends in economic viability, industry buy-backs may or may not reduce the vulnerability of the sector overall and of the operators remaining to climatic and non-climatic perturbation (see more detail under effort).

The nature of recreational fishing industry is somewhat different to the commercial sector. However, some of the issues around industry organisation are relevant to the adaptive capacity of recreational fishing groups. In particular, the increasing recognition of the economic importance of the recreational sector (e.g., in the northern territory), and the sector’s efforts to organise into representative associations (e.g., Sunfish and Ecofishers) are perceived to be strengthening the industry’s legitimacy and level of participation in broader fisheries and tourism policy and management planning. There is mounting pressure on the industry associations to comprehensively encompass and represent members of the recreational fisheries sector, although buy-in from members is still a challenge, considering that recreational fishing is primarily a leisure activity. Adaptation at the industry level aims to account for the concerns and capacities of fishers and the broader industry (suppliers, traders etc). The association representatives included in this research find most benefit in working closely with fishers and associates in the tackle trade and tourism industries. A climate change action plan is in review. Nevertheless, organisation of the industry and representation by industry associations are not yet perceived by some recreational fishers to be bringing benefits to individual recreational fishers in terms of greater enjoyment of the resource, at least not in Queensland.

The GBR tourism industry is characterised by strong representation from industry associations. These associations help the industry adapt through planning, marketing, and business support. According to the industry representatives we spoke to, the Australian tourism industry is highly regulated (building codes, licensing, insurance etc), with high labour costs compared with competing markets in South-East Asia and the Pacific, and is thereby disadvantaged in the extravagance of the experience it can offer. Industry associations focus a lot of attention on mitigating this market disadvantage and trying to promote the strengths and unique products of the industry. With respect to climate change, participants suggested that the challenge is to portray the real extent of change, to manage tourism numbers in sensitive areas, to market the ongoing strengths of the region regardless of change, and to maintain the viability of the industry throughout the region. The industry is generally a high turn-over industry, with many operators moving into and out of the sector. Similar to the commercial fishing sector, there are those who constantly innovate and remain profitable, despite the myriad of recent impacts on the industry, and there are some that don’t innovate and adapt or whose efforts to do so are overwhelmed by the persistence of recent disturbance events (economic and climate related). Business planning is considered critical to
raising the adaptive capacity of individual operators in order to ensure a sustainable industry overall.

**Business planning:** In the scenarios, enhanced business planning is suggested as a key strategy for effectively buffering the impacts of climate change under both best-case and worst-case climate risks (scenario 1b and 2b).

Many individuals and businesses within the GBR fishing and tourism industries have experience of adapting to a range of perturbations from which they can learn (e.g., the Representative Areas Programme, Global Financial Crisis, fisheries management plans, cyclones). However, according to industry representatives, many operators do not have a business plan, let alone a business plan that can help them understand what happens to their businesses in times of change. To some extent the uncertainty in these industries makes it difficult to plan precisely. Nevertheless, a number of business planning skills could improve adaptive capacity of operators and the industry, no matter what size they are or what business model they use, including enhanced forecasting, financial management, marketing, and networking.

*It’s more about making people aware of the changes ahead and to draw on their experiences* (Fishing industry representative, 01 April 2011)

**Forecasting:** Fishers are particularly renowned for dealing well with uncertainty and, in some cases, for being able to interpret and respond to environmental signals. However, climate change is expected to increase the variability in weather patterns and environmental signals and to result in impacts that are more long-term and widespread, less temporary and localised. At the same time, climate change adds yet another dimension to the uncertainties and pressures already felt by Reef industries. To deal with the increased variability and uncertainty, scientific tools are being developed to model and forecast biophysical and ecological changes at smaller resolutions and to provide this information to the fishing, tourism and agricultural industries to support planning. A recent example is the regional projections developed by the Queensland Climate Change Centre of Excellence (QCCCE, n.d). An example was provided in the workshops of dynamic climate forecasting improving the capacity of fishing operators in Western Australia to more precisely target lobster populations that are shifting in response to the La Niña weather pattern, thereby reducing fuel costs and preserving yields (Representative of the scientific community, 01 April 2011). These types of forecasting tools work better for some sectors than others, depending on the correlation between climate change trends and predictability of impacts, such as stock availability or visitation numbers.

Other decision-making tools are also emerging to aid vulnerability assessment, adaptation planning, and business planning. For example, there are computer work-packages now available to allow businesses to input different figures into a spread-sheet to understand what revenues are required to maintain a profit margin under a range of input cost scenarios (e.g., Tourism Queensland, n.d). Similar, activities are emerging in the fisheries sector.

*What I’ve been trying to do with our fishery is to model some scenarios, in terms of ‘what are you going to do if you’re price of electricity goes up say 20 percent or the price of fuel goes up? How are you going to change your business model?’ At an industry level, we can [deliver] information and modelling scenarios, but because*
each business model is different, it’s going to come down to working with each different enterprise. (Fishing industry representative, 01 April 2011)

It was suggested that one component of better forecasting is better monitoring. This is being facilitated in the GBR, through community-based monitoring programmes (e.g., BleachWatch), and improved technologies which allow electronic and real-time recording of catch to gain insight into spatial and temporal distribution.

It’s our fishery feedback. The line fishery, the net fishery, we are all trying to feedback this data and collect this data so we can really monitor, so we can really take out the guess work out (Fishing industry representative, 01 April 2011).

According to one respondent, the next step is to get electronic synthesis and rapid feedback of information to inform management decisions.

Improved forecasting can enable operators to better allocate resources within their business. For instance, there was an example in the tourism industry where operators in two complementary sectors, alpine ski areas and Airlie beach, Whitsundays, arranged to share staff to meet their seasonal requirements whilst ensuring retention of skilled labour. There was also an example where business advice on ‘weather proofing’ businesses prior to cyclone Yasi, enabled operators to explore and action contingency plans. In one case an operator took their boat out of the water and arranged for senior staff to be employed through another operator for the season. However, it was also argued that this kind of resource sharing perhaps doesn’t occur often enough and businesses need to get better at forecasting and cooperating to improve their capacity to buffer seasons such as the 2010/2011 Queensland floods and cyclone Yasi (Tourism industry representative, 25 March 2011).

Financial management: Regardless of the added threat of climate change, the adaptive capacity and general viability of many enterprises within the GBR is already undermined by a general lack of business accounting and financial management skills.

We hosted a number of business consultants who took individual operators and we went through their businesses and their cash flows. The amount of those businesses that were running at a loss was incredible (Representative of the fishing industry, 01 April 2011).

Respondents felt that a vital component of adaptation planning at the industry and enterprise level is equipping operators with this knowledge.

We say to people [tourism operators] that yield management is the most important thing for them - know what it costs to open your business and know what it costs to not open your business for a start, which a lot of our guys don’t know (Representative of the tourism industry, 25 March 2011).

The best thing that ever happened to me, I found out that once we [fishing industry] were under the primary industries umbrella, I could go and see the financial adviser and sit down with him for free and go through all our stuff. We’re suddenly starting to see the benefits of it now. It was great. It didn’t cost me any money, but I got expert advice. I couldn’t afford to get advice anyway at the time, because we were really struggling (Representative of the fishing industry, 01 April 2011)
In general, financial capital can enable innovation and facilitate a number of other adaptation strategies. However, high capital investment in fixed assets can also prove the biggest burden and constraint on adaptation in times of turmoil. It is therefore vital to understand the implications of highly capitalised and low capital business models for periods of stability and change. Further, climate change adds another dimension to financial management by potentially affecting input costs such as fuel (through carbon taxes) and insurance (through post-disaster premiums). Forecasting is one element of effective financial planning. It can help owner/operators to foresee perturbation and develop contingency plans accordingly. However, forecasting and financial planning cannot completely ‘climate proof’ businesses particularly in periods of composite disturbance.

So we’ve [tourism industry] lost businesses that will never come back. They’ve had such a soft last 12 months and lost the fat because of this global economic crisis. And then the rain, we’ve had 12 months of unseasonal rain in the time it should be dry (Tourism industry representative, 25 March 2011).

Marketing: A critical and widely recognised opportunity for owner/operators in the GBR is the potential of improved marketing skills to strengthen their businesses overall, thereby building buffering capacity, and to directly enable adaptation actions such as diversification. Marketing includes improved packaging and advertising of a product to make it more appealing, but also brand management and reputation, so can apply to the recreational fishing industry as well as the commercial fishing and tourism sectors. Many operators in the GBR were described by our participants as price takers not price makers, particularly in the fishing industry, and the challenge is described as maintaining, rather than improving prices. Strategies to tackle this include efforts to constrain competition within the Australian market itself, so operators do not try and compete on price thereby lowering profit margins further, as well as efforts to take advantage of the synergies between sectors, for instance the provision of Australian seafood to the tourism sector. However, operators, particularly fishers, have not traditionally been strong in marketing and can struggle to offer product that competes in terms of reliability and convenience in the food service industries.

Fisherman would have been working last night. They want to come home the next morning, put their fish into a market place, be it a wholesaler, and walk away. They don’t care after that, because ‘I’ve done my bit’ That’s the way its operated for 30-40 years. The average age of the fisherman is 50 plus...there’s no young heads in the game, and you try and get those guys to change the way they do their business. It’s really hard (Fishing industry representative, 25 March 2011)

Further, increasing global market integration is forcing both tourism and fisheries products in Australia to compete with products from countries overseas, which often do not have comparable legislative and management frameworks and which typically have far lower base costs, including labour.

You’re at the mercy of the market with your price, but there are things that you can do in the business model that you operate within (Fishing industry representative, 01 April 2011)

We’re quite highly ranked as far as an aspirational region, but so are other places. If I’ve got a choice of coming here, then I will make that decision based on a whole lot
of things but one of them is cost...We are so well regulated, our building codes are much better...They [oversees operators] offer an experience that looks very flash and we have an experience that’s very practical and very safe...They don’t pay anything in wages, we obviously pay more. The levels of staffing is how you work out what a 5 star is, the number of staff per guests, so we can never get there (Tourism industry representative, 25 March 2011).

Employing market positioning strategies such as eco-labelling, carbon footprinting, buy-local campaigning and other niche marketing can help maintain market value nationally and abroad, although more so in Europe and America than other expanding economies.

In price responsive markets like China and India and South America, those issues of market positioning don’t apply, and they just happen to be the most populous and obviously the largest markets in the world, so that’s a limitation (Fishing industry representative, 01 April 2011)

These approaches to gaining market share can have the added advantage of triggering stewardship standards over and above that of legislated management. Collaborating on pricing, labelling and marketing is an advantage to both individuals and industries, and according to the representatives we spoke to, the industry peak bodies perceive a greater role for themselves in this regard. Collective marketing strategies for the fishing and tourism industries, driven by industry associations, are more recently contributing, not just to product marketing, but to broader re-branding of GBR industries as sustainable and well-managed.

We have only recently started, since Cyclone Larry, we started calling the reef ‘the best managed reef in the world’. GBRMPA worked really closely with us to get a whole lot of stats and every time something blows up here, we just send it all back to our American staff and our British staff to say ‘yes there was a cyclone, yes this part of the reef has been severely damaged, but its actually 1/20th of the entire reef size and we don’t go there anyway’. So we work really closely with GBRMPA to make sure we’ve got that sort of messaging (Tourism industry representative, 25 March 2011)

Networks and partnerships: Underlying individuals’ and industry adaptive capacity is the capacity to network, which is included here as a key business skill. Networking is considered, by our workshop participants to be particularly important for the adaptive capacity of those in the industry who are least profitable and most vulnerable to disturbance

All of these things that you’ve been seeing here in terms of joining up with cooperatives and associations and companies and all the rest, what that’s fundamentally doing is increasing your networks and increasing your options and getting you to understand that it’s not possible to come up with adaptation strategies by yourself. The more you brainstorm as a collective, we tend to, and we see it again and again, you come up with much more creative solutions (Representative of the scientific community, 01 April 2011).

Links among operators, across industries, and to government and research underpin many of the new innovations in coastal and marine management, business planning and adaptation. Networks can influence to what extent particular relationships exist as trade-offs or synergies.

For instance, it was felt that recreational fishing could benefit from closer formal networks
with tourism, directly between the industries themselves and within government departments. Workshop participants also discussed the potential for partnerships between fishing businesses and community, for instance, to strengthen local marketing and buy-local opportunities, or between fisheries and tourism for local product supply and seasonal produce campaigning or through tours for tourists on fishing vessels and so on.

Community could help to drive that change to having more local markets (Non-governmental organisation representative, 25 March 2011).

However, it was noted by workshop participants that individual operators often don’t have the skills or capital to network and promote themselves and their interests, particularly within the commercial fisheries sector.

A lot of people go to sea because they don’t have to talk to anyone else, and quite seriously they’re really good at fishing, because they can be away for a very long time. These guys are fishers because of their personality type in many ways, which makes them really good at fishing, but particularly bad at networking (Representative of the scientific community, 01 April 2011)

Networks can be fostered among individuals, as demonstrated by an example in agriculture that is moving into the fisheries sector:

In another program called climate champions, we’ve got 34 innovative farmers across Australia sharing their ideas. They’re talking to their peers right across Australia, across commodities. We resource them in a couple of ways: one, we give them a bit of money to travel around; more importantly, we resource them by giving them access to scientists and others, to ask questions (Representative of the scientific community, 01 April 2011)

They’re looking at ways of getting innovators in Queensland to talk to innovators in Western Australia. They might be totally different, it might be an oyster farmer talking to a prawn trawler, but there might be something that he’s trialled, something that will spark a light bulb in the other fisherman, and it’s really good. The funding is just been into the research of it, but the outcomes will be that there will be all avenues for all fishermen in Australia to communicate with each other and that’s never been done before (Representative of the scientific community, 01 April 2011).

Networks can also be facilitated by industry peak bodies, government and scientists. Indeed strengthened partnerships over the past five years are credited with progressing a large number of stewardship initiatives to the benefit of both management and industry. To some extent, climate change, as a common problem, is said to have contributed to these improved relationships.

It has been the biggest change in our industry that I’ve seen in 30 years. It’s this communication. It’s this bringing everyone together and sharing information. It will make fishermen more resilient to climate change with that attitude and the government is fostering that, GBRMPA are fostering that, so it’s a good environment now (Fishing industry representative, 01 April 2011)
If you’ve got a really good network of industry, different industries, working in partnership and managers working in partnership, you could do anything, but it all takes time and motivation to do it...15 years of trust and relationship building, that I think is what is takes to get there (Tourism industry representative, 25 March 2011).

An important trend that emerged from the workshops was the increasing support provided to operators to enhance their business skills, whether it is forecasting, financial management, marketing or networking. The reason for this relates back to the issue of industry organisation. The long-term viability and the potential for adaptation of the whole industry, including the innovative operators, depend on the operators who make up the bulk and the lower, more vulnerable quadrant of the industry. The overall profitability of the industry, the potential for stewardship, the reputation of an industry, the relationships with government and other partners depend on the most and least able, the conformers and the non-compliers. Therefore, a whole-industry approach is needed. It was suggested that on one hand, this involves equipping all industry operators with the knowledge to improve their businesses and their adaptive capacity and on the other hand, it involves succession planning for the business which cannot remain viable under the current and future contexts of these industries, in order to facilitate a more dignified exit that keeps other options open to people.

There’s this gap between the innovation and the innovators and the rest of the industry, eventually the industry gets dragged up (Fishing industry representative, 01 April 2011)

Certainly, but there are limits to it. Once you’ve reached a point we’re you’re no longer competitive and you’ve made your inputs and business models as efficient as you can get, then there’s little value in being involved in that anymore. I think that part of the business planning around climate change is looking at a succession plan and if that includes exiting the industry and transitioning into another form of employment, then that is something that we need to seriously look at, rather than falling through the cracks, which often happens (Fishing industry representative, 01 April 2011).

**Stewardship:** Stewardship refers to demonstrated ability to ensure sustainable practices. Stewardship is essential to protecting the resilience of the marine and coastal ecosystems on which the GBR tourism and fishing industries depend. It is also an important mechanism by which GBR industries and individuals can build legitimacy, market advantage, and self-esteem. In the limited adaptation scenarios, climate change does not trigger an increased interest in stewardship (scenarios 1a and 2a). Indeed, under a worst-case climate situation, it is projected that stewardship declines with the reorganisation of the industry into large corporations (scenario 2a). Under ideal adaptation, stewardship is a key adaptation strategy (scenarios 1b and 2b). The importance of stewardship in GBR industries in general is demonstrated by the following statement.

Before climate change became the elephant in the room, sustainability was the tree we were all trying to bark up. Sustainability is ultimately what we as reef managers want, but it’s also what the fishermen want, particularly the small local fishermen. They want long term sustainability, a guaranteed future. They’re interested in managing the reef appropriately (Government representative, 25 March 2011).
Stewardship seems to be an increasingly valued characteristic of GBR management and business strategy, which has emerged over the last 20 years in response to the global environmental movement, new coral reef and fisheries science, and awareness of its use in market positioning. 

Most people on the reef, in tourism, actually understand the asset and I wouldn’t have said that 20 years ago. I actually do believe that people understand the asset and they understand that they need to protect the asset that they are working on. So that’s great. That’s a huge leap forward (Tourism industry representative, 25 March 2011)

It is acknowledged by workshop participants that stewardship is first and foremost about maintaining the resilience of the coastal and marine ecosystems on which GBR industries and communities depend. But, it is also recognised that demonstrating stewardship, aided by technologies to record data and processes to conduct audits and impact assessment, can also benefit social adaptation in many ways. It can help build trust between managers and industry which may help relax regulatory management and enable more flexibility, innovation and experimentation.

The government is recognising working in partnerships and experimenting. Like, I can experiment with anything on my boat now, as long as I can document it and I feedback to the gear technologist. We have a permit, it’s very liberal what we can do, as long as our outcome is to reduce by-catch, reduce sea snake retention, to maximise our yield, they’re willing to go along with it. Two or three years ago, that was unheard of (Fishing industry representative, 01 April 2011).

We have an accreditation program that’s been agreed to, which goes through Eco Tourism Australia. X [name removed for anonymity] was able to show GBRMPA that if a company went through and was accredited by Eco Tourism Australia to the highest level, not only were they developing a relationship with GBRMPA, but they were also showing that they are a better business. You can get a 14 or 15 year permit if you’re GBRMPA and Eco Tourism accredited. You can get a seven or 10 year permit if you’re not (Tourism industry representative, 25 March 2011).

Demonstrating stewardship can also build trust between industry and consumers, thereby strengthening reputations, brand, and market position. Raising the profile and market values of fisheries and tourism in the GBR is central to developing more viable businesses and strengthening both buffering and adaptive capacity of enterprises.

I know in the south east corner now, there’s been a big shift where the community is saying ‘I want local produce’. We’re seeing a lot more of the community going to the water front and buying direct from trawlers, where they have a perception that they are supporting local industry. ‘I’m getting a fresh local product’. A lot of the fishermen there are getting a better price than if they’re putting it into the larger markets (Fishing industry representative, 25 March 2011).

Workshop participants suggested that in many cases, innovation for stewardship was found to make business sense and to cut costs. Stewardship emerges in a number of ways and is fostered through a range of strategies and programmes within the GBR. In the fishing industry, stewardship is said to be linked to lifestyle values. So, in the commercial fishing industry, stewardship is enhanced in fisheries with a higher proportion of lifestyle fishers and
declines in fisheries with a higher proportion of buy-in from large business. Stewardship is also said to be high in recreational fisheries because of the nature of the activity often involving families and cross-generational interaction. In the tourism industry stewardship is perceived to be linked to business ownership. So, for instance, developers who have no intention of running the enterprise as a business, only of recouping costs, are said to be less likely to act as custodians of a particular area.

One of the problems with Great Keppel is the fact that the current lease holders aren’t interested in running that resort long term. They’re actually interested in trying to get as much approval as they can to basically Hamilton Islandise the place, which really doesn’t belong in Queensland’s tourism anymore... Just north of it is the North Keppel Environmental Education Centre, where the whole place is run on solar and wind power. It uses compost toilets. There’s a whole range of costs saving effective ways to sustainably manage a resort right there, its next biggest island, its nearest neighbour. Yet the developer that’s currently there is reluctant to show interest in that sort of resort (Tourism industry representative, 25 March 2011)

Stewardship in individual businesses is then enhanced in cases where operators are risk-takers and innovators, and where they have the capital to innovate. In both fisheries and tourism stewardship is fostered by local engagement and local knowledge, so is highest when recreational fishers can act as guides to visiting fishers, when commercial fishers target areas and species they know well, and when tourism operators understand their asset and support guided recreational fishing.

It’s a little hard to deal with in a recreational sense, where we want our visitors to feel welcome. There’s this giant coastline and the nuances from fishing in Lucinda are different even to fishing in Cardwell, and we need to understand how that works. We can only do that on a fine art basis, by local knowledge. We have species of conservation significance and blow in fishermen have been accused of interacting with them because they just don’t know what they’re doing, like dugong (Tourism industry representative, 25 March 2011)

I have a fair bit of contact with people that come up here from down south, that come up here and go fishing, and they have no idea about the current zones. So it’s up to me or another local to explain to them, green zones you can’t fish in, yellow zones 1 hook and 1 line per person and then all the bag limits (Fishing industry representative, 25 March 2011).

Networking and emergence of industry associations has supported stewardship trends by developing standards over and above those designated in management. A diversity of government initiatives in partnership with industry are also driving improved stewardship. An example is the Reef Guardian programme led by the GBRMPA. The programme involves Reef Guardian Schools, Reef Guardian Councils, Reef Guardian Fisheries, and Reef Guardian Farms. The highlights of the fisheries programme according to workshop participants are training of crew, mentoring of young fishers or new entrants, and auditing and certification of Reef Guardian businesses. The potential for the scheme to lead to permitting based on this accreditation or to leverage further funds to support stewardship action were also discussed (e.g., Coca-Cola and sugar cane farming best practice).
It’s the branding, so we’ll have it on the side of our trawler, we’ll have it on our prawn boxes that we’re a reef guardian and we will have to be audited (Fishing industry representative, 01 April 2011)

The GBRMPA also work closely with the Tourism industry to develop key statistics and to communicate information on the ecological state of the reef through worksheets for tourists. Further developing skills within government and industry to communicate science to the public was suggested by participants as a critical opportunity to improve stewardship and adaptation. An example of even broader public messaging is the upcoming advertising campaign, supported by government, to re-position the commercial fishing industry as a healthy and sustainable consumer choice.

The federal government has actually given funding for an advertisement that we’ll be seeing on TV. They’re going to blanket advertise fishermen that are proud of what they’ve done. Ten years ago it was all about fishermen trawling on the reef, really, really bad. The science now says trawling is sustainable. We have done a lot of things. So they’re trying to increase the dignity... we want fisherman to be proud that he’s a fisherman not that he’s a raper and a pillager on the reef (Fishing industry representative, 01 April 2011)

While there are many opportunities to improve and communicate stewardship, stakeholders we spoke to also identified a number of constraints that limit the capacity of this strategy to reduce the vulnerability of GBR industries to climate change. For instance, there are still a number of issues around communicating this stewardship to consumers.

We’ve got so many labels: Friends of the Sea, the Marine Stewardship Council, etc. Whose label do I believe? We’ve got a label that we call Queensland Catch, now Queensland Catch has got no money, no international influence, but that label, even the way it just stands today, because of the management structure and everything we have underneath it, exceeds those other label standards. What we need to do as our adaptation policy is to get our partners, to give tourism something they can stand with, which is the Queensland Catch logo or the Aussie kangaroo with a fishing rod, or whatever (Non-governmental organisation representative, 25 March 2011).

The reputation of commercial fisheries, and in many cases recreational fisheries, is still far from ideal according to respondents, with deeply held beliefs about the scale of extraction among communities and with opposition from some powerful conservation groups who are more adept at campaigning than fishers.

We’re probably catching fish from the most sustainably managed reef ecosystem in the world. Now how good a job are we doing at marketing that? Pretty awful (Fishing industry representative, 25 March 2011)

We don’t take people to abattoirs. Whereas, when you caught your 30 tonne, all of those people are going ‘Oh my god look at that guy, he’s raped and pillaged the world’. Pulling up on the dock unloading, people are just seeing fish after fish after fish. They don’t care how far you had to go to catch them or how many people they are going to feed. There’s been a lot of talk lately about trying to get the community to view the fishing industry in the same eyes that they view the farming industry (Non-governmental organisation representative, 25 March 2011)
The biggest hurdle is the contradicting statements coming out. You have Tourism Queensland and Fisheries Queensland advertising ‘Come to this great place. You can fish, swim, dive all these other things. Then you have the groups like Pew and AMCS saying ‘No we need to stop this. We need to stop interfering with the reef at all. Everything that you do to the reef is bad’ (Non-governmental organisation representative, 25 March 2011)

Perceptions currently pose a considerable limit to adaptation across the GBR industries. Entrenched community perceptions of commercial fishing as unsustainable combined with indiscriminate consumption of imported fish products limit the market value of GBR fisheries and lower the capacity of businesses to buffer and adapt to change.

The potential of stewardship to reduce vulnerability is also complicated by the challenge of balancing voluntary stewardship and regulation. According to our respondents, the perception within industries, including commercial and recreational fisheries and the tourism sector, is that over-regulation of their activities, rather than supported stewardship, reduces their adaptive capacity and increases conflict within and among sectors. On one hand, changes in regulations cost operators time and money to understand and adapt to, and can distract them from other issues. Where industries perceive themselves to be good environmental stewards, the imposition of regulation is particularly contested. On the other hand, it could be argued that experience in adapting to regulatory change can furnish businesses and individuals with experience and knowledge of adaptation more generally, with potential benefits for future adaptation. There are ongoing calls from industry for the government to move towards more flexible regulatory mechanisms. This is recognised in recent climate change planning documents (E.g., Great Barrier Reef Climate Change Action Plan 2007-2012). However, there is a difficult balance to be struck between overly rigid regulation and non-compliance where regulation is too lenient, flexible or transient. Further, openness from industry about when and where sustainability is being achieved and where more work is needed, can foster a move towards more autonomous stewardship. In particular within the recreational fisheries sector, there remains significant contestation over to what extent the industry is contributing to sustainable fisheries, whether through voluntary stewardship or through regulation.

Most people [recreational fishers] will catch a few fish and they can’t quite envisage....you see these pictures of a family catching a bag of fish and a net hauling a tonne of fish onto the beach...But what they forget is that for every one commercial fisherman we’ve probably got about 1000 recreational fishermen. They don’t see that balance and how big an impact that can have (Fishing industry representative, 25 March 2011).

Other constrains to stewardship are somewhat more intractable. For instance, the social-ecological system of the GBR is so interconnected that actions to improve stewardship in one area may increase impacts on another area. An example given a workshop participant representing the fishing industry is the added pressure on the more vulnerable cod fishery by recreational fishers following recent temporary closures of the snapper fishery. Another example is the shift of long-line commercial fishers to deeper waters to avoid impacts on turtles, with consequent increased pressure on Albacore tuna. Adaptation strategies, even those motivated by stewardship, are not guaranteed to reduce threats to the marine and coastal ecosystems of the GBR. Part of the problem is that we don’t yet understand enough about what key ecosystem structures, functions and services and social benefits we want to
protect above others, where trade-offs are inevitable. Participants in our research noted that building knowledge and monitoring impacts, particularly of complex system interactions, is in many cases prohibitively expensive.

In other cases, we do understand the trade-offs but the interests of different stakeholder groups are strongly in opposition and the processes to reconcile divergent interests are not fully developed. Many examples were discussed of where we continue to prioritise provision of services that benefit a minority to the detriment of services that benefit a majority. The issue of no-take MPA networks is one key example in the GBR. From an industry perspective there is great concern that the climate change debate will be used to further a conservation agenda. Similar concern was expressed over increased protection of functional groups (e.g., piscivores versus herbivores), where these coincide with key commercial species. These reflect examples of trade-offs between use and protection. Other examples relate to the trade-off in allocating use benefits between different people.

Currently we have a handle on what we’re talking in terms of sustainability, but we have a resource sharing conundrum about whether we take a little bit more from the commercial guys to give to the recreational [fishers] or vice versa (Non-governmental organisation representative, 25 March 2011).

Similarly, a clear example of trade-offs related to coastal development policy which allows minority interests to develop sensitive areas despite the clear and known implications for habitat connectivity and risks to infrastructure. The powerful vested interests wrapped up in coastal development are an important limit to adaptation through stewardship.

Coastal development is probably one of the biggest threats that we have. We tried with the coastal management plan a number of years ago but it’s just gone from bad to worse. It’s not really getting the political mileage that it needs (Government representative, 25 March 2011)

We’re pleading with the government [agencies responsible] to really start enforcing the coastal land use [policy] (Government representative, 25 March 2011).

Currently you don’t have councils that recognise the value of those industries and will do anything about that [habitat change] (Representative of the scientific community, 25 March 2011).

Another important example is the issue of water quality and run-off from agricultural practices in the GBR affecting fishers and the tourism industry. Community awareness and action, local government regulation, and appropriate compensatory schemes (carbon offset or compensatory habitat) were all suggested by participants as necessary mechanisms for stewardship of coastal habitat to benefit GBR industries and communities. Catchment management and regulation of coastal development are recognised as critical contributions to better overall outcomes for GBR industries in regards to climatic and non-climatic impacts.

**Mobility:** Temporary mobility or permanent migration can be used to shift impacts from extraction and use by the fishing and tourism industries to the benefit or detriment of marine and coastal ecosystems and can be used to buffer negative social impacts or take advantage of economic opportunity. In the limited adaptation scenarios mobility is used primarily to chase resources and optimise economic advantage, which it is suggested does not reduce
vulnerability to climate change (scenarios 1a and 2a). In the ideal adaptation scenarios mobility is used to manage and reduce effort as and when necessary and to take advantage of economic opportunity in order to minimise the negative impacts from climate change on the ecosystem and its industries in the long term (scenarios 1b and 2b).

Mobility can involve permanent shifts of industry in response to climate risks. In the GBR this might involve shifts southwards by fishing and tourism operators in line with potential species or habitat shifts south. An example was provided of peanut farmers who have permanently relocated their businesses to the Northern Territory in anticipation of climate change. However, permanent migration was not in general was not considered a viable adaptation strategy for the GBR by the participants in our research. The option of permanent migration was seen as potentially detrimental to businesses already operating in the areas which may be targeted as relatively low impact areas. It also signifies considerable social disruption to families of operators.

The problem with that is that the likes of X [name of operator removed for anonymity] is doing quite well at the southern end of the reef. If he suddenly has all these other operators come down round his part of the world....that’s quite a conflict of interest and it’s quite likely they wouldn’t get the permissions from us that they require to operate anyway (Tourism industry representative, 25 March 2011).

Instead, adaptation aims to protect, diversify, and market the industries in their current locations.

Part of the adaptation for us is to convince people that it’s great to dive with the big [massive, more heat-resistant] coral. We adapt so that we don’t lose our industry in Port Douglas and Cairns and here (Tourism industry representative, 25 March 2011)

Cairns...relies on its tourism business. So what we have to do is to help them make it. We need to give them something they can do. So it can’t be an option to say, yep pack up and move, because it’s what the industry, it’s what the region relies on. I’m buoyed by the fact that the reef isn’t going to disappear, it’s going to change, so as long as we don’t over promise, as long we’re honest in what the people are going to see, they are still getting a better experience than if they were diving off the Florida Keys or if they were diving off Thailand. I think we can’t under sell the fact (Tourism industry representative, 25 March 2011)

Temporary migration may provide more useful for adaptation and there are examples of where it has been used to buffer and adapt to disturbance events in the GBR. For instance, recreational fishers often travel to find new fishing areas, over a weekend, on holiday or as ‘grey nomads’ or retirees. This mobility is often motivated by pursuit of new and different experiences, with potential added benefits to the tourism industry (but with mixed implications for stewardship, as discussed above).

Fishing is more like a family trait. It’s something that they do through the generations for all time, and you’ll find that while you’ve got families that are fishing locally, if they go on holidays, it will be a holiday where they’ll go fishing, and when they get to retirement they’re the grey nomads who fish up the coast. So they are very mobile and they do change what they’re doing depending on where they’re going. That’s why we’ve started to link heavily with the tourism groups because they are a huge tourist
In some cases, this mobility is also motivated by non-climatic disturbance. For instance many recreational fishers are said to now travel to the Northern Territory to fish because Queensland is generally viewed as over-regulated and unfriendly. Fishers themselves experience more enjoyment in areas where recreational fishing is better catered for, although they may resent being forced to travel, but there is arguably an opportunity lost for tackle and tourism businesses in Queensland who may have benefited from the recreational fishing trade in the past (Fishing industry representative, 31 May 2011).

There are a number of challenges associated with mobility. For the commercial fishing industry, one challenge is the need to develop supply and market networks along the coast to cater for mobility and the social dislocation from family for long periods at a time. Another considerable challenge is the way fisheries management and regulation is set up. Fisheries legislation currently functions at the state level, meaning that cross-boundary movements are restricted. A current trend for fishers in New South Wales to buy up Queensland fisheries licenses in anticipation of changes to marine management and continued coastal development illustrates what might be the reverse in anticipation of climate change when stocks shift far enough south. However, for some GBR fishery operators, buying up licenses elsewhere may not be possible if numbers of licenses are restricted or are too expensive.

New management arrangements, for instance shifting from spatial to stock entitlements or addressing the issue of cross-boundary permitting, may be needed to facilitate mobility in some cases. A recent example is the shift to stock entitlements in the aquarium fishery.

\begin{quote}
We went through this process with the coral fishery from having a tenure arrangement for a licensee, you might have a number of different reefs that they can work from, to shifting to a roving harvest and a total allowable catch and individual transferrable quota. What it in effect did, was it allowed every operator and there’s 59 entitlements split between 16 businesses, to fish anywhere within the marine park which is the boundary of the fishery...If they want to expand on that quota because they want to capitalise on markets or whatever then they’ve got to further invest, in other words they’ve got to buy quota off other quota holders and that price is determined by market forces, so supply and demand...it manages itself (Fishing industry representative, 01 April 2011).
\end{quote}

Nevertheless, the transfer of effort through temporary migration, like permanent migration, has implications for those already using these areas or stocks. It is argued by our research participants that whilst this adaptation strategy may work for individual operators it does not work for the industry as a whole. In time, this challenge may become more important as potential conflicts rise. For instance, there are populations that reside north of Australia (Papua New Guinea, Indonesia) that may move into Australian waters in pursuit of stocks that were once abundant in their territorial waters.

\begin{quote}
There might be an increase in pelagic activity and there’s one fishery off the east coast here, the eastern tuna fishery, which deals with that fishery. Currently we don’t have methods like purse seining occurring off Queensland although there may be some pressure if there’s a south ward shift. There’s quite a large perse seining fishery in [Papua] New Guinea that extends down to the borders of our waters, so if those
\end{quote}
tuna schools would now occur here, there will be pressure from international companies for access there (Non-governmental organisation representative, 25 March 2011).

There is also evidence to suggest that mobility may not necessarily work to reduce the vulnerability of individuals where ecological impacts are widespread, and effort is high and concentrated by other factors.

For the inshore fishery, over half the industry doesn’t move more than 100km from their home base. For the reef line fishers, which are the more mobile of all the fishers, when cyclone Hamish came along and wiped out the bottom half of the reef and they couldn’t get any fish there, 80% of the industry moved. But they couldn’t move too far from Bowen, because that’s where they got the best price for their product. So, they all moved on top of each other. So their mobility was limited not by any regulation, not by any limit of fish distribution, but by where there market was, they needed to stay near Bowen, because they got much more for their fish than they would if they had gone up to Cairns (Representative of the scientific community, 25 March 2011).

Nevertheless, to keep options open and to enable mobility where no other adaptation option is available or sufficient, workshop participants argue that management needs to anticipate climate change and be more responsive to disturbance events.

A classic example of this in recent history is the floods in Moreton Bay. We have fishermen there who worked in the mouth of the river, who couldn’t work because of the flood, the debris, the whole thing. Now there are some areas in the GBR that are not trawl areas, you can’t trawl there, but they’re not actually a green zone or one of those precious things that we should all protect. So we could have an interim decision that says even though [where you normally work] may recover in 3 months, we’ll close it for 12 months and you can shift your effort over to here (Fishing industry representative, 25 March 2011).

Management is beginning to respond in the tourism sector, after a long investment in partnership building, but less so in the commercial fishery sector.

If my area is Green Island but I didn’t have a permit for Arlington can I go and get that tomorrow? Yes but its only really recently. So GBRMPA will look at it and go ‘you’re devastated, where am I willing to allow you to take your passengers?’ GBRMPA have been fabulous with that, because they weren’t but now they are (Tourism industry representative, 25 March 2011).

Effort: In addition to mobility there are other means of increasing or decreasing effort to anticipate or respond to climate change impacts. In the scenarios we suggest that under limited adaptation, effort is increased. In the fisheries industries this is achieved through improved technologies, such as fishing gear, and spending more time at sea (scenarios 1a and 2a). Under the more extreme climate scenario this is facilitated by the organisation of the commercial fishing industry into large international companies and the use of off-shore docks and motherships to reduce travel times and maximise time spent at sea (scenario 2a). In the tourism industry increased effort is reflected in concentration of operators into key sites, manipulation of sites through coral farming, fish feeding and fish aggregation devices, and aggressive marketing (scenarios 1a and 2a). In contrast, under ideal adaptation effort is
reduced and dispersed (scenarios 1b and 2b). Under the more extreme climate scenario these adaptations include the reduction of numbers of operators in both the fisheries and tourism industries (scenario 2b).

There are a number of drivers of increased effort that are not necessarily directly motivated by profit making by operators. For instance, effort creep can result from improved technologies, other than gear, such as Geographical Positioning Systems (GPS), which enable fishers to more efficiently navigate and pinpoint favourite fishing spots. Overall effort can also increase as a result of much broader development and urbanisation trends. For example, in the recreational fishery, numbers of fishers increase in urban centres and following injections of cash from new economic developments, such as mines. To control effort, the GBR industries are regulated. Commercial fishing and tourism are capped, in most places, to regulate the number of licensed operators, alongside other regulations that may restrict yield (fish catch or tourist numbers).

_The fishing industry has a finite number of licences. So, there’s a cap on that. It’s probably realistic to say that some of these caps are a little high_ (Non-governmental organisation representative, 25 March 2011)

_But that’s only within the commercial industry. There’re no caps on charter or rec [fishing]_ (Representative of the scientific community, 25 March 2011)

_Businesses go out of business and sell the licence back to GBRMPA. It sits there until another business comes along and says ‘I’d like to work in this region’. ‘Look there’s a licence’. Or ‘I’d like to work in this region’. ‘There’s no licence available there, but there’s a licence available down in this part of the reef’. So it’s very well regimented._ (Tourism industry representative, 25 March 2011)

_We see caps on effort. In places like Lord Howe, only 400 [people are] allowed on the island, plus locals, and on Hamilton Island you can only get so many people there because you run out of beds. So there’re caps that are in place both by physical impediment or legislation....._ (Tourism industry representative, 25 March 2011).

The charter and recreational fisheries are not capped, so total numbers can grow, but effort is regulated through catch limits (bag size) (Recreational fishing rules and regulations for Queensland, 2010).

Strategic management of effort, as an adaptation strategy, occurs to different extents throughout the GBR. For the most part, voluntarily operating as a fisher or tourist venture for fewer days is unrealistic and is not used as an adaptation strategy, except where it costs more to open a business, in the off-season for example, than to keep it closed. Understanding when costs exceed benefits was mentioned as a key component of forecasting and financial management in business planning. Often tourist operations manage effort by trading full time when business is good in order to compensate for the fact that demand is seasonal, although this differs by location. Managing effort in other ways can in some contexts reduce vulnerability of individual operators when there is no alternative. For example, there was an example shared in the workshops of effort being managed to reduce impacts on sensitive ecosystems, but this was more an example of shifting rather than reducing effort.
When we have a coral bleaching event or a cyclone or flooding, we alter the way we undertake our activity. We nominate, I think there are 16 herbivorous grazers or scrapers that we don’t collect at any depth and that’s around about preventing phase shifts and reversing them. Some of the species feature fairly substantially on stock lists so it’s a sacrifice not a green wash (Fishing industry representative, 01 April 2011)

By the same token, effort metrics are complex. Regardless of the number of operator days, other actions can represent an increase or decrease in impact. For instance earlier we referred to effort creep. Where fishers, for example, become more efficient through gear technology or use of motherships and thereby extract more over a shorter space of time, overall impact and system vulnerability will increase, despite a reduced or static effort in terms of nights fished. Alternatively, where fishers operate ‘smarter’ by reducing costs, diversifying product and so on, effort can remain the same or increase, but both social and ecological vulnerability can be reduced.

Permanently removing effort or capacity from industries may prove a more reliable adaptation strategy, although obviously the social implications of this strategy must be accounted for. Strategic removal of capacity in industries, versus the more arbitrary exiting of operators who cannot achieve sufficient profitability, is at present more a discussion point in commercial fisheries than it is in the recreational fisheries or tourism industry. Succession planning and sector buy-outs are deliberated by many commercial fishing sectors and there are a couple of puerus experiences from which to draw. Some fisheries have organised themselves and undertaken effort reduction, often through forming co-operatives or taking loans from government for buy-outs.

The government becomes the guarantor on the loan and the fisherman pay them back over time. To do that you need to ensure there’s good profitability in those fisheries (Non-governmental organisation representative, 25 March 2011)

We used to have 700 prawn trawlers in Queensland. We’ve got about 250 operating at the moment, with 300 licences. It looks like the really good number for profitability is about 185. How we get from 250 or 300 down to 185 is a loan buy-back. The trouble with some of these mechanisms is that unless it’s an instant action to get to 180 licences, you don’t get the profitability curve kicking in (Non-governmental organisation representative, 25 March 2011).

However, getting the process right is essential to effective buy-backs and permanent effort reduction. Many examples to-date do not set good precedents for effective process.

I don’t really want to go backwards, but we need to say the RAP [Representative Areas Programme] was a very imperfect thing. People who had a 25 million dollar on-shore business, that was a family business, did not get compensation under the RAP because their business made no profit. They paid wages to nine family members but on paper you’re not a viable business, so under the rules you got nothing (Non-governmental organisation representative, 25 March 2011).

There are a number of issues that constrain the effectiveness of buy-back schemes. The first is that under current legislation government support of buy-backs only occurs under a sustainability clause. So unless current effort is unsustainable fishers cannot typically initiate
an effort buy-back with financial help. This excludes fishers from using this strategy to improve profitability or buffering capacity of their sector in circumstances where sustainability is not threatened. Further, there are technical issues around latent effort and assets. Latent or unused effort refers to old licenses, effort units or quota, which are not currently in use, but which still designate entitlements. A buy-back scheme must account for latent effort and take into consideration the infrastructure and assets tied up with the industry.

*The fear of latent effort is if we get to downturn in the economy people are going to pick up fishing licences and go fishing...Because you can get your recreational fishing boat, 7 and half metres and turn it into a commercial fishing boat like that* (Non-governmental organisation representative, 25 March 2011)

*We’ll buy you’re permits, worth $100, we won’t buy your boat, because you can sell that to somebody else, and then we’ll pay for 6 weeks retraining* (Non-governmental organisation representative, 25 March 2011)

*There were a few instances where active licences were being bought back by the government and then those blokes, who obviously still have their boats and everything, are going to an old mate who has a licence that hasn’t been used for 20 years and buying that* (Non-governmental organisation representative, 25 March 2011)

If not done properly, effort reduction can fail to reduce social and ecological vulnerability. Experience with these kinds of management or adaptation strategies have found that impact on ecosystems remains, where effort is concentrated due to efficiency or regulation, and where effort is simply transferred, i.e., when assets and infrastructure are not removed from the industry in addition to active and latent licenses and quota. More importantly, if not done properly, effort reduction, which may reduce vulnerability to risk at the industry level can have serious social impacts on individuals.

*In the northern prawn there’re still boats on the hard in Cairns that they can’t sell. In fact some of those people have bankrupted themselves because they can’t pay the bill to keep the boat on the hardstand and they can’t afford to cut it up... Following some of the exit and buy out strategies there are still a lot of people on social benefit and unemployed... If you followed it up, two thirds of those people are receiving social benefits. So we didn’t do the job properly* (Non-governmental organisation representative, 25 March 2011)

*So the other side of it, I’m 50 years old, I’ve been a commercial fisherman since I was 16, sure I’ve got a ticket to say I can drive a wave piercer, but it would probably send me insane because I’m used to working my own hours and everything else...it’s the identity issue. The identity is so strong. You associate with being a fisherman. They can’t do anything else* (Representative of the scientific community, 01 April 2011)

Finally, there are also circumstances under which effort reduction through buy-backs may not reduce vulnerability of those operators remaining in the sector, such as in cases where effort or resource-allocation is not the primary constraint on profitability. For instance, there is some dispute over whether buy-backs in the East Trawl Fishery can ensure profitability of remaining operators when catch is variable and profit more highly influenced by market price than by yield (Fishing industry representative, 03 June 2011).
**Diversification:** Diversification can be achieved in multiple ways. In the fisheries sector this may include diversity in: i) gear or technology (extraction method), ii) target species, iii) processing and packaging, iv) market and, v) income source (individual or household). For recreational fishers diversity might include changes to gear type and target species, but also diversity in leisure activity, both associated with recreational fishing, such as swimming and snorkelling, as well as an alternative to recreational fishing. In the tourism industry this strategy could include diversity in: i) visitation sites, ii) activities at sites, iii) land and sea-based activities iv) product packaging, v) market, and vi) income source (individual or household). Some of these diversification strategies may buffer impacts from climate change and reduce vulnerability but it depends to what extent climate change also affects alternative target species, alternative sites and so on. Diversification into non-climate sensitive activities is likely to offer the best opportunity to reduce negative outcomes. In the scenarios, under a limited adaptation situation, diversification is forced on industries and operators. In the ideal adaptation situation diversification happens in anticipation of climate changes. It is expected that in the latter case, diversification activities are more strategic, more varied, and more likely to appropriately respond to the threats and opportunities that result from climate change.

Economic diversity at the scale of cities, communities and states plays an important role in setting the broader context for diversification at the industry and individual level. A broad economic diversity can contribute to adaptive capacity of communities at large and can facilitate alternative income generation at the household and individual level. As an example, the lack of diversity in economic opportunities in Cairns (and other areas dependent on primarily reef-bases tourism, for instance the Whitsundays) was recognised by participants in this research as a key source of vulnerability for this population, who may experience impacts directly as businesses but who may also experience knock-on effects from the impacts on others’ businesses.

*Cairns went through a totally different version of the GFC [global financial crisis] to everyone else. They lost flights because basically an airline pulled out the route from Cairns to Japan within a short period of time. They lost about 2000 seats a week, so that’s every week, and that damages people, that’s 2000 less bodies in restaurants, in hotels and going out to the reef. But because we don’t have that diversification up there, just that lack of 2000 seats has a massive impact... Even the state government has talked about moving government departments up there ...to give Cairns a better base to work from* (Tourism industry representative, 25 March 2011).

Diversity is also important at the scale of industries, businesses and individuals. In the workshops, diversity was seen as a means to increase current business viability and profitability, and thereby buffering capacity, and as a strategy for managing variability, “taking the points off the troughs” (Fishing industry representative, 01 April 2011), and change. Diversity or ‘flexibility’, a term often used by GBR stakeholder in our meetings and interviews, can however mean many things, not all of which are effective actions for building buffering and adaptive capacity. Diversifying does not necessarily reduce vulnerability when the alternative is exposed and equally sensitive to the same climate risks (in the sense of the three components of vulnerability, following the IPCC, 2007). For example, a workshop participant related some research on peanut farmers, and more recently on cyclone affected fishers and tourism operators, which finds that broadly speaking ‘flexibility’ did not increase
adaptive capacity where flexibility was based on multiple activities within the same industry that are equally affected by the climatic event, i.e., the cyclone.

*We need to be really careful and articulate it really, really clearly, because it’s going to fundamentally change the way we look at towards adaptation. When we talk about flexibility, what are we actually talking about because if we’re looking at the same resource then, no we’re not increasing our resilience in any way at all. So if we’re talking about flexibility, it’s probably doing things like having fishing and having a newsagency, it’s not just whether you’ve got 4 hooks or 1 hook. It’s really quite radical* (Representative of the scientific community, 01 April 2011).

Further, like mobility and effort, diversification can also increase pressure on the coastal and marine ecosystem, for instance when businesses diversify and expand without reducing effort or pressure elsewhere, which would lead to reduced vulnerability of industries to climate risks in the long term. Diversifying to take advantage of new opportunities that emerge from climate change and diversifying into alternative markets and incomes sources (rather than other fisheries or other reef sites) are likely to be the best long-term adaptation strategies to reduce vulnerability of operators and ecosystems in the GBR.

Workshop respondents were sceptical that diversifying to take advantage of new opportunities that simply emerge from climate change would be effective. For instance, it was suggested that if new fish species would enter Australian waters, either regulations would exist or be introduced to prevent use of these new resources or that exploitation of new resources would happen so rapidly that the new fishery would be over-exploited and would not contribute to reduced vulnerability in the long-term. Instead, participants argued that deliberately creating their own opportunities to diversify was critical. ‘Professional’ businesses were seen to have diversified interests to spread risks. For example, in the commercial fishing industry, certain sectors are strategically diversifying into higher value product, enabled by regulations that enable operators to respond to climatic and market variation (Fishing industry representative, 01 April 2011). In the tourism sector businesses have often had a range of options available to account for weather and consumer preferences, but have also been forced to diversify in response to economic and climatic perturbation (Tourism industry representative, 25 March 2011).

*Backpackers seem to want to have the one day experience where they can do a resort dive, they can go and jump out of a perfectly good plane strapped to an instructor, they can go on a sea kayaking tour with a guide, but they want it all in the one location* (Tourism industry representative, 25 March 2011).

*Tourism has been a very restrictive market and has been promoted mainly to the overseas market and the high end market. It’s only been in the last few years where there’s been the big downturn in the international market that we’ve realized how big a market domestic tourism there is, and those relationships are only just now starting...The intrastate stuff is what is keeping them afloat* (Tourism industry representative, 25 March 2011).

For diversification to be effective in the tourism and fishing industries it needs to be complemented by an effective marketing strategy that promotes the strengths and assets of a particular place or product without over-extending the promise to consumers. On one hand,
this was said to be about convincing consumers to accept a degree of diversity and variability in the product.

*From a fisherman’s point of view, we get everything in gluts or droughts* (Fishing industry representative, 25 March 2011).

On the other hand it is about the industries being honest about what they are offering and responding to consumer preference and demand.

*It’s actually matching you’re tourism market with what you have to offer* (Tourism industry representative, 25 March 2011).

In many cases, opportunities to promote diversity through green marketing are growing.

*Down at Lady Elliott Island, [name removed for anonymity] got $200,000 from the federal government to put his solar panels in. He ended up spending $600,000 and he ended up selling one of his planes to actually finish paying off his solar panels. But, he went from 750 litres per day to 250 litres per day of diesel, being used on the property. So that’s 500 litres per day not crossing the Great Barrier Reef on a flat bottom barge and that’s obviously not 500 litres per day that’s causing carbon to go back into the atmosphere. Now he’s full all the time because he puts that message out there* (Tourism industry representative, 25 March 2011).

*Market the safety aspect because that’s what you were saying, play to your strengths. This is one of the safest destinations and you know in tourism research, safety is valued highly...And it’s a sustainable destination* (Tourism industry representative, 25 March 2011).

*We’re [fishing industry] not marketing that well and we’re not saying that we’re doing it in a World Heritage Area. We’re missing that hook.* (Non-governmental organisation representative, 25 March 2011)

There are also opportunities to more directly develop and market new products.

*We [tourism industry] have just done an experiences audit of the Great Barrier Reef and that’s where we’ve come up with our big 8. So we are now starting to market it* (Tourism industry representative, 25 March 2011).

*There’s a massive market for voluntourism... If they could dive and they knew that by taking photos they would be helping scientists understand the changes of the reef, basically giving the science community more staff, that’s a great saleable point, anything like that that we can work with* (Tourism industry representative, 25 March 2011).

*There’s a handful of guys that do it really well, they have really good product, really well presented, they get good dollar for their money, they present well to restaurants. Probably over the next 20 or 30 years things like that will change. They will maybe be catching less but getting better price for their product...I think you need a name change, slimy mackerel. Silver cobbler sounds much better than catfish. Bassa, catfish, they actually changed it last year. Finger mark is now golden snapper, it’s...*
much better. We have standard fish names now at least (Non-governmental organisation representative, 25 March 2011).

Several factors constrain diversification activities and limit the potential of diversification to reduce the impacts from perturbation including climate risks. First, the need to significantly diversify is a relatively recent issue and the skills to develop and market new products, market links, or to explore alternative income generating activities are fairly limited, with some sectors being worse than others. Second, is the speed at which change is occurring and at which innovation has to happen.

It’s a global market, and the product that comes from other parts of the world that doesn’t operate within the same legislative and management framework that we operate within, their cost base is so much lower, yet their product sits on the shelf beside ours (Fishing industry representative, 01 April 2011).

10, 15, 20 years ago there weren’t any imports. There weren’t any other competing products in the market place. Fishermen by their very nature are very poor at demanding or changing their methods to suit a different market place and then demanding to be paid what it’s worth (Fishing industry representative, 25 March 2011).

Like the reef life fishery, they did try to diversify their catch a couple of years ago, after Cyclone Hamish, but they didn’t have much luck. That’s something that they recognized that they needed to do (Representative of the scientific community, 25 March 2011).

Diversification strategies are often risky and incur costs. In the fishing and tourism industries these costs can be prohibitive and constrain innovation.

The thing with tourism is that it’s a high turn-over industry and that’s a really significant limit to investing in adaptation, especially capital (Tourism industry representative, 25 March 2011).

These economic limits are particularly pertinent in contexts of high market competition and low or declining profitability.

The profitability of fishing has been on a downward trajectory for quite a long time as markets become deregulated and trade barriers disappear and all the rest of it. We’ve seen prices remain stagnant for a long time, a very long time, whereas fuel prices have gone through the roof (Fishing industry representative, 25 March 2011).

At the same time, workshop respondents in the commercial and recreational fisheries sectors and the tourism industry identified management regulations as a limit to effective diversification.

Some [commercial] fisherman have explored this type of option. One of the issues is about the legislative restrictions on what they could do on these boats...and the insurance liabilities (Fishing industry representative, 25 March 2011).
Yes we [recreational fishers] can adapt to climate change. The issue that we have is that with the climate change pressure from government, the changes that will be made under management plans...it’s going to be increasingly more difficult for us to adapt to some of the other changes that are forced on us and that conflict, like at Port Douglas and some other areas, are perfect examples of that (Fishing industry representative, 01 April 2011).

We’ve got way too many regulations. That’s the only reason. We are so well regulated, our building codes are much better. They [tourism operations in less regulated, competitor countries] can put a whole lot of stuff into their buildings that we can’t because it’s not safe. So, they get an experience that looks very flash and we get an experience that’s very practical and very safe (Tourism industry representative, 25 March 2011).

With perhaps the exception of the recreational fisheries, there was some acknowledgement that a degree of flexibility in management and regulation, in terms of leeway in permitting of activities, was emerging to enable diversification (and mobility) in light of economic pressure on industries and disturbance events such as cyclones.

Regardless of the opportunities fostered at the industry level and the various constraints on diversification, there are particular operators who generally seem more willing and able to employ this adaptation strategy effectively. In the fishing industry, the innovators are said to be able to navigate markets, regulations and other constraints to diversification (and other complementary adaptations) in order to build highly profitable business and buffer change. Often these people could function in any type of industry effectively. They are not particularly attached to any particular lifestyle. They are entrepreneurs. Workshop respondents argue that on the other end of the spectrum are the lifestyle fishers who struggle with the capital investment and level of risk involved in diversification, and other adaptation options.

**Technology**: Technology can enable many of the adaptation strategies described above, with differing consequences for the vulnerability of the GBR and its industries. In the limited adaptation scenarios (1a and 2a) we suggest that technologies are used to maintain the status quo or a previous system configuration. In the ideal adaptation scenarios (1b and 2b), technology is used to essentially reduce input costs and/or minimise negative environmental outcomes on the premise that these would contribute to reducing the vulnerability of the system as a whole.

In the workshops, technologies were typically referred to in the context of reducing input costs and achieving efficiencies. In the commercial fisheries, and less so the recreational fishery, technologies included new engine technology to gain fuel efficiency or boat and gear technology to improve streamlining and catch per unit effort.

Now we’ve got special software were we look at where the prawns are moving out of the green zones. We create a 3 dimensional image of all those lines looking for gutters and recording tides and water temperatures to try and benefit (Fishing industry representative, 01 April 2011)

In the tourism industries technologies might include improved building materials and standards as well as alternative energy technologies.
It happened because he went solar. A company had a really efficient desal [desalination] plant and contacted him and said ‘Would you mind trialing our desal plant because we’d like to trial it on a sand based island?’ It’s a third the size and it takes up no fuel compared to what it used to be. So there’s a whole lot of stuff that happens if you do it right and if you promote it well, and he’s full (Tourism industry representative, 25 March 2011).

Most of the guys now working on the reef have either paid to have their engines retro fitted or they’re using bio diesels to some extent. I know the Green Island guys have increased the journey time but decreased their fuel usage, they’re all doing something because they know that they just can’t afford to keep paying huge prices for their diesel (Tourism industry representative, 25 March 2011).

Uptake of new technologies as adaptation is constrained by both cost and uncertainty on return on investment. It is generally perceived by those we spoke to that the cost of alternative technologies is high in Australia compared to other countries, and that the high turn-over in the tourism industry and declining profitability in the commercial fisheries render these costs prohibitive in many cases, particularly for smaller operators. High initial investment generally means a long time lag on return on investment, which may not pay off considering general uncertainty on potential future economic, regulatory and climatic change. Even for the recreational fishers, investment in new technologies is risky considering the changing management environment. Further to this, with the suggestion that regulation will eventually be bought in to ensure operators update to new technology, operators are reticent to invest now in case that investment is needed elsewhere to address legislated change in the near future.

Infrastructure development: The issue of coastal development in a changing climate is complex. Here, we concentrate on industry infrastructure, rather than the broader security of communities to which fishing and tourism operators belong, although this is an integral dimension of their vulnerability to climate change. In the scenarios, we contrast adaptation responses that fortify infrastructure and resist change (scenarios 1a and 2a) with responses that retrofit and relocate infrastructure (scenarios 1b and 2b) in anticipation of climate change. We suggest that the first type of response will lead to abandonment of infrastructure and expensive rebuilding, and represents a limited adaptation strategy. In contrast, the latter strategy will spread the costs of relocating over time and maintain the function of critical on-shore facilities that better enable the industry and individuals to buffer impacts. In an ideal adaptation scenario we also suggest that planned retreat activities complement habitat restoration through stewardship action.

Workshop participants suggested that there was already considerable momentum around continued development and fortification style strategies, orchestrated by local government and often driven by wealthy private interests.

As far as whether to fortify...those decisions are already being made...we’re seeing it very subtly done in Australia now with marina developments where they’re putting up sea walls. My local council has sent out a new flyer where there’s a new wall going up at Redcliffe along the foreshore. Those decisions are already being made. Where there’s a high financial investment in the development, it won’t be a choice of fortify or retreat, it will be ‘we must fortify’ (Government representative, 01 April 2011).
Council already has a shore line erosion plan, which is basically looking at defence, retreat or do nothing responses for all of its coastal beaches that are populated or where there is development. That was done in I think 2006 and that's where the Clifton beach sea wall came out of (Government representative, 01 April 2011).

From an enterprise perspective many of these developments, they're not looking to 2050 or 2070, they're only looking for a 8 to 10 year time frame to make their profits. So I think fortifying and carrying on as if nothing happened is probably going to be a large part of our response to coastal development whether we like it or not, it’s just an economic imperative (Government representative, 01 April 2011).

They don’t get that say in the market place anymore and they don’t get the power in the community to have that Fisherman's Wharf right here because some other development has a higher priority in the eyes of Government. So they get pushed into somewhere where they’re unseen and unheard (Non-governmental organisation representative, 25 March 2011).

Many of these activities appear to have a number of detrimental implications for the GBR industries, in particular fisheries, both in terms of physical space allocation onshore and in terms of productive coastal habitat. This highlights the critical trade-offs that might result from adaptation, whereby community or local government adaptation action is increasing the vulnerability of the GBR fishing and reef-interested tourism industries.

The fishing industry, even the recreationals now, we’re given less and less space in the port. The water view in the port is more valuable than putting a bunch of trawlers there or a boat ramp. So we’re getting pressure, even for the tourist boats (Non-governmental organisation representative, 25 March 2011).

The trend is that physical barriers and protective measures for communities including dams and weirs will increase and that’s the conundrum for the resilience of both the natural ecosystems bordering that and how recreational and commercial fishers will adapt. For argument sake, mullet, like prawns are heavily reliant on the connectivity of our coastal rivers and mangroves for the juveniles to have protection. So species like that are more than likely to have a downward trend...Part of our adaptive strategy as a community in regard to commercial fishing is to maintain or enhance productivity...So if our community adaptation process is more physical barriers and less mangroves, then we’re going to get a lower end productivity. The community has to be made to understand what the trade off is (Fishing industry representative, 01 April 2011).

In Ross River at the moment, they’re put a bridge across for the Port Road. You’ll no longer be able to get commercial sales boats underneath that bridge. So you can no longer get to the river. They’re putting a marina in but if the port is anything like Port Hinchinbrook after a cyclone, I wouldn’t want my boat to be in there, but you won’t be able to get up the river anymore to a safe place...They’ve blocked it (Representative of the scientific community, 25 March 2011).

Further, the compensation agreements that may or may not accompany such decisions are rarely adequate to negate the increased pressure on GBR ecosystems and industries.
At Gladstone and Bowen at the moment they’re ripping up sea grass beds and as far as the recreational sector are concerned, they said well we’ll give you an artificial reef. Well it’s not an appropriate sell (Fishing industry representative, 01 April 2011).

In Abbott Bay where X is putting a new coal terminal for another 12 or 24 coal vessels, they’re looking at buying the fishermen out. They’re [government] saying ‘well we’re not going to stop the development’...certainly in Queensland, it’s identifying those people that are going to lose out and compensating those people. But to me, the environment is definitely going to lose in the long term. How’s that going to affect our whole industry? It is a big worry (Fishing industry representative, 01 April 2011).

Workshop participants felt that communities and local government (regional councils) need to better recognise the value of the fishing and reef-based tourism industries in order to account for current habitat loss and the potential need in future to enable habitat shifts inshore and upstream. Policy to encourage coastal buffer zones has been developed by the Department of Environment and Natural Resources but these policies are recommendations only not legislation so “nine times out of ten they [property developers and local government] just ignore it” (Government representative, 25 March 2011).

Importantly, once these decisions are made and habitat lost to development there is very little opportunity to reverse decisions and re-design coastal planning and habitat protection. Already historical structures place constraints on future adaptation options and thereby increase the vulnerability of GBR ecosystems and industries to future risk.

At the industry level, it seems that adaptation through either retreat or fortification of onshore infrastructure is not yet considered at the strategic or industry level but is left to individual operators to weigh up their own risks and opportunities.

Looking at boats landing at a wharf and unloading their product into some sort of shore-based facility that acts as a wholesaler or a distribution warehouse if you like, that’s the decision that’s made it an enterprise level. Look at what happened to X’s [name removed for anonymity] factory down at Bundaberg when the floods came through recently. He suffered a whole heap of damage. The question for X, if he’s still going to be in business, is would he rebuild there or would he link the unload to a facility that was on higher ground and hire a truck or something like that, which would be an enterprise decision, which is really what adaptation is all about (Fishing industry representative, 01 April 2011).

So there is an element where, so if we take a cyclone event rather than climate change perhaps, where the impacts are not just about the fish availability afterwards but also about the integrity of your coastal infrastructure and things like offloading facilities, freezer works, wharfage (Fishing industry representative, 01 April 2011).

Finally, it was also noted in the workshop and interviews that while leaving a degree of coastal infrastructure adaptation decision-making to individuals was fine, the recovery costs were nevertheless borne by the whole community, through recovery funds or increased insurance premiums.
**Emergency planning:** Again, we discuss this adaptation strategy in the context of GBR industries only. We suggest in the scenarios, that under extreme climate change and an ideal adaptation situation, the fishing and tourism industry adopt some responsibility for emergency planning, which better protects the safety of operators and their property (scenario 2b).

If the choice is between preventative action and emergency response, the latter arguably increases the vulnerability of communities and regions over time as a result of the sheer expense of emergency action. Nevertheless, it was noted in the Townsville workshop (25 March 2011) that preventative action was a more unpopular and difficult political position than emergency response, despite the costs. However, if the choice is between pre-planned and well-managed emergency response and a reactive response, the former could considerably reduce the negative impacts of extreme events. Workshop participants suggested that while the emergency response to the Brisbane floods and Cyclone Yasi were generally well managed, there are some serious concerns about the quality of the emergency infrastructure and evacuation options in many coastal cities and towns in Queensland.

At the industry level, emergency and recovery planning appears to be a strategy much more closely associated with the tourism industry than the fishing industries at present. The industry representative bodies were heavily involved in both emergency action, including relocating tourists and advising businesses on how to prepare (e.g., storing records and guest registers in safe places), and immediate government recovery response, which channelled A$12 million into boosting the tourism economy in Queensland (Tourism industry representative, 03 June 2011).

### 3.4 Discussion

Limits to adaptation render adaptation ineffective as a response to climate change (Adger et al., 2007). Ecological limits prevent ecological entities from negating climate risk or benefiting from climate change through acclimatisation, adaptation or distributional change. Economic limits essentially occur when the costs of adaptation exceed the costs of the impacts averted. Economic limits also occur when the financial resources required for adaptation action now are lacking and are traded-off against other existing needs (education, health, disaster response). Institutional limits exist where rules, norms and strategies render adaptation ineffective at reducing vulnerability of GBR industries and individuals, or where they prevent more appropriate and effective adaptation options from being pursued. Our results suggest that social adaptation, in particular, is complicated and multi-dimensional, and is influenced by a number of ecological, economic and institutional opportunities and limits. Indeed, often current limits are identified as potential opportunities, rather than as absolute thresholds. We suggest that because economic and institutional limits and the desirability of adaptation outcomes are to some extent socially constructed or subjective, they are not insurmountable but can be turned into opportunities through innovative re-thinking and potential re-organisation of management and industry (Adger et al., 2009). Further, distinct adaptation strategies are seemingly influenced by sets of interacting limits, which are difficult to isolate. We have, therefore, categorised bundles of interacting limits which have subtly different implications for different industries in the GBR.
3.4.1 A whole of industry perspective

Effective adaptation will protect the sustainability or resilience of the GBR and enhance or at least maintain the future viability or profitability of GBR industries and individuals, or in the case of recreational fisheries maintain fishers’ enjoyment of the reef. Our findings suggest that adaptation at the individual operator level is not necessarily adequate to achieve either sustainability or viability for all. Instead a ‘whole of industry’ approach is required. Indeed, it appears that under some circumstances a ‘integrated industry’ approach would be beneficial.

In the commercial fishing industry, different fishery sectors are characterised by slightly different sets of limits. In the Coral Reef Fish Fishery, sustainability and profitability are challenged by the fishery resources itself (abundance and distribution); the sector’s highly specialised market for live reef fish trade; and by resource allocation between the commercial and recreational fishers. These factors limit the potential for adaptation through mobility, diversification and effort management. Co-ordinated action within the sector and between the commercial and recreational sectors is required to address these limits. In the East Coast Trawl Fishery profitability is the primary concern. The sector as a whole is unviable. A few individuals are profitable. Most others have experienced a declining trend in profitability over time. A proportion of operators are already unprofitable. Yet the effort units are widely distributed through the sector, so no one operator owns more than approximately three percent of the effort. Profitability is challenged by the variability of the resource, in particular prawns; the technologies used to trawl, which limit space covered over time; the diversity and variability in price of catch (prawns, scallops, bugs); and the highly competitive domestic and international markets. Operators are already highly mobile and most operator families already rely on diversity in household income. The potential of other adaptation options to improve the viability of the sector is limited by the factors described above. For instance, forecasting and financial management is limited by the variability of the resource and market price. Effort management is currently lauded as a key opportunity for the industry to remove the unprofitable contingent. However, the sector cannot co-ordinate or afford to finance the buy-back itself, nor can it afford to buy up the assets from operators that exit the fishery following a government buy-back of effort. Further, a decrease in numbers of operators may not lead to increased profitability for those that remain because the limiting factors are not resource availability or over-exploitation. Marketing product to enhance product price, which requires co-operation within the sector and with industry peak bodies and government, was identified as perhaps the only adaptation strategy that could address the declining profitability of the sector.

The tourism industry has also experienced a decline in international market position over time and has recently been exposed to the composite risks of the Global Financial Crisis and a La Niña weather pattern, with associated floods and cyclones. At the individual level, limits to adaptation include the costs of investment in alternative technologies and marketing, which are often prohibitive. At the industry level, limits to adaptation in the industry include the state and reputation of the reef; the intensely competitive international market; and the regulations and base costs of working in Australia. Industry representatives suggested that there was a fine balance between using the iconic GBR to highlight the importance of reefs and the vulnerability of coral reefs to global threats, in particular climate change, and maintaining its reputation as a healthy and well-managed reef. In general, scientific and management information campaigns that often highlight threats and degradation were perceived to have created a perception abroad that that GBR was already highly degraded and not necessarily worth visiting. A set of critical adaptation strategies at the industry level is
therefore to market and advertise the real extent of damage after events such as cyclone Yasi, to provide accurate information on the health of the reef, and to develop new products around the reef experience, such as identifying the eight most iconic marine species. However, it is also recognised that communities that are highly dependent on tourism, such as Cairns and the Whitsundays, are highly vulnerable to climatic and non-climatic disturbance that affect the tourism industry, regardless of all the potential adaptation strategies available to them. A broader policy of economic diversification is needed in these areas to support these communities when tourism revenue is low.

Desirable adaptation outcomes for the recreational fishing sector, in particular enjoyment, are challenged by the changing regulatory landscape in Queensland, related to the GBR re-zoning and general fisheries regulation; and conflict between commercial and recreational sectors in some areas. Climate change may not directly increase these risks to the recreational fishing sector, but it is felt that management responses to climate change will. Two primary adaptation strategies have been employed by the sector to address the challenges to sustainability and their enjoyment of fishing. The first is mobility. Recreational fishers throughout Australia have apparently shifted their focus and interest to other states, particularly the Northern Territory, which represents a loss of revenue and investment in Queensland. In general, the recreational sector argues that the synergy between the tourism and recreational fishing sector industries is an opportunity that has, to-date, been lost in Queensland. The second primary adaptation is political voice. While this strategy has not necessarily been effective in restoring enjoyment of the GBR, it is influencing negotiations over reef spatial management in other states. However, there is a key limitation to this strategy at present. In general, recreational fishers see themselves as environmental stewards and do not perceive that their activities as individuals, or in aggregate, contribute to over-fishing or threaten sustainability in the GBR. This limits the extent to which they engage in discussion and adaptation strategies related to their own effort or capacity. Recreational fishers do, however, believe that the commercial fisheries have dramatic impacts on sustainability, with this perception being strongly associated with inshore net fishing. However, arguably the general unwillingness of recreational fishers to examine their own impacts and to organise into representative organisations (although this is changing) reduces their influence over other fishing sectors and other GBR stakeholders more generally.

3.4.2 Uncertainty and system connectivity

It has been suggested that the current range of climate projections is too broad to allow for meaningful decision-making at the household, business, sector or societal level (Garnaut, 2008). Uncertainty around how climate change will manifest and the impacts it will have underpins a number of limits to adaptation. Uncertainty around the perceptions and vulnerabilities (sensitivity and adaptive capacity) to climate change of the resource dependent communities in the GBR region is also problematic (Fenton and Beeden 2006; Marshall and Marshall, 2007). Uncertainty is magnified by the varying spatial and temporal scales at which climate change and action can occur and is also complicated by the many interests and values that are influenced by climate change, representing multiple claims on limited resources. Uncertainty makes it very difficult for GBR stakeholders to systematically evaluate what are the most cost-effective options along a spectrum from zero adaptation to full adaptation, when is the most pertinent time to tie up financial capital in adaptation, and who should pay the costs. Further, crafting and co-ordinating institutions at multiple scales to address multiple issues and interests in a context of uncertainty, and judging to what extent self-organisation
versus government co-ordination or regulation are better strategies in the long term are extremely challenging.

GBR stakeholders identified uncertainty as a factor limiting most adaptation options, including: i) the effectiveness of industry organisation, whereby different models are appropriate for different industry sectors at different times; ii) business planning, in that forecasting and financial management remain huge challenges in highly variable industries; iii) stewardship due to the uncertainty of the science of ecological sustainability and the cost of monitoring; iv) mobility due to variability in stock abundance and distribution, and market price; v) effort management because of its ambiguous outcomes to-date; vi) diversification because of uncertainty around the sensitivity of other activities to climatic and non-climatic impacts; and; vii) technological investment because of uncertainty around effectiveness and return on investment.

The GBR stakeholders we spoke to noted, however, that uncertainty was exacerbated by the connections, linkages and relationships that characterise the GBR region as a social-ecological system. Almost all adaptation strategies have implications elsewhere in the system. Some may be beneficial, for instance, joint marketing and supply benefits for fisheries and tourism. But many are often inadvertently negative. Examples discussed include: i) shifting of effort away from particular species or areas, in an effort to improve stewardship, which may result in impacts on other species (e.g., shift from snapper to cod in the recreational fishery, and impacts shifting from turtles to albacore tuna in particular commercial sectors); ii) coastal adaptation strategies to protect valuable land assets, in particular fortification strategies having major implications for coastal habitat, biodiversity and fisheries resources, and; iii) catchment use and management strategies having critical implications for coastal and reef habitat, aesthetics of the reef, and availability of fisheries resources. Appropriately managing these system interactions is difficult, particularly across jurisdictional and sectoral boundaries (Orth et al. 2006; Lovelock and Ellison, 2007). Responding appropriately to these interactions and understanding when and how vulnerability at the individual and system level is reduced is limited by the diversity and geographical spread of operators, the costs of monitoring and divergence in scientific agendas, and the conflicting and changing perceptions and value systems of GBR stakeholders, including civil society, the private sector and government.

3.4.3 Private action for public goods

Real and perceived climate change emphasises, to some extent, the trade-offs between divergent interests because it introduces an added layer of risk and potential opportunity to a broad spectrum of society. As a result, effective, broad scale adaptation and the public goods or outcomes it can deliver will often depend on co-ordinated collective action. However, because of the increasing privatisation of property rights in Australian, in terms of infrastructure and land ownership, or fisheries quota for example, the issue becomes more one of co-ordinated private action for public goods. This was referred to as the ‘privatisation of public responsibility’ in the Townsville workshop (25 March 2011). Designing institutions or economic incentives to motivate private action for the public good is notoriously difficult. For instance, along the GBR it is the right of individual property owners to fortify and protect their properties from climate change but when the majority of the coastal population pursue this adaptation response the effects for the GBR ecosystems and dependent industries can be devastating. However, asking property owners to respect and minimise impacts on these industries may require them to incur financial and other costs for benefits that they as
individuals do not experience directly. Similarly, motivating individual property owners to build to high standards of safety and efficiency, or ensuring that property developers adequately accommodate for public services in design and implementation of new developments, as part of long-term planned adaptation, can minimise the financial costs of emergency response and recovery for government and individuals (insurance premiums and recovery levies). But, as noted in the workshops, emergency response is a more politically popular response than regulation to enforce an adequate standard of quality for coastal development, hence the former is more often pursued.

Historical, ethical and political factors play a role in limiting adaptation related to private action for public goods. It was often noted by GBR participants that many decisions had already been made about economic and coastal development trajectories in the GBR that could not easily or ever be reversed, particularly where physical structures were built. Related to this are the strong identities tied up with coastal lifestyles and Australian primary industries (in particular beef and sugar cane), which mean there are limits on the degree to which primary industry and associated environmental stressors such as pollution and coastal development can be removed or reduced considering the growing population and the multiple uses of the GBR region. Finally, strong political interests are tied up with these identities and development trajectories, meaning Federal and State governments are often unwilling to take action which contravenes the immediate economic and political interests of their constituents.

3.4.4 Perceptions and reputations

Perceptions play a role in limiting or enabling effective adaptation on a number of levels. The perceptions of the operators and individuals that make up the GBR industries influence what they view as negative impacts and opportunities from climate change, and what they consider to be viable adaptation options and desirable outcomes. For instance, many of the commercial fishing operators are described as lifestyle fishers, though it is noted that it is increasingly difficult to be a lifestyle as opposed to a professional, profit driven fisher. Certain adaptation options, such as exiting the fishery or diversifying livelihoods are, therefore, limited by virtue of not being considered to be desirable alternatives. Tied up with this, are the broad personality traits of commercial fishers, which were identified as a strength in terms of fishing activities and length of time at sea, but which limit the capacity of some fishers to network, market and be politically active. Perceptions also play a strong role in limiting adaptation within the recreational fishing sector. For example, recreational fishers on the whole do not perceive there to be an impact on fisheries resources from the recreational sector, meaning that management and adaptation actions to address sustainability outcomes are not considered necessary. Reinforcing this is a widespread scepticism of climate change trends and future impacts. According to participants in our research, recreational fishers believe that if climate change happens they will easily be able to respond to the ecological impacts, but what they cannot adapt to is the associated regulatory changes. Many GBR industry representatives perceive regulation to be a key barrier to adaptation and there is some concern that the climate change agenda will drive and be used to justify additional top-down management. The industries are attempting to counter-act this by demonstrating self-organisation and stewardship. The GBR respondents also acknowledge that this is changing slowly with regulations becoming more flexible and with the climate change agenda increasingly driving collaboration rather than conflict.

Despite considerable progress in the stewardship practices of GBR industries and more broadly in management of the GBR region, the perceptions of the consumers of fisheries and
tourism products still limit effective adaptation. In the tourism sector, the product offered by the Australian, Queensland and GBR-specific tourism sector is seen as aspirational and of high quality, but increasingly a pessimistic view of the GBR and its future prospects are pervading consumer perceptions thereby limiting market share and profitability of the industry. Partnerships between industry and Federal and State governments have been developed to address this, for instance, the injection of an A$12 million recovery fund for Queensland’s Tourism. Similarly, the reputation of the GBR commercial fisheries, as highly and irresponsibly extractive continues to limit market share and market price. The Reef Guardian programme and associated advertising, recently aired on national television, are trying to address this, often misinformed perception.

Finally, government perceptions of industry are also a factor in driving or limiting adaptation. The extent to which different stakeholders are supported by government may depend on how they are viewed by government and management agencies and how different claims are heard and traded-off. For instance, it is often assumed that coastal adaptation would benefit all actors equally. However, particularly in areas where fishing communities are already being marginalized by tourism development, they may not by prioritised and as such, fishing facilities may be among the most vulnerable of those found in coastal communities (Brander et al. 2007). It was often expressed by both commercial and recreational fisheries respondents in interviews, more so than in the workshops, that they felt unwanted and under-valued as GBR industries, which often marginalises sections of these industries from mainstream processes of management and adaptation planning.

3.4.5 Australia in a globalised world

An important factor limiting current viability of GBR industries and the potential of adaptation to reduce the vulnerability of industries and individuals to climatic and non-climatic drivers of change is the integration of the Australian economy in global markets. In the commercial fisheries sector, competition within the domestic market between domestic and international goods drives down prices, threatening to render fishery activities completely cost-ineffective and limiting the potential for business planning and diversification to improve the viability of the industry and the profitability of individuals. Similarly, competition between the Queensland tourism industry and international tourism markets presents a considerable challenge to the industry, particularly in light of more lax regulatory frameworks and lower base costs (energy and labour) in other countries. Perversely, the expansion of the Australian economy, driven by mining and market linkages with China, are strengthening the Australian dollar and driving up living expenses in mining-associated communities, e.g., Mackay and Townsville, thereby affecting export markets and expenses of GBR industries. Further, the economic burden of coastal governance and climate change adaptation occur in a wider context of economic volatility. Many of the sectors in the GBR are reliant on the energy sector to a greater or lesser extent (e.g., the agriculture sector’s reliance on fuels, electricity, fertilisers, agro-chemicals), and consequently global, regional and local market shifts in these commodities may place further financial strain on resource-users, thereby further limiting their adaptation options (Keating and Carberry, 2010).

3.5 Conclusion

This project on the limits to climate change adaptation in the GBR region aimed to scope: i) the limits and opportunities that characterise adaptation, ii) the trade-offs and synergies that
occur between sectors, and iii) possible conflicts that arise from climate change adaptation in the GBR region. Our findings highlight some important issues related to these objectives. First, social limits to adaptation, including economic and institutional limits are subjective, as are the outcomes of adaptation action, meaning that limits are rarely absolute or insurmountable. Indeed many of the conditions that reduce the effectiveness of adaptation can also be viewed as key opportunities. Second, these conditions often appear to exist as sets of interacting limits. It is very difficult to isolate a particular ecological, economic or institutional limit as the key factor rendering adaptation ineffective as a response to perturbation. We have categorised factors or conditions into bundles of limits that are shared among the GBR industries though they manifest in subtly different ways. There are, therefore, many examples where addressing limits to adaptation could benefit the GBR industries simultaneously, particularly in regards to catchment management and coastal development, although clearly there are trade-offs with other land-users in such cases. Trade-offs within the fisheries and tourism industries were noted but there were far more opportunities for collaboration discussed than there were issues of contestation. Indeed, in general, relationships among the industries and between the industries, government and scientists seem markedly improved compared to 5-10 years ago. Climate change issues, among other things, appear to be bringing stakeholders together rather than creating conflict. There is some concern that the climate change agenda will be used to justify more regulation, something viewed as undesirable in all the GBR industries, according to our respondents, but this has not yet been the case and instead it is fostering more dialogue amongst stakeholders.

There are two final points to note. Effective adaptation includes actions very closely tied to broad environmental management and business planning and it was emphasised throughout the research that adaptation planning and action is one component of broader environmental and development policy, not something to be addressed in isolation. Further, while we focused on broad adaptation strategies, there is considerable diversity within the tourism and fisheries industries, and, therefore, there is no adaptation blue-print or guarantee that a particular strategy will work in every case. A broad enabling approach that perhaps focuses on the themed bundles of limits indentified, rather than on specific constraints to specific adaptations might be one approach to flexible and context-sensitive adaptation policy.

3.6 Caveats and future research

This project is a scoping study to empirically explore social limits to climate change adaptation in the Great Barrier Reef region. The complexity of both the subject area and the case-study region mean there are a number of caveats associated with the work and a number of opportunities to take the research forward for future policy development.

3.6.1 Caveats

We highlight three main caveats to this work.

1. Our research focuses on climate change impacts, adaptation and outcomes under moderate and extreme climate outlooks. We used future scenarios to elicit discussion on these issues. Our scenarios assume that under the best-case climate situation mitigation has occurred but we do not directly explore the implications for industries of Australian mitigation policy. We acknowledge rising fuel costs but we suggest that costs are spread over 40 years and are comparable to rises in the cost of fuel due to oil
scarcity under a non-mitigated scenario. You could argue that our scenarios also assume that for the most part the costs of mitigation are absorbed by other industries, such as mining. As such, we suggest that the fishing and tourism industries will be able to continue to function as they are and also that the adaptation strategies suggested in scenarios 1a and 1b are feasible regardless of mitigation policy. This may not necessarily be the case, but to understand this fully would be another study entirely.

Nevertheless, as stated repeatedly, the scenarios were used as a research tool to prompt discussion on impacts, adaptation and outcomes and are not ‘results’ or policy guides. The GBR stakeholders we spoke to in this research drew on a range of experiences with adaptation both related to and independent of climatic events (not necessarily attributed to climate change). Therefore, the insights into adaptation and limits to adaptation are valid for a range of contexts of change; some of the adaptation strategies outlined under ‘ideal adaptation’ may even be useful as responses to the effects of mitigation policy

2. In the initial phases of this scoping study we took a broad approach. We reviewed the literature on agriculture and conservation, as well as fisheries and tourism, and invited scenario responses from scientists working on these issues in the GBR catchment. However, we focused the truth-grounding exercises on fisheries, tourism and environmental management in order to gain depth in our analysis. The participants in our workshops and interviews were representatives of their organisations, rather than individual owner/operators except where individuals had been put forward by their associations. The data obtained through the multi-stakeholder workshop discussions and the interviews is diverse and rich, providing a good source of knowledge on adaptation and potential limits to adaptation. But, the sample size is relatively small and does not provide a representative assessment of limits within these industries across the GBR region. Future research could take this work forward through assessment of large sample sizes.

3. The scenarios we developed looked to 2050. While we did not specify particular timelines in the stakeholder discussions but we did ask participants to consider future contexts and possibilities. These futures are developed within our existing or current knowledge and value frameworks, but values change. What people view as negative impacts, opportunities, and desirable or undesirable outcomes now may well be very different to what they perceive as good or bad, acceptable or unacceptable in 10, 25, 50 years. As such, climate change research, policy and action must take a flexible and long term approach that accounts for shifting perceptions on climate change impacts, adaptation and outcomes.

3.6.2 Future research

This research shows that limits to adaptation have real and practical importance for climate change policy and action. There are two main future research directions, which we feel would directly improve the policy relevance of this initial empirical work. The first is to conduct a large-N study to investigate to what extent the limits or bundles of limits identified in this study affect individual business and limit current adaptation to climatic and non-climatic disturbance or are perceived by individuals to be a real concern for future adaptation. As part of this, one respondent in our dissemination workshop suggested that a simple but necessary
addition to climate change adaptation science was to ask a representative sample of business owners and operators what ‘good adaptation’ means to them.

The second opportunity is to explore different combinations of industries and issues within the GBR region. Multi-stakeholder discussions are really useful for understanding synergies and trade-offs within and between industries, but can only reasonably address a few industries or issues at a time. We selected to look at fisheries, tourism and environmental management. Other combinations, such as coastal development and conservation, agriculture and fisheries, tourism and traditional owners would add to our understanding of how limits to adaptation are unique to or shared among industries and issues.

Conceptually, there are also a number of possibilities to further this research, such as exploring the relationship between limited adaptation and maladaptation; barriers and limits; limits to adaptation to single stochastic events versus composite or long-term change; and many more.

Finally, there is also an opportunity to develop methods and frameworks to assess or evaluate adaptation options ex ante. To date, many vulnerability or risk assessments go as far as identifying adaptation strategies, but few include comprehensive approaches to then selecting appropriate actions for implementation. A ‘limits to adaptation’ focus would be an important dimension to such an assessment, considering the real implications of limits to adaptation outcomes.
4. REFERENCES


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APPENDIX A: Project brief

PROJECT BRIEF: Limits to climate change adaptation in the Great Barrier Reef

THE GREAT BARRIER REEF

The Great Barrier Reef (GBR) (350,000 km²) and its catchment (425,964 km²) are of significant national and international importance (Fig. 1). In recognition of this, the GBR has been designated as both a Marine Park (1975) and a World Heritage Area (1981). Climate change is already evident in the region and is seen, by some, as the greatest future threat to both ecological and human communities. Adaptation to climate change by marine organisations and people is, therefore, critical to the region’s future.

PROJECT OVERVIEW

The National Climate Change Adaptation Research Facility (NCCARF) is funding a project on the Limits to Adaptation. Five studies are being completed by different research teams across Australia, with overall co-ordination by Professor Jon Barnett of the University of Melbourne. The ARC Centre of Excellence for Coral Reef Studies is heading the research on the limits to climate change adaptation in the GBR.

PROJECT OBJECTIVES

1. To develop four alternative future scenarios (see Fig. 2 overleaf) and present these to stakeholders in the GBR region for discussion.
2. To hold multi-stakeholder focus groups and interviews to understand i) how the different scenarios might play out in the different regions, ii) to what extent the scenarios reflect desirable/acceptable/undesirable futures, iii) what the residual impacts of climate change might be after ‘limited’ and ‘ideal’ adaptation, and iv) what limits ‘ideal’ adaptation.
3. To identify and prioritise options for addressing limits to adaptation.
4. To disseminate research findings in a final workshop of key decision-makers and industry representatives.

PROJECT OUTPUTS

1. Engagement of scientists, stakeholders, managers and policy-makers in the research process.
2. Publication of four alternative scenarios on climate change and adaptation for the GBR region.
3. Publication of project reports and peer-reviewed journal articles on limits to ecological and societal adaptation to climate change in the GBR region.
4. Sharing of all project outputs with all project participants.
5. Dissemination of outputs through the Communications and Knowledge Adoption section of NCCARF for ongoing delivery to policy and decision-makers in appropriate formats.
ADAPTATION AND LIMITS TO ADAPTATION

Adaptation to climate change is adjustment in natural or human systems in response to actual or expected climate change or its impacts, which aims to reduce harm or exploit benefits (adapted from the IPCC 4th Assessment Report). Adaptation can occur before or after climate changes and can be ad hoc or planned. It occurs over a range of scales: from individuals to societies; species to ecosystems; local to global; short to long term; and generational to evolutionary.

Limits to adaptation are the conditions or factors that make adaptation ineffective as a response to climate change (Adger et al., 2007). So, for example, adaptation is limited when a particular adaptation strategy does not reduce the vulnerability of an organism, individual, group or society to climate change. Limits also prevent a more appropriate adaptation strategy from being pursued by an organism, individual, group or society. Limits include ecological, institutional and economic limits. They are largely insurmountable but are not absolute. Examples of ecological limits can range from limits to the physiological acclimation or behavioural adaptation of corals or fish, to limits on shifts in ecological communities, or potential evolutionary change. Institutional examples can range from the constraints that societal pressures place on our identity and our expectations, to limits to our ability to develop and coordinate appropriate policy for change. Economic examples range from limits to our capacity to fund pre-emptive adaptation action in the face of other pressures and priorities, to limits to our knowledge about the economic costs of inaction at community and societal levels. Underlying limits, in particular institutional and economic limits, are social and cultural factors that influence how climate change impacts and adaptation options are seen – How urgent is action? How feasible are different options? What are our individual and collective responsibilities? Do we have the capacity to respond? These perceptions affect to what extent we view interventions to stretch ecological limits as acceptable, institutional processes for adaptation as legitimate, and different options for adaptation as economically achievable.

SCENARIO DEVELOPMENT

Whether we reduce CO₂ emissions to mitigate climate change now will influence the types of impacts we face in the future. We explore two paths. In the first, climate mitigation happens and temperature increases are minimised. Air temperatures rise by no more than 1.5°C above 1960-1990 averages (2.0°C above pre-industrial temperatures). In the second path, mitigation action is delayed or non-existent and temperature increases are not minimised. Air temperatures rise by at least 2.5°C above 1960-1990 averages (3°C above pre-industrial temperatures) (Fig. 2). A process of scientific consultation asked respondents to outline the potential impacts of these trends and to explore and imagine ecological and societal adaptation responses for two possibilities: one in which adaptation is constrained by ecological, institutional, and economic limits; and another in which ecological adaptation is optimal (although still constrained by what is possible), and institutional and/or economic adaptation responses are ideal or completely unconstrained (Fig. 2).

![Fig. 2: Four alternative scenarios representing two possible climate change trends and two adaptation pathways.](image-url)
APPENDIX B: Scenario response template

We have provided the basic context for each of the four scenarios below. For each scenario, please provide a description (between 200-500 words per scenario) of how you see the status and trends of the GBR in 2050. Your response can focus on ecological or social dimensions, or both, at different scales, depending on your expertise and interests.

Please respond by 20th December 2010.

In responding, please consider the following:
1. Focus primarily on marine and coastal areas.
2. Make explicit the limits to adaptation you have imagined or imposed on scenarios 1a and 2a.
3. Emphasise key synergies and trade-offs between and within sectors (e.g., fisheries, tourism, agriculture, conservation), where important.
4. Provide a descriptive name for each of your scenarios.

As you know, there is a high level of uncertainty around the future we face in light of climate change. As such, there are no right answers so be imaginative and as hopeful or pessimistic as you wish.

This expert elicitation process is deliberately open-ended in order to maximise the diversity and novelty of the information gathered for development of the four alternative future scenarios. We acknowledge and greatly appreciate the time you spend in responding.

Many thanks.
1a: Climate change is minimised, but adaptation is constrained by ecological, institutional, and economic limits.
It is 2050. Average air temperatures are not more than 1.5°C above those experienced 60 years ago (1990). Sea surface temperature has increased by just over 1°C in the same time period. Sea level has risen by around 0.13 m, corresponding to a recession (of sandy beaches) of 13 m, and continues to rise at a rate of approximately 1 mm/year (due to residual effects of warming). The pH of the ocean has declined by 0.15 since 2010. Rainfall has become moderately more variable and extreme events, such as cyclones, more intense, although they have not changed in frequency or distribution.

These climate change trends have affected ecological and human communities in the GBR by... *(please continue, or delete and begin with a statement you prefer)*

Adaptation responses are varied and include... *(please continue)*

These adaptation responses are constrained by the following ecological, institutional, and economic limits... *(please continue)*

Anything else you want to add...

1b: Climate change is minimised and there are no limits to what we can achieve through adaptation. Ecological adaptation is optimal and institutional and economic adaptation responses are ideal.
It is 2050. Average air temperatures are not more than 1.5°C above those experienced 60 years ago (1990). Sea surface temperature has increased by just over 1°C in the same time period. Sea level has risen by around 0.13 m, corresponding to a recession (of sandy beaches) of 13 m, and continues to rise at a rate of approximately 1 mm/year (due to residual effects of warming). The pH of the ocean has declined by 0.15 since 2010. Rainfall has become moderately more variable and extreme events, such as cyclones, more intense, although they have not changed in frequency or distribution.

These climate change trends have affected ecological and human communities in the GBR by... *(please continue, or delete and begin with a statement you prefer)*

Ecological adaptation is optimal (though not inconceivable), and human ingenuity has achieved profound feats of adaptation, unconstrained by institutional or economic limitations. These adaptation responses include... *(please continue)*

 Anything else you want to add...
2a: Climate change is not minimised and adaptation is constrained by ecological, institutional, and economic limits.

It is 2050. Average air temperatures are more than 2.5°C above those experienced 60 years ago (1990). Sea surface temperature has increased by as much as 2°C in the same time period. Sea level has risen by around 0.68 m, corresponding to a recession (of sandy beaches) of 68 m, and continues to rise at a rate of approximately 2 mm/year (due to residual effects of warming). The pH of the ocean has declined by 0.25 since 2010. Rainfall has become considerably more variable and extreme events, such as cyclones, much more intense, although they have not changed in frequency or distribution.

These climate change trends have affected ecological and human communities in the GBR by... (please continue, or delete and begin with a statement you prefer)

Adaptation responses are varied and include... (please continue)

These adaptation responses are constrained by the following ecological, institutional, and economic limits... (please continue)

Anything else you want to add...

2b: Climate change is not minimised but there are no limits to what we can achieve through adaptation. Ecological adaptation is optimal and institutional and economic adaptation responses are ideal.

It is 2050. Average air temperatures are more than 2.5°C above those experienced 60 years ago (1990). Sea surface temperature has increased by as much as 2°C in the same time period. Sea level has risen by around 0.68 m, corresponding to a recession (of sandy beaches) of 68 m, and continues to rise at a rate of approximately 2 mm/year (due to residual effects of warming. The pH of the ocean has declined by 0.25 since 2010. Rainfall has become considerably more variable and extreme events, such as cyclones, much more intense, although they have not changed in frequency or distribution.

These climate change trends have affected ecological and human communities in the GBR by... (please continue, or delete and begin with a statement you prefer)

Ecological adaptation is optimal (though not inconceivable), and human ingenuity has achieved profound feats of adaptation, unconstrained by institutional or economic limitations. These adaptation responses include... (please continue)

Anything else you want to add...
APPENDIX C: Workshop agenda

Limits to climate change adaptation in the Great Barrier Reef

08.30 – 09.00 Welcome tea & coffee

09.00-09.30 Welcome and personal introductions
09.30-10.00 Project background and introduction to alternative scenarios on the GBR
10.00-11.00 Grounding scenarios: are the scenarios a reasonable projection of the future for the region?

11.00-11.15 Tea & coffee

11.15-12.15 Identifying limits: do particular adaptation strategies reduce vulnerability of individuals and industry under different climate scenarios?
   - Industry organisation & individual business planning
   - Stewardship (catchment, marine, fisheries management & coastal development)

12.15-13.00 Lunch

13.00-14.45 Identifying limits continued: do particular adaptation strategies reduce vulnerability of individuals and industry under different climate changes?
   - Managing effort
   - Diversification
   - Mobility
   - Retreat
   - Emergency response

14.45- 15.00 Tea & coffee

15.00-15.45 Implications: what are the implications of different effective/ineffective adaptation strategies for individuals and industry under different climate scenarios?
   - Profitability
   - Sustainability
   - Conflict / trade-offs
   - Identity / lifestyle values

15.45-16.15 Addressing limits: what is stopping us achieving ‘ideal’ adaptation? How can we address these?
APPENDIX D: Informed consent form for the workshops

INFORMED CONSENT FORM FOR FOCUS GROUPS

Principal investigator: Dr. Louisa Evans
Project title: Limits to adaptation and conflict management in the Great Barrier Reef
School: ARC CoE for Coral Reef Studies

The aim of this project is to develop our understanding of three issues at the frontier of climate change research: i) the limits to adaptation (including ecological, institutional and economic limits), ii) the trade-offs and synergies that are likely to occur between sectors (e.g., fisheries and tourism) and issues (e.g., resource use and biodiversity) and, iii) potential conflict related to climate change in this multi-use coastal system.

You are under no obligation to participate in this focus group. You have the right to end your participation at any point, please just inform the facilitator. You can also withdraw any statements made during the focus group by telling the facilitator during or after the interview or by contacting Louisa Evans on louisa.evans@jcu.edu.au or (07)4781 6749 (this contact information is on your invitation letter).

I............................................................(please insert name) have understood the objectives of this project and that my participation will involve participation in this two day focus group.

I understand that I am under no obligation to participate in the focus group.
I understand that I can end my participation at any point.
I understand that I can withdraw any or all statements made during this focus group at this or a future point in time.

I consent to participate

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
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I understand that any personal information I give will be kept strictly confidential and that my name will not be used to identify me with this study without my approval.

I consent to the use of the name of the organisation that I represent beside any statements I make

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<th>Yes</th>
<th>No</th>
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Signature:...........................................................  Date:.....................................................

For any independent queries or feedback on the ethics of this study please contact Sophie.Thompson@jcu.edu.au Ph: (07) 4781 6575
APPENDIX E: Interview schedule

Outline
- Introduction to project
- Ethics
- Talk through scenarios
- Discuss adaptation strategies and to what extent they effectively reduce vulnerability to climate risks

Introduction to project
- Introduce climate change and adaptation
- One of 5 projects exploring Limits to Climate Change Adaptation.
  - By limits I mean... Adaptation ceases to reduce vulnerability / We cannot adapt how we would like to
- We have developed a set of scenarios
- We conducted a couple of workshops – Townsville and Cairns
- We are now finishing up with interviews in Bowen and Mackay
- We will disseminate findings in a final workshop in Brisbane

Ethics
- Informed consent
- Permission to record the interview

Background
- Represented industry:
- Date and time of interview:

Scenarios
- Explore two climate change trends: best-case and worst-case
- Broad impacts on corals, habitat and fisheries / tourism

Adaptation
- Industry organisation
  - How is your industry currently organised?
  - Does this benefit operators and enable adaptation?
  - What would be the implications of amalgamation into big international companies?
  - What would be the implications of organising into co-operatives
  - Who in the industry can adapt? Who in the industry cannot adapt? What does this mean for the whole industry?

- Business planning
  - What business skills are useful for adapting to change?
  - Do most operators have these skills?
  - Does possessing these skills reduce the vulnerability of business to climate change risks under different climate scenarios?
  - How are these skills developed?
  - What are the challenges to promoting business skills in industry
• **Stewardship**
  o What does stewardship mean to your industry?
  o Can stewardship reduce the vulnerability of businesses to climate change risks under different scenarios?
  o How can stewardship be fostered?
  o What are the challenges to promoting stewardship in your industry?

• **Mobility**
  o Do the industry use mobility as an adaptation strategy?
  o Can mobility reduce the vulnerability of businesses to climate change risks under different scenarios?
  o How can mobility be fostered?
  o What are the challenges to promoting mobility in your industry?

• **Effort (as above)**
• **Diversification (as above)**
• **Technology (as above)**

• **Infrastructure**
  o Does the industry manage their on-shore facilities?
  o Would this reduce the vulnerability of business in your industry?
  o What are the implications for the industry of adapting or not adapting, with regards to infrastructure planning?

• **Emergency planning**
  o Does the industry conduct emergency planning?
  o Would this reduce the vulnerability of business in your industry?
  o What are the implications for the industry of adapting or not adapting, with regards to emergency planning?
APPENDIX F: Informed consent form for the interviews

INFORMED CONSENT FORM FOR INTERVIEWS

Principal investigator: Dr. Louisa Evans
Project title: Limits to climate change adaptation in the Great Barrier Reef region
School: ARC CoE for Coral Reef Studies

The aim of this project is to explore different climate change impact and adaptation pathways and their implications for the Great Barrier Reef (GBR) and its fishing and tourism industries. In particular, the project aims to understand:

- Ecological, economic and institutional limits to adaptation
- Trade-offs and synergies that are likely to occur between sectors (e.g., fisheries and tourism) and issues (e.g., resource use and biodiversity)

You are under no obligation to participate in the interview. You have the right to end the interview at any point, please just inform the interviewer. You can also withdraw any statements made during the interview by telling the interviewer during or after the interview or by contacting Louisa Evans on louisa.evans@jcu.edu.au or (07)4781 6749.

I............................................................(please insert name) have understood the objectives of this project and that my participation will involve an interview of between approximately 60 minutes.

I understand that I am under no obligation to undertake this interview.
I understand that I can end the interview at any point.
I understand that I can withdraw any or all statements made during this interview at this or a future point in time.

I consent to be interviewed
I consent for the interview to be audio-taped
I understand that any personal information I give will be kept strictly confidential and that my name will not be used to identify me with this study without my approval.

I consent to the organisation I represent being acknowledged in the outputs of this research

Signature:..........................................................  Date:.....................................................

For any independent queries or feedback on the ethics of this study please contact Sophie.Thompson@jcu.edu.au  Ph: (07) 4781 6575
APPENDIX G: Ethics clearance form

<table>
<thead>
<tr>
<th>ETHICS REVIEW COMMITTEE</th>
<th>Human Research Ethics Committee</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPROVAL FOR RESEARCH OR TEACHING INVOLVING HUMAN SUBJECTS</td>
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<table>
<thead>
<tr>
<th>PRINCIPAL INVESTIGATOR</th>
<th>Dr Louisa Evans</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO-INVESTIGATOR(S)</td>
<td>Mr Pedro Fidelman &amp; Miss Christina Hicks (ARC Centre of Excellence)</td>
</tr>
<tr>
<td>SCHOOL</td>
<td>ARC Centre of Excellence</td>
</tr>
<tr>
<td>PROJECT TITLE</td>
<td>Limits to adaptation and conflict management in the Great Barrier Reef</td>
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<th>APPROVAL DATE</th>
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<th>EXPIRY DATE</th>
<th>30 Jun 2011</th>
<th>CATEGORY</th>
<th>1</th>
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This project has been allocated Ethics Approval Number H3808 with the following conditions:

1. All subsequent records and correspondence relating to this project must refer to this number.
2. That there is NO departure from the approved protocols unless prior approval has been sought from the Human Research Ethics Committee.
3. The Principal Investigator must advise the responsible Human Ethics Advisor appointed by the Ethics Review Committee:
   • periodically of the progress of the project;
   • when the project is completed, suspended or prematurely terminated for any reason;
   • notify within 48 hours of any adverse effects on participants occur; and if any unforeseen events occur that might affect continued ethical acceptability of the project.
4. In compliance with the National Health and Medical Research Council (NHMRC) “National Statement on Ethical Conduct in Human Research” (2007), it is MANDATORY that you provide an annual report on the progress and conduct of your project. This report must detail compliance with approvals granted and any unexpected events or serious adverse effects that may have occurred during the study.

<table>
<thead>
<tr>
<th>Human Ethics Advisor:</th>
<th>Cottrell, Alison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email:</td>
<td><a href="mailto:alison.cottrell@jcu.edu.au">alison.cottrell@jcu.edu.au</a></td>
</tr>
</tbody>
</table>

ASSESSED AT MEETING

Date: 25 Aug 2010

APPROVED

Date: 25 Aug 2010

Professor Peter Leggat
Chair, Human Research Ethics Committee

Sophie Thompson (Sophie.Thompson@jcu.edu.au)
Human Ethics and Grants Administrator
Research Services

Date: 22 September 2010
The view expressed here is not necessarily the views of the National Climate Change Adaptation Research Facility.

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