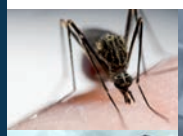
Update 2012

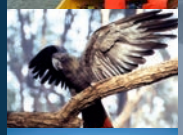
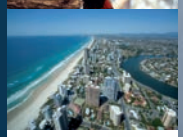
NCCARF
National
Climate Change Adaptation
Research Facility

National Climate Change
Adaptation Research Plan

Marine Biodiversity and Resources

Update 2012





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The role of the National Climate Change Adaptation Research Facility is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government and in vulnerable sectors and communities to manage the risks of climate change impacts.

National Climate Change Adaptation Research Plan

Marine Biodiversity and Resources

Update Report

April 2012

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EXECUTIVE SUMMARY

Development of National Climate Change Adaptation Research Plans is a key function of NCCARF. These Plans (referred to as NARPs) are produced for nine key sectors where adaptation response will be critical in safeguarding against climate risks to social, economic and environmental well-being.

The purpose of a NARP is to identify priority needs over the next few years in developing knowledge on how governments, businesses and communities can best adapt to climate change risks. They provide a national blueprint for research investment by research organisations and knowledge user stakeholders. Development of NARPs involves the active contribution of both the research community and adaptation knowledge users.

The NARP for Marine Biodiversity and Resources (Marine NARP) (Mapstone *et al*. 2010) is concerned with identifying priority research questions for marine climate change adaptation issues, including conservation, fisheries and tourism. Research focused on these priority questions should support governments, conservation agencies, fishers, businesses, landholders, community organisations and individuals to make sound decisions about climate change adaptation initiatives for marine issues. These decisions should be able to take advantage of opportunities for marine biodiversity and resources that result from climate change and to reduce unavoidable detrimental climate change impacts.

The Marine NARP has been revisited in 2012 and the priority research questions have been updated to ensure currency and to provide guidance for research investment over the next five years.

Updated priority research questions are identified based on:

- Changes to stakeholder needs since the Marine NARP was completed in 2009;
- Relevant research published since the Marine NARP was completed; and
- Areas of current research focus in relation to the Marine NARP.

Stakeholder information needs have not changed significantly. However, stakeholder needs have become more clearly stated or relatively more important. These are:

- communication and education especially targeted, clear and accessible information exchange about climate change adaptation;
- a greater focus on estuaries; and
- a greater focus on adaptation issues and decisions affecting the land / marine interface, including (a) marine impacts arising from the effects of climate change impacts on land and (b) adaptation initiatives taken in response to those impacts.

Climate change adaptation for marine biodiversity and resources is a rapidly expanding research area. Holbrook and Johnson (2012) reviewed over 145 research articles and other publications in the last few years since the Marine NARP was completed.

In the past few years Australia has invested in research about climate change marine biodiversity and resources through a number of programs.

The jointly funded research program supported by the Adaptation Research Grants Program (ARGP) and the Fisheries Research and Development Corporation (FRDC) comprises 17 research projects. The NCCARF/ARGP contribution was $3.5 million, and the total value of the research program totals more than $17 million (cash and in-kind).

Other NCCARF research will also be relevant to some of the Priority research questions in the Marine NARP or more broadly will help inform climate change adaptation decisions or investments pertinent to marine biodiversity and resources. This includes research in both the ARGP and Synthesis and Integrative Research (SIR) programs.

In addition to the joint ARGP/FRDC research program, the ARC is supporting 34 projects relevant to a greater or lesser extent to the Marine NARP Priority research question, with a value of $11.8 million.

A draft of this report was circulated to about 70 key stakeholders nationally and to an international reviewer. The comments received have been incorporated in this final Update Report. The conclusion of this revisit and update is that all existing Marine NARP priority research questions should be retained. However, the prioritisation of several should be changed, two should be extended in scope, five new cross-cutting research priorities should be included, and other significant but relatively minor changes should also be made, as summarised below. The major thematic change is a shift from a focus on research about the impacts of climate change on marine biodiversity and resources to research about adaptation to climate change, reflecting a greater recognition that adaptation decisions will be required using information then available.The specific changes are as follows:

- Four research priorities concerned with 'overcoming barriers to adaptation' have been altered to include reference to using 'enablers' or 'facilitators' of adaptation:

  This affects research priorities 1.5, 2.7, 2.8 and 3.3.

- In two cases, two research priorities have been combined and simplified; research priority 2.7 has been simplified and combined with both 2.5 and with 2.6, with research priority 2.8 being renumbered to 2.7. Research priorities 2.5 and 2.6 now read as follows:

  2.5 What options or opportunities are there for commercial fishers in identified impacted fisheries to adapt to climate change effects through changing target species, capture methods and management regimes, industry diversification, relocation or disinvestment? What are the enablers and barriers to fishers implementing such options?

  2.6 What options or opportunities exist or might become available for recreational fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species or preferred fishing method or travelling to pursue their preferred target species or method? What are the enablers and barriers to fishers implementing such options?

- One research priority has been restated to clarify its historical perspective Note – renumbered 2.8 as 2.7):

  2.7 How have enablers to adaptation been used and barriers to adaptation been overcome? What significant changes in fisheries have occurred before because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?

- One research priority has been restated to include social and ecosystem factors:

  4.5 What social, ecosystem-based, engineering and technical approaches might reduce risks to marine tourism infrastructure from increased weather severity?

- Three research priorities focussed on climate change impacts have been reduced from 'High' to 'Medium' priority:

  1.1 Which farmed species in which locations are most likely to be impacted as a result of climate change?

  2.1 Which fishery stocks, in which locations, are most likely to change as a result of climate change? What will those changes be (e.g., in distribution, productivity) and when are they likely to appear under alternative climate change scenarios?

  4.1 What are the predicted regional impacts of climate change for marine tourism assets (e.g. what tourism sites will be most vulnerable to change and to what degree)?

- One research priority has been reduced from 'Medium' to 'Low' priority:

  1.2 What are the most likely effects of climate change on key environmental variables affecting aquaculture operations, including ocean temperature, stratification and oxygenation,

freshwater runoff or availability, and extreme wind and wave events and which regions are most vulnerable to such changes?

- Four research priorities focussed on adaptation to climate change impacts have been increased from 'Medium' to 'High' priority:

  1.3 What are likely policy changes driven by climate change that will affect aquaculture businesses either directly through changes in access to suitable locations, and natural resources such as freshwater or marine-based feeds or indirectly because of changes in harvest marine policies, affecting feed supplies or non-marine climate adaptation and mitigation policies?

  2.5 What options or opportunities are there for commercial fishers in identified impacted fisheries to adapt to climate change effects through changing target species, capture methods and management regimes, industry diversification, relocation or disinvestment? What are the enablers and barriers to fishers implementing such options?

  2.6 What options or opportunities exist or might become available for recreational fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species or preferred fishing method or travelling to pursue their preferred target species or method? What are the enablers and barriers to fishers implementing such options?

  2.7 How have enablers to adaptation been used and barriers to adaptation been overcome? What significant changes in fisheries have occurred before because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?

- One research priority has been increased from 'Low' to 'Medium' priority:

  4.6 Are current safety standards and protocols for marine activities adequate to deal with future conditions under climate change?

- Two research priorities have been changed by the addition to each of a question pertaining to policies, frameworks and tools:

  2.4 What are the likely policy changes driven by climate change that will affect commercial fisheries either directly through changes in harvest policies or indirectly because of changes in non-harvest marine policies or changes in non-marine climate adaptation or mitigation policies? <u>What policies will maintain or improve the sustainability of Australia's fisheries in a changing climate?</u>

  3.1 Which ecosystems and species of conservation priority most require adaptation management and supporting research, based on their status, value, vulnerability to climate change and the feasibility of adaptive responses? <u>What adaptation management frameworks and tools will identify vulnerable species and habitats within ecosystems, and how can these approaches build adaptive capacity and/or resilience?</u>

- Five cross-cutting research priorities have been added, with two assessed to be 'High' priority and three assessed to be 'Medium' priority:

  5.2 What are the most appropriate techniques for preserving estuarine systems in the face of climate change? (High priority)

  5.3 How can land-based climate change adaptation decisions be developed and implemented to also support adaptation for marine water quality and marine resources and biodiversity, including aquaculture, fisheries, conservation and tourism, taking account of multiple stressors, the cumulative pressures of co-occurring factors and flow-on effects for industries and ecosystem health? (High priority)

  5.4 What are the long-term consequences of ocean acidification, particularly for acclimatisation or adaptation of marine organisms and ecosystems, and what adaptation options are available to the managers of marine biodiversity and resources? (Medium priority)

5.5 How can mitigation initiatives in marine environments, such as carbon sequestration initiatives in coastal or marine areas, contribute to adaptation outcomes? (Medium priority)

5.6 How can climate change-induced changes to the distribution and effect of marine diseases, predators, pests and other problem organisms be managed? (Medium priority)

- Research priority 3.5 has been moved from Section 4.3 (Conservation Management) to Section 4.5 (Cross-cutting) to become Research Priority 5.7:

  5.7 What are the major sources of social resilience, and the processes by which stakeholders and organisations interact, negotiate, and build alliances? What roles do varying perceptions among stakeholders play in adaptive management and how do they change over time?

An updated table of high priority research questions is provided in section 6 of this report, and an updated research prioritisation table is provided in Appendix 2 of this report.

1. INTRODUCTION

Development of National Climate Change Adaptation Research Plans is a key function of NCCARF. These Plans (referred to as NARPs) are produced for nine key sectors where adaptation response will be critical in safeguarding against climate risks to social, economic and environmental well-being.

The purpose of a NARP is to identify priority needs over the next few years in developing knowledge on how governments, businesses and communities can best adapt to climate change risks. They provide a national blueprint for research investment by research organisations and knowledge user stakeholders. Development of NARPs involves the active contribution of both the research community and adaptation knowledge users.

The NARP for Marine Biodiversity and Resources (Marine NARP) (Mapstone *et al*. 2010) is concerned with identifying priority research questions for marine climate change adaptation issues, including conservation, fisheries and tourism. Research focused on these priority questions should support governments, conservation agencies, fishers, businesses, landowners, community organisations and individuals to make sound decisions about climate change adaptation initiatives for marine issues. These decisions should be able to take advantage of opportunities for marine biodiversity and resources that result from climate change and to reduce unavoidable detrimental climate change impacts.

The Marine NARP has been revisited in 2012 and the priority research questions have been updated to ensure currency and to provide guidance for research investment over the next five years.

The revisit and update is informed by:

- a comprehensive review of the literature undertaken since December 2008 (Holbrook and Johnson 2012) when the Marine NARP was originally drafted,
- current research addressing research priorities identified in the Marine NARP,
- a report on priority needs of marine stakeholders in Australia (Holbrook 2011) and
- input from the Marine Adaptation Research Network and from key stakeholders.

Other reports have also contributed to this update, including the State of the Environment Report 2011 (SEWPaC 2011).

This report identifies updated research priorities, based on:

- changes to stakeholder needs since the Marine NARP was completed;
- relevant research published since the Marine NARP was completed; and
- areas of current research focus in relation to the Marine NARP.

A discussion of each research priority and and any amendements to them are set out in section 4 of this report.

A draft of this report was circulated to about 70 key stakeholders nationally and to an international reviewer. Comments received have been incorporated in this final Update Report.

An updated table of priority research questions resulting from this revisit is provided in section 6. An updated research prioritisation table is provided in Appendix 2 of this report.

2. MAJOR CHANGES TO STAKEHOLDER INFORMATION NEEDS SINCE 2009

Australian marine stakeholder needs in a changing climate, identified through a set of focus meetings and responses to a questionnaire, were reported in Holbrook (2011). These priority needs are summarised as follows (page 2):

> *"Priorities varied both within sector (i.e. across government and peak body organisations), and between states/NT. The highest sectoral priorities identified across states/NT were as follows:*
>
> - *Aquaculture - Biosecurity and disease.*
> - *Commercial Fishing – Flexible or adaptive management (government); consultation and collaboration (industry/peak body).*
> - *Recreational Fishing – Communication/education (government); and risk and impact assessments (Industry/Peak body/NGO); both closely followed by consultation and collaboration.*
> - *Marine conservation – Communication/education.*
> - *Marine Tourism – Risk and impact assessments (government); communication/education and consultation/collaboration (industry/peak body).*
>
> *… the most significant message arising from the focused strategy meetings was interpreted to be the high importance placed on communication and education comprising of targeted, clear and accessible information exchange."*

General findings of this consultative process were, first, a move from a sectoral focus to a systems focus by stakeholder groups, second, recognition that adaptation responses would need to take account of complex biophysical, social and economic interactions, including cross-sectoral interests and considerations, and, finally, that research should if possible be undertaken at temporal and spatial scales relevant to decision-making. These findings with respect to stakeholder needs are incorporated in the priority revision process in Section 4.

3. RESEARCH FINDINGS AND ACTIVITIES SINCE 2009

Published findings

Research published since the Marine NARP was completed has been reviewed by Holbrook and Johnson (2012). They reviewed and summarised over 145 relevant research publications published between 2009 and 2012. Their report was structured around the research priorities of the Marine NARP, allowing some key knowledge gaps to be identified, including five further 'cross-cutting' research issues: consideration of estuaries, land-marine adaptation interactions, biogeochemical impacts of elevated CO_2 due to ocean acidification, mitigation of climate change and disease and pest issues. Key findings have been extracted from that report and included in Section 4, with representative references. See Holbrook and Johnson (2012) for a full review of publications.

Current research

Australia has invested in research about climate change adaptation and marine biodiversity and resources through a number of programs.

The jointly funded research program supported by the Adaptation Research Grants Program (ARGP) and the Fisheries Research and Development Corporation (FRDC) comprises 17 research projects. The NCCARF/ARGP contribution was $3.5 million, and the total value of the research program is more than $17 million (cash and in-kind). These projects are listed in Box 1, with more detailed information provided in Appendix 3.

Other NCCARF research will also be relevant to Priority research questions in the Marine NARP or more broadly will help inform climate change adaptation decisions or investments for marine biodiversity and resources. This includes research in both the ARGP and Synthesis and Integrative Research (SIR) programs.

The ARC is supporting 34 projects relevant to a greater or lesser extent to the Marine NARP Priority research question, with a value of $11.8 million. These projects are listed in Box 2.

All of these research projects are referred to throughout Section 4, where appropriate.

Box 1: Joint NCCARF (ARGP) / FRDC research projects for Marine Biodiversity and Resources

(Note: further information about these projects is available in Appendix 3 and at http://www.nccarf.edu.au/research/thematic/398)

Research Project Title	**Principal Investigator**	**Institution**
FRDC 2010/506 - Adaptive management of temperate reefs to minimise effects of climate change: developing effective approaches for ecological monitoring and predictive modelling	Neville Barrett	University of Tasmania
FRDC 2010/510 - Adapting to the effects of climate change on Australia's deep marine reserves.	Ron Thresher	CSIRO
FRDC 2010/521 - Vulnerability of an iconic Australian finfish (Barramundi, *Lates calcarifer*) and related industries to altered climate across tropical Australia.	Dean Jerry	James Cook University
FRDC 2010/524 - Identification of climate-driven species shifts and adaptation options for recreational fishers: learning general lessons from a data rich case. ()	Daniel Gledhill	CSIRO
FRDC 2010/532 - Changing currents in marine biodiversity governance and management responding to climate change.	Michael Lockwood	University of Tasmania
FRDC 2010/533 - Human adaptation options to increase resilience of conservation-dependent seabirds and marine mammals impacted by climate change.	Alistair Hobday#1	CSIRO
FRDC 2010/534 - Ensuring that the Australian oyster industry adapts to a changing climate: a natural resource and industry spatial information portal for knowledge action and informed adaptation frameworks.	Andrew Davis	University of Woollongong
FRDC 2010/535 - Management implications of climate change effects on fisheries in Western Australia.	Nick Caputi	WA Fisheries and Marine Research Laboratories
FRDC 2010/536 - Beach and surf tourism and recreation in Australia: vulnerability and adaptation.	Mike Raybould	Bond University
FRDC 2010/542 - A climate change adaptation blueprint for coastal regional communities.	Stewart Frusher & Nadine Marshall	U of Tasmania & CSIRO
FRDC 2010/554 - Effects of climate change on reproduction, larval development and population growth of coral trout.	Morgan Pratchett	James Cook University
FRDC 2010/564 - Pre-adapting a Tasmanian coastal ecosystem to ongoing climate change through reintroduction of a locally extinct species.	Nicholas Bax	University of Tasmania

FRDC 2010/565 - Management implications of climate change impacts on fisheries resources of tropical Australia.	David Welch	James Cook University
FRDC 2011/039 - Preparing fisheries for climate change: identifying adaptation options for four key fisheries in South Eastern Australia.	Gretta Pecl	University of Tasmania
FRDC 2011/040 - Estuarine and nearshore ecosystems – assessing alternative adaptive management strategies for the management of estuarine and coastal ecosystems.	Marcus Sheaves	James Cook University
FRDC 2011/233 - Growth opportunities & critical elements in the value chain for wild fisheries & aquaculture in a changing climate.	Alistair Hobday#2	CSIRO
FRDC 2011/503 - Climate change adaptation - building community and industry knowledge.	Jenny Shaw	WA Marine Science Institution

Box 2: NCCARF Synthesis and Integrative Research projects relevant to Marine Biodiversity and Resources

(Note: further information about these projects is available at http://www.nccarf.edu.au/research/s-and-i)

Research Project Title	**Principal Investigator**	**Institution**
P2LTA1- Limits to adaptation and conflict management in the Great Barrier Reef (GBR).	Dr Louisa Evans	James Cook University
P2LTA3- Limits to adaptation – Coorong Wetlands.	Ms Catherine Gross	Charles Sturt University
P2CES1- Climate change responses and adaptation pathways in Australian coastal ecosystems: Synthesis Report.	Wade Hadwen Samantha Capon	Griffith University

4. UPDATED INFORMATION FOR SECTION 4 OF THE MARINE NARP

This section summarises information that has become available since the Marine NARP was completed and outlines the consequences for research prioritisation. The information in this section is based on Holbrook and Johnson (2012) and Hobday and Poloczanzka (2010).

Section 4 of the Marine NARP is structured into four marine sector themes (aquaculture, commercial and recreational fishing, conservation management, and tourism and non-extractive industries) and a fifth cross cutting theme.

The discussion in this section is organised in relation to each research question in the Marine NARP. All research questions listed in a NARP are priority questions that merit research support. They are prioritised 6 criteria:

1. Severity of potential impact to be avoided or degree of potential benefit to be derived (essential);
2. Immediacy of required intervention or response (essential);
3. Need to change current intervention and practicality of alternative intervention (essential);
4. Potential for co-benefit (desirable);
5. Cross-sectoral relevance (desirable);
6. Equity considerations (desirable).

As a result of the information and analysis in this section, the priority of some research questions has been changed (eg from ‘High’ to ‘Medium’) indicating a change in the relative importance of a

research question from a national perspective. However, the relative prioritisation between research questions may differ between regions, stakeholders or research investors, a matter that is not considered here.

NARP Section 4.1 Aquaculture: Priority research questions

1.1 Which farmed species in which locations are most likely to be impacted as a result of climate change?

Hobday and Poloczanska (2010) summarised climate change impacts for aquaculture in Australia. Other recent publications provide relevant research findings in relation to particular locations, aquaculture farming operational types and species (e.g. Battaglene *et al*. 2008, De Silva and Soto 2009, Walker and Mohan 2009).

Current research:

- One NCCARF/FRDC Marine theme research project is relevant to this topic (**FRDC 2010/534)** (See Box 1).

Summary: Holbrook and Johnson (2012) conclude that the major gap in knowledge for this research topic concerns thresholds for vulnerable species beyond which they will no longer be viable to farm, and the best sites for future operations.

Update outcome: Retain Priority research question 1.1 unchanged, but reduce its priority from 'High' to 'Medium' to highlight the need to focus on adaptation research, to support sound decisions using available information.

1.2 What are the most likely effects of climate change on key environmental variables affecting aquaculture operations, including ocean temperature, stratification and oxygenation, freshwater runoff or availability, and extreme wind and wave events and which regions are most vulnerable to such changes?

Hobday and Poloczanska (2010) identified the key environmental impact of climate change as increased frequency of occurrence of extreme high water temperatures and changes to temperature regimes likely to affect aquaculture production in Australia, and threats to aquaculture from projected increased storm intensity. Holbrook and Johnson (2012) summarised recent research regarding the impacts on aquaculture from storm intensity, sea level rise and salt water intrusion to coastal deltas (De Silva and Soto 2009), sea level rise in coastal areas (Barange and Perry 2009), higher sea or pond temperatures (Walker and Mohan 2009, Parker *et al*. 2009, Lavitra *et al*. 2010) and higher acidity (Welladsen *et al*. 2010).

Current research:

- One NCCARF/FRDC Marine theme research project is relevant to this topic (**FRDC 2010/534)** (See Box 1).

Summary: There has been a substantial amount of research on this topic and further research is currently under way.

Update outcome: Retain Priority research question 1.2 unchanged and reduce its priority from 'Medium' to 'Low'.

1.3 What are likely policy changes driven by climate change that will affect aquaculture businesses either directly through changes in access to suitable locations, and natural resources such as freshwater or marine-based feeds or indirectly because of changes in harvest marine policies, affecting feed supplies or non-marine climate adaptation and mitigation policies?

Potential implications for aquaculture of climate change-induced policy changes have been noted from quota reductions in wild capture fisheries (De Silva and Soto 2009, Hobday and Poloczanska 2010, FAO 2010), greenhouse emission reduction policies (Cochrane *et al* 2009, De Silva and Soto 2009), and climate change adaptation by other industries or sectors (Cochrane *et al* 2009).

Summary: Holbrook and Johnson (2011, page 7) conclude that the major current research focus for adaptation policy concerns how coastal and urban planning decisions could affect the capacity of aquaculture operations to relocate to more suitable locations.

Update outcome: Retain Priority research question 1.3 unchanged but increase its priority from 'Medium' to 'High' in view of the implications for marine aquaculture of decisions in other industries and sectors, particularly land use and coastal planning.

1.4 Which local or regional communities or economies are most dependent on aquaculture businesses and how will changes in aquaculture production (especially decline in activity) affect those vulnerable communities socially and economically?

Holbrook and Johnson (2012) note that while research being undertaken about vulnerable species and locations, there is little research about the vulnerability of Australian communities to changes in aquaculture production.

Current research:

- One NCCARF/FRDC Marine theme research project is relevant to this topic (**FRDC 2011/233)** (See Box 1).

Summary: Holbrook and Johnson (2012) conclude that a better understanding is required of the relationship between vulnerable aquaculture operations and the communities and economies that depend on them, and the social and economic impacts of declines in aquaculture activity. Hobday and Poloczanska (2010) suggested that development of integrated models to enable the projection of socio-economic impacts from climate change-induced impacts on aquaculture be a priority.

Update outcome: Retain Priority research question 1.4 unchanged with a 'Medium' priority.

1.5 What options are there for businesses to adapt to climate change effects either by minimising adverse impacts or taking advantage of opportunities, including through selective breeding, changing or diversifying farmed species, relocating, expanding or contracting business sites or improving environmental control through infrastructure development? What are the barriers to implementing such changes and how might they be overcome?

Recent studies have identified a range of adaptation options, including breeding programs and genetic selection (e.g., Leith and Haward 2010), new crops and products (Hobday and Poloczanska 2010), diversification and insurance (De Silva and Soto 2009, FAO 2010). Relocation (De Silva and Soto 2009, Hobday and Poloczanska 2010) or redesign (Della Patrona *et al.* 2011) of operations have also been suggested to cope with saltwater intrusion, increasing water temperatures or sea level rise. Better weather forecasting and warning systems and stronger infrastructure (De Silva and Soto 2009) and better information generally (Hobday and Poloczanska 2010) will improve the decisions and resilience of aquaculture businesses.

Current research:

- One NCCARF/FRDC Marine theme research project is relevant to this topic (**FRDC 2011/233)** (See Box 1).Summary: Holbrook and Johnson (2012) note that few studies have investigated the specifics of economic or other barriers to effective adaptation by businesses.

Update outcome: Retain Priority research question 1.5 with changes as set out below and maintain its 'High' priority.

Priority research question 1.5 as amended:

- 1.5 What options are there for businesses to adapt to climate change effects either by minimising adverse impacts or taking advantage of opportunities, including through selective breeding, changing or diversifying farmed species, relocating, expanding or contracting business sites or improving environmental control through infrastructure development? What are the facilitators and barriers to implementing such changes and how might they be managed for effective adaptation outcomes?

1.6 What significant changes in aquaculture have already occurred because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?

Holbrook and Johnson (2012) note that while most research into this topic is based on overseas circumstances, such as China (e.g. De Silva and Soto 2009), they can provide useful indications for aquaculture in Australia (e.g. Hobday and Poloczanska 2010).

Summary: Holbrook and Johnson (2012) highlight the value of this kind of research for drawing lessons on climate-proofing infrastructure, undertaking risk assessment for stock losses, reducing reliance on particular feed stocks or adapting to increased water temperatures.

Update outcome: Retain Priority research question 1.6 unchanged with a 'Medium' priority.

NARP Section 4.2 Commercial and recreational fishing: Priority research questions

2.1 Which fishery stocks, in which locations, are most likely to change as a result of climate change? What will those changes be (e.g., in distribution, productivity) and when are they likely to appear under alternative climate change scenarios?

Australian fisheries climate change hotspots have been identified (Ling *et al*. 2009a) where increasing temperatures are likely to affect marine and estuarine species (Stuart-Smith *et al*. 2010, Booth *et al*. 2011). Potential implications of strengthening currents have been noted (e.g. Ridgway and Hill 2009, Feng and Hill 2009, Holbrook *et al*. 2009, Hobday and Lough 2011). Possible effects of these changes have been reported for some temperate fisheries in south eastern Australia (Hobday and Poloczanska 2010) and Tasmania (Ling *et al*. 2009b, Pecl *et al*. 2009).

The most immediate effects of climate change on coastal fishery species will be manifest through ongoing degradation of key habitats (sea grasses, coral reefs etc.) (Pratchett *et al*. 2011a; Pratchett *et al*. 2011b).

Pörtner and Peck (2010) noted that climate change would affect marine communities and ecosystem processes, and distributional shifts have been attributed to warming oceans (Last *et al.* 2010, Stuart-Smith *et al*. 2010, Pitt *et al*. 2010, Johnson *et al.* 2011). Climate change impacts to tropical marine habitats will likely affect northern fisheries that depend on those habitats (Pratchett *et al*. 2009, Badjeck *et al.* 2010, Bell *et al*. 2011). Recent studies have investigated the relationship between fisheries catch rates and climate (e.g., Ives *et al*. 2009, Gillson *et al*. 2009, Meynecke and Lee 2011, Booth *et al*. 2011). Implications of future climate conditions have been modelled (e.g., Brown *et al*. 2010, Plaganyi *et al*. 2011b, Fulton 2011, Hobday 2011).

Current research:

- Three NCCARF/FRDC Marine theme research projects are relevant to this topic (**FRDC 2010/535; FRDC 2010/554; FRDC 2010/565)** (See Box 1).

Summary: Holbrook and Johnson (2012) conclude that current knowledge indicates that the greatest impacts of climate change on fishery stocks are likely to occur in south eastern and south western Australia (Hobday and Poloczanska 2010), and for some fisheries in tropical regions (Pratchett *et al*. 2009).

Update outcome: Retain Priority research question 2.1 unchanged but reduce its priority from 'High' to 'Medium' to highlight the need to focus on adaptation research, to support sound decisions using available information.

2.2 What and where are the most likely effects of climate change on key variables affecting fishery access, including wind and wave climatologies and boating access?

The implications for fisheries of changed storm intensity and severe weather occurrence in tropical Australia have been projected (Daw *et al*. 2009, Badjeck *et al*. 2010), as have the potential impacts of increased storm and wave activity in Australia more broadly (Hobday and Poloczanska 2010).

Tobin *et al.* (2010) reported that while severe tropical cyclones can affect access to fisheries for an extended period, each cyclone is likely to have a unique set of impacts. Distribution shifts of key commercial species (Booth *et al*. 2011) and changed access and property rights resulting from such shifts (Hobday and Poloczanska 2010) will be key factors.

Summary: Holbrook and Johnson (2012) note the need for research on predicting distributional shifts of key commercial species and on the impacts of these shifts.

Update outcome: Retain Priority research question 2.2 unchanged and maintain its 'Medium' priority.

2.3 Which local or regional communities or economies, if any, are dependent on commercial or recreational fishing? How will changes in fisheries (especially decline in activity) affect those vulnerable communities socially and economically?

Grafton (2010) identified the characteristics of communities having lower relative resilience to changes in fisheries. Tobin *et al*. (2010) suggested that reliance on a single species limits adaptation capacity.

Current research:

- One NCCARF/FRDC Marine theme research project is relevant to this topic (**FRDC 2010/536)** (See Box 1).

Summary: Holbrook and Johnson (2012) suggested that further work is required in Australia to identify dependent communities most at risk from climate-related changes to their fisheries, and the likely social and economic impacts.

Update outcome: Retain Priority research question 2.3 unchanged and maintain its 'Medium' priority.

2.4 What are the likely policy changes driven by climate change that will affect commercial fisheries either directly through changes in harvest policies or indirectly because of changes in non-harvest marine policies or changes in non-marine climate adaptation or mitigation policies?

Hobday and Poloczanska (2010) suggested that competition between conservation and fisheries could result from distribution changes caused by climate change. Greenhouse gas emission reduction policies will likely have financial implications for fisheries activities (OECD 2010). Climate change adaptation in other sectors could exacerbate the direct impacts of climate change on fisheries (Badjeck *et al*. 2010, Koehn *et al*. 2011).

Summary: Plaganyi *et al*. (2011b) noted that the effectiveness of fisheries management to cope with climate change implications for fisheries will affect future fisheries sustainability, and suggested adaptive management frameworks as the best tools.

Update outcome: Modify Priority research question 2.4 to include reference to changes required to fisheries management, keep as a 'Medium' priority; and include a further Cross-cutting Priority research question pertaining to the implications for fisheries of climate change adaptation in other sectors (see Priority research question 5.3).

Priority research question 2.4 as amended:

2.4 What are the likely policy changes driven by climate change will affect commercial fisheries either directly through changes in harvest policies or indirectly because of changes in non-harvest marine policies or changes in non-marine climate adaptation or mitigation policies? What policies will maintain or improve the sustainability of Australia's fisheries in a changing climate?

2.5 What options or opportunities are there for commercial fishers in identified impacted fisheries to adapt to climate change effects through changing target species, capture methods and management regimes, industry diversification, relocation or disinvestment?

For fisheries to adapt to climate change flexible management and policy will be required, with an adaptive management paradigm that can manage for uncertainty (Brander 2010, Grafton 2010, Johnson and Welch 2010, OECD 2010), such as through near-real-time information (Hobday *et al*. 2009), integrating longer- and shorter-term priorities (Pecl *et al*. 2009) and diversifying livelihoods (Badjeck *et al*. 2010). Other options include incorporating climate change responses into fishery management plans (Cooley and Doney 2009), reducing physical exposure to extreme climate events (Hobday and Poloczanska 2010), disaster risk-reduction/early warning systems (Daw *et al*. 2009, Badjeck *et al*. 2010), conserving mangroves as natural barriers and changing resource property rights to more flexible access (Badjeck *et al*. 2010).

Current research:

- Five NCCARF/FRDC Marine theme research projects are relevant to this topic (**FRDC 2010/521; FRDC 2010/554; FRDC 2010/564; FRDC 2010/565; FRDC 2011/233)** (See Box 1).

Summary: This research question is focussed on adaptation, builds on research commissioned for other research questions and delivers information to decision makers. Note that research question 2.7 relates very closely to this research question.

Update outcome: See 'Update Outcome for Priority Research Question 2.7.

2.6 What options or opportunities exist or might become available for recreational fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species or preferred fishing method or travelling to pursue their preferred target species or method?

Recreational fishers have an inherent flexibility to adapt to changes in fish distribution (Hobday and Poloczanska 2010). Such flexibility may also be available to charter fisheries (Hobday 2010).

Current research:

- Two NCCARF/FRDC Marine theme research projects are relevant to this topic (**FRDC 2010/524; FRDC 2011/233)** (See Box 1).

Summary: This research question is focussed on adaptation, and builds on research commissioned for other research questions. Note that research question 2.7 relates very closely to this research question.

Update outcome: See '*Update Outcome*' for Priority Research Question 2.7.

2.7 What are the barriers to fishers implementing such options, including reliability of information about species changes; cost–benefit analyses of different options; current or prospective availability of support industries and services in new locations; prospects of adjustment and flexibility; jurisdictional, legal, administrative or regulatory uncertainties or constraints; and market drivers and constraints?

Brander (2010) and Johnson and Welch (2010) identified factors limiting adaptability to climate change by fisheries: the projected rapid rate of change; the compromised resilience of fisheries already under pressure from fishing, loss of biodiversity, habitat destruction, pollution, introduced and invasive species and pathogens; weak social and economic structures; a high dependence on fisheries; and inflexible management regimes. Other factors identified include uncertainty about future climate conditions and economic constraints (McIlgorm *et al*. 2010), financial constraints (Tobin *et al*. 2010), resource access and allocation arrangements (Daw *et al*. 2009, OECD 2010), political (Worm et al. 2009) and community (OECD 2010) opposition. From an economic

perspective, larger fisheries operators have an adaptive advantage in comparison with smaller operators (Fulton 2011).

Current research:

- One NCCARF/FRDC Marine theme research project is relevant to this topic (**FRDC 2010/524)** (See Box 1).

Summary: Holbrook and Johnson (2012) concluded that while commercial fisheries have a range of adaptation options at the individual operator, community and government levels, identifying the most appropriate measure is not straightforward; further research is thus required to inform decisions and develop tools to avoid or reduce the risk of maladaptation. Stakeholder comments suggest two changes to the text of the Priority Research Question: (a) include enablers as well as barriers, and (b) simplify the question. Note also that this Priority research question refers directly to Priority research questions 2.5 and 2.6, and the text of 2.7 only has meaning when it is read with 2.5 or 2.6.

Update outcome: Simplify Priority research question 2.7 and combine it with 2.5 and 2.6 and raise their priority from 'Medium' to 'High' in view of the importance of enabling effective adaptation in practice.

Priority research questions 2.5 and 2.6 as amended:

- 2.5 What options or opportunities are there for commercial fishers in identified impacted fisheries to adapt to climate change effects through changing target species, capture methods and management regimes, industry diversification, relocation or disinvestment? What are the enablers and barriers to fishers implementing such options?

- 2.6 What options or opportunities exist or might become available for recreational fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species or preferred fishing method or travelling to pursue their preferred target species or method? What are the enablers and barriers to fishers implementing such options?

2.8 How might barriers to adaptation be overcome? What significant changes in fisheries have occurred before because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?

Fisheries already adapt to climate variation (e.g., Holbrook *et al*. 2009, Hobday *et al*. 2009) and to other impacts (e.g., FAO 2010, OECD 2010). Options for addressing the potential rigidity of quota-based resource allocation systems have been proposed (e.g., OECD 2010, McIlgorm *et al*. 2010), and roles for government in removing institutional barriers to change and providing incentives of various types (OECD 2010). However, change will require ongoing industry-government co-management and industry self-governance (McIlgorm 2010), multi-stakeholder participation, a long-term perspective, and flexible income and governance options (Plaganyi *et al*. 2011a).

Summary: Very few research publications were found in relation to this research topic and only three in relation to Australia, yet it is critical to understand the effectiveness of past activities for future effective adaptation. Stakeholder comments suggest that the text of the Priority Research Question be amended to include enablers as well as barriers.

Update outcome: Retain Priority research question 2.8 as set out below, renumber to 2.7 and increase its priority from 'Medium' to 'High' in view of the importance of enabling effective adaptation in practice.

Priority research question 2.7 as amended:

- 2.7 How have enablers been used and barriers to adaptation been overcome? What significant changes in fisheries have occurred before because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?

NARP Section 4.3 Conservation management: Priority research questions

3.1 Which ecosystems and species of conservation priority most require adaptation management and supporting research, based on their status, value, vulnerability to climate change and the feasibility of adaptive responses?

High latitudes and the tropics (Cheung *et al*. 2009), coral reefs and coastal habitats including wetlands (Steffen *et al.* 2009), are projected to be most affected by climate change impacts. Local pressures will likely make tropical marine habitats more vulnerable to future climate change impacts (Veron *et al*. 2009, Waycott *et al*. 2009, Anthony *et al*. 2011, Bell *et al*. 2011). Recent evidence of climate change responses in Australia's tropical marine ecosystems includes coral bleaching and mortality, seabird foraging and breeding success, coral calcification, reef community structure, impaired ability of larval fish to detect predators, fish aerobic capacity and invertebrate growth (Holbrook and Johnson 2011). Increased CO_2 concentrations and higher acidity levels (8.1 to 7.8) have been observed to result in reduced coral diversity, recruitment and abundance of certain corals, and shifts in relative competitive interactions (Fabricius *et al*. 2011) While coral cover remained constant over the 8.1-7.8 pH range, reef development ceased below pH 7.7. Climate variation appears to have different impacts on different bird species (Devney *et al*. 2009).

Modelling has predicted biomass increases for functional groups of conservation interest, except where local influences resulted in declines (Brown *et al*. 2010), with local extinctions and species invasions also being projected (Cheung *et al*. 2009).

Current research:

- Two NCCARF/FRDC Marine theme research projects are relevant to this topic (**FRDC 2010/506; FRDC 2010/510; FRDC 2010/533; FRDC 2010/535)** (See Box 1).
- Three NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P2LTA1; P2LTA1; P2CES1**) (See Box 2).

Summary: Holbrook and Johnson (2012) noted that the responses of many species of conservation priority to climate drivers and their adaptive capacity have not been studied in detail, and that further research to understand the long-term consequences of ocean acidification is needed, particularly for acclimatisation or adaptation. Social values will also be an important consideration.

Update outcome: Retain Priority research question 3.1 as set out below and maintain its 'High' priority, given the complexity of responses to the many climate factors involved; and include a further Cross-cutting Priority research question pertaining to the implications for conservation of increased CO_2 concentrations and reduced pH (see Priority research question 5.4).

Priority research question 3.1 as amended:

- 3.1 Which ecosystems and species of conservation priority most require adaptation management and supporting research, based on their status, value, vulnerability to climate change and the feasibility of adaptive responses? What adaptation management frameworks and tools will identify vulnerable species and habitats within ecosystems, and how can these approaches build adaptive capacity and/or resilience?

3.2 What are the critical thresholds to ecosystem change and how close is the ecosystem to such 'tipping points'? How can we improve our measurement of marine ecosystems to account for ecosystem dynamics and processes?

Holbrook and Johnson (2012) report that most recent research on critical thresholds for marine ecosystem change has been concerned with tropical marine ecosystems. This includes research on the effects of atmospheric CO_2 concentrations on coral reefs (Veron *et al*. 2009), temperature (Eakin *et al.* 2009), and nutrients (Wooldridge and Done 2009). Subtropical reefs may be more susceptible to thermal stress than tropical reefs (Dalton and Carroll 2011). Recovery after a coral bleaching event demonstrates the dynamic nature of resilient reefs (e.g., Diaz-Pulido *et al.* 2009; Bruno *et al*. 2009). Anthony *et al*. (2011) projected that severe acidification and ocean warming would lower reef resilience under the SRES A1FI scenario. Upper thermal incubating thresholds for

marine turtles are likely to be exceeded by 2070 at some Queensland nesting sites and as early as 2030 at Ashmore Island (Fuentes *et al.* 2009). While historic reef records indicate that coral reef development was inhibited with a 2-3 m sea-level rise during the last interglacial period (Blanchon *et al*. 2009), mangroves are expected to benefit from projected sea level rise (Steffen *et al.* 2009).

Current research:

- Three NCCARF/FRDC Marine theme research project is relevant to this topic (**FRDC 2010/506; FRDC 2010/510; FRDC 2010/533)** (See Box 1);
- Three NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P2LTA1; P2LTA1; P2CES1**) (See Box 2).

Summary: Holbrook and Johnson (2012) concluded further research is required on critical thresholds for marine ecosystems and species and methods for measuring ecosystem dynamics and processes, to identify species and ecosystems that require immediate assistance, and to inform future adaptation management.

Update outcome: Retain Priority research question 3.2 unchanged and maintain its 'Medium' priority.

3.3 How will goals and governance for conservation of Australia's marine biodiversity need to change to adapt to climate change impacts? What are the barriers, limits and costs to implementing adaptation and effective policy responses to climate change?

The goals of climate-aware conservation will need to acknowledge the inherent dynamic nature of ecosystems rather than focussing on a return to historical baselines (Hobday 2011). Brierley and Kingsford (2009) suggest that conservation management will need to take an ecosystem approach that explicitly considers the cumulative effects of several stressors, species and ecosystem interactions (Walther 2010), and ecosystem function (Willis *et al*. 2010).

A resilience-based management approach that builds an improving understanding of ecosystem dynamics, thresholds and system feedbacks has been suggested (Obura and Grimsditch 2009, Hughes *et al*. 2010) and the importance of learning how to avoid or reverse undesirable phase shifts noted (Hughes *et al*. 2010). The role of disturbance in resilience could have important implications for management (Cote and Darling 2010). Management may also need to consider net primary production (Brown *et al*. 2010), ecosystem processes (Casini *et al*. 2009), trophic cascades (Veron *et al*. 2009) and ecosystem structure and function (Planque *et al*. 2010). Management approaches developed for terrestrial conservation may provide guidance for management of marine conservation (e.g., Iwamura *et al*. 2010). Lawler (2009) noted that climate change will affect marine biota and ecosystems at a range of scales – cellular, genetic, species, population and ecosystem, requiring management responses acting over many spatial and temporal scales.

Current research:

- Two NCCARF/FRDC Marine theme research projects are relevant to this topic (**FRDC 2010/532; FRDC 2011/040)** (See Box 1).

Summary: This topic will require ongoing research. Stakeholders suggested including 'enablers' as well as 'barriers, limits and costs'.

Update outcome: Retain Priority research question 3.3 as set out below and maintain its 'Medium' priority.

Priority research question 3.3 as amended:

- 3.3 How will goals and governance for conservation of Australia's marine biodiversity need to change to adapt to climate change impacts? What are the enablers, barriers, limits and costs to implementing adaptation and effective policy responses to climate change?

3.4 How should conservation managers and planners adapt their practices to ameliorate climate change risks and enhance adaptation options? What intervention strategies will increase system resilience and improve the time within which biological systems can adjust to a future climate?

DCCEE has published a first pass national assessment of the risks of climate change for Australia's coasts, including a coastal biodiversity vulnerability assessment that should provide valuable information on where conservation actions are most important. As the speed of climate change impacts challenges the rate of evolutionary processes, existing genetic diversity and management to increase resilience will be major factors for marine ecosystem survival (Veron *et al*. 2009, Anthony *et al*. 2011). In reef systems, management efforts to control local pressures will become increasingly critical as atmospheric CO_2 levels rise above 450–500 ppm (Anthony *et al*. 2011). Addressing local scale impacts on tropical marine ecosystems through cross sectoral management is considered critical to maintain healthy ecosystems that are resilient to future climate change, and to secure future adaptation options (Hoegh-Guldberg *et al*. 2009, Waycott *et al*. 2009, Anthony and Maynard 2011, Wilkinson and Brodie 2011).

Marine reserves or marine protected areas (MPAs) (or no-take areas) can benefit mobile species (Graham *et al*. 2011), benthic communities (e.g., increasing coral cover), biodiversity conservation (McCook *et al*. 2010), and protect genetic diversity for future adaptation (Sanford and Kelley 2011), but may offer only limited resilience to climate impacts (Selig and Bruno 2010, Graham *et al*. 2011). However, the utility of MPAs may lie in their ability to protect ecosystem connectivity and recovery after climate disturbance (Munday *et al*. 2009) suggesting that future conservation needs to consider habitat fragmentation and connectivity when designing MPAs and increasing the size of MPAs. Modelling suggests that the adaptive capacity of corals (Baskett *et al*. 2010) and ecosystem recovery post-disturbance (Cote and Darling 2010) would be improved by protecting and connecting areas expected to have lower exposure to climate drivers, with affected areas likely to be affected by climate change. Flexibility in MPA design (both spatial and temporal) has been identified as critical to allow for climate-related changes in marine environments, with mobile MPAs proposed as an option for protecting species as they change their distribution (Hobday 2011). Guidelines for incorporating connectivity into MPAs have been developed by McCook *et al*. (2009), and McLeod *et al*. (2009) provided guidance on the size, spacing, shape, risk spreading (representation and replication), critical areas, connectivity, and maintenance of ecosystem function for designing MPA networks that are more robust in the face of climate change.

Current research:

- Two NCCARF/FRDC Marine theme research projects are relevant to this topic (**FRDC 2010/532; FRDC 2011/040)** (See Box 1);
- Three NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P2LTA1; P2LTA1; P2CES1**) (See Box 2).

Summary: Holbrook and Johnson (2012) note that further consideration of MPAs as tools for addressing climate impacts on marine systems is required including optimum design and flexibility (both spatial and temporal); with further work required to better understand the spatial and temporal drivers at specific locations, and monitoring to assess the effectiveness of MPAs for reducing long-term climate change risks.

Update outcome: Retain Priority research question 3.4 unchanged and maintain its 'High' priority.

3.5 What are the major sources of social resilience, and the processes by which stakeholders and organisations interact, negotiate, and build alliances? What roles do varying perceptions among stakeholders play in adaptive management and how do they change over time?

Most recent publications about social resilience and ways to measure and/or enhance it, are concerned with general concepts rather than practical examples (e.g., Obura and Grimsditch 2009, Marshall *et al*. 2010) and relate to international circumstances (e.g., McClanahan *et al*. 2009, Obura and Grimsditch 2009, Marshall *et al*. 2009, Wongbusarakum and Loper 2011).

The interaction between management and stakeholders is critical to social adaptation (Marshall *et al*. 2010), and designing co-management arrangements involving social integration, self-organisation and autonomous control by stakeholders is critical for building the adaptive capacity of social systems (Kalikoski and Allison 2010). Stakeholder perception of resource condition and future impacts of climate change contribute to their participation in adaptation measures (Obura and Grimsditch 2009, Marshall *et al*. 2010, Wongbusarakum and Loper 2011).

Summary: Holbrook and Johnson (2012) note that significant work remains to understand the nuances of negotiating and alliance building, and how perceptions change over time. This was noted by key stakeholders as relevant to all sectors.

Update outcome: Retain Priority research question 3.5 unchanged and maintain its 'Medium' priority but move it to Section 4.5 (and see also Cross-cutting research topic 5.7).

NARP Section 4.4 Tourism and non-extractive recreational uses: Priority research questions

4.1 What are the predicted regional impacts of climate change for marine tourism assets (e.g. what tourism sites will be most vulnerable to change and to what degree)?

The Great Barrier Reef, Ningaloo Reef, coastal wetlands in the Northern Territory, Ningaloo Reef, coastal islands and beaches are at risk from climate change impacts (DCC 2009, Turton *et al.* 2009, Moreno and Becken 2009). Tropical north Queensland is probably the most threatened major tourism region in Australia, but other popular marine tourism assets (e.g., the Gold Coast, Sunshine Coast and Fraser Island) are also vulnerable. When tourism assets are impacted, flow-on impacts affect tourism-dependent regional communities and economies (DCC 2009). Coral reefs and reef condition are particularly important for tourism (Miles *et al*. 2009, Harding *et al*. 2010) but are expected to be highly vulnerable to climate change. The Cairns region will be the most susceptible, followed by the Mackay-Whitsundays region and then Townsville (Miles *et al*. 2009). Increased incidence of poor weather that results in seasickness, cold and wet conditions, reduced water visibility, and difficult snorkelling/diving conditions reduces overall visitor satisfaction, and decreases the tourist experience (Coghlan and Prideaux 2009).

Summary: This topic will require ongoing research to generate more specific information for major destinations and further information for secondary destinations.

Update outcome: Retain Priority research question 4.1 unchanged and reduce its priority from 'High' to 'Medium' priority.

4.2 How can the impacts on tourism, if any, of public perceptions of climate impacts on Australia's marine biodiversity and resources be minimised?

Few recent studies fully examine the public perception of climate change impacts on Australia's marine tourism destinations. Recent studies about public perceptions of climate change impacts on terrestrial tourist destinations such as Kakadu and the Blue Mountains (Turton *et al*. 2009) provide lessons that may potentially be applied to marine tourism resources and destinations, such as a consistent and coordinated public campaign to address negative public views and to highlight positive destination aspects. For instance, communicating an impression that north Queensland and the GBR may be 'buffered' from extreme climate impacts, relative to other regions (Turton *et al*. 2009), might be used as a marketing advantage.

Summary: Holbrook and Johnson (2012) suggest that understanding public perception of climate change impacts on Australia's marine tourism destinations, and how negative views can be minimised will be important for regions that rely on domestic beach recreation.

Update outcome: Retain Priority research question 4.2 unchanged and maintain its 'Low' priority.

4.3 How can the links between resource condition and marine-dependent tourism business vitality be modelled and evaluated?

Few models can link marine resource condition and tourism viability. However, Bohensky *et al.* (2011) developed a scenario-based approach to link the condition of marine ecosystem goods and services to regional communities and industries. Pham *et al*. (2010) developed an approach to examine the potential economic impacts of climate change on tourism in five selected Australian tourism destinations.

Summary: Holbrook and Johnson (2012) recommend further research about the links between resource condition and vitality of marine-dependent tourism businesses in Australia, to inform future adaptation to climate change.

Update outcome: Retain Priority research question 4.3 unchanged and maintain its 'Low' priority.

4.4 What is the adaptive capacity of the marine tourism industry and how can it be enhanced to cope with climate change impacts?

While the tourism industry has a number of climate change adaptation options (Burns and Bibbings 2009), and coastal tourism as a whole may have considerable resilience to climate change impacts, small to medium sized operators are likely to have less adaptive capacity (Burns and Bibbings 2009, DCC 2009, Turton *et al*. 2009) due to lower mobility and flexibility, and greater vulnerability to significant economic effects (DCC 2009). Smaller operators generally have shorter planning time frames and need to see clear benefits from simple, cheap and effective adaptation options (Turton *et al*. 2009). Miles *et al*. (2009) reported that north Queensland tourism businesses have reasonable adaptive capacity to respond to changed conditions, but they need to know what those changed conditions are likely to be, and fifty percent of business operators perceived opportunities as a result of climate change. This positive attitude was also reported from a workshop of tourism stakeholders (Dwyer 2009). However, a survey of tourism stakeholders found limited understanding of climate change adaptation (Turton *et al*. 2010). Key factors for enhancing the adaptive capacity of Australia's marine tourism include climate projections with good confidence levels, motivation to avoid risk or take up opportunities, new technologies having demonstrated effectiveness, transitional and legislative support from government, resources from public and private sectors, and effective monitoring and evaluation (Turton *et al*. 2009).

Summary: Current research will help inform this research priority, but further research will be required because of the large number of stakeholders and destinations.

Update outcome: Retain Priority research question 4.4 unchanged and maintain its 'High' priority.

4.5 What engineering and technical solutions might reduce risks to marine tourism infrastructure from increased weather severity?

Engineering standards and benchmarks need to incorporate climate change projections and include specifications for the resilience and life of buildings and building materials. *Climate Change Risks to Australia's Coast: A First Pass National Assessment* (Dcc 2009) identifies 'hard' and 'soft' technical solutions and the role of coastal ecosystems for protecting coastal infrastructure. A project run by Department of Climate Change and Energy Efficiency (DCCEE) and Engineers Australia is currently underway to update two engineering guidelines and produce a new third guide identifying the range of engineering options to address coastal hazards in a changing climate. The guidelines being updated are 'Guidelines for responding to the effects of climate change in coastal and ocean engineering' and 'Coastal engineering guidelines for working with the Australian coast in an ecologically sustainable way'. On a more geographically limited scale, the *GBR Tourism Climate Change Action Strategy* (TCCAG 2009) has identified environmental management and engineering strategies to address climate change impacts on marine tourism infrastructure.

Summary: This research topic will require ongoing attention to deliver successively more detailed information and guidelines as improved knowledge of climate projections and local conditions become available.

Update outcome: Retain Priority research question 4.5 as set out below and maintain its 'Medium' priority.

Priority research question 4.5 as amended:

- 4.5 What social, ecosystem-based, engineering and technical approaches might reduce risks to marine tourism infrastructure from increased weather severity?

4.6 Are current safety standards and protocols for marine activities adequate to deal with future conditions under climate change?

Increasing threats to maritime safety have been identified as a matter of concern for fisheries operations (Daw *et al.* 2009, Hobday and Poloczanska 2010, Bell *et al*. 2010), tourism (TCCAG 2009) and shipping.

Summary: Holbrook and Johnson (2012) noted an extensive review of the literature and relevant websites did not reveal research that addressed the adequacy of marine safety standards and protocols for future climate conditions.

Update outcome: Retain Priority research question 4.6 unchanged and raise its priority from 'Low' to 'Medium' priority.

4.7 What are the most appropriate techniques for preserving beaches in the face of rising sea levels?

Rising sea levels are likely to cause accelerated erosion for many beaches around the Australian coastline. The switch from generally accreting beaches to a receding coastline is a key threshold for coastal management and is not well understood. Revegetation and better coastal management have reversed erosion where vegetation removal had made dunes unstable (DCC 2009). Hard engineering and development on fore dunes coupled with rising sea level have resulted in erosion hotspots.

Responses to climate-induced erosion include beach replenishment, dune protection and hardening, and progressive retreat (DCC 2009). However, beach replenishment is costly and ongoing if the cause of erosion is not addressed, and longer-term solutions will be required (Parkinson 2009).

Summary: This is an important issue for Australian tourism and many coastal settlements. The objective of 'preserving' beaches might be more realistically stated as 'managing'.

Update outcome: Retain Priority research question 4.7 unchanged and retain its 'Medium' priority.

5. CROSS-CUTTING ISSUES: PRIORITY RESEARCH QUESTIONS

The priority cross-cutting issue in the 2009 Marine NARP (5.1) was derived from discussion throughout the NARP development and consultation process. In this section, five additional cross-cutting issues are introduced that are derived from this revisit and update and one (5.7) has been moved from another section of the NARP to this section.

5.1 What are the key intersections across sectors, cumulative impacts and cross-jurisdictional issues that will affect the development of adaptation strategies in each sector and how can these cross- and multi-sectoral issues best be addressed?

This issue underpins practical and effective adaptation that is able to gain from actions in other sectors and contribute to adaptation in other sectors.

Current research:

- One NCCARF/FRDC Marine theme research project is relevant to this topic (**FRDC 2011/040)** (See Box 1).

Summary: This remains a fundamental research area for all NCCARF themes.

Update outcome: Retain Priority research question 5.1 unchanged and maintain its 'High' priority.

5.2 What are the most appropriate techniques for preserving estuarine systems in the face of climate change?

Estuaries are highly productive biologically, and are typically important habitats across all sectors: for conservation, commercial and recreational fishing, and tourism, and offer unique and variable habitats that exist at the land-marine interface with aquatic influences. They are highly diverse across Australia and within localities. Several current NCCARF and FRDC research activities focus on or consider climate change adaptation for estuaries, but significant further research is required.

Current Research

- One NCCARF Synthesis and Integrative Research project is relevant to this topic (**P2CES1**) (See Box 2).

Summary: Holbrook and Johnson (2012) note that there is a need to better understand estuarine systems, and their vulnerability in the face of climate change risks.

Update outcome: Introduce new Priority research question 5.2 with a 'High' priority.

5.3 How can land-based climate change adaptation decisions be developed and implemented to also support adaptation for marine water quality and marine resources and biodiversity, including aquaculture, fisheries, conservation and tourism, taking account of multiple stressors, the cumulative pressures of co-occurring factors and flow-on effects for industries and ecosystem health?

Holbrook and Johnson (2012) noted a broad recognition that marine biodiversity and resources would be affected by climate change impacts to terrestrial and aquatic ecosystems and water bodies, such as changes to the quality, quantity and periodicity of river discharges, and by adaptation to climate change in other sectors, such as coastal development and protection.

Current research:

- Three NCCARF Synthesis and Integrative Research projects are relevant to this topic (**P2LTA1; P2LTA1; P2CES1**) (See Box 2).

Summary: Integrated climate change adaptation analyses and responses are becoming increasingly important.

Update outcome: Introduce new Priority research question 5.3 with a 'High' priority.

5.4 What are the long-term consequences of ocean acidification, particularly for acclimatisation or adaptation of marine organisms and ecosystems, and what adaptation options are available to the managers of marine biodiversity and resources?

Anthony *et al*. (2011) projected that severe acidification and ocean warming would lower reef resilience under the SRES A1FI scenario. Increased CO_2 concentrations and higher acidity levels (8.1 to 7.8) have been observed to result in reduced coral diversity, recruitment and abundance of certain corals, and shifts in relative competitive interactions (Fabricius *et al*. 2011).

Summary: Hoffman *et al*. (2011) noted that further research to understand the long-term consequences of ocean acidification is needed, particularly for acclimatisation or adaptation.

Update outcome: Introduce new Priority research question 5.4 with a 'Medium' priority.

5.5 How can mitigation initiatives in marine environments, such as carbon sequestration initiatives in coastal or marine areas, contribute to adaptation outcomes?

Coastal ecosystems, including tidal marshes, mangroves and seagrasses, have the capacity to sequester and store large quantities of carbon in organic forms (e.g., plants, sediments), a process termed 'Blue Carbon' (IUCN 2011). Carbon enhancement initiatives for these ecosystems can help stabilise them and so contribute to the resilience of coastal areas and to fisheries production.

Summary: IUCN (2011) noted that there is currently no strategic policy to promote carbon sequestration in coastal and marine areas.

Update outcome: Introduce new Priority research question 5.5 with a 'Medium' priority.

5.6 How can climate change-induced changes to the distribution and effect of marine diseases, predators, pests and other problem organisms be managed?

Some organisms are more efficient in using new habitat niches or opportunities than those organisms that are currently present in the affected locations. This can result in undesirable changes to the distribution and viability of all organisms present, the composition of ecosystems and the delivery of ecosystem services.

Summary: This issue was raised by several stakeholders in their responses to the draft Update Report.

Update outcome: Introduce new Priority research question 5.6 with a 'Medium' priority.

5.7 What are the major sources of social resilience, and the processes by which stakeholders and organisations interact, negotiate, and build alliances? What roles do varying perceptions among stakeholders play in adaptive management and how do they change over time?

Most recent publications about social resilience, and ways to measure and/or enhance it, are concerned with general concepts rather than practical examples (e.g., Obura and Grimsditch 2009, Marshall *et al*. 2010) and relate to international circumstances (e.g., McClanahan *et al*. 2009, Obura and Grimsditch 2009, Marshall *et al*. 2009, Wongbusarakum and Loper 2011).

The interaction between management and stakeholders is critical to social adaptation (Marshall *et al*. 2010), and designing co-management arrangements involving social integration, self-organisation and autonomous control by stakeholders is critical for building the adaptive capacity of social systems (Kalikoski and Allison 2010). Stakeholder perception of resource condition and future impacts of climate change contribute to their participation in adaptation measures (Obura and Grimsditch 2009, Marshall *et al*. 2010, Wongbusarakum and Loper 2011).

Summary: Holbrook and Johnson (2012) note that significant work remains to understand the nuances of negotiating and alliance building, and how perceptions change over time. This was noted by key stakeholders as relevant to all sectors.

Update outcome: Retain Priority research question 3.5 unchanged and maintain its 'Medium' priority, but move it to section 4.5 as cross-cutting priority research question 5.7.

6. CHANGES TO THE RESEARCH TOPICS AND PRIORITIES

This update has resulted in changes to the Priority Research Questions of the Marine NARP as follows:

Four research priorities concerned with 'overcoming barriers to adaptation' have been altered to include reference to using 'enablers' or 'facilitators' of adaptation:

This affects research priorities 1.5, 2.7, 2.8 and 3.3.

In two cases, two research priorities have been combined and simplified; research priority 2.7 has been simplified and combined with both 2.5 and with 2.6, with research priority 2.8 being renumbered to 2.7. Research priorities 2.5 and 2.6 now read as follows:

2.5 What options or opportunities are there for commercial fishers in identified impacted fisheries to adapt to climate change effects through changing target species, capture methods and management regimes, industry diversification, relocation or disinvestment? What are the enablers and barriers to fishers implementing such options?

2.6 What options or opportunities exist or might become available for recreational fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species or preferred fishing method or travelling to pursue their preferred target species or method? What are the enablers and barriers to fishers implementing such options?

One research priority has been restated to clarify in historical perspective; Note: renumbered 2.8 as 2.7):

2.7 How have enablers to adaptation been used and barriers to adaptation been overcome? What significant changes in fisheries have occurred before because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?

One research priority has been restated to include social and ecosystem factors:

4.5 *What social, ecosystem-based, engineering and technical approaches might reduce risks to marine tourism infrastructure from increased weather severity*?

Three research priorities focussed on climate change impacts have been reduced from 'High' to 'Medium' priority:

1.1 Which farmed species in which locations are most likely to be impacted as a result of climate change?

2.1 Which fishery stocks, in which locations, are most likely to change as a result of climate change? What will those changes be (e.g., in distribution, productivity) and when are they likely to appear under alternative climate change scenarios?

4.1 What are the predicted regional impacts of climate change for marine tourism assets (e.g. what tourism sites will be most vulnerable to change and to what degree)?

One research priority has been reduced from 'Medium' to 'Low' priority:

1.2 What are the most likely effects of climate change on key environmental variables affecting aquaculture operations, including ocean temperature, stratification and oxygenation, freshwater runoff or availability, and extreme wind and wave events and which regions are most vulnerable to such changes?

Four research priorities focussed on adaptation to climate change impacts have been increased from 'Medium' to 'High' priority:

1.3 What are likely policy changes driven by climate change that will affect aquaculture businesses either directly through changes in access to suitable locations, and natural resources such as freshwater or marine-based feeds or indirectly because of changes in harvest marine policies, affecting feed supplies or non-marine climate adaptation and mitigation policies?

2.5 What options or opportunities are there for commercial fishers in identified impacted fisheries to adapt to climate change effects through changing target species, capture methods and management regimes, industry diversification, relocation or disinvestment? What are the enablers and barriers to fishers implementing such options?

2.6 What options or opportunities exist or might become available for recreational fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species or preferred fishing method or travelling to pursue their preferred target species or method? What are the enablers and barriers to fishers implementing such options?

2.7 How have enablers been used and barriers to adaptation been overcome? What significant changes in fisheries have occurred before because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?

One research priority has been increased from 'Low' to 'Medium' priority:

4.6 Are current safety standards and protocols for marine activities adequate to deal with future conditions under climate change?

Two research priorities have been changed by the addition to each of a question pertaining to policies, frameworks and tools:

2.4 What are the likely policy changes driven by climate change that will affect commercial fisheries either directly through changes in harvest policies or indirectly because of changes in non-harvest marine policies or changes in non-marine climate adaptation or mitigation policies? What policies will maintain or improve the sustainability of Australia's fisheries in a changing climate?

3.1 Which ecosystems and species of conservation priority most require adaptation management and supporting research, based on their status, value, vulnerability to climate change and the feasibility of adaptive responses? What adaptation management frameworks and tools will identify vulnerable species and habitats within ecosystems, and how can these approaches build adaptive capacity and/or resilience?

Five cross-cutting research priorities have been added, with two assessed to be 'High' priority and three assessed to be 'Medium' priority:

5.2 What are the most appropriate techniques for preserving estuarine systems in the face of climate change? (High priority)

5.3 How can land-based climate change adaptation decisions be developed and implemented to also support adaptation for marine water quality and marine resources and biodiversity, including aquaculture, fisheries, conservation and tourism, taking account of multiple stressors, the cumulative pressures of co-occurring factors and flow-on effects for industries and ecosystem health? (High priority)

5.4 What are the long-term consequences of ocean acidification, particularly for acclimatisation or adaptation of marine organisms and ecosystems, and what adaptation options are available to the managers of marine biodiversity and resources? (Medium priority)

5.5 How can mitigation initiatives in marine environments, such as carbon sequestration initiatives in coastal or marine areas, contribute to adaptation outcomes? (Medium priority)

5.6 How can climate change-induced changes to the distribution and effect of marine diseases, predators, pests and other problem organisms be managed? (Medium Priority)

Research priority 3.5 has been moved from Section 4.3 (Conservation Management) to Section 4.5 (Cross-cutting) to become Research Priority 5.7:

5.7 What are the major sources of social resilience, and the processes by which stakeholders and organisations interact, negotiate, and build alliances? What roles do varying perceptions among stakeholders play in adaptive management and how do they change over time?

An updated table of high priority research questions is provided in Section 8 of this report, and an updated research prioritisation table is provided in Appendix 2 of this report.

7. HIGH PRIORITY RESEARCH QUESTIONS (2012)

High priority research questions (2012)
1. Aquaculture
1.3 What are the likely policy changes driven by climate change that will affect aquaculture businesses either directly through changes in access to suitable locations, and natural resources such as freshwater or marine-based feeds or indirectly because of changes in harvest marine policies, affecting feed supplies or non-marine climate adaptation and mitigation policies?
1.5 What options are there for businesses to adapt to climate change effects either by minimising adverse impacts or taking advantage of opportunities? What are the facilitators and barriers to implementing such changes and how might they be managed for effective adaptation outcomes?
2. Commercial and recreational fishing
2.5 What options or opportunities are there for commercial fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species, capture methods and management regime, or industry diversification, relocation or divestment? What are the enablers and barriers to fishers implementing adaptation options?
2.6 What options or opportunities exist or might become available for recreational fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species or preferred fishing method or travelling to pursue their preferred target species or method? What are the enablers and barriers to fishers implementing adaptation options?
2.7How have enablers to adaptation been used and barriers to adaptation been overcome? What significant changes in fisheries have occurred before because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?
3. Conservation management
3.1 Which ecosystems and species of conservation priority most require adaptation management and supporting research, based on their status, value, vulnerability to climate change and the feasibility of adaptive responses? What adaptation management frameworks and tools will identify vulnerable species and habitats within ecosystems, and how can these approaches build adaptive capacity and/ or resilience?
3.4 How should conservation managers and planners adapt their practices to alleviate climate change risks and enhance adaptation options? What intervention strategies will increase system resilience and increase the time within which biological systems are given the opportunity to adjust to a future climate?
4. Tourism and recreational uses
4.4 What is the adaptive capacity of the marine tourism industry and how can it be enhanced to cope with climate change impacts?
5. Cross-cutting issues
5.1 What are the key interactions across sectors, cumulative impacts and cross-jurisdictional issues that will affect the development of adaptation strategies in each sector and how can these cross- and multi-sectoral issues best be addressed?
5.2 What are the most appropriate techniques for preserving estuarine systems in the face of climate change?
5.3 How can land-based climate change adaptation decisions be developed and implemented to also support adaptation for marine water quality and marine resources and biodiversity, including aquaculture, fisheries, conservation and tourism, taking account of multiple stressors, the cumulative pressures of co-occurring factors and flow-on effects for industries and ecosystem health?

8. ACRONYMS

AIMS	Australian Institute of Marine Science
ARC	Australian Research Council
ARGP	Adaptation Research Grant Program (Commonwealth Funding to support adaptation research commissioned against priorities identified in NARPs.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCC	Department of Climate Change
DCCEE	Department of Climate Change and Energy Efficiency
FRDC	Fisheries Research and Development Corporation
GBRMPA	Great Barrier Reef Marine Park Authority
WAMSI	Western Australian Marine Science Institution

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APPENDIX 1: CRITERIA FOR SETTING RESEARCH PRIORITIES

The criteria listed below will guide the research planning process to set research priorities.

1. **Severity of potential impact or degree of potential benefit**

   What is the severity of the potential impact to be addressed or benefit to be gained by the research? Potentially irreversible impacts and those that have a greater severity (in social, economic or environmental terms) will be awarded higher priority.

2. **Immediacy of required intervention or response**

   Research will be prioritised according to the timeliness of the response needed. How immediate is the intervention or response needed to address the potential impact or create the benefit? Research that must begin now in order to inform timely responses will receive a higher priority than research that could be conducted at a later date and still enable a timely response.

3. **Need to change current intervention and practicality of intervention**

   Is there a need to change the intervention used currently to address the potential impact being considered. If yes, what are the alternatives and how practical are these alternative interventions? Research that will contribute to practicable interventions or responses will be prioritised. Does research into the potential impact of the intervention being considered contribute to the knowledge base required to support decisions about these interventions?

Desirable

4. **Potential for co-benefits**

   Will the research being considered produce any benefits beyond informing climate adaptation strategies?

5. **Potential to address multiple, including cross-sectoral, issues**

   Will the research being considered address more than one issue, including cross-sectoral issues?

APPENDIX 2: RESEARCH PRIORITISATION TABLE

Research question	Essential			Desirable		Overall
	Severity of harm or level of benefit	**Immediacy of research need**	**Need to change current intervention / practicality of new intervention**	**Potential co-benefits**	**Cross-sectoral relevance**	
1. Aquaculture						
1.1 Which farmed species in which locations are most likely to be impacted as a result of climate change?	**High** – Significant scope to ameliorate adverse impacts and seize new opportunities	**Medium** – Some research needed to commence now in order to inform staged interventions	**Medium** – Interventions to be evaluated for practicality			**Medium**
1.2 What are the most likely effects of climate change on key environmental variables affecting aquaculture operations, including ocean temperature, stratification and oxygenation, freshwater runoff or availability, and extreme wind and wave events and which regions are most vulnerable to such changes?	**Low** –Scope exists to ameliorate adverse impacts and seize new opportunities	**Medium** – Substantial research undertaken will inform staged interventions	**Low** – Interventions to be evaluated for practicality: engineering solutions possible to ameliorate impacts; research likely to be specific to locations, industries and operations			**Low**
1.3 What are likely policy changes driven by climate change that will affect aquaculture businesses either directly through changes in access to suitable locations, and natural resources such as freshwater or marine-based feeds or indirectly because of changes in harvest marine policies, affecting feed supplies or non-marine climate adaptation and mitigation policies?	**High** – Important to understanding of broad socio-economic context if industry adaptation is to be designed most effectively	**High** –Policy changes will be required	**Medium** – Full information about range of variables affecting marine policy is likely to improve intervention	Understanding of policy context should assist industry, regardless of climate change	Policy context likely to have similar impacts on commercial fishing and tourism operations	**High**
1.4 Which local or regional communities or economies are most dependent on aquaculture businesses and how will changes in aquaculture production (especially decline in activity) affect those vulnerable communities socially and economically?	**Medium** – Adaptation options need to be location/community-specific	**Medium** – Medium/longer-term need	**Low** – Considerable inertia in transforming communities	Should contribute to broader resilience	Findings will inform similar work in the recreational and commercial fishing areas	**Medium**

1.5 What options are there for businesses to adapt to climate change effects either by minimising adverse impacts or taking advantage of opportunities, including through selective breeding, changing or diversifying farmed species, relocating, expanding or contracting business sites or improving environmental control through infrastructure development? What are the facilitators and barriers to implementing such changes and how might they be managed for effective adaptation outcomes?	**High** – Significant social and economic disruption if industries threatened by climate change impacts: high benefit to identifying alternatives	**High** – Some research needed to commence now in order to inform staged interventions	**High** –Business decisions are required in the short term			**High**
1.6 What significant changes in aquaculture have already occurred because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?	**Medium** – Useful to inform adaptation options	**Medium** – Evaluation of past experience will provide helpful guidance on future options	**Medium** – Lessons learned from past efforts will contribute to practicability of new interventions			**Medium**

Research question	Essential			Desirable		Overall
	Severity of harm or level of benefit	**Immediacy of research need**	**Need to change current intervention / practicality of new intervention**	**Potential co-benefits**	**Cross-sectoral relevance**	
2. Commercial and recreational fishing						
2.1 Which fishery stocks, in which locations, are most likely to change as a result of climate change? What will those changes be (e.g., in distribution, productivity) and when are they likely to appear under alternative climate change scenarios?	**High** – Understanding adverse impacts critical to informing fisheries policy and fishing operations, including to seize new opportunities	**Medium** –This is impacts rather than adaptation research	**Medium** – Considerable research has already taken place on these topics	Better knowledge should also enhance conservation efforts	Findings will inform tourism sector adaptation	**Medium**
2.2 What and where are the most likely effects of climate change on key variables affecting fishery access, including wind and wave climatologies and boating access?	**High** – Understanding adverse impacts critical to informing fisheries operations, infrastructure and policy, including to seize new opportunities. Less critical than biological change.	**Medium** – Some research needed to commence now in order to inform staged interventions	**Medium** – Interventions to be evaluated for practicality: change of fishery or practices likely to be practicable in some areas	Better knowledge should also enhance conservation efforts	Findings will inform other coastal infrastructure and tourism requirements	**Medium**
2.3 Which local or regional communities or economies, if any, are dependent on commercial or recreational fishing? How will changes in fisheries (especially decline in activity) affect those vulnerable communities socially and economically?	**High** – Adaptation options need to be location/community-specific	**Medium** – Medium/longer-term need	**Medium** – Interventions to be evaluated for practicality	Should contribute to broader resilience	Findings will inform tourism and aquaculture sector adaptation	**Medium**
2.4 What are the likely policy changes driven by climate change that will affect commercial fisheries either directly through changes in harvest policies or indirectly because of changes in non-harvest marine policies or changes in non-marine climate adaptation or mitigation policies? What policies will maintain or improve the sustainability of Australia's fisheries in a changing climate?	**High** – Important to understanding of broad socio-economic context if industry adaptation is to be designed most effectively	**Medium** – Medium/longer-term need	**Medium**	Understanding of policy context should assist industry, regardless of climate change	Policy context likely to have similar impacts on aquaculture and tourism operations	**Medium**

2.5 What options or opportunities are there for commercial fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species, capture methods and management regime, or industry diversification, relocation or divestment? What are the enablers and barriers to fishers implementing adaptation options?	**High** – Significant social and economic disruption if industries threatened by climate change impacts: high benefit to identifying alternatives	**High** – Some research needed to commence now in order to inform staged interventions or prepare for possible adjustment	**High** – Reason to believe some adaptation options will be effective for some fishers/locations			**High**
2.6 What options or opportunities exist or might become available for recreational fishers in identified vulnerable fisheries to adapt to climate change effects through changing target species or preferred fishing method or travelling to pursue their preferred target species or method? What are the enablers and barriers to fishers implementing adaptation options?	**High** – Social disruption to recreational fishing may have indirect economic consequences	**High** – Significant scope for autonomous adaptation in the short term but consideration for medium to long term	**Medium** – Significant scope for autonomous adaptation		Shifts in recreational fishing practices may have effects elsewhere	**High**
2.7 How have enablers been used and barriers to adaptation been overcome? What significant changes in fisheries have occurred before because of extrinsic factors and what can be learned from those changes that will inform adaptation to climate change?	**High** – Essential to achieve effective adaptation outcomes	**High** – Stocktake of past experience will provide helpful guidance on how future options can be successfully implemented	**Medium** – Overcoming barriers is essential for change.	Removal of barriers will assist in fisheries and natural resource management adaptation for non-climate change drivers of change		**High**

Research question	Essential			Desirable		Overall
	Severity of harm or level of benefit	**Immediacy of research need**	**Need to change current intervention / practicality of new intervention**	**Potential co-benefits**	**Cross-sectoral relevance**	**Overall**
3. Conservation management						
3.1 Which ecosystems and species of conservation priority most require adaptation management and supporting research, based on their status, value, vulnerability to climate change and the feasibility of adaptive responses? What adaptation management frameworks and tools will identify vulnerable species and habitats within ecosystems, and how can these approaches build adaptive capacity and/ or resilience?	**High** – Significant threats to some regions/ecosystems/species	**High** – Information needed to underpin further work	**High** – Targeted actions will maximise research and policy effort and outcomes	Potential to inform broader conservation strategies	May affect planning processes in other sectors, especially for areas of high conservation value	**High**
3.2 What are the critical thresholds to ecosystem change and how close is the ecosystem to such 'tipping points'? How can we improve our measurement of marine ecosystems to account for ecosystem dynamics and processes?	**High** – Significant threats to some regions/ecosystems/species that support users: high benefit to enhance understanding of ecosystem dynamics	**High** – Information needed to inform conservation management immediately	**Low** – Unclear whether greater certainty or identification of thresholds is possible or will change management interventions	Identifying critical thresholds will inform fishing and tourism impact assessments. Measurement will inform tourism and fishing adaptation timing.		**Medium**

3.3 How will goals and governance for conservation of Australia's marine biodiversity need to change to adapt to climate change impacts? What are the enablers, barriers, limits and costs to implementing adaptation and effective policy responses to climate change?	**High** – Significant need to review agility of conservation governance and management to ensure responsiveness to conservation needs. High benefit in responding to impacts and ensuring effective and efficient investment.	**Medium** – Research needed in order to inform development and testing of management options	**Medium** – Practicality of interventions to be evaluated. Reason to believe some targeted management can assist. Stakeholders may resist change in policy direction.	Improved policy direction will create more effective and efficient conservation management beyond climate change impacts	Identifying more effective conservation policy in line with directional change will support efforts to effectively manage other marine resource developments such as fishing. Where management requires land-based intervention, potential for both positive and negative impacts on primary industries and coastal development.	**Medium**
3.4 How should conservation managers and planners adapt their practices to ameliorate climate change risks and enhance adaptation options? What intervention strategies will increase system resilience and improve the time within which biological systems can adjust to a future climate?	**High** – Effective design and delivery of information and tools critical for success of conservation management interventions	**High** – Research needed now in order to inform research design and delivery strategies	**High** – Reason to believe interventions will be practicable	Developing information, guidelines and tools will support better delivery beyond climate change		**High**

Research question	Essential			Desirable		Overall
	Severity of harm or level of benefit	**Immediacy of research need**	**Need to change current intervention / practicality of new intervention**	**Potential co-benefits**	**Cross-sectoral relevance**	
4. Tourism and recreational uses						
4.1 What are the predicted regional impacts of climate change for marine tourism assets (i.e., what tourism sites will be most vulnerable to change and to what degree)?	**High** – Understanding adverse impacts critical to informing tourism, fisheries and conservation policy with respect to the marine environment, including to seize new opportunities	**Medium** – Considerable research has been undertaken	**Medium** – Change of tourism location or practices likely to be practicable in some areas		Findings will inform fishing adaptation	**Medium**
4.2 How can the impacts on tourism, if any, of public perceptions of climate impacts on Australia's marine biodiversity and resources be minimised?	**Medium** – Secondary factor contributing to economic impacts	**Low** – Useful to understand best strategies in order to be prepared for negative media coverage of major events as they occur	**Low** – Practicability requires further assessment			**Low**
4.3 How can the links between resource condition and marine-dependent tourism business vitality be modelled and evaluated?	**Low** – Important contribution to understanding vulnerability	**Low** – Medium-term	**Medium** – Reason to believe that better understanding of links can assist in refining adaptation options			**Low**
4.4 What is the adaptive capacity of the marine tourism industry and how can it be enhanced to cope with climate change impacts?	**High** – Significant social and economic disruption if industries threatened by climate change impacts: high benefit to identifying alternatives	**Medium** – Some research needed to commence now in order to inform staged interventions or prepare for industry shifts	**High** – Reason to believe that some adaptation options will be effective for some locations	Understanding and enhancing marine tourism industry ability to cope with climate change impacts will support adaptation to other drivers of change		**High**
4.5 What social, ecosystem-based, engineering and technical approaches might reduce risks to marine tourism infrastructure from increased weather severity?	**Medium** – Risks to infrastructure require assessment	**Medium** – Some research needed to commence now	**Medium** – Some interventions may be practicable; but closely aligned with broader adaptation options	Technical solutions can be applied beyond climate change		**Medium**

4.6 Are current safety standards and protocols for marine activities adequate to deal with future conditions under climate change?	**Medium** – While safety standards already designed to consider range of weather variability, integration of projected climate change impacts is now warranted	**Low** – Medium-term: issues already arise in severe weather conditions unrelated to climate change	**Medium** – Higher standards likely to improve safety		Safety standards are designed to deal with a range of conditions and tourism operators need to amend their safety plans.	**Medium**
4.7 What are the most appropriate techniques for preserving beaches in the face of rising sea levels?	**Medium** – Major issue but likely to be addressed under Settlements and Infrastructure theme	**High** – Research needed immediately to identify and refine best techniques for specific locations	**Medium** – Reason to believe that some interventions will be practicable		Significant cross-sectoral benefits for settlements and infrastructure	**Medium**

Research question	**Essential**			**Desirable**		**Overall**
	Severity of harm or level of benefit	**Immediacy of research need**	**Need to change current intervention / practicality of new intervention**	**Potential co-benefits**	**Cross-sectoral relevance**	
5. Cross-cutting issues						
5.1 What are the key interactions across sectors, cumulative impacts and cross-jurisdictional issues that will affect the development of adaptation strategies in each sector and how can these cross- and multi-sectoral issues best be addressed?	**High** – need for integrated, systems approach well recognised	**High** – Research needed immediately to inform adaptation policy	**Medium** – Reason to believe that some interventions will be practicable		**High** – significant scope for contributing to systems-based analysis of adaptation options in other themes	**High**
5.2 What are the most appropriate techniques for preserving estuarine systems in the face of climate change?	**High** – These critical environments will require an integrated, systems approach	**High** – Estuaries are highly productive and vulnerable	**High** – it is important to determine what options and outcomes are realistic		**High** – this is cross-sector in nature	**High**

5.3 How can land-based climate change adaptation decisions be developed and implemented to also support adaptation for marine water quality and marine resources and biodiversity, including aquaculture, fisheries, conservation and tourism, taking account of multiple stressors, the cumulative pressures of co-occurring factors and flow-on effects for industries and ecosystem health?	**High** – need for integrated, systems approach well recognised	**High** – important to avoid perverse outcomes as land-based adaptation commences	**High** – There is an opportunity to identify mutually effective adaptation options across terrestrial and marine environments		**High** – this is cross-sector in nature	**High**
5.4 What are the long-term consequences of ocean acidification, particularly for acclimatisation or adaptation of marine organisms and ecosystems, and what adaptation options are available to the managers of marine biodiversity and resources?	**High** – increased acidity likely to affect many marine organisms	**Medium** – this is a long term issue	**Medium** – management options not apparent		**High** – this could affect all marine sectors	**Medium**
5.5 How can mitigation initiatives in marine environments, such as carbon sequestration initiatives in coastal or marine areas, contribute to adaptation outcomes?	**High** – Potential benefit to vulnerable systems and areas; need to avoid perverse outcomes	**Medium** – this is an emerging opportunity and issue	**Medium** – management options not yet apparent		**Medium** – the opportunities are not yet clear	**Medium**
5.6 How can climate change-induced changes to the distribution and effect of marine diseases, predators, pests and other problem organisms be managed?	**High** – Potential benefit to vulnerable systems, industries and areas	**Medium** – this is an emerging opportunity and issue	**Medium** – management options will be diverse and likely to be case-specific		**Medium** – the issues are not yet clarified	**Medium**
5.7 What are the major sources of social resilience, and the processes by which stakeholders and organisations interact, negotiate, and build alliances? What roles do varying perceptions among stakeholders play in adaptive management and how do they change over time?	**High** – Changes in the use and management of marine biodiversity and resources will need to be driven by government, industry etc, so understanding social factors will be critical to success	**Medium** – Useful to understand best mechanisms for implementing adaptation options; needed before such options are implemented	**Medium** – Useful to understand best mechanisms for implementing adaptation options; needed before such options are implemented	Determining the major sources of social resilience, and the processes by which stakeholders and organisations interact, negotiate, and build alliances will support adaptation beyond climate change		**Medium**

APPENDIX 3: CURRENT NCCARF (ARGP) / FRDC RESEARCH PROJECTS

NCCARF and the Fisheries Research and Development Corporation are jointly supporting seventeen research projects commissioned to address the high research priorities in the original Marine Biodiversity and Resources NARP.

(In the table (below) the projects are ordered by FRDC Project #).

Project Title (FRDC Project #)	Lead Organisation	Lead Investigator
Adaptive management of temperate reefs to minimise effects of climate change: developing effective approaches for ecological monitoring and predictive modelling (FRDC 2010/506)	**University of Tasmania**	**Neville Barrett**
The aims of this project are to: Collate and analyse the long-term ecological records for SE Australian reefs and develop quantitative relationships between species distributions and abundances and key physical processes; Identify optimal locations and species for monitoring programs to best inform adaptive management via delivery of up-to-date relevant information on change; Assess the costs and benefits of existing temperate MPAs for biodiversity conservation management in response to climate change; and Develop models that quantify and predict the impacts of climate change on inshore reef fishes, invertebrates and macroalgae so potential management responses can be identified, considered and developed appropriately		
Adapting to the effects of climate change on Australia's deep marine reserves. (FRDC 2010/510)	**CSIRO**	**Ron Thresher**
The aims of this project are to: develop practical options for DEWHA to manage the impacts of climate change on the South-east Commonwealth Marine Reserve; and develop a generic model that can be applied to forecasting the impacts of climate change on other deep sea biota		
Vulnerability of an iconic Australian finfish (Barramundi, *Lates calcarifer*) and related industries to altered climate across tropical Australia. (FRDC 2010/521)	**James Cook University**	**Dean Jerry**
The aims of this project are to: Define current thermal tolerances and associated physiological/energetic consequences of thermal adaptation in genetically divergent barramundi stocks across tropical Australia; Develop predictive models incorporating new physiological and genetic data with available population genetic, environmental and fisheries data to identify vulnerable wild stocks and associated stakeholders under realistic climate change predictions. Opportunities for expansion of fisheries and aquaculture will be determined; Establish genetic basis of thermal tolerance differences through identification of candidate thermal tolerance related genes within functionally/genetically divergent stocks. These candidate genes can be used as biomarkers for the aquaculture industry in the identification of fish with genetic tolerance to thermal stress; and Quantify parasite impacts on sea-cage barramundi under different temperature, pH and salinity and develop adaptive management strategies to minimize impacts under altered climate change scenarios.		

Project Title (FRDC Project #)	Lead Organisation	Lead Investigator
Identification of climate-driven species shifts and adaptation options for recreational fishers: learning general lessons from a data rich case. (FRDC 2010/524)	**CSIRO**	**Daniel Gledhill**
The aims of this project are to: Determine changes in distributions of rocky reef fish in eastern Australia over the past four decades, and establish correlation of these changes to climate induced environmental change (e.g. temperature); Determine perceptions of the test group regarding climate-induced changes to fish distributions and abundance and identify adaptation options; and Develop and test a "process model" for engagement and development of climate change adaptation options suitable for deployment to other fishing sectors and user groups, including commercial fishers		
Changing currents in marine biodiversity governance and management responding to climate change (FRDC 2010/532)	**University of Tasmania**	**Michael Lockwood**
The aims of this project are to: identify the requirements for adaptive marine biodiversity conservation governance and management in the context of climate change; assess how well current regimes, with a particular focus on marine protected areas, meet these requirements, and determine any necessary changes; identify alternatives to current regimes that are likely to enhance adaptivity and assess their governance and management effectiveness; and offer advice to governance and management authorities on how regime reform might be achieved		
Human adaptation options to increase resilience of conservation-dependent seabirds and marine mammals impacted by climate change (FRDC 2010/533)	**CSIRO**	**Alistair Hobday#1**
The aims of this project are to: Connect researchers, managers and policy makers, to focus on climate-ready monitoring and adaptation options for conservation-dependent seabirds and marine mammals; Link ongoing monitoring programs around Australia for seabirds and marine mammals with relevant wildlife and conservation management agencies; Extract climate signals for selected time series around Australia using cutting-edge statistical approaches; Develop protocols for monitoring impacts of environmental variation on indicator species and develop an indicator suite of spatial and temporal metrics for climate change impacts; Combine the indicator metrics to develop multi-species productivity indicators for Australian regions; and Provide practical adaptation guidelines for science and management, including on-ground monitoring protocols		
Ensuring that the Australian oyster industry adapts to a changing climate: a natural resource and industry spatial information portal for knowledge action and informed adaptation frameworks.	**University of Woollongong**	**Andrew Davis**

Project Title (FRDC Project #)	Lead Organisation	Lead Investigator
(FRDC 2010/534)		
The aims of this project are to: To source and review spatially referenced data for relevance to the oyster industry and it's response to natural resource management and climate change, and align primary and meta-data standards; To engage the oyster industry in developing the content style and delivery of natural resource and industry information in an online portal, including industry sourced data from Quality Assurance Programs and Environmental Management Strategies; To deliver a pilot, online, spatially-referenced, natural resource and industry information portal, making use of extensive primary data sources, meta-data standards and national spatial data delivery initiatives; and Identify pathways for the spatial information portal to inform governance and statutory authorities (e.g. NRM, State and LGA), monitoring programs, strategies (e.g. oyster industry and NRM strategies), planning policies (e.g. development application processes).		
Management implications of climate change effects on fisheries in Western Australia. (FRDC 2010/535)	**WA Fisheries and Marine Research Laboratories**	**Nick Caputi**
The aims of this project are to: Assess future climate change effects on Western Australia marine environments using a suite of IPCC model projections, downscaled to the key shelf regions and the spatial and temporal scales relevant for key fisheries; Examine the modeled shelf climate change scenarios on fisheries and implications of historic and future climate change effects; and Review management arrangements to examine their robustness to possible effects of climate change		
Beach and surf tourism and recreation in Australia: vulnerability and adaptation (FRDC 2010/536)	**Bond University**	**Mike Raybould**
The aims of this project are to: an LGA/site scale identification and assessment of the vulnerability to climate change of assets that are key drivers of marine and coastal tourism and recreation; the valuation of existing income streams due to beach-related tourism and recreation in case study locations; an application of valuation tool (developed in previous stage) in identified seachange localities to test transferability of results; to identify social and behavioural responses to climate change impacts on vulnerable tourism and recreation assets; and to report on the net vulnerability of regional locations to climate change		
A climate change adaptation blueprint for coastal regional communities. (FRDC 2010/542)	**University of Tasmania & CSIRO**	**Stewart Frusher & Nadine Marshall**
The aims of this project is to develop the tools that provide the relevant information to reduce risks and increase capacity to cope with, and benefit from change is urgently needed for coastal regional communities		

Project Title (FRDC Project #)	Lead Organisation	Lead Investigator
Effects of climate change on reproduction, larval development and population growth of coral trout (FRDC 2010/554)	**James Cook University**	**Morgan Pratchett**
The aims of this project are to: assess sensitivities of coral trout to climate-related changes in temperature and seawater chemistry, during fertilisation and early larval development; test the effects of increasing temperature and ocean acidification on growth, condition, behaviour and survivorship of early post-settlement coral trout; test for spatial variation in sensitivities to increasing temperatures for coral trout in three distinct sectors along the Great Barrier Reef; and measure coral-dependence at different ontogenetic stages, to test whether coral trout will be adversely affected by climate-induced bleaching and coral loss		
Pre-adapting a Tasmanian coastal ecosystem to ongoing climate change through reintroduction of a locally extinct species (FRDC 2010/564)	**University of Tasmania**	**Nicholas Bax**
The aims of this project are to: Develop and promote a national framework to evaluate potential translocations of native marine species; Determine the feasibility of reintroducing blue groper as a test case; Design a monitoring and evaluation program to determine the effects of a trial re-introduction; and Reach the critical decision point on whether to re-establish blue groper in Tasmania, or to take an alternative approach indicated by the research. Develop a proposal to support this outcome.		
Management implications of climate change impacts on fisheries resources of tropical Australia (FRDC 2010/565)	**James Cook University**	**David Welch**
The aims of this project are to: Describe the projected climate-driven changes that are relevant to northern Australian marine fisheries; Assess the potential impacts of climate change on key fisheries and species in northern Australia; and Assess current management to identify approaches that are adaptive to potential climate change scenarios.		
Preparing fisheries for climate change: identifying adaptation options for four key fisheries in South Eastern Australia. (FRDC 2011/039)	**University of Tasmania**	**Gretta Pecl**
This project will provide the scientific information on the likely effects of climate change on rock lobster, abalone, blue grenadier and snapper that is needed (see National Climate Change Action Plan) to ensure that: 1) stock assessment procedures and harvest strategies can be established that perform effectively under predicted scenarios; 2) management arrangements can be refined to allow the profitability of commercial fisheries and participation in recreational fisheries to be maximised and 3) monitoring systems can be established that are suitable for measuring the likely impacts of climate change and other drivers on these key species.		

Project Title (FRDC Project #)	Lead Organisation	Lead Investigator
Estuarine and nearshore ecosystems – assessing alternative adaptive management strategies for the management of estuarine and coastal ecosystems. (FRDC 2011/040)	**James Cook University**	**Marcus Sheaves**
The project focuses on developing and assessing adaptation strategies for estuaries and other coastal ecosystems to optimise ecosystem functions, fisheries outcomes and biodiversity values in a changing world. The aim is to develop strategies and tools to facilitate management that are sensitive to (a) regional and typological differences, (b) the inherently complex nature of estuary ecology the features a complexly interacting mosaic of interacting habitats where biological connectivity is a key attribute, (c) the far reaching implications of estuary adaptation strategies for the full spectrum of services and values connectivity to other stuff and (d) the competing needs, scales of influence, impacts, outcomes, consequences and costs across the spectrum of sectors affected by Climate Change and adaptation responses (policy, management, environment, social, urban, financial, industry etc.). The project will take knowledge feeds from complimentary NARP projects and all other relevant sources and value add by integrating available inputs and knowledge to develop meaningful adaptation strategies, decision frameworks, policy options and decision tools. It will also exchange information and ideas with other projects to maximise joint outcomes for climate change adaptation. The project recognises the key role of connectivity in estuary ecology, support for fisheries stocks, transmitting impacts to other biological and anthropogenic systems and values. Understanding and recognising the connectivities in systems is intrinsic to managing them. Consequently, a key focus is on how adaptation can be optimised in estuarine/coastal ecosystems that feature complex mosaics of interconnected habitats, and in which maintaining connectivities is often as important as protecting individual habitat units, and how adaptation strategies interact with the other components connected system. The project also recognises the complex spatial and conceptual framework in which estuary adaptation is set, and the need to evaluate issues of scale. These issues include region differences in impact nature and intensity; typological differences among estuaries; the extent of the match or mismatch between process, planning, management, impact and outcome; the differing needs of the various stakeholders; and the profitability of management of individual estuaries in a space-based context (the traditional approach) versus a systems-based approach focused on optimising outcomes for particular estuary types, assemblages and functions.		
Growth opportunities & critical elements in the value chain for wild fisheries & aquaculture in a changing climate. (FRDC 2011/233)	**CSIRO**	**Alistair Hobday#2**
Development of realistic adaptation management and policy options to enhance cost-effectiveness along the supply chain. Generate targeted recommendations in relation to efficiencies and reduction of the carbon footprint.		
Climate change adaptation - building community and industry knowledge. (FRDC 2011/503)	**WA Marine Science Institution**	**Jenny Shaw**
Foster climate change understanding and knowledge development in 3 coastal regions, in both community and marine-related industries. [Project builds on and helps disseminate all relevant research projects to these coastal regions and supports the Community Blueprint Project. (FRDC 2010/542)		

NCCARF

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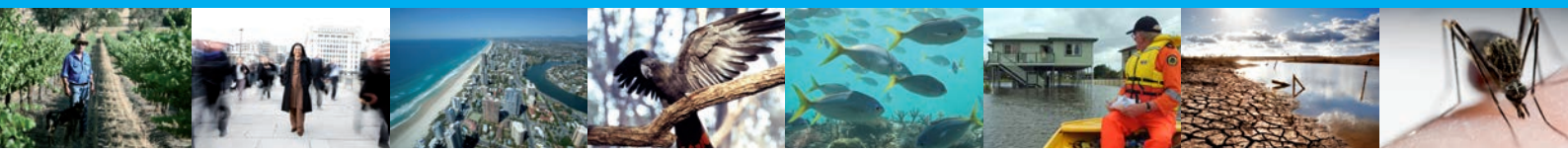

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