

NCCARF

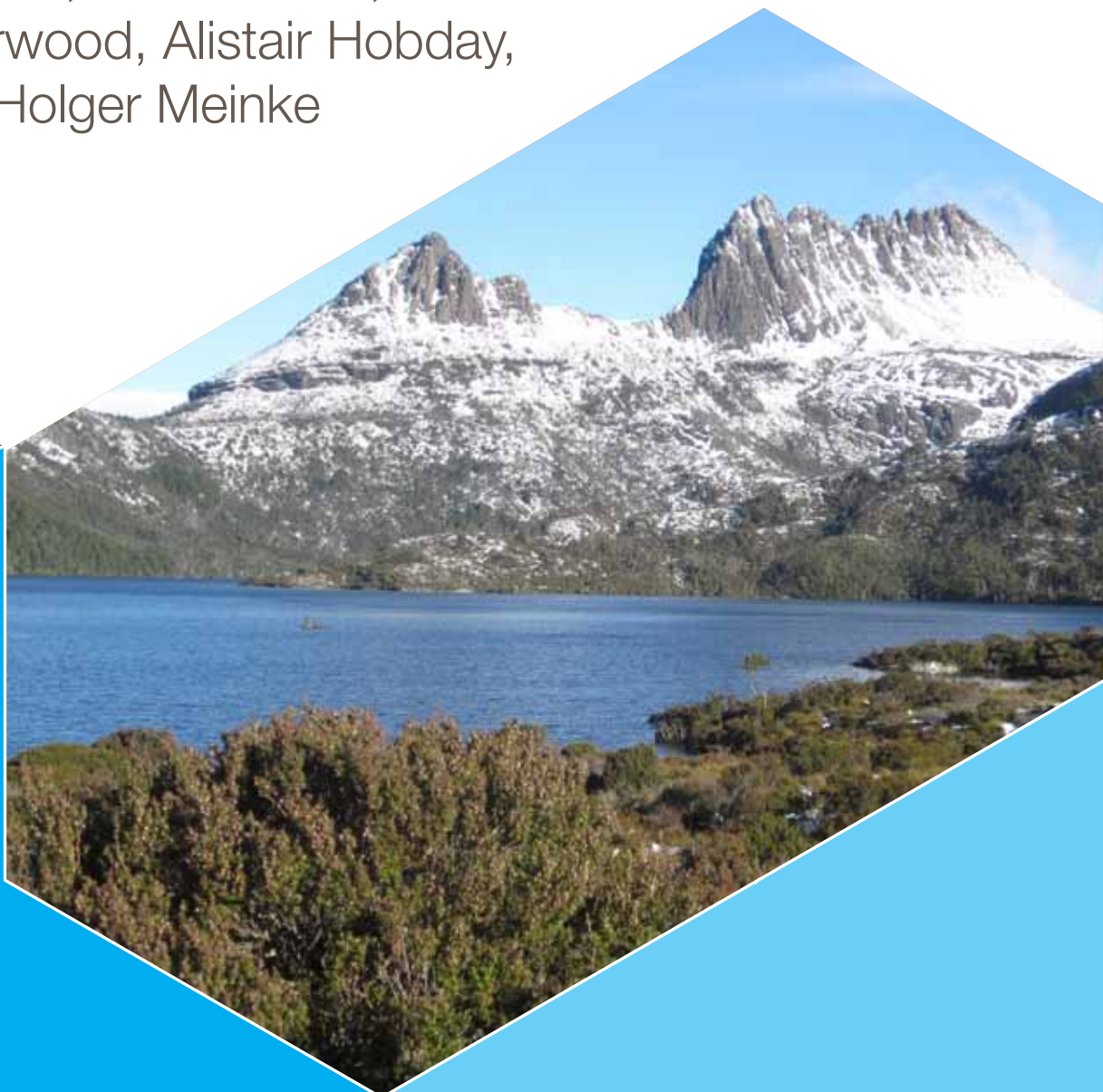
National
Climate Change Adaptation
Research Facility

Synthesis and Integrative Research

Final report

Supporting evidence-based adaptation decision-making in Tasmania: a synthesis of climate change adaptation research

Jan McDonald, John Harkin,
Andrew Harwood, Alistair Hobday,
Anna Lyth, Holger Meinke



SUPPORTING EVIDENCE-BASED ADAPTATION DECISION-MAKING IN TASMANIA

A synthesis of of climate change adaptation research

JAN MCDONALD

JOHN HARKIN

ANDREW HARWOOD

ALISTAIR HOBDAY

ANNA LYTH

HOLGER MEINKE



National Research
FLAGSHIPS



Published by the National Climate Change Adaptation Research Facility

ISBN: 978-1-925039-81-8 NCCARF Publication 110/13

© 2013 University of Tasmania

This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without prior written permission from the copyright holder.

Please cite this report as:

McDonald, J, Harkin, J, Harwood, A, Hobday, A, Lyth, A & Meinke, H 2013, *Supporting evidence-based adaptation decision-making in Tasmania: A synthesis of climate change adaptation research*, National Climate Change Adaptation Research Facility, Gold Coast, 111 Hpp.

Acknowledgements

This work was carried out with financial support from the Australian Government (Department of Climate Change and Energy Efficiency) and the National Climate Change Adaptation Research Facility.

The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

Graphics for the icons representing the terrestrial biodiversity, policy and governance, business and industry, and emergency management sectors, human health and community well-being were supplied by AECOM. Icons used to represent infrastructure and essential services, primary industries, land use planning, and marine biodiversity and fisheries were modified by Louise Bell, CSIRO, from those supplied by AECOM. Louise Bell designed the icon for Indigenous issues.

Disclaimer

The views expressed herein are not necessarily the views of the Commonwealth or NCCARF, and neither the Commonwealth nor NCCARF accept responsibility for information or advice contained herein.

Cover picture © 2013 Jan McDonald

Alpine areas are considered vulnerable to climate change in Tasmania.

Contents

EXECUTIVE SUMMARY	7
PROJECT BACKGROUND.....	7
CURRENT AND FUTURE CLIMATE IN TASMANIA	7
SYNTHESIS OF FINDINGS BY SECTOR	9
CROSS-CUTTING THEMES.....	14
CONCLUSIONS.....	14
1 INTRODUCTION.....	17
1.1 PROJECT BACKGROUND.....	17
1.2 PROJECT PURPOSE AND OBJECTIVES.....	17
2 PROJECT METHODOLOGY.....	20
2.1 PROJECT SCOPING AND PRELIMINARIES	20
2.2 LITERATURE REVIEW AND SYNTHESIS.....	21
2.3 CRITERIA FOR INCLUSION.....	23
2.4 SECTOR EXPERT INTERVIEWS.....	25
2.5 PROJECT WORKSHOP	25
2.6 REVIEW AND DEVELOPMENT OF CROSS-CUTTING THEMES	26
2.7 PROJECT LIMITATIONS	27
3 ADAPTATION CONTEXT	28
3.1 ENVIRONMENTAL CONTEXT	29
3.2 SOCIO-ECONOMIC CONTEXT	29
3.3 CLIMATE PROJECTIONS.....	30
4 RESEARCH FINDINGS BY SECTOR.....	35
4.1 PRIMARY INDUSTRIES	35
4.2 TERRESTRIAL AND FRESHWATER BIODIVERSITY	43
4.3 MARINE BIODIVERSITY AND RESOURCES	56
4.4 LAND USE PLANNING	67
4.5 INFRASTRUCTURE AND ESSENTIAL SERVICES.....	76
4.6 HUMAN HEALTH AND COMMUNITY WELLBEING	83
4.7 BUSINESS AND INDUSTRY.....	89
4.8 EMERGENCY MANAGEMENT	96
4.9 POLICY AND GOVERNANCE	101
4.10 INDIGENOUS ISSUES	107
5 SYNTHESIS AND CROSS-CUTTING THEMES.....	113
5.1 DRIVERS OF ADAPTATION.....	113
5.2 FUTURE VISIONS: COMMON ELEMENTS AND THEMES	119
5.3 BARRIERS TO ADAPTATION.....	124
5.4 SECTORAL DEPENDENCIES.....	132

6	CONCLUSIONS.....	139
6.1	THE STATE OF ADAPTATION ACTIVITY AND RESEARCH	139
6.2	RESEARCH GAPS AND PRIORITIES.....	140
6.3	FUTURE DIRECTIONS	144
	BIBLIOGRAPHY.....	146
	APPENDIX 1 STAKEHOLDER AND RESEARCHER REFERENCE GROUPS MEMBERSHI.....	168

List of tables

Table 1. The objectives and content of report sections _____	19
Table 2. Websites searched _____	22
Table 3. Academic databases searched _____	23
Table 4. Ongoing research relevant to Tasmania _____	50
Table 5. Marine biodiversity and resources projects relating to Tasmania _____	62
Table 6. NCCARF projects of likely significance to Tasmanian business and industry _____	94
Table 7. NCCARF projects of potential significance to Tasmanian Indigenous communities _____	110
Table 8. Workshop participant opinions on drivers of climate change adaptation interest and action _____	115
Table 9. Barriers to adaptation identified by interviewees, categorised against the elements of the Moser and Ekstrom (2010) framework _____	130
Table 10. Summary of sectoral adaptation research priorities _____	141

List of figures

Figure ES1. The state of adaptation activity and awareness for 10 Tasmanian sectors and the degree to which research, sectoral needs, and government policy influence. The size of the circles indicates the relative influence for each category _____	15
Figure 1. Project methodology _____	20
Figure 2. Composition of project workshop participants _____	26
Figure 3. Sectoral representation at project workshop in each of 10 categories _____	26
Figure 4. Current and projected air temperature for Tasmania Mean historical daily temperature from the Bureau of Meteorology high-quality climate site data for Tasmania and projections from downscaled CFT modelling simulations under the A2 and B1 emissions scenarios. The time series plot shows the 11-year moving average the high-quality climate site data (black line), the six-model mean (A2 = bold red line, B1 = bold blue line) and the range of the six models (respective faint lines) _____	31
Figure 5. Ensemble average ocean warming for south-east Australia by 2050 relative to 1990 _____	31
Figure 6 Total annual rainfall projections for Tasmania under the A2 emissions scenario For the six-model-mean proportional change in rainfall between 30-year periods indicated by numerals _____	32
Figure 7. Hydrological risks to native fish condition where blue indicates a positive impact and red indicates a negative impact (original Figure 15 in Barmuta et al 2012) _____	54
Figure 8. Map of planning regions in Tasmania _____	73
Figure 9. TCAP Pathway process _____	104
Figure 10. Top 10 drivers of climate change adaptation interest and activity _____	118
Figure 11. Barriers framework used in the project to evaluate stakeholder perceptions about sectoral barriers _____	126
Figure 12. Example of scoring for the barrier analysis, for the first element in the framework _____	128
Figure 13. Average scores for each of the nine elements in the barriers framework _____	129
Figure 14. Average scores for each of the three stages (each composed of three elements) for researchers and non-researchers _____	129
Figure 15. A worksheet used by workshop participants to identify sectoral dependencies _____	133
Figure 16. Dependency diagram: Influence of Marine biodiversity & resources on other sectors, national scale _____	134
Figure 17. Average number of linkages identified by workshop participants at three spatial scales _____	135
Figure 18. Aggregated sectoral linkages identified by workshop participants _____	136
Figure 19. Proportion of 'influenced by' and 'influence on' linkages _____	137
Figure 20. The state of adaptation activity and awareness for 10 Tasmanian sectors and the degree to which research, sectoral needs, and government policy influence _____	140

List of photos

<i>Photo 1. Participants at the project workshop, Photo: Holger Meinke</i>	25
<i>Photo 2. Poppy production could increase under climate change Photo: Mark Dowsett</i>	37
<i>Photo 3. The amount and reliability of water for irrigation will become increasingly important Photo: Veronica Foale</i>	40
<i>Photo 4. The Burrowing Crayfish may have reduced distribution in the future Photo: Thomas-Stromberg</i>	46
<i>Photo 5. Movement of grazing animals into alpine areas will change vegetation patterns Photo: Patrick Medved</i>	52
<i>Photo 6. The value of the seafood industry makes the impacts of climate change a major concern Photo: Alistair Hobday</i>	58
<i>Photo 7. Poleward range expansion of <i>Centrostephanus rodgersii</i> creates species 'barrens' Photo: Scott Ling</i>	59
<i>Photo 8. High summer temperatures pose significant risks to salmon production systems Photo: Alistair Hobday</i>	61
<i>Photo 9. Climate change will exacerbate existing exposure to coastal hazards Photo: Alistair Hobday</i>	70
<i>Figure 8 Map of planning regions in Tasmania</i>	73
<i>Photo 10. The TCAP project involved significant engagement with the community at Lauderdale</i>	74
<i>Photo 11. Hydro Tasmania has explored the impacts and risks for its hydro electricity generation capacity Photo: Anna Lyth</i>	81
<i>Photo 12. The 2013 bushfires highlighted the potential impacts of climate-related events on infrastructure. Photo: Sarah Brabazon</i>	82
<i>Photo 13. Storm damage to world heritage listed Port Arthur Historic Site, 2011, Photo: Port Arthur Historic Site Management Authority</i>	91
<i>Photo 14. Circular Head is significant for education in traditional use of land and sea Photo: DCCXLIX, Flickr</i>	108
<i>Photo 15 Workshop participants were asked to identify significant drivers of adaptation. Photo: Holger Meinke</i>	114
<i>Photo 16. Workshop participants assessed barriers to adaptation using TurningPoint® software. Photo: Holger Meinke</i>	127

Shortened forms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ACCARNSI	Australian Climate Change Adaptation Research Network for Settlements and Infrastructure
ACE CRC	Antarctic Climate & Ecosystems Cooperative Research Centre
ACOSS	The Australian Council of Social Services
AFAC	Australasian Fire and Emergency Service Authorities Council
ALCT	Aboriginal Land Council of Tasmania
ALGA	Australian Local Government Association
ARIES	Australian Research Institute in Education for Sustainability
BAL	Bushfire Attack Level
BRAM	Bushfire Risk Assessment Model
CCAP	Climate Change Adaptation Planning
CCRLUS	Cradle Coast Regional Land Use Strategy
CCRPI	Cradle Coast Regional Planning Initiative
CFEV	Conservation of Freshwater Ecosystem Values
CFT	Climate Futures Tasmania
CIS	Conservation Information System
CMAR	CSIRO Marine and Atmospheric Research
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCC	Department of Climate Change
DCCEE	(Commonwealth of Australia) Department of Climate Change and Energy Efficiency
DEDTA	Department of Economic Development, Tourism and the Arts
DIER	Department of Infrastructure, Energy and Resources
DPAC/DPC	Department of Premier and Cabinet
DPIW	Department of Primary Industries and Water [former name for DPIPWE]
DPIPWE	Department of Primary Industries, Parks, Water and Environment
DPSIR	Driving forces-Pressures-States-Impacts-Responses
EAC	East Australian Current
FACE	Free Air CO ₂ Enrichment Facility
GHG	Greenhouse Gas
HIA	Housing Industry Association
IPCC	Intergovernmental Panel on Climate Change
LAPP	Local Adaptation Pathways Program
LGAT	Local Government Association of Tasmania
NARP	National Adaptation Research Plan
NCCARF	National Climate Change Adaptation Research Facility
NGO	Non-Governmental Organisation
NRM	Natural Resource Management
NTRCA	Northern Tasmania Regional Councils Authority
NVA	Natural Values Atlas

PPRR	Prevention-Preparedness-Response-Recovery
RCCCAP	Regional Councils Climate Change Adaptation Project
SEAP	South-East Australia Fisheries and Climate Change Program
SCCC	(COAG) Select Committee on Climate Change
SLR	Sea-Level Rise
SME	Small to Medium Enterprise
SRES	Special Report on Emissions Scenarios
SST	Sea-Surface Temperature
STCA	Southern Tasmanian Councils Association
STCRC	Sustainable Tourism Cooperative Research Centre
STRLUS	Southern Tasmania Regional Land Use Strategy
STRPP	Southern Tasmania Regional Planning Project
TAC	Total Allowable Catch
TAC	Tasmanian Aboriginal Centre
TALSC	Tasmanian Aboriginal Land and Sea Council
TasCOSS	Tasmanian Council of Social Services
TCAP	Tasmanian Coastal Adaptation Decision Pathways Project
TCCI	Tasmanian Chamber of Commerce and Industry
TCCO	Tasmanian Climate Change Office
TFGA	Tasmanian Farmers and Graziers Association
TIA	Tasmanian Institute of Agriculture
TICT	Tourism Industry Council Tasmania
TSIC	Tasmanian Seafood Industry Council
WWHA	Wilderness World Heritage Area

EXECUTIVE SUMMARY

Project background

Tasmania faces unique challenges under climate change. It is likely to become a climate refuge for Australia in a number of contexts – it represents the southernmost refuge for a range of terrestrial and marine species and may become a residential destination for mainland émigrés and industries displaced by significant warming or other climate change related consequences. It has a unique socio-economic profile with a limited mix of industry, a low-density dispersed population. There are also some distinct regional socio-economic, geographic and climatic differences.

While the focus of the international community and national government has been on policies aimed at reducing atmospheric greenhouse gas concentrations in an attempt to avoid dangerous climate change, there is now increasing recognition of the need simultaneously to adapt to the impacts of unavoidable climate change. The National Climate Change Adaptation Research Facility (NCCARF) was established in 2008 to harness Australian research capabilities to support adaptation decision-making. Through the NCCARF program, more than 100 research projects have been funded to support decision makers in climate change adaptation.

This report contributes to the emerging body of adaptation research relating to Tasmania. Undertaken with funding from NCCARF's synthesis and integrative research program, the report evaluates the current state of adaptation knowledge in Tasmania, based on published and on-going research and applied research findings. The findings seek to inform public and private sector decision-makers, improve awareness of adaptation issues and challenges, and contribute to the uptake of adaptation strategies by stakeholders and sectors most likely to be affected by climate change in Tasmania.

The project methodology was designed to reflect the specific circumstances of adaptation research and practice in Tasmania. In particular, the small number of agencies, organisations and actors active in adaptation presented an opportunity to engage widely and deeply across the adaptation community. In addition to reviewing the published adaptation literature relating to Tasmania, the project was informed by interviews with, and two workshops of, adaptation practitioners, stakeholders and researchers.

Current and future climate in Tasmania

Tasmania's current climate is cool temperate, with four distinct seasons. Since 1950, mean land surface temperatures have increased by an average of 0.10° C per decade, a slower rate of increase than that experienced by mainland Australia (Grose et al. 2010). Projections for changes over the 21st century indicate that average annual temperatures across

What is adaptation?

This project adopts the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as:

'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'

(IPCC 2007)

Tasmania will increase between 1.6° C to 2.9° C by 2100, lower than projections for global and national increases, due to the moderating effect of the Southern Ocean.

Waters off Tasmania's east and north-east coast are warming at a rate almost four times the global average (Holbrook & Bindoff 1997; Ridgway 2007), resulting in the area being recognised as part of a global warming 'hot spot'. Mean sea surface temperatures are projected to increase around Tasmania in all seasons by the end of the century. Southward extension and strengthening of the east Australian current is likely to result in east coast water temperatures rising by up to 2°–3° C by 2070 relative to 1990 levels (Grose et al. 2010).

Since the 1970s, Tasmania has experienced a general trend of reduced annual average rainfall, and greater year-to-year variability in rainfall (Grose et al. 2010). These trends in rainfall are projected to continue, but with significant regional differences and seasonal variation. The central highlands and parts of the north-west are likely to experience increased drying, while the east and west coasts are projected to experience increased rainfall (Grose et al. 2010).

Changes to key climate variables such as temperature and rainfall are likely to amplify aspects of existing climate variability and result in changes in the intensity and frequency of extreme weather events (White et al. 2010), including intense rainfall events and localised flooding and storm surge, and extreme heat and fire danger days.

In Tasmania, sea-level rises have been slightly slower than global trends (Steffen & Hughes 2011). It is estimated that sea-levels will rise by 0.76 m on 2010 levels by 2100 (TCCO 2012a).

The *Climate Futures for Tasmania* (CFT) project is widely regarded as providing an excellent foundation upon which to undertake more detailed adaptation planning at the enterprise-, sector- or region-specific level. These projections have allowed most Tasmanian sectors to understand future environmental risk and several projects have used them to further inform sectoral adaptation plans.

Synthesis of findings by sector



Primary Industries

- ◆ Extreme variability in micro-climates, soils and production systems across the state makes it hard to translate climate impacts into state-wide sectoral impacts.
 - ◆ The effects of climate change impacts on demand-side issues and the implications of transformational change are poorly understood.
 - ◆ The plans of government agencies, suppliers, corporate agricultural business and individual farms in Tasmania already reflect the need to respond to climate variability and change.
 - ◆ Conditions for particular industries will change over time, so the trade-offs required across agricultural sectors will also need to vary.
 - ◆ Options analysis needs to take a systems approach that considers industries re-locating to Tasmania, and biosecurity threats under changed climatic conditions.
 - ◆ A key research priority is understanding how multi-level and indirect impacts of climate change can best be recognised in sector-specific adaptation research for Tasmanian primary industries.
-



Terrestrial and freshwater biodiversity

- ◆ Climate change represents a significant threat to Tasmania's endemic and refuge fauna (species extinct on the mainland) and associated ecosystems. Changes to fire regimes, increased shrub and tree invasion of alpine regions, and changes in runoff will threaten Tasmania's terrestrial and freshwater ecosystems.
- ◆ Government departments have developed a range of planning and management options for Tasmanian species and ecosystems.
- ◆ Management of non-climate threats to build ecosystem resilience to climate change is a key element in adaptation planning.
- ◆ Protecting individual species may not be viable under climate change, and a focus on continued delivery of ecosystem services is emerging as a complimentary adaptation strategy.
- ◆ Species distribution modelling and limited experiments are informing development of conservation strategies, including reserve design and active interventions, such as translocation.

- ◆ Key research priorities include: determining the effectiveness of reducing non-climate stressors, changing agricultural practices, and fire management for building resilience to climate change; and developing policies with regard to Tasmania's role in preserving biodiversity from mainland Australia.
-



Marine biodiversity and resources

- ◆ The east coast of Tasmania is part of a global warming hotspot where the rate of ocean warming is about four times above the global average. The East Australia Current has strengthened, carrying warmer water southward which, with the background warming, has led to many new species extending their range into Tasmania.
 - ◆ Changes in species composition have led to declines in marine productivity and generally negative effects.
 - ◆ In some regions, aquaculture is experiencing production impacts due to warming waters and the presence of novel species, including blooming algal species.
 - ◆ Reduction of non-climate threats through fisheries management and marine protected areas has been an adaptation focus to date.
 - ◆ Recognition of climate threats has led to changes in management by fisheries and aquaculture and limited experiments with translocation and ecosystem-based management, such as protection of large predators.
 - ◆ Arrival of new species will offer some new opportunities for commercial and recreational fishers, although declines in productivity mean these arrivals are not likely to offset losses.
 - ◆ Identification and protection of 'refuge areas', careful use of management options such as translocation, and reduction of non-climate stressors will all be important strategies.
 - ◆ The focus on ocean warming as the prime driver of change in Tasmania's marine environment should be complemented by additional targeted research on ocean acidification.
 - ◆ Development of strategies to respond to observed change are being developed, but additional simulation testing can further inform stakeholders about their response options.
-



Land use planning

- ◆ Land use planning can minimise or avoid the location of new settlements in vulnerable areas; and reduce the exposure of and promote adaptation efforts in existing settlements.
 - ◆ The state has introduced sea-level rise planning allowances and a Bushfire Planning Code. Regional land use strategies all refer to the need to minimise exposure of new and existing settlements to climate change hazards.
 - ◆ Transferring the lessons learned from numerous local and regional initiatives, such as the Tasmanian Coastal Adaptation Pathways project, will facilitate statewide improvements in planning.
 - ◆ The current ambit of land use planning will need to be extended to promote adaptation for existing settlements and infrastructure.
 - ◆ Key research priorities include how best to apply and transfer adaptation planning insights across places and projects; and assessing the suitability of the current governance arrangements for planning in Tasmania for adaptation needs.
-



Infrastructure and essential services

- ◆ The degree of vulnerability of infrastructure to climate change depends on the severity of climate change impacts, the adaptive capacity of the local community, and the location, age, design and construction method of the physical infrastructure.
 - ◆ Several recent local projects and assessment tools reflect best-practice for climate change risk assessments for infrastructure.
 - ◆ Little is known about the flow-on effects to communities and economies from disruption or damage to infrastructure or essential services.
 - ◆ Climate change is being reflected in the management plans for several departments and organizations, including the Department of Primary Industries, Water, and Environment, and Hydro-Tasmania.
 - ◆ Where location or relocation to hazard-free areas is not feasible, new technologies, design and construction standards, and management, operating and maintenance protocols will be required to minimise risks to infrastructure.
 - ◆ The 2013 bushfires should be used as a case study to understand the full costs of infrastructure disruption and how to avoid these costs through design, modification, re-engineering of processes or other techniques.
-



Human health and community wellbeing

- ◆ The health impacts of climate change include respiratory illnesses caused by changes in pollen allergens and bushfire smoke; infectious diseases; and mental health and overall community wellbeing issues associated with direct climate impacts, including disruption from extreme events and prolonged conditions, such as drought.
 - ◆ There is virtually no adaptation activity occurring in respect of human health, but research is examining impact assessment tools and early warning techniques for dangerous weather conditions. Assessments of risk, vulnerability and adaptive capacity have been conducted for Ross River virus.
 - ◆ A deeper understanding is needed at regional and community levels of indirect impacts from biophysical changes and the risks and social vulnerability associated with these.
 - ◆ Key research gaps and priorities include: regionally-focussed vulnerability and risk assessment and monitoring; and techniques for improving the responsiveness and management of health impacts or events as they arise, as well as preparing communities for longer term adjustment to changing environmental and health conditions.
-



Business and industry

- ◆ The implications of temperature increases, regional changes in rainfall patterns, and increased frequency and intensity of extreme weather events have not yet been assessed for business and industry sectors.
 - ◆ There will be direct physical disruptions to business operations from extreme events, and indirect impacts on the production and supply chains of Tasmanian businesses resulting from the effects of climate change elsewhere.
 - ◆ There may be opportunities flowing from business relocations and shifts in consumer preference, but there is very little evidence of businesses or industry addressing climate change impacts.
 - ◆ Limited adaptation research and practice relating to Tasmanian businesses suggests that businesses are likely to respond reactively rather than proactively to climate change impacts as they occur.
 - ◆ A key challenge will be to change the attitudes of businesses to medium-to-longer term climate-related threats.
 - ◆ Business- and industry-specific research is needed to understand climate change impacts and adaptation options at temporal and spatial scales suited to specific planning and decision-making processes.
-



Policy and governance

- ◆ There is growing recognition that climate change impacts are likely to place pressure on existing governance arrangements and on the allocation of roles, responsibilities and resources between levels of government, and between government and private actors.
 - ◆ The impacts of climate change on coastal hazards are the major focus of current adaptation policy.
 - ◆ The Regional Councils Climate Adaptation Project has enabled climate change impacts and adaptation options to be considered and incorporated into a Southern regional adaptation strategy and council adaptation plans.
 - ◆ There is a growing consensus that transformative change is necessary to transition successfully to a climate change-adapted society.
 - ◆ The barriers to both incremental and transformative change require close attention.
 - ◆ Research emphasises the need for attenuated engagement processes that recognise and respond to characteristics of individual communities rather than attempting to impose uniform, top-down policy responses.
-



Indigenous issues

- ◆ Tasmanian Aboriginal cultural heritage is particularly at risk from sea level rise and associated impacts, since many sites are located in intertidal and sub-tidal areas.
 - ◆ There has been no specific assessment of the vulnerability of Indigenous communities in Tasmania to the direct or indirect impacts of climate change, based on socio-economic, geographical, or cultural differences.
 - ◆ A clearer understanding of impacts and vulnerabilities is needed before future options can be considered.
 - ◆ A proper assessment of the impacts of climate change on Tasmanian Indigenous communities is needed, taking into account the vulnerability and adaptive capacity of Indigenous individuals, households, communities, businesses and institutions.
-

Cross-cutting themes

Drivers of adaptation

The most important drivers of adaptation in Tasmania are: general risk management, the desire to avoid catastrophic change or loss, mitigating discomfort of change and transformation, avoiding legal liability, and developments in research and understanding, capacity and know-how. Changes in policy and political environment and community or public pressure are important in some sectors. The desire to seize new opportunities or to act for the benefit of future generations is considered less influential as drivers of adaptation.

There is very little evidence of transformative change or even discussion of the need for such change in the near- or medium-term future. To the extent that any industry is currently undertaking adaptation measures, they are driven by understandings of short-term changes that are likely to affect profitability within budgetary planning horizons.

Visions for a climate-adapted future Tasmania

While it is impossible to articulate a single vision, or even a set of visions, for adaptation in Tasmania, the following themes cut across all sectors:

- the need for adaptation to become more integrated and mainstreamed into core business decision-making and policy-making;
- improved governance for adaptation, including better cross-sectoral arrangements and processes;
- better resourcing and training for adaptation;
- moving from planning to implementation; and,
- the need for monitoring and evaluation of adaptation strategies.

Barriers to adaptation

Barriers exist at all three stages of adaptation: understanding, planning and managing. Higher barriers were recognised at the planning stage than at the earlier understanding stage, while the barriers were higher again at the implementation stage. Overcoming these barriers would go far in delivering the common elements of the adaptation visions identified in this report.

Sectoral dependencies

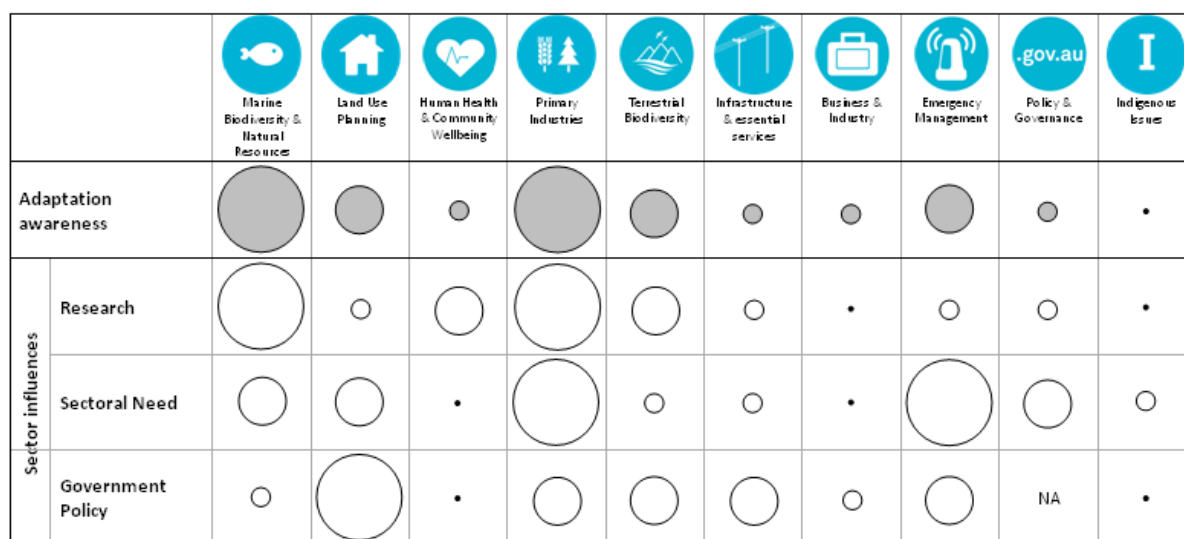
As a small state with a small population, the activities of, and issues facing, one sector have a significant impact on others. While some may view these sectoral dependencies as a barrier to adaptation, they also create opportunities for more embedded and holistic approaches that achieve efficiencies across the entire community, economy and environment. Developing consultation, policy- and decision-making processes that reflect these interdependencies will be challenging, but could have spin-off benefits for good governance more generally.

Conclusions

There are significant differences between sectors in terms of their perceptions of climate change impacts and the need for response. A subjective assessment was made of the state of adaptation, based on the synthesis of literature and stakeholder consultation information

(Figure ES1). Awareness and motivation for adaptation is highest in the marine, primary industries, and emergency management sectors. This awareness and motivation appears linked, in part, to one or more of three main influences on adaptation: research, sectoral needs, and/or government policies. In some sectors, such as marine and primary industries, research has played a major role, while in others any adaptation that has occurred has been driven almost entirely by issues relating specifically to the sector (e.g. emergency management), or to policy-related drivers (e.g. land use planning)(Figure ES1).

The report highlights areas of significant research strength in Tasmania, and others where there is little or no research specific to the state. Research is strongest in marine biodiversity and resources, and to a lesser extent primary industries and terrestrial and freshwater biodiversity. There is no Tasmania-specific work relating to the impacts of climate change on Indigenous Tasmanians, and very little coverage of health and community well-being issues or business and industry perspectives (other than the primary industries). Some major recent projects of relevance to coastal adaptation, land use planning and (to a lesser extent) infrastructure and emergency management have started to fill significant policy gaps in these areas.



Legend





				NA
High	Moderate	Minimal	None or virtually none	Not applicable

Figure ES1. The state of adaptation activity and awareness for 10 Tasmanian sectors and the degree to which research, sectoral needs, and government policy influence. The size of the circles indicates the relative influence for each category

Given the qualitative relationship between research strength and sectors with greatest climate adaptation awareness, investment in research is clearly important to develop climate impact and adaptation strategies in Tasmania. Thus, strategies for increasing and maintaining high quality research should be a government priority.

Significant gaps remain in our understanding of adaptation needs and successes across all sectors. There is a range of research priorities that seek to clarify the application of national or international research in Tasmania or further develop earlier findings of Tasmanian projects, including action research such as the Coastal Adaptation Pathways Projects. These priorities fall into one of three general categories: climate and system understanding; evaluating adaptation options; and resolving societal issues around adaptation. Research investment is needed in all three areas and future research endeavours should engage stakeholders and end-users in the earliest stages of research design, including the refinement of research objectives and questions.

Wherever possible, opportunities for multi-sectoral synergies and relevance should be maximised as the dependencies identified in this project showed strong connectivity in Tasmania.

1 INTRODUCTION

1.1 Project background

Tasmania faces unique challenges under climate change. It is likely to become a climate refuge for Australia in a number of contexts - it represents the southernmost refuge for a range of terrestrial and marine species and may become a residential destination for mainland émigrés and industries displaced by significant warming or other climate change related consequences. It has a unique socio-economic profile with a limited mix of industry, a low-density dispersed population. There are also some distinct regional socio-economic, geographic and climatic differences.

While the focus of the international community and national government has been on policies aimed at reducing atmospheric greenhouse gas concentrations in an attempt to avoid dangerous climate change, there is now increasing recognition of the need simultaneously to adapt to the impacts of unavoidable climate change. The National Climate Change Adaptation Research Facility (NCCARF) was established in 2008 to harness Australian research capabilities to support adaptation decision-making. Through the NCCARF program, more than 100 research projects have been funded to support decision makers in climate change adaptation.

This report contributes to the emerging body of adaptation research relating to Tasmania. Undertaken with project funding from NCCARF's synthesis and integrative research program, the report assesses the current state of adaptation knowledge in Tasmania, based on published and on-going research and applied research findings.

The project team consisted of:

- Professor Jan McDonald (PI), Faculty of Law, University of Tasmania
- Mr John Harkin, Tasmanian Climate Change Office, Department of Premier and Cabinet
- Dr Alistair Hobday, CSIRO Climate Adaptation Flagship
- Dr Anna Lyth, School of Geography and Environmental Studies, University of Tasmania
- Professor Holger Meinke, Director TIAR, University of Tasmania
- Dr Andrew Harwood, Project Officer, University of Tasmania.

1.2 Project purpose and objectives

This synthesis seeks to understand the emerging state of adaptation research and practice in Tasmania, in order to inform public and private sector decision-makers, improve awareness of adaptation issues and challenges, and contribute to the uptake of successful adaptation approaches by stakeholders and sectors most likely to be impacted by climate change in Tasmania. It adds value to existing research by aggregating the findings of individual research reports and publications to extract common themes.

The objectives of the project were to:

- identify and review the adaptation research projects specific to Tasmania;
- identify the relevance of existing adaptation research from across Australia for Tasmania, based on information from the mainland Australia project;
- prepare sector summaries, map linkages between direct and indirect climate change impacts, consequences for individual sectors and across sectors, and the adaptation responses and implementation actions;
- identify recurring themes regarding how adaptation research recommendations may be better implemented;
- support adaptation in Tasmania by providing information to inform adaptation policy, investment and decision-making; and
- identify critical information gaps, barriers, and research opportunities as a basis for future planning of research investment and projects to develop and implement adaptation policy.

1.2.1 Structure of this report

The report consists of six parts and one appendix, the objectives and contents of which are set out in Table 1.

Table 1. The objectives and content of report sections

Report section	Objectives	Content
1. Introduction	To explain project background, context and objectives	Project background, purposes and objectives, report structure; project scope
2. Project methodology	To describe the project methodology	Description of project methodology, including identification of participants, modes of participation and literature review processes; project limitations
3. The context of climate adaptation in Tasmania	To summarise current research relating to current climate and future climate projections for Tasmania	Description of Tasmania’s environmental and socio-economic context and current and projected climate conditions
4. Research findings by sector	To synthesise adaptation research reviewed based on ten sectors	Key findings and summaries for the following sectors: primary industries; terrestrial and freshwater biodiversity; marine biodiversity and resources; land use planning, infrastructure and essential services; emergency management; human health and community well-being; industry and business; policy and governance; and indigenous issues
5. Cross-cutting themes	To present common themes of Importance for private sector, state and local government policy and decision-making.	Discussion of the following themes: Drivers of adaptation; future visions; governance; resourcing; implementation, monitoring and evaluation, attitudinal change; opportunities; research and action; barriers to adaptation; sectoral dependencies.
6. Conclusions	To summarise key lessons and articulate key challenges facing public and private decision-makers	Evaluation and assessment of current state of adaptation action and research, summary of adaptation challenges and opportunities for Tasmania, lessons for decision-makers and future research opportunities.
Appendix 1 Memberships of Research and Stakeholder Reference Groups		
Bibliography	To present the complete list of research reports reviewed for the project	The bibliography includes all research cited or reviewed for the project.

2 PROJECT METHODOLOGY

The project has been undertaken in five phases (see Figure 1):

1. project scoping and preliminaries;
2. literature review and sectoral synthesis;
3. sector expert interviews;
4. project workshop; and
5. review and development of cross-cutting themes.

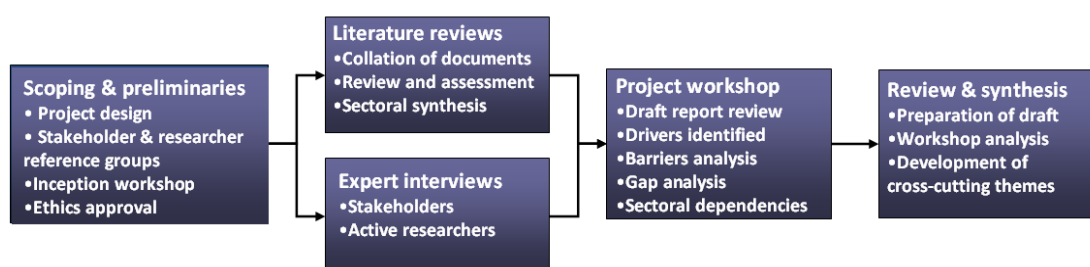


Figure 1. Project methodology

Each of these phases is discussed below.

2.1 Project scoping and preliminaries

2.1.1 Project design and methodology

This project was designed to reflect the specific circumstances of adaptation research and practice in Tasmania. In particular, the small number of agencies, organisations and actors active in adaptation presented an opportunity to engage widely and deeply across the adaptation community.

The call for expressions of interest in this project indicated a strong preference for stakeholder-driven research. Accordingly, this project engaged the Tasmanian adaptation stakeholder and researcher community from the very earliest stages of project design during preparation of the project proposal. A representative from the Tasmanian Climate Change Office – the key State Government agency responsible for mainstreaming adaptation policy into State Government business – was included as part of the project team and advised on appropriate stakeholder groups.

2.1.1.1 Establishment of stakeholder and researcher reference group

Separate researcher and stakeholder reference groups were established to advise on the project. During development of the project proposal, the project CI emailed a wide range of researchers known to be active in adaptation research at the University of Tasmania and CSIRO, to gauge interest in the project and, in particular, involvement in either the project team or an advisory role. Responses from this initial correspondence enabled the resulting project team to adopt a snow-ball technique for identifying additional researchers. Researchers gave their in-principle support for participating in the researcher reference group, and confirmed their involvement when the project formally commenced.

A similar approach was taken to the membership of the stakeholder reference group. The TCCO provided contact details of key industry and sector stakeholder groups. A personal email was sent to each of the contact persons associated with these groups, in order to raise their awareness of the project and gain their support. Virtually all groups contacted gave in-principle support for involvement in the stakeholder reference group prior to submission of the project proposal, and confirmed their involvement when the project formally commenced. Several organisations and individuals were added following project commencement, based on the suggestions of project team members and other stakeholders/researchers.

Membership of these groups is listed in Appendix 1.

2.1.1.2 Inception workshop

The stakeholder reference group met at an inception workshop held on 14 August 2012, to discuss and refine objectives, determine their information priorities, and identify the most appropriate forms of deliverables. The stakeholder reference group also provided the project team with information about adaptation projects completed or underway within their industry or organisation, and the outcomes of those initiatives. To the extent that they are relevant, these initiatives are discussed in each of the sectoral summaries in section 6 of this report.

2.1.2 Ethics approvals

Since the project involved interviews and workshop activities, Human Research Ethics Approval was required. Documentation including draft interview protocols and invitations to workshops was prepared in July 2013, and approval for the project was granted on 14 August 2012 (Ethics Ref No: H001267).

2.2 Literature review and synthesis

The second phase of the project involved the assembly, compilation and synthesis of published results of past and current research projects funded by NCCARF and other bodies, as well as other adaptation policies and initiatives.

The identification and compilation of literature for review and synthesis was conducted using four techniques:

- materials already known by the research team
- materials provided by the research and stakeholder reference groups
- searches of University of Tasmania online databases of scholarly journals
- searches of government and other websites.

Literature was gathered between August and November 2012. Research not publicly available by November 2012 was only included if nominated during stakeholder and researcher discussions.

Table 2 lists the government and other websites searched for adaptation-relevant documents. Table 3 lists the academic databases searched.

Table 2. Websites searched

Website	Address
Housing Industry Association	http://hia.com.au/
Tasmanian Council of Social Services (TasCOSS)	http://www.tascoss.org.au/
Tasmanian Seafood Industry Council	http://www.tfic.com.au/
Tasmanian Farmers & Graziers Association	http://www.tfga.com.au/
Tasmanian Land Conservancy	http://www.tasland.org.au/
Tasmanian Minerals Council	http://tasminerals.com.au/home/
Tasmanian Conservation Trust	http://www.tct.org.au/
Tourism Industry Council of Tasmania	http://www.tict.com.au/
Wine Tasmania	http://winetasmania.com.au/
Tasmanian Chamber of Commerce & Industry	http://www.tcci.com.au/tcci/
Tasmanian Aboriginal Centre	http://www.tacinc.com.au/
Sustainable Living Tasmania	http://www.sustainablelivingtasmania.org.au/
Property Council of Australia	http://www.propertyoz.com.au/
Fruit Growers Tasmania	http://www.fruitgrowerstas.com.au/
Forest Industries Association of Tasmania	http://www.fiatas.com.au/
City of Clarence	http://www.ccc.tas.gov.au/page.aspx
Hobart City Council	http://www.hobartcity.com.au/Home
Kingborough Council	http://www.kingborough.tas.gov.au/page.aspx
Launceston City Council	http://www.launceston.tas.gov.au/lcc/
Southern Midlands Council	http://www.southernmidlands.tas.gov.au/
Southern Tasmanian Councils Authority	http://stca.tas.gov.au/
Cradle Coast Authority	http://www.cradlecoast.com/
Cradle Coast NRM	http://www.cradlecoastnrm.com/
NRM North	http://www.nrmnorth.org.au/
NRM South	http://www.nrmsouth.org.au/home/
Local Government Association of Tasmania (LGAT)	http://www.lgat.tas.gov.au/page.aspx
Forestry Tasmania	http://www.forestrytas.com.au/
Hydro Tasmania	http://www.hydro.com.au/
State Emergency Services Tasmania	http://www.ses.tas.gov.au/
Forest Practices Authority	http://www.fpa.tas.gov.au/
Department of Premier and Cabinet	http://www.dpac.tas.gov.au/
Environmental Protection Authority Tasmania	http://epa.tas.gov.au/epa/
Department of Primary Industries, Parks, Water and Environment (DPIPWE)	http://www.dpiw.tas.gov.au/inter.nsf/Home/1?Open
Department of Infrastructure, Energy & Resources	http://www.dier.tas.gov.au/
Tasmanian Climate Change Office (TCCO)	http://www.climatechange.tas.gov.au/
Department of Economic Development, Tourism & the Arts	http://www.development.tas.gov.au/
Department of Treasury and Finance, Tasmania	http://www.treasury.tas.gov.au/
State Library of Tasmania	http://www.linc.tas.gov.au/
University of Tasmania	http://www.utas.edu.au/
Institute for Marine and Antarctic Studies (IMAS)	http://www.imas.utas.edu.au/
Australian Maritime College (AMC)	https://www.amc.edu.au/marine-environment
Tasmanian Institute of Agriculture	http://www.tia.tas.edu.au/
Integrated Marine Observing System (IMOS)	http://imos.org.au/

Website	Address
National Climate Change Adaptation Research Facility (NCCARF)	http://www.nccarf.edu.au/
CSIRO	http://www.csiro.au/
CSIRO Marine & Atmospheric Research (CMAR)	http://www.cmar.csiro.au/
CSIRO Climate Adaptation Flagship	http://www.csiro.au/en/Organisation-Structure/Flagships/Climate-Adaptation-Flagship.aspx
Antarctic Climate & Ecosystems Cooperative Research Centre (ACE-CRC)	http://www.acecrc.org.au/
Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)	www.abares.gov.au
Australian Centre of Excellence for Local Government	http://www.acelg.org.au/
Australian Emergency Management Institute	http://www.em.gov.au/Pages/default.aspx
Climate Change Research Strategy for Primary Industries (CCRSPI)	http://www.ccrspi.org.au/
Australian Government Climate Commission	http://climatecommission.gov.au/
Australian Government Department of Resources, Energy and Tourism	http://www.ret.gov.au/Pages/default.aspx
Australian Government Department of Climate Change and Energy Efficiency (DCCEE)	http://www.climatechange.gov.au/
The Australian Research Institute for Environment and Sustainability	http://aries.mq.edu.au/
Australian Government Department of Agriculture, Fisheries & Forestry (DAFF)	http://www.daff.gov.au/
AusIndustry	http://www.ausindustry.gov.au/Pages/default.aspx
Australian Antarctic Division (AAD)	http://www.antarctica.gov.au/
Cooperative Research Centre for Forestry	http://www.crcforestry.com.au/

Table 3. Academic databases searched

SUMMON	Current Contents Connect
Scopus	Wiley Online Library
Web of Science	GeoRef
Taylor & Francis	CAB Abstracts
SAGE Journals	Google Scholar
JSTOR	Informit
ProQuest	Geobase

2.3 Criteria for inclusion

Literature was included in the review if it:

- was a primary research report or peripheral/secondary research outputs (such as fact sheets)
- was publicly available
- specifically considered the impacts of climate change, vulnerability and/or responses to future climate change
- related specifically to Tasmania.

The project took a broad view of published research. Government reports, consultant reports that form part of local or regional adaptation projects, and other material was analysed provided it was in the public domain or forthcoming.

The time and resource constraints of the project meant that the following material was excluded:

- international adaptation research, unless it was specific to Australia or offered a specific analytical tool
- climate change science research, unless it specifically related to Tasmania
- research of relevance to adaptation, such as human health or disaster management, unless to expressly mentioned climate change.

2.3.1 Sectoral classification

Literature was assigned to one or more of ten focal area/sectoral categories:

- primary industries
- terrestrial biodiversity
- marine biodiversity and resources
- land use planning
- infrastructure
- human health and community wellbeing
- business and industry
- emergency management
- policy and governance
- indigenous issues.

These sectors were selected following early consultations with NCCARF and the Forum for NCCARF, States and Territories (FORNSAT) and with the project team's expert judgment about the categorisation of existing research and areas of research need. The choice of sectors was discussed and validated at the project inception meeting.

It is recognised that other sectors or differently constituted categories are possible, and we recognise the potential limitations of any attempt to break into 'sectors' the complex array of cross-cutting issues and available literature. As noted above, the multi-sectoral relevance of many documents was partially overcome by allocating documents to more than one sector where there was clear overlap or relevance to multiple areas. Omissions and overlaps are unavoidable in any selection of themes and sectors, and the project sought to minimise those issues and maximise the synergies across sectors as much as possible.

2.3.2 Sectoral analysis and synthesis

The next phase involved the preparation of the draft sectoral findings.

The project team reviewed each document and used expert judgment to extract the findings most relevant to each sector. The Driving forces-Pressures-States-Impacts-Responses (DPSIR) framework was considered a useful platform for each sectoral analysis, because it

provided a logical structure and ensured thorough coverage of issues. The terminology was modified, however, to reflect the limited state of research available and to enhance the accessibility of the content and concepts. The resulting sectoral summaries synthesised research according to:

- the nature of the climate change impacts;
- the implications of sector-specific vulnerabilities;
- current adaptation efforts;
- future options; and
- research gaps and opportunities.

2.4 Sector expert interviews

In addition to the literature review, this mapping and synthesis exercise drew on semi-structured telephone or in-person interviews with members of the researcher and stakeholder reference groups (active researchers (n~13) and stakeholders (n~23)). These interviews explored participants involvement in adaptation research, models of collaboration across researchers and end-users, challenges faced in undertaking adaptation research and in converting research findings into policy or practical outcomes. The results of these interviews helped inform the identification of common themes, gaps and opportunities, and future research directions.

2.5 Project workshop

The Project workshop was held on December 11, 2012. A draft project report was prepared and distributed to Researcher and Stakeholder Reference Groups in advance of the project workshop, to enable the project team to verify the comprehensiveness and accuracy of content, and to provide a foundation of discussion at the workshop.



Photo 1. Participants at the project workshop, Photo: Holger Meinke

The workshop reviewed the focal area/sectoral summaries; mapped linkages within and between sectors and from direct to indirect impacts; explored drivers of adaptation and barriers to effective adaptation; and identified key gaps in adaptation knowledge/capacity/practice and future priorities. All members of the Researcher and Stakeholder Reference Groups were invited to the workshop. Those individuals were also invited to suggest other invitees. Including the project team, the workshop involved ten researchers and ten stakeholders.

While several participants indicated that they sat across both researcher and stakeholder communities, when asked to identify with one group, a total of ten of workshop participants described themselves as researchers, eight described themselves as research end-users and five as research managers (Figure 2). Participants elected to represent one of the ten sectors covered in this project, and the breakdown of sectoral representation is presented in Figure 3.

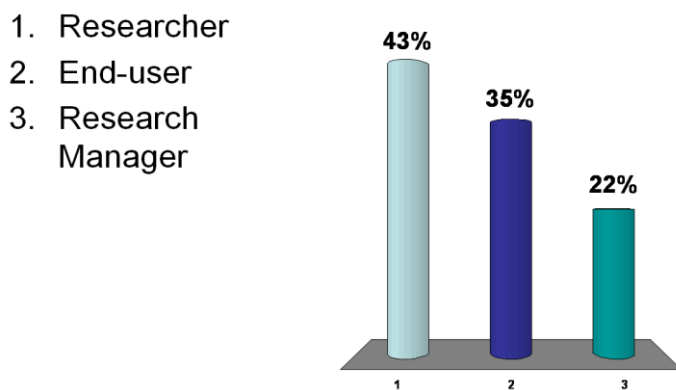


Figure 2. Composition of project workshop participants

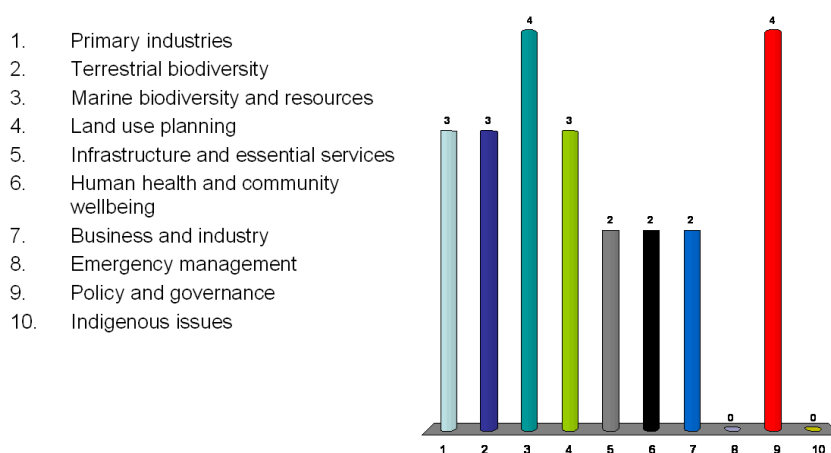


Figure 3. Sectoral representation at project workshop in each of 10 categories

2.6 Review and development of cross-cutting themes

In the final phase, the project team refined the project findings and developed the cross-cutting themes. Cross-cutting themes were identified from the workshop discussions as well as expert review based on interview analysis and workshop discussions. With these new

sections included, and existing material refined, the draft project report was then subject to a second round of consultation and feedback from researchers and stakeholders.

2.7 Project limitations

This project assesses the state of adaptation research *in Tasmania*. National work of specific relevance to Tasmania is discussed but the project does not, and cannot, purport to evaluate in detail the growing national and international adaptation literature that may also offer insights for the Tasmanian context. The companion project conducted for the Australian mainland state and territories by AECOM reviews and synthesises national material, and the results of that project also offer insights for Tasmania. This means that some of the sectoral analyses contained in part 4 of this report are more detailed than others, based on the availability and sophistication of research that relates specifically to Tasmania.

3 ADAPTATION CONTEXT

Adaptation has been defined as the process of developing local responses to climate change and involves deliberate change in anticipation of or in reaction to external stimuli and stress (Nelson et al. 2007). In some contexts, adaptation can be either autonomous biological (e.g. changing distribution or growth rates) or directed (biological, infrastructural, socio-economic adaptation) (e.g. coastal planning may set new limits given expected physical change). Here we focus on the body of adaptation research that can inform directed adaptation.

The likely changes in climate that Tasmania will experience as a result of changes in global climate drivers need to be understood within the context of how Tasmania's geographical position, island geography and topography interact with complex global, regional and local climate dynamics. For example, being located in the Southern Ocean exerts a moderating effect on some key global climate variables, such as increases in land surface temperatures. Likewise, the impacts of changes to climate and the associated emerging risks and adaptation challenges also need to be understood in the context of Tasmania's social, cultural, economic and political geographies:

What is adaptation?

This project adopts the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as

'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2007b).

While Tasmania is expected to experience less severe climate change impacts compared to other parts of Australia (due to its temperate maritime climate), it is important to recognise that these impacts will have an effect. Further, the effects will be particularly felt by socially, physically and economically vulnerable communities who may not have the capacity or resources to effectively adapt to climate change (TCCO 2012a, p.3).

Tasmania has the benefit of strong regionally specific climate change modelling, by virtue of the *Climate Futures for Tasmania* (CFT) project. The CFT was jointly funded by the Tasmanian Government, NCCARF and Hydro Tasmania (ACE CRC 2010). It adopted six global climate model simulations and used dynamic downscaling to produce fine-resolution (approximately 10km x 10km) projections of key climate variables for Tasmania over the 21st century. These projections are based on two IPCC emissions scenarios (one high, A2 and the other low, B1). Detailed accounts of how shifts in key climate drivers (such as El Niño Southern Oscillation, Indian Ocean Dipole, Southern Annular Mode, and blocking highs) will affect Tasmanian climate, are contained in the CFT reports (available from <http://www.acecrc.org.au/Research/Climate%20Futures>), particularly the *General Climate Impacts Technical Report* (Grose et al. 2010) and the *Extreme Events Technical Report* (White et al. 2010).

At the time of writing, the CFT was the best regional-level information in the country. As climate modelling and downscaling techniques improve, they are likely to reveal the project's limitations (see, for example, Risbey & O'Kane 2011), but for present purposes CFT continues to provide an invaluable platform for adaptation planning. Below we provide a brief overview of the environmental and socio-economic context for adaptation in Tasmania, then outline some of the anticipated key climate changes that Tasmania will experience over the coming century, based on CFT findings.

3.1 Environmental context

Tasmania is located in the path of the 'Roaring Forties' winds, which circulate around the Southern Ocean. Most recently, it separated from the Australian mainland some 6000–10000 years ago, when sea level rose at the end of the last ice age. Its rugged mountainous topography results in part from glaciation in some parts of the island, which has also had an influence on soil quality and hence vegetation patterns.

Tasmania's geographical and genetic isolation have preserved a unique combination of flora and fauna, with remnant Gondwanan taxa that provide insights into evolutionary processes. Close to half of the state's land mass is located in some form of conservation reserve, although these areas are principally alpine and low-productivity environments. Tasmania's natural values are already affected by a range of threats, including fire, weeds, pests and diseases (TPC 2009).

3.2 Socio-economic context

Tasmania has a population of 512 000, divided into 29 local government areas. About half of the state's population lives in southeast Tasmania, in the greater Hobart area. The state's economy is heavily dependent on environmental goods and services, dominated by mining, tourism, fisheries and aquaculture, forestry, and primary industries. Tasmania's current economic performance is ranked eighth of the eight states and territories (ComSec 2013) in the following sectors: economic growth; retail spending; equipment investment; construction work done; population growth; housing finance and dwelling commencements; and seventh of eight in unemployment (ComSec 2013).

There is considerable public debate about the state's future social and economic well-being. Recent discussions have highlighted Tasmania's low levels of post-year ten educational retention and attainment; high levels of welfare dependence, public sector employment and teenage pregnancy; and an underdeveloped private sector (Cica 2013, West 2013). At the same time, however, others have noted the overall high levels of satisfaction among the state's residents: accordingly to Gale, a 2012 survey of community attitudes showed that nearly 90% of Tasmanians were satisfied or very satisfied with their own life and personal circumstances (Gale 2013).

3.3 Climate projections

3.3.1 Temperature

3.3.1.1 Land temperatures

Tasmania's current climate is cool temperate, with four distinct seasons. Throughout the first half of the 20th century, Tasmania experienced a stable mean land temperature. Since 1950, mean land surface temperatures in Tasmania have increased by an average of 0.10° C per decade, which is a slower rate of increase than that experienced by mainland Australia (0.16° C per decade) (Grose et al. 2010). Steffen and Hughes (2011) note that average annual temperatures in Tasmania have increased by around 0.8° C over the last 100 years. Projections for changes over the 21st century indicate that average annual temperatures across Tasmania will increase between 1.6° C to 2.9° C by 2100 (Figure 4).

Increases in temperature for Tasmania are less than that projected for global average temperatures and for the Australian mainland, mainly due to the moderating effect of the Southern Ocean. Increases in average land surface temperatures are matched by increases in both maximum and minimum temperatures, with daily minimum temperatures projected to increase slightly more than daily maximum temperatures. Notwithstanding existing variations in temperature based on changes in elevation, the average annual increase is anticipated to be relatively uniform across the island. There are, however, seasonal spatial differences in projected temperature rises, with the west coast of Tasmania experiencing greater increases during summer (Grose et al. 2010). Increases in temperature are likely to be associated with changes in a number of other climate variables. According to the ACE CRC (2010d: np), temperature increases are likely to result in 'increases in evaporation, decreased average cloud cover, increases in relative humidity and increased winds in spring'.

Mean historical daily temperature from the Bureau of Meteorology high-quality climate site data for Tasmania and projections from downscaled CFT modelling simulations under the A2 and B1 emissions scenarios. The time series plot shows the 11-year moving average the high-quality climate site data (black line), the six-model mean (A2 = bold red line, B1 = bold blue line) and the range of the six models (respective faint lines).

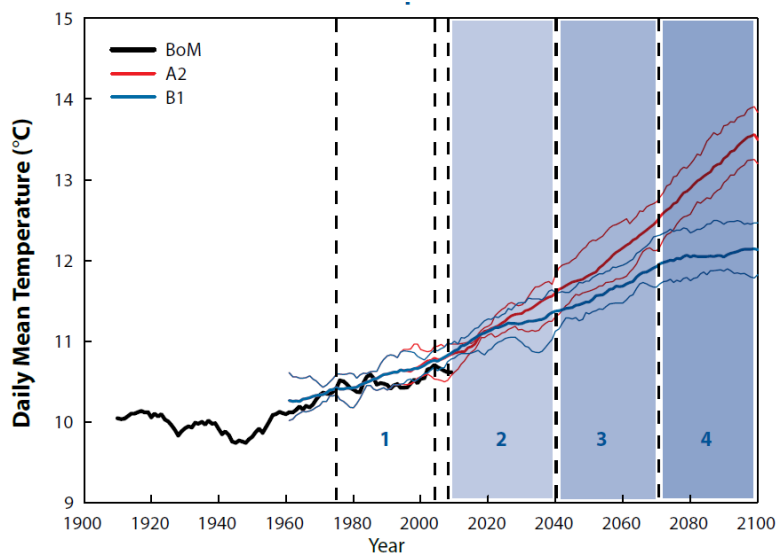


Figure 4. Current and projected air temperature for Tasmania Mean historical daily temperature from the Bureau of Meteorology high-quality climate site data for Tasmania and projections from downscaled CFT modelling simulations under the A2 and B1 emissions scenarios. The time series plot shows the 11-year moving average the high-quality climate site data (black line), the six-model mean (A2 = bold red line, B1 = bold blue line) and the range of the six models (respective faint lines)

Source Figure 6.1 in Grose et al. 2010

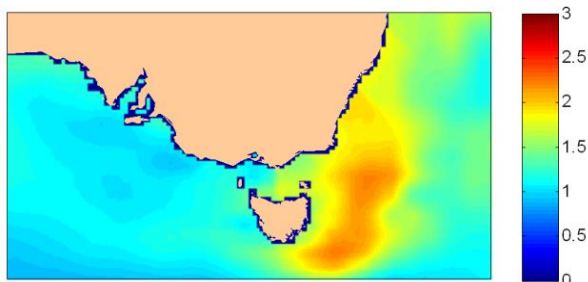


Figure 5. Ensemble average ocean warming for south-east Australia by 2050 relative to 1990

Source: Hobday & Lough, 2011

3.3.1.2 Ocean temperatures

Globally, sea-surface temperatures (SST) have risen by an average of around 0.8° C since 1910 (IPCC 2007b). Increases in ocean temperatures are seasonally, regionally and locally distributed, and consequently the waters around Tasmania are warming at different rates. Significantly, waters off Tasmania's east and north-east coast are warming at a rate almost four times the global average (Holbrook & Bindoff 1997; Ridgway 2007), resulting in the area being recognised as part of a global warming 'hot spot'. Mean SSTs are projected to increase around Tasmania in all seasons by the end of the century (Grose et al. 2010, p.56). Southward extension and strengthening of the east Australian current is likely to result in east coast water temperatures rising by up to 2°C to 3°C by 2070 relative to 1990 levels (see Figure 5, above, and Grose et al. 2010). Increases in SST have already resulted in significant changes to Tasmania's marine biology and biophysical processes, with major implications for both wild fisheries and aquaculture.

3.3.2 Rainfall

Since the 1970s, Tasmania has experienced a general trend of reduced annual average rainfall, and greater year-to-year variability in rainfall (Grose et al. 2010). These trends are projected to continue. The modelling of changes to rainfall carried out by CFT under the A2 (high) emissions scenario suggests a change in the total annual rainfall for Tasmania of less than 100 mm by the end of the 21st century. This minor state-wide change masks significant changes in regional and seasonal rainfall and runoff patterns, which are also affected by temperature and soil dryness (Figure 6).

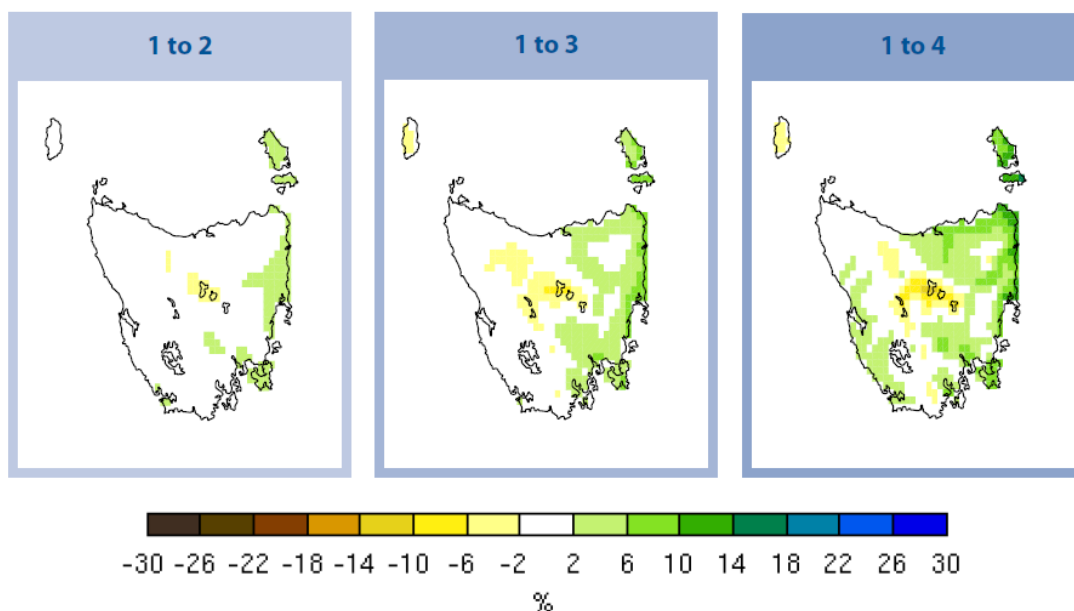


Figure 6 Total annual rainfall projections for Tasmania under the A2 emissions scenario For the six-model-mean proportional change in rainfall between 30-year periods indicated by numerals (1 = 1978-2007, 2 = 2010-2039, 3 = 2040-2069, 4 = 2070-2099). Source: Figure 6.5, Grose et al 2010.

Source Figure 6.5 in Grose et al. 2010

Risbey and O’Kane (2011) highlight that it is currently impossible to provide meaningful sub-regional rainfall projections to 2100 for anywhere in the world, including Tasmania. The CFT’s projections to 2100 should be considered with this proviso in mind, but projections for near- and medium-term can be considered with greater confidence. The CFT project concluded that both emissions scenarios project significant regional differences in rainfall, with ‘a steadily emerging pattern of drying in the central highlands and parts of the north-west, and an increase in rainfall on the east and west coasts’ (Grose et al. 2010, p. 29). This pattern is also seasonal. During summer and autumn, the west coast is anticipated to experience reduced rainfall, while the coastal margin on the east coast will experience increased rainfall. During winter and spring, rainfall in the west is expected to increase, while rainfall in the east is expected to decrease slightly. Lower rainfall across all seasons is likely in the central plateau (Grose et al. 2010, p. 31).

Runoff in Tasmania’s Central Highlands will decrease by 2100, with implications for water resources used in hydro-electricity generation (Bennett et al. 2010). Conversely, it is

anticipated that runoff will increase in certain regions, such as the Midlands and in the Derwent Valley, with potential benefits for agricultural production. In addition to changing seasonal and regional patterns in rainfall, it is anticipated that there will be an increase in extreme rainfall events, with 'more extreme wet days, more intense rainfall and more dry days – that is, less 'average' conditions' (Steffen & Hughes 2011, p. 3).

3.3.3 Extreme weather events

Changes to key climate variables (such as temperature and rainfall) in Tasmania are likely to amplify aspects of existing climate variability, resulting in changes in the intensity and frequency of extreme weather phenomenon and shifts in a number of climate indices (White et al. 2010). Some of these changes are summarised below.

- Tasmania will likely experience more intense rainfall events and a greater number of extreme wet days in the south-west and north-east (White et al. 2010), resulting in an increased risk of localised flooding in these regions. Overall, the number of rain days will decrease for the island as a whole, with the north-west experiencing the brunt of this change. It is projected that there will be increases in periods of both drier and wetter conditions across Tasmania (White et al. 2010).
- For most regions, there will be an increase in the number of summer days (maximum temperatures over 25° C), 'tropical nights' (minimum temperatures over 20° C) and greater frequency of heat waves (where maximum temperatures exceed 28°C for more than three consecutive days) (White et al. 2010). Steffen and Hughes (2011) note that the number of days above 25° C is projected to double or triple and some areas may experience an additional 40 days above 25° C per year by the end of the century. There will also be a concomitant reduction in the frequency of cold waves (where maximum temperatures do not exceed 5° C for three consecutive days), particularly in the central highlands (White et al. 2010). These changes in climate are likely to result in a corresponding increase in the number of fire danger days and associated bushfire risk.
- There is anticipated to be a halving in the incidence of severe frosts, and a shortening of the period of frost risk from March to December, to May to October in many areas (Holz et al et al. . 2010).. Changes to the incidence and timing of frosts are likely to impact on both the natural environment and agricultural production.


3.3.4 Sea-level rise

During the 20th century, global sea levels have risen by around 20cm through thermal expansion and the melting of glaciers and ice sheets (Hunter et al. 2012). This corresponds to an average sea-level rise of around 1.7mm per year, although the rate of sea-level rise is accelerating. From 1993 to 2009 it was recorded as being between 2.8mm and 3.2mm per year (Hunter et al. 2012). Spatial variations in the extent of sea-level rise are thought to be due largely to regional differences in the rate of thermal expansion and salinity levels and the location of sources of melting ice (Hunter et al. 2012). In Tasmania, sea-level rises have been slightly slower than global trends (Steffen & Hughes 2011). Estimations of future sea-level rise are complex, because of the multiple uncertainties surrounding future greenhouse gas levels and emissions trajectories, differences between climate models, and the response

of glaciers and ice caps (Hunter et al. 2012). Based on IPCC modelling, it is anticipated that sea levels will rise by between 0.2m to 0.8m by 2100, while other estimations based on semi-empirical models project greater increases of up to 1.6m by the end of the century (Hunter et al. 2012). In Tasmania, it is estimated that sea levels will rise by around 0.76m by 2100 (TCCO 2012a).

4 RESEARCH FINDINGS BY SECTOR

4.1 Primary Industries

 Key findings – Primary industries	
Climate change impacts	<ul style="list-style-type: none"> ◆ projected temperature increases of up to 2.9C by 2100, although this average may mask changes in overall variability ◆ projected changes in rainfall are less reliable, and may be buffered by wider use of irrigation
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ extreme variability in micro-climates, soils and production systems across the state makes it hard to translate climate impacts into state-wide sectoral impacts ◆ the effects of climate change impacts to demand-side issues and the implications of transformational change are poorly understood
Current adaptation efforts	<ul style="list-style-type: none"> ◆ the plans of government agencies, suppliers, corporate agricultural business and individual farms already reflect the need to respond to climate variability and change
Future options	<ul style="list-style-type: none"> ◆ conditions for particular industries will change over time, so the trade-offs required across agricultural sectors will also need to vary ◆ options analysis needs to take a systems approach that considers industries re-locating to Tasmania, and biosecurity threats under changed climatic conditions
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ understanding how multi-level and indirect impacts of climate change can best be recognised in sector-specific adaptation research for Tasmanian primary industries

This section considers the impact of climate change on Tasmania's agricultural sector, and the sector's response to those impacts. Many of the outcomes reported here are direct or indirect consequences of the *Climate Futures for Tasmania* (CFT) project that was jointly funded by The Tasmanian Government, NCCARF and Hydro Tasmania (ACE CRC 2010d). Follow-on work led to the development of a series of fact sheets for agriculture, produced by the Tasmanian Institute of Agriculture (TIA), in partnership with the Tasmanian Government (see Section 5.1.2 below).

Although there exists a plethora of peer-reviewed articles and research reports about adaptation to climate change in Australia (e.g. Stokes et al. 2008; Stokes & Howden 2010), publications that explicitly relate to Tasmania are rare. This is in spite of Tasmania's

institutions being proactive and highly engaged in the debate (e.g. the Tasmanian Government's (2011) contribution to the Productivity Commission Inquiry into 'Barriers to Effective Climate Change Adaptation'). Most of the articles cited in this review are therefore of a more general nature, unless specifically stated otherwise.

4.1.1 Understanding climate change impacts

The *Climate Futures for Tasmania* (CFT) project provides an excellent starting point to assess the likely physical changes related to climate change that have already occurred and that are likely to occur in the future. Particularly relevant for agriculture, mean annual temperature has increased by 0.1°C per decade since the 1950s. Daily minimum temperatures have increased more than daily maximum temperatures. Total annual rainfall has decreased, with the greatest reduction in autumn.

Average temperatures across the state are projected to increase by around 2.9° C by the end of the century, which is low compared to the rest of Australia (projections are based on the A1FI high emissions SRES scenario). Coupled with the fact that Tasmania has a relatively cool-to-mild and maritime climate, such changes appear to be within the envelope of the adaptive capacity of the agricultural sector. However, care needs to be taken with such projections that are based on likely changes to the average as climate change might result in increases to the overall variability.

Most agricultural systems are particularly sensitive to extreme conditions. This is of particular concern in regard to issues such as damaging frosts that could locally increase even as the underlying average temperatures are increasing (Crimp et al. 2008). Similarly, changes to rainfall variability are important, as the damaging floods of the recent La Niña season (2010/11) have shown (Hart 2011). While changes to rainfall are a lot less certain, Tasmania is in the fortunate position of having access to substantial fresh water reserves for irrigation that can mitigate against possible downwards shifts in rainfall (Gaydon et al. 2012): a fact often quoted is that Tasmania has just over 1% of Australia's agricultural land use, but over 12% of Australia's fresh water reserves. Large irrigation schemes are currently being developed and rolled out to make better use of this valuable resource (<http://www.tasmanianirrigation.com.au/>).

4.1.2 Understanding sectoral vulnerabilities

Tasmania has a strong and diverse agricultural sector that contributes about \$1.15 billion annually to the Tasmanian economy (2009/10 figures). Important sub-sectors include mixed farming enterprises, dairy, fruit, vegetables, red meat, wool (Harle et al. 2007), poppies, pyrethrum and viticulture (Cozzolino et al. 2010) as well as many niche products (TCCO 2012). Translating the impacts of climate change into an assessment of the likely effects on production remains challenging (Stone & Meinke 2006), especially in Tasmania, which is characterised by extreme variability in micro-climates, soils and production systems.

Occupying the coolest and most maritime climate in Australia means that Tasmanian conditions cannot immediately be compared with similar (analogue) locations on the mainland – in many cases they simply don't exist. Tasmania's unique and diverse production systems further complicate the assessment and prediction of climate change impacts on the

various sectors. Tasmania grows crops such as poppies and pyrethrum that cannot be compared to any other production environments (over 50% of all commercially produced alkaloids globally come from Tasmania as well as over 70% of the world's pyrethrum production). Tasmania's current climate is ideal for cool wine production, and the conditions to produce milk on highly productive pastures are amongst the best in the world. Hence, any climatic changes pose an immediate threat to these industries, unless adaptive measures are developed early and are ready for deployment.



Photo 2. Poppy production could increase under climate change Photo: Mark Dowsett

Farmers have been exposed to climate variability (and hence risk) ever since farming was invented; they have always adapted to highly variable and at times changing climates. Changes in temperature and rainfall will impact differently on the various sectors of Tasmania's diverse agriculture industries. However, the translation of climate information into real-life action requires three essential components: salience (the perceived relevance of the information), credibility (the perceived technical quality of the information) and legitimacy (the perceived objectivity of the process by which the information is shared) (Meinke et al. 2006). A culture of resilience and adaptation has already developed in Tasmania. Farmers need to continue to respond to immediate and short-to-medium term climate variability, as well as start preparing for longer-term changes in climate.

A series of information sheets about climate change impacts and opportunities for Tasmanian primary producers has been developed by TIA and the State Government. These information sheets identify climate impacts and opportunities for Tasmanian

agriculture. The series includes an overview (Phelan et al. 2012c) and specific information sheets for: dryland pastures and red meat production (Bridle et al. 2012a); extensive dryland pastures and wool production (Bridle et al. 2012b); irrigated pastures and dairy production (Phelan et al. 2012b); wheat production (cereals, Lisson et al. 2012); wine grape production (Bridle et al. 2012c); special regions and crops (Meander Valley – barley, poppies, pyrethrum, blueberries and hazelnuts under irrigation, Phelan et al. 2012a); and farmer perceptions of climate change (Bridle et al. 2012c). A full set of these fact sheets can be downloaded from www.dpipwe.tas.gov.au/climatechange. Other adaptation research funded by NCCARF in Tasmania focussed mainly on issues such as biodiversity and marine systems, rather than agriculture (NCCARF 2012).

Research to date suggests a range of direct and indirect impacts of climate variability and change on agriculture in the State (Holz et al. 2010). Chill hours are projected to decrease at lower elevations of Tasmania and increase at higher elevations. This may have localised impacts on crops that require a period of cold before they can bud, flower and set fruit. A growing number of warmer days are projected with time. This will impact on the performance of crop types and varieties. For example, by mid-century wine varieties such as cabernet sauvignon are predicted to ripen reliably in some areas, but by 2085 will do so in all wine growing regions of Tasmania.

These projected impacts pose a range of challenges on-farm, across industry sectors, and across markets. Complex systems interactions need to be thought through. For instance, new crop opportunities will need to be carefully managed to avoid the establishment of new pests and weeds in the state. Integration of climate-change with other risk factors, such as market, environmental or social risks is becoming increasingly important and will require active research and support (Howden et al. 2007).

In addition to production or management-related issues, the post-farm gate consequences of climate changes on the entire value chain have not yet been assessed. These can relate to multiple drivers influencing the demand for agricultural produce, such as demographic changes, changes in costs and prices, storage and transport issues and the marketing of often perishable produce.

In addition, the design of policies for risk management in agriculture raises many challenges. These policies range from generating sound, quantitative information on the types of risks and the tools available to deal with them (Maia & Meinke 2010), to creating incentives that encourage farmers to adopt a proactive risk management strategy (Meinke et al. 2009). It is now widely accepted that this requires participatory approaches, whereby farmers become valued members of research teams (e.g. Crimp et al. 2008; Howden et al. 2007; Meinke et al. 2009; Stone & Meinke, 2006).

Changes to the socio-economic conditions of rural enterprises and communities will be inevitable through the introduction of transformational changes (Gaydon et al. 2012; Park et al. 2012). These impacts need to be carefully considered so that benefits can be maximised and potential downsides managed. At a national scale, research into the climate vulnerability of Australian rural communities is just beginning to emerge. Current research is dominated by hazard/impact modelling, drawing on a heritage of managing the risks posed by seasonal climate variability (Nelson et al. 2010a, 2010b). There is a natural tendency to use the same

risk management approach to understand the emergent nature of vulnerability. Nelson et al. (2010a, 2010b) explore the consequences for policy advice of imperfectly examining vulnerability through the lens of an impact/hazard modelling approach to risk management. They show how hazard/impact modelling can be complemented with more holistic measures of adaptive capacity to provide quantitative insights into the vulnerability of Australian rural communities to climate variability and change. Transformational changes usually result in winners and losers. Hence a clear a priori understanding of the likely impact of transformational change is paramount.

4.1.2.1 Existing adaptation efforts

Issues related to climate change are included in most if not all strategic plans (or other planning documents) of Australia's R&D corporations, and where appropriate extension is included. Climate change is also included in the plans of all Government departments (e.g. TCCO 2012a; Tasmanian Government 2011) and some major input suppliers. These include hybrid seed companies, who must breed plants for the new realities. It also includes fertiliser and agricultural chemical companies who are faced with providing inputs in a changed environment where fertiliser efficiency is critical, and new biotic challenges due to changes in generation, time and location of incidence of pests, weeds and diseases are driving new or modified management strategies.

Many corporate agricultural business (Galbreath 2011) and farm plans already reflect an understanding of and need to respond to climate variability and change. For example: the wine industry's selection of varieties (Galbreath 2011); the roll out of irrigation schemes to buffer against future rainfall variability (Gaydon et al. 2010); protecting high value crops via risk management strategies such as netting (for cherries); and breeding for varieties that are best adapted to local climates and stresses (such as barley).

4.1.2.2 Understanding future options

As noted above, there are several projections in the black and grey literature about the likely future impacts of climate change on particular regions. These projections can be used to consider what the possible responses from a manager's or policy maker's perspective could be. Structured systems analysis and simulation modelling combined with some facilitated 'foresighting' can help in the development of responses to such projected changes (Meinke et al. 2009). In this context, it is important to consider the extent to which research on adaptation to climate change in farming systems is different or additional to research on farming systems in a variable climate (Hayman et al. 2012).

Below are some specific examples of such projections and the opportunities and challenges they present

- By 2085, dry land pasture production from ryegrass is projected to increase in some regions of Tasmania, particularly those that are currently temperature limited. Irrigated ryegrass yields are projected to increase by around 20 to 30% by 2040 but thereafter decline to current levels due to increases in the number of hot days during summer months (ACE CRC 2010d). This might allow for an extension of the dairy industry into those regions, particularly if access to irrigation is secured.

- A reduction in drought in the south-east, north-east and south-west and an increase in drought for the central to north-west regions of Tasmania is projected. Hence, the amount and reliability of irrigation water becomes a critically important factor for long-term, strategic business plans (Gaydon et al. 2012).
- Given that most agricultural regions in mainland Australia will be adversely affected by climate change, a relocation of agricultural enterprises to Tasmania is a distinct possibility (Linnenluecke et al. 2011). This could have profound impacts on our local industries. There is evidence that this might already be occurring in both the vegetable and wine industries.
- Changing climate, in particular increasing temperature, will alter the spread and impact of invasive species and predators. Some pests and diseases already present in a region are likely to become more virulent and widespread. In areas where higher temperatures are also coupled with reduced rainfall, a reduction in fungal infections or the preferential promotion of pest predators may occur. For example, the mild Tasmanian climate is currently unsuitable for the Queensland fruit fly. With a warming climate, populations could more easily establish on the Bass Strait islands and then move into the north and eventually across the state (ACE CRC 2010c).

A systems-approach based on bio-physical modelling of the climate – soil – crop – management interface often assists in gaining additional insights into likely consequences of G x E x M (genotype x environment x management) interactions (Crimp et al. 2008; Meinke & Stone 2005). Outcomes of such modelling exercises can be used with agricultural stakeholders to underpin discussions about future management options. This can provide useful discussion support, rather than decision support (Hochman & Carberry 2011; Meinke & Stone 2005; Stone & Meinke 2006).



Photo 3. The amount and reliability of water for irrigation will become increasingly important Photo: Veronica Foale

A realignment of some industries might be required in order to benefit from the market opportunities that emerge through, for instance, earlier or later availability of quality product. Opportunities are mostly likely to emerge slowly, so the immediate and short-term economic impacts are likely to be small and perhaps not even identified as being a result of climate change. Real business opportunities require a confluence of unrelated factors such as market opportunities, skills and reliable value chains. Climate is only one of the critical components that must converge for opportunities to be turned into reality. However, availability of water in Tasmania, coupled with constraints being imposed on water availability in the Murray Darling Basin and other mainland production regions will provide increasing opportunities for Tasmania. Whole new industries could emerge, and although many options are actively debated (e.g. industrial hemp); there is no immediately-obvious large-scale industry. Many of these require large investments in processing capacity, which appears unlikely in the near future given the current economic environment. What is more likely is the emergence of small niche market industries servicing the changing food tastes or the market demands created by the rapidly expanding middle classes in Asia.

In addition to research that can improve on-farm management of climate change risks, research has been undertaken in Tasmania to understand how best to effect behavioural changes more rapidly. Using Tasmania as a case study Fleming and Vanclay (2010) found that discourse analysis is useful in understanding how to affect beliefs, values and behaviours of farmers. Interviews were conducted in 2008 with 63 respondents, including 22 apple growers, 29 dairy farmers and 12 agricultural consultants across Tasmania. The authors identified four specific discourses as being important in shaping farmers' perspectives of climate change and sustainability: money, earth, human responsibility and questioning. They found that each discourse contributed to resistance to changing behaviour in particular ways. An understanding of these discourses might offer an alternative approach to facilitating behaviour change.

4.1.3 Research gaps and future opportunities

Climate change presents threats and opportunities for Tasmania's primary industries sector. The choice of adaptation options needs to recognise the potential for multi-level impacts – across geographical and temporal scales. Allenby and Sarewitz (2011) point out that good local decisions generally don't add up to good global outcomes. Adaptation to climate change involves issues of 'wicked' complexity; what is regarded as either 'smart' or 'dumb' depends on the actors' world views, priorities and ultimately who benefits from a certain type of action and when. Allenby and Sarewitz (2010, p.110) write:


Something that may be unimportant in one area, such as how much atmospheric N is being deposited on agricultural land, may be quite important elsewhere (for example, in an estuary), and one society may be seriously engaged with questions of global climate-change policy while another is simply trying to find enough food and relatively clean water to keep people alive and the economy growing.

Research into how multi-level and indirect impacts can best be recognised in Tasmania would enhance the efficiency, equity and effectiveness of adaptation efforts and should be a cross-cutting priority for primary industries research, as well as for other sectors.

Other specific research gaps have already been identified in NCCARF's National Adaptation Plan for Primary Industries (<http://www.piarn.org.au/about-piarn/national-adaptation-research-plan>). Priorities specifically for Tasmania include:

- understanding trends in variability and the impact and frequency of extreme events (Maia & Meinke 2010);
- evaluating alternative cropping options for a wide range of locations throughout Tasmania; and
- understanding the likely socio-economic and environmental consequences of adaptation options (Lawrence et al. 2012; Meinke et al. 2009; Nelson et al. 2010a, 2010b).

4.2 Terrestrial and freshwater biodiversity

 Key findings – Terrestrial and freshwater biodiversity	
Climate change impacts	<ul style="list-style-type: none"> ◆ historical warming over the past 50 years and a general drying trend and reduction in stream flow since the 1970's ◆ future projections suggest further warming, at rates slightly slower than for mainland Australia, and drying for the east coast
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ climate change represents a significant threat to Tasmania's endemic and refuge fauna (species extinct on the mainland) and associated ecosystems ◆ changes to fire regimes, increased shrub and tree invasion of alpine regions, and changes in runoff will threaten Tasmania's terrestrial and freshwater ecosystems
Current adaptation efforts	<ul style="list-style-type: none"> ◆ government departments have developed a range of planning and management options for Tasmanian species and ecosystems ◆ management of non-climate threats to build ecosystem resilience to climate change is a key element in adaptation planning
Future options	<ul style="list-style-type: none"> ◆ protecting individual species may not be viable under climate change, and a focus on continued delivery of ecosystem services is emerging as a complimentary adaptation strategy ◆ species distribution modelling and limited experiments are informing development of conservation strategies, including reserve design and active interventions, such as translocation
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ determining the effectiveness of reducing non-climate stressors, changing agricultural practices, and fire management for building resilience to climate change ◆ developing policies with regard to Tasmania's role in preserving biodiversity from mainland Australia

This section includes a summary of both freshwater and terrestrial biodiversity impacts and adaptation options for Tasmania and the close islands, but not sub-Antarctic territories (Macquarie Island, Heard Island). The summary reports produced by DPIPWE (DPIPWE

2010a; Gilfedder et al. 2012) provide outstanding recent reviews, and this section draws heavily on these summaries which have synthesised information from many primary publications and from the *Climate Futures for Tasmania* (CFT) project.

4.2.1 Understanding climate change impacts

Tasmania has a temperate climate, with much of the state having a mild summer, and the Central Highland and alpine areas having a cool summer. Annual rainfall ranges from <700 mm to 2,300 mm (DPIPWE 2010a). Most of Tasmania has a wetter winter than summer, with the exception of the east and south-east of Tasmania which have no dominant rainfall season.

Much of Tasmania has experienced a warming in average maximum temperatures since the 1950s, with an average temperature rise of 0.10° C per decade, compared to 0.16° C per decade average rise for Australia as a whole (Grose et al. 2010). Since 1970, there have been strong decreases in rainfall across Tasmania, typically around 20 to 40 mm per decade (DPIPWE 2010a). Most of Tasmania experienced the three driest years on record in 2006-2008. Decreased rainfall leads to decreased stream flow, and stream gauge sites in Tasmania show a 15 to 30% reduction in stream flow over the last 15 years compared to historic records. The decrease in stream flow in turn leads to an increase in water temperature in small pools. There is anecdotal evidence for a reduction in the amount and duration of snow in the Tasmanian alpine regions in the past few decades but historical data is not available for Tasmanian snowfields. Sea level has risen 10 to 20 cm in the last century, including a 14 cm rise on the south-east Tasmanian coast.

The *Climate Futures for Tasmania* (CFT) project produced fine-scale dynamically downscaled projections (resolution ~10 km) based on six IPCC AR4 climate simulation models (Corney et al. 2010). The CFT projections are the highest resolution for Australia, and have provided a unique resource for climate scale planning in Tasmania. Over the coming decades Tasmania is expected to experience increased land and sea temperatures, changes to rainfall patterns and higher evaporation in most areas, wind speed changes; and sea level rises. The range of projected mean temperature rises for Tasmania to 2100 (1.6° C to 2.9° C) are lower than the projected globally-averaged mean temperature rises (1.8° C to 3.4° C) (Grose et al. 2010).

Climate change is likely to lead to ecosystem changes, including transformed and novel ecosystems, and local species extinctions. Changes such as decreased rainfall and increased temperature, and increased frequency of extreme events such as drought, storm surges, and fire, will variably impact on biodiversity in different regions in Tasmania. Tasmania's natural values are already affected by a range of threats and disturbance regimes such as fire, weeds and diseases – climate change may exacerbate these or lead to complex and cumulative interactions.

Tasmania has been isolated from the Australian mainland for the last 10,000 years, and supports a wide variety of plants and animals. Tasmania contains a wide range of rock types, landforms and soils. Climate change will impact on geomorphic process, landforms and soil systems both directly and indirectly, with fluvial (rivers, lakes and wetlands) and

coastal/estuarine (particularly soft, sandy coasts) systems likely to be impacted most significantly. Climate-induced changes to rainfall intensity, vegetation cover, fire frequency and intensity, and windstorm intensity all have the potential to impact on soils leading to changes in soil hydrology, soil organic carbon, salinity, erosion and sedimentation. Since soils form a critical link between landforms and vegetation type, provide valuable ecosystem services, influence vegetation health, and moderate infiltration and runoff, impacts on soils represent a key process in understanding broader climate change impacts.

4.2.2 Understanding sectoral vulnerabilities

Tasmania has been described as one of Australia's large regional hotspots of botanical diversity and endemism, with elements of biodiversity and geological diversity that reflect southern biogeographic and Gondwanan affinities (DPIPWE 2010a). There are approximately 1,900 native plant species, 34 native terrestrial mammals, 159 resident terrestrial species of birds, 21 land reptiles, 11 amphibians and 44 freshwater fish. Many of the Gondwanan elements are endemic to Tasmania – 20% of the flowering plant species are found nowhere else, and these endemics tend to be concentrated in alpine and rainforest environments in western Tasmania. High levels of endemism can also be found in invertebrate taxa (up to 100% for some groups) and for freshwater fish, with these endemics concentrated in western and central Tasmania (DPIPWE 2010a).

Tasmania has provided a refuge for species that have either died out or are threatened with extinction on the Australian mainland, and it has been protected from most of the introduced animal species that have so greatly affected the flora and fauna of mainland Australia. The dingo is absent, and feral goats and pigs have restricted distributions in Tasmania, however, the recent introduction of the fox is considered a major threat to native wildlife and an eradication program is underway (Dennis 2002). Reintroduction of the Tasmanian Bettong from Tasmania to mainland Australia (www.mfgowoodlandexperiment.org.au/bettong.html) has also demonstrated the value of Tasmania as a refuge for threatened species. Several other species may also be the focus of such reintroduction programs in the future. The other stressors to biodiversity in Tasmania include fire, invasive species, wildlife disease and pathogens, and landscape change as a result of anthropogenic activities (DPIPWE 2010a).

Over 40% of the state is protected in reserves, including the Tasmanian Wilderness and Macquarie Island World Heritage areas (DPIPWE 2010a), and so non-climate threats to biodiversity might be considered lower than elsewhere in Australia. However, more than 600 species of plant and animal are listed under Tasmania's Threatened Species Protection Act 1995, and climate change is likely to exacerbate some existing threats.

Terrestrial ecosystems considered potentially highly vulnerable include alpine ecosystems, moorlands and peatlands, particularly to altered fire regimes (Sharples 2011). Increased shrub and tree invasion in these ecosystems could lead to significantly transformed ecosystems, including increased fuel loads (DPIPWE 2010a). In addition, Tasmanian moorlands and peatlands may shift from accumulating carbon to releasing carbon into the atmosphere. Species distribution modelling has shown that moorland fauna such as the broad-toothed rat and burrowing crayfish are sensitive to climate change and may have reduced distribution in the future (DPIPWE 2010a).



Photo 4. The Burrowing Crayfish may have reduced distribution in the future Photo: Thomas-Stromberg

Species with restricted ranges such as mountain tops or low-lying islands and coasts, or those with life strategies or specialised habitats and ecological requirements are also at risk to the impacts of climate change (DPIPWE 2010a). Loss of some species is also projected under climate change, with the decline of the Central Plateau endemic miena cider gum (*Eucalyptus gunnii* subsp. *divaricata*) the best known Tasmanian case study (DPIPWE 2010a) It is sensitive to the effects of drought, which has led to the death of mature trees in relatively large patches since the mid 1990s. The species is listed as endangered under state and federal legislation.

Tasmania's freshwater ecosystems are also considered to be vulnerable to climate change as a result of changes in rainfall and to human demands for declining water resources

(DPIPWE 2010a). Reductions in rainfall and runoff have the potential to reduce the amount of suitable habitat available for aquatic species, as flows decline and parts of river systems are either reduced to pools or dry up. Freshwaters on Tasmania's Central Plateau will experience the most significant declines in runoff, with average projected decreases of between 15 and 35% by 2100. Lakes in the Central Plateau region support six endemic fish species, all likely to be affected by climate change in addition to significant existing stressors (Morrongiello et al. 2011). Declining water flows are also exacerbated by rising water temperatures, which may be significant for some species (e.g. giant crayfish). Tasmania's 'swamp forests' are another freshwater ecosystem that will be potentially affected by climate change and associated sea level rise (DPIPWE 2010a).

Potential impacts for a range of species, habitats and ecosystems are summarised by Gilfedder et al. (2012). These are based on limited Tasmanian-specific research and thus largely on parallels with national and internationally similar systems.

Impacts on plant species include:

- changes to timing and success of germination, recruitment, and establishment processes;
- changes in native species composition (e.g. species re-sorting);
- changes to species' habitat (e.g. changed fire regimes, changed soil hydrology, flooding);
- changes in species' geographic distributions; and
- increased pests that will prey on, or compete with, native plant species.

Impacts on animal species include:

- thermal tolerance of some species being exceeded;
- changes to species' habitat (e.g. changed fire regimes) affecting breeding success and survival;
- changes to species interactions and communities;
- changes in extent of some communities (due to direct impacts of climate change as well as indirect impacts relating to changed land use);
- reduced health/resilience of some communities;
- changes to disturbance regimes affecting component species and processes;
- release thresholds for some species being crossed, leading to changes to community type (e.g. buttongrass succession to dry forest);
- changed timing of seasonal events (e.g. flooding, burning, fish spawning) and potential mismatches in timing between species; and
- increased spread of pests and pathogens.

Changes to ecosystem structure and function include:

- changes in nutrient status of soils or changes to nutrient cycling;
- decreased opportunities for recruitment events reducing long-term ecosystem persistence;
- changes to structural dominants;

- changes to hydrological processes;
- changes to perenniality/ephemerality; and
- potential loss of key species, which may affect ecosystem processes.

Coastal wetlands will be particularly vulnerable to changes in hydrology and the impacts of sea level rise. Climate change influences on bushfires in Tasmania may have a significant negative impact on the natural environment by liberating stores of carbon in the soils and vegetation. One of the most significant contributions that Tasmania can make to the level of global atmospheric greenhouse gases is to ensure that natural carbon stores are also protected from catastrophic natural events and uncontrolled releases of the carbon they contain (TCCO 2008).

4.2.3 Existing adaptation efforts

The terrestrial biodiversity sector has benefitted from a number of government-led strategic planning documents (DPIPWE 2010a; Gilfedder et al. 2012) identifying areas for attention with regard to adaptation, including the World Heritage Areas (Sharples 2011) and prioritising ongoing monitoring (RMC 2012). The DPIPWE (2010a) review identified four adaptation priorities for marine, terrestrial and freshwater systems:

1. Ensuring scientific research provides a firm foundation for taking action in different regions and different sectors by measuring and predicting climate change and identifying new approaches.
2. Giving individuals, communities and businesses appropriate information, resources, skills and incentives to plan and adapt to climate change and manage their own risks.
3. Providing an adequate and appropriate emergency response to more frequent and intense events, such as bushfires, floods and storms, and assisting communities to recover from such events.
4. Managing risks to public infrastructure, assets and values (including roads, biodiversity, national parks and reserves), and protecting industry and the community against health and bio-security risks.

It is not clear whether these have guided research outside the state agency, as funding for external scientists has been limited. Partnerships between state and university researchers have been established which should see the perspectives of the government agencies guiding research efforts.

Existing adaptation for terrestrial biodiversity, particularly landscapes, has focussed on reduction of existing threats (Dunlop & Brown 2008). Gilfedder et al. (2012) emphasise the importance of minimising current threats and disturbances (e.g. from fire, pests, weeds, disease and inappropriate land management) as a foundation for future adaptation in all ecosystems. Other conservation adaptation goals identified for ecosystems in general included:

- protect and maintain connectivity (especially for species whose current location may become unsuitable);
- facilitate species movement;
- identify and protect contemporary and future refuges;

- minimise the impacts of current threats and land-use change, including through creation and protection of 'no go' areas in which access would be controlled to protect particularly fragile and vulnerable species and ecosystems;
- protect, maintain and increase extent of habitat, including restoration of degraded habitat; and,
- protect keystone species.

Gilfedder et al. (2012) provide more detail on adaptation options for terrestrial and freshwater systems. A measure of last resort for Tasmanian plants, *ex situ* conservation, has also been initiated in Tasmania, with collaboration between DPIPWE, Tasmanian Botanical Gardens and the Kew Gardens Millennium seed bank (DPIPWE 2010a).

The National Environmental Research Program Landscapes and Policy hub is developing tools, techniques and policy options to integrate biodiversity into regional scale planning using the Tasmanian midlands as a case study (see: <http://dev.nerplandscapes.edu.au/home>). On-going projects with outcomes relevant to Tasmania are listed in Table . The results are expected in 2013.

Table 4. Ongoing research relevant to Tasmania

Title	Objectives
<p>The TasFACE Project</p> <p>Mark Hovenden (University of Tasmania)</p>	<p>TasFACE (Free Air CO₂ Enrichment Facility) is a state of the art facility for investigating the impact of global climate change on an intact native grassland at Pontville, just north of Hobart, Tasmania, Australia.</p> <p>The experiment investigates the way that increasing temperature and atmospheric carbon dioxide concentrations affect the growth and nature of an ecosystem important from both an agricultural and conservation point of view. Investigations going on in the experiment cover the whole range of possible impacts from the growth, physiology and reproduction of individual species to community interactions and ecosystem level processes such as nutrient cycling and pasture feed quality.</p> <p>(http://www.utas.edu.au/plant-science/about/facilities/tasface)</p>
<p>Contributing to a sustainable future for Australia's biodiversity under climate change: conservation goals for dynamic management of ecosystems.</p> <p>Michael Dunlop (CSIRO Climate Adaptation Flagship)</p>	<p>The objectives of this project are to:</p> <ol style="list-style-type: none"> 1. Review existing conservation and NRM goals and objectives in Australia as set out in legislation, policies, strategies, plans and other documents relevant to national, state and territory, and regional scales and how these inform investment in conservation. 2. Explore the implications of climate change for the effectiveness of existing goals based on the underpinning conservation and ecological theory and observed and projected climate and ecological changes (using available existing environmental and ecological projections). 3. Identify existing, revised and new goals and objectives that might be achievable under climate change to conserve Australia's terrestrial and freshwater biological heritage and ecosystem services, through prioritised, focussed case studies with relevant conservation agencies (policy and management), NRM bodies and private organisations (i.e., that may reflect contrasting values for biodiversity). 4. Communicate the outcomes of the research to these stakeholders and provide tools (e.g., conceptual models, adaptation guidelines) for decision- and policy-makers who are preparing to act on the implications of climate change by transforming goals and objectives. <p>(http://www.nccarf.edu.au/content/contributing-sustainable-future-australias-biodiversity-under-climate-change-conservation)</p>

Title	Objectives
<p>Identification and characterisation of freshwater refugia in the face of climate change</p> <p>Jeremy VanDerWal (James Cook University)</p>	<p>Objectives</p> <p>A) identify, characterise and map the biophysical environments that will enhance the persistence of freshwater biodiversity across Australia providing an invaluable resource to better inform climate change adaptation actions; and</p> <p>B) inform the selection and implementation of appropriate adaptation actions for the protection of freshwater refugia.</p> <p>Freshwater ecosystems have very high biodiversity relative to their areal extent. They are particularly vulnerable to climate change because of their limited extent, their limited connectivity and, in much of Australia, their susceptibility to drying resulting from the vagaries of temperature and rainfall. The possible impacts of climate change on fresh waters must be assessed in relation to changes in both temperature and riverine networks (e.g., flow and linear connectivity) and their interactions with existing stressors (e.g., impoundments, agriculture, urbanization) and the surrounding landscape (e.g., topographic features and riparian vegetation). Here we propose to:</p> <ol style="list-style-type: none"> 1. Define a typology of refugia for freshwater ecosystems. <p>This will include a literature review in addition to a PI and stakeholder workshop to identify, review and synthesise existing knowledge on the biophysical attributes of freshwater ecosystems that are likely to act as refugia that will enhance the persistence of freshwater biodiversity into the future.</p> <ol style="list-style-type: none"> 2. Identify the spatiotemporal extent and quality of freshwater refugia under a range of future climate scenarios. <p>This will bring together knowledge, data, novel analysis and state-of-the-art modelling techniques to identify the location, extent and quality of freshwater refugia now and into the future. This will be done, where possible, across Australia at spatial and temporal scales necessary to inform adaptation actions at the local, catchment and regional scales. Calibration and validation of refugia identification will utilise biodiversity datasets in several fine-scale case studies across the country.</p> <ol style="list-style-type: none"> 3. Inform the selection and implementation of appropriate adaptation actions for the protection of freshwater refugia <p>Using a consistent approach across Australia, a decision tree and broad spatial optimisation framework will be created to inform the selection and implementation of appropriate adaptation actions to protect and enhance freshwater refugia at catchment and regional scales under a range of scenarios.</p> <p>(http://www.nccarf.edu.au/content/identification-and-characterization-freshwater-refugia-face-climate-change)</p>

4.2.4 Understanding future options

Future responses to climate change, and hence some of the response options have been explored with experimental systems and species distribution modelling. Using experimental systems such as the free CO₂ (FACE) system has shown that some species will be advantaged by climate change, while others will not (Hovenden et al. 2006; Williams et al. 2007). Species distribution modelling has been important in identifying future distribution and refugia (e.g. Prober et al. 2012).

Results from these and other studies suggest that future conservation goals may need to be revised. Prober and Dunlop (2011) suggest it will be important to shift our focus from preserving species and current species composition towards maintaining ecological and evolutionary processes.

Establishing new conservation reserves is a key management response to promote the persistence of biodiversity under climate change. Mokany et al. (2013) simulated a number of reserve design strategies for Tasmania using a dynamic macroecological modelling approach to compare the outcomes under climate change for plant biodiversity in Tasmania (a set of 2051 species). The most effective reserve design strategy under climate change depended on the specific conservation goal and demonstrated that adherence to a single habitat configuration strategy, such as connectivity, is unlikely to result in the best outcomes for biodiversity under climate change. The best reserve design strategy under climate change will vary between regions due to unique combinations of attributes and between taxa due to contrasting dispersal abilities. More quantitative assessments are required to identify Tasmania's reserve configurations that will best retain the biodiversity of each region under climate change.



Photo 5. Movement of grazing animals into alpine areas will change vegetation patterns
Photo: Patrick Medved

The future options will include selection of a combination of passive (e.g. reduce stressors) and active management (e.g. translocation). The balance of these will differ by region and ecosystem – tools to select these options are needed. In freshwater systems for example, translocation of species and control of invasive species are considered the main active adaptations. Reducing impacts of water consumption and protecting or restoring connectivity and refugia are examples of passive adaptations for conservation of freshwater ecosystems (Jenkins et al. 2011; Morrongiello et al. 2011). Development of holistic catchment impact and management plans (e.g. NRM South Tasman Catchment Report) will form a baseline for planning climate adaptation.

Monitoring change in terrestrial systems is underway in Tasmania, particularly in World Heritage areas (RMC 2012), and for iconic alpine species (e.g. pines, Fitzgerald 2011).

The availability of the Climate Futures Tasmania model projections has supported development of an adaptation planning framework for freshwater biodiversity. Barmuta et al. (2012) investigated how these projections could be coupled with more detailed hydrological models and freshwater biodiversity data to evaluate adaptation actions at local, regional and state scales for Tasmania, and to explore how adaptation priorities might be set. This research showed that downscaled climate modelling, linked with modelling of catchment and hydrological processes, led to improved projections for climate-driven risks to aquatic environments, allowing for comparisons between biodiversity assets. These projections at a river scale allowed visualization of regions that differed in climate-related risk (Figure 7).

The framework developed in this project for using and downscaling outputs from improved global climate models allow for improved and timely modelling, but projections are still dependent on the underlying biological data. In the freshwater systems investigated by Barmuta et al. (2012), improved data on thermal tolerances of freshwater biota are also needed. Climate model output may not represent the suite of variables needed for biological modelling, and so improved methods for predicting key variables from say, air temperature are also needed. In the case of freshwater systems, projections also need improved and high quality biodiversity data sets, and better spatially explicit information on the contributions of groundwater to surface waters and rates of recharge.

A range of adaptation options in four classes were derived to enhance the resilience of freshwater systems to climate change, including:

- direct interventions with in-stream, riparian or wetland habitats, such as fencing to exclude farm stock;
- water management options including dam management strategies or trading in water licenses;
- catchment management options including incentives for changes to farm management or incentives for riparian management; and,
- policy options that impact water or biodiversity management in freshwater environments, including management of freshwater fisheries or Ramsar listing of wetlands.

Organising these options by assessment of costs, benefits, feasibility and social acceptability should help with setting priorities (Barmuta et al. 2012). The next stage for Tasmanian water managers and users is to evaluate the range of options, and meet the challenge of water management for both biodiversity and human usage.

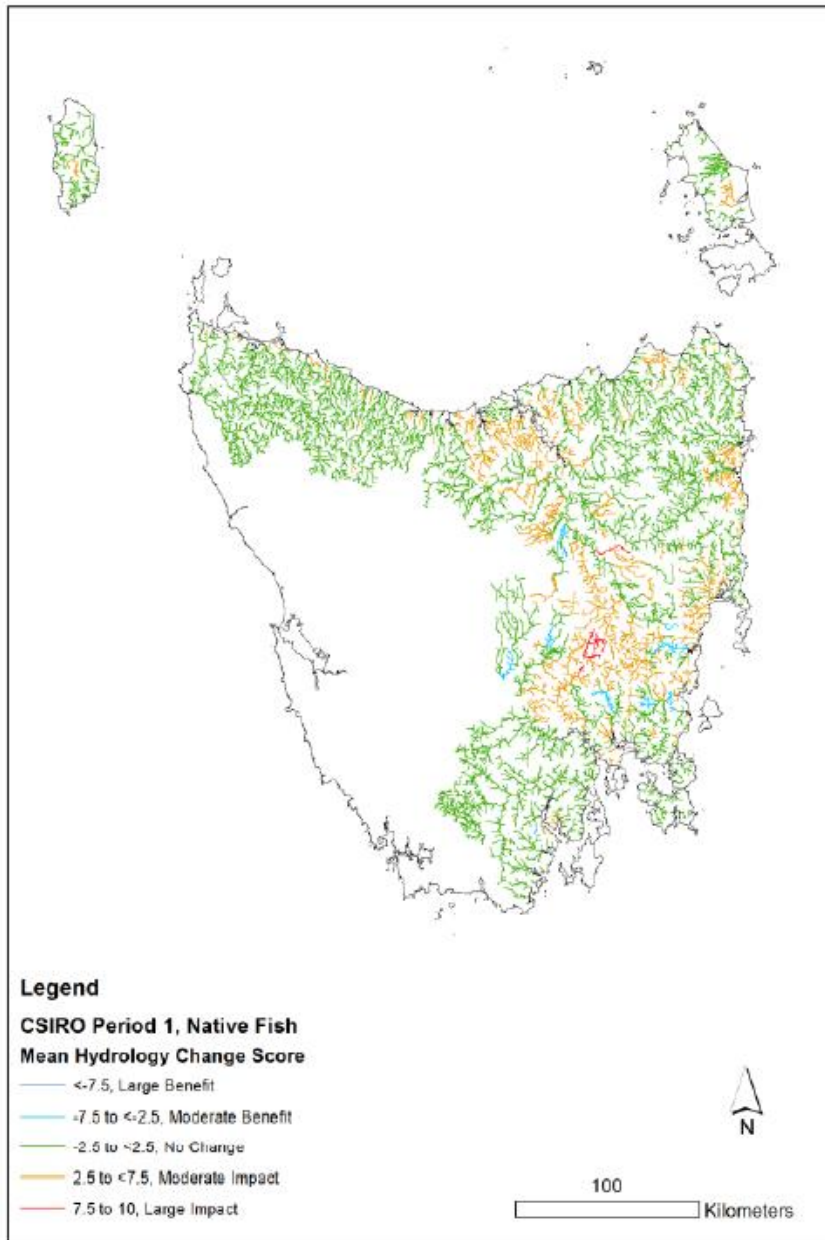


Figure 7. Hydrological risks to native fish condition where blue indicates a positive impact and red indicates a negative impact (original Figure 15 in Barmuta et al 2012)

4.2.5 Research gaps and future opportunities

Research on the impacts of climate change on Tasmanian terrestrial and freshwater species will continue to guide adaptation planning. However, given the number of species (e.g. 1,900 plants, 44 fresh water fish, 34 mammals), it is impossible to follow an ‘impact to adaptation’ pathway for most species. Priority species should continue to be those that are known to be threatened or vulnerable to existing threats. Vulnerability assessments based on coarse

taxonomic groupings, or the limited available data can also direct particular attention to some species, but again dedicated impacts research might take many years to complete. Even without proof of climate impact, some testing of adaptation options can occur now. For example, studies evaluating the success of translocations to higher mountains to provide altitudinal refuge could be undertaken, building both the skill base of researchers and managers, and providing insurance populations for restricted species. This will require some more effort into distribution mapping, both of species, ecosystems and landscape stressors. Together, these approaches will help identify regions of Tasmania where opportunities for improved outcomes exist.

However, just as a complete set of species-level studies cannot underpin timely adaptation planning and action for Tasmanian biodiversity, so too is species-by-species implementation of adaptation options unrealistic and undesirable. This reality is reflected in recent calls for a shift in focus from individual species management to an ecosystem-level approach (Prober & Dunlop 2011). Thus, research on impacts and adaptation options for whole systems, while limited, are a priority. Research gaps at this scale include:

- determining the advantage of reducing the non-climate stressors on species and landscapes. For example, does improved water flow lead to more resilient watersheds, that can better cope with climate related trends and extremes?
- how should agricultural practices (such as wind breaks) and rotation of livestock be managed to increase biodiversity outcomes.
- how should fire management practices consider biodiversity impacts. Current debates around burning off to protect infrastructure and conservation management will intensify as dangerous fire weather days become more frequent.


Finally, adaptation to climate change in Tasmania cannot be considered in isolation, as Tasmania will both gain and lose species. Tasmania will be a natural refuge for some species, including those that can cross Bass Strait autonomously, but directed translocations are also an option, both from and to Tasmania. Policy may need to be updated to accommodate or prevent proposed translocation adaptation options, and will need to address questions such as:

- Should Tasmania be a refuge for mainland Australia?
- What species should be accepted as climate refugees to Tasmania?

In preparing adaptation options, it is important to consider the community support for a range of options, and social research is needed to determine where extension and education will be needed to overcome barriers to some adaptation options.

Lessons learned from Tasmania's terrestrial and freshwater environments could be extended to other regions in Australia, where stressors are less easily manipulated (e.g. water flow management).

4.3 Marine biodiversity and resources

 Key findings – Marine biodiversity and resources	
Climate change impacts	<ul style="list-style-type: none"> ◆ The east coast of Tasmania is part of a global warming hotspot where the rate of ocean warming is about four times above the global average. ◆ The East Australia Current has strengthened, carrying warmer water southward which, with the background warming, has led to many new species extending their range into Tasmania.
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ Changes in species composition have led to declines in marine productivity and generally negative effects. ◆ Increased availability of northern fish species has been welcomed by recreational fishers. ◆ In some regions, aquaculture is experiencing production impacts due to warming waters and the presence of novel species, including blooming algal species.
Current adaptation efforts	<ul style="list-style-type: none"> ◆ Reduction of non-climate threats through fisheries management and marine protected areas has been a focus. ◆ Recognition of climate threats has led to changes in management by fisheries and aquaculture and limited experiments with translocation and ecosystem-based management, such as protection of large predators.
Future options	<ul style="list-style-type: none"> ◆ Arrival of new species will offer some new opportunities for commercial and recreational fishers, although declines in productivity mean these arrivals are not likely to offset losses. ◆ Identification and protection of 'refuge areas', careful use of management options such as translocation, and reduction of non-climate stressors will all be important strategies.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ The focus on ocean warming as the prime driver of change in Tasmania's marine environment should be complemented by additional targeted research on ocean acidification. ◆ Development of strategies to respond to observed change are being developed, but additional simulation testing can further inform stakeholders about their response options.

4.3.1 Understanding climate change impacts

Tasmania lies at the intersection of three ocean currents – the warm southward flowing east Australia Current along the east coast, the southward flowing Zeehan (or Leeuwin current) on the west coast, and the circumpolar flow of southern ocean waters (Cresswell 2000). These currents are responsible for the movement of heat, nutrients, and a range of species to Tasmanian waters. The east coast of Tasmania has warmed at almost four times the global average rate (Holbrook & Bindoff 1997; Ridgway 2007). Reports of this rapid warming led to recognition of the south-east Australia marine region as one of about two dozen global marine ‘hotspots’ – where warming is in the fastest 10% of regions worldwide (Hobday & Pecl in press).

Marine research in this area has a long history. Time series are available of various physical and biological parameters essential for a detailed understanding of physical properties of the ocean and to identify trends and changes in these properties (Lough & Hobday 2011). Between the 1940s and 1970s, some 45 coastal monitoring stations were established around Australia. By 2000, only three monitoring sites remained, including one located off the east coast of Tasmania close to Maria Island. Oceanographic analyses based on this time series and nearby data showed that over recent decades, Australia’s south-east marine waters have warmed rapidly (Holbrook & Bindoff 1997; Ridgway 2007) as a result of increased southward penetration of the East Australia Current (EAC) (Ridgway 2007). Satellite altimetry (post-1990) together with *in situ* subsurface temperature and salinity measurements suggested that the EAC extension is likely to be due to the decadal-scale ‘spin-up’ of the South Pacific Gyre (Roemmich et al. 2007). Furthermore, ocean modelling studies suggested that the spin-up of the gyre is caused, in part, by the combination of greenhouse warming and ozone depletion (Cai 2006; Cai et al. 2005).

Average sea surface temperatures in this region are projected to be 2 to 3° C higher than the 1990–2000 average by 2050 (Hobday & Lough 2011), due in part to increased southward flow of the EAC (Cai et al. 2005). Inter-annual variability (e.g., El Niño – Southern Oscillation (Holbrook et al. 2012)) also results in warmer than average marine conditions in some years and can affect fishery production and profits (e.g. salmon, Battaglione et al. 2008). Thus, operating in a warmer ocean climate is both a current and a long-term challenge for many marine users and industries (Hobday et al. 2008).

Changes in other ocean variables also have an impact on Tasmanian marine waters, but temperature and ocean circulation are the dominant factors reported to date (Lough & Hobday 2011). Ocean acidification may be important in future, but no impacts have been detected in our region (Poloczanska et al. 2012a). To the south, changes in phytoplankton species composition have been attributed to ocean acidification (Cubillos et al. 2007).

There have been documented changes at most levels of the marine food chain in south-east Australia (Frusher et al. in press). In Tasmania, changes include poleward range shifts for 50% of intertidal invertebrates (Pitt et al. 2010); the sub-tidal urchin *Centrostephanus rodgersii* (Ling et al. 2009a; Ling et al. 2009b); over 45 coastal fish species (Last et al. 2011); phytoplankton (Hallegraeff 2010; McLeod et al. 2012a; Thompson et al. 2009); and several

zooplankton species (Johnson et al. 2011). There have also been changes in recruitment in lobster populations (Pecl et al. 2009) and regional changes in prey availability for small pelagic fishes (McLeod et al. 2012b), which may have changed the relative abundance and distribution of small pelagic fishes such as jack mackerel and redbait.

Observational evidence from commercial and recreational fishers reporting sightings of species that were new to southern waters has become common, even if climate change is not seen as the driver of change (Nurse-Bray et al. 2012). However, many commercial fishers now realise that their target species may be potentially vulnerable to climate related changes.



Photo 6. The value of the seafood industry makes the impacts of climate change a major concern Photo: Alistair Hobday

4.3.2 Understanding sectoral vulnerabilities

These changes in distribution and abundance have an impact on fisheries, conservation and aquaculture (e.g. Madin et al. 2012). Fisheries impacts garner much of the attention (e.g. Hobday et al. 2008). Australia's fishery production (wild and aquaculture) was worth \$2.18 billion in 2009–10 (ABARES 2011). Tasmania accounted for the largest share of gross value of production (26%), followed by South Australia (18%) and Western Australia (17%). In Tasmania, seafood contributes over a third of the state's overall agricultural production, and so impacts of climate change are of particular concern. Additional statistics for seafood value by species are available from ABARES (2011).

4.3.2.1 Recreational fishing

Recreational fishing is a major activity with nearly 28% of Tasmanians actively involved (Henry & Lyle 2003). The sector is anticipating the increased occurrence or arrival of sought-after recreational species such as yellowfin tuna, marlin, pink snapper, king george whiting, and yellowtail kingfish. Declines in availability of popular species such as rock lobster, abalone, and striped trumpeter have been attributed to commercial overfishing, rather than recreational impact, or climate change.

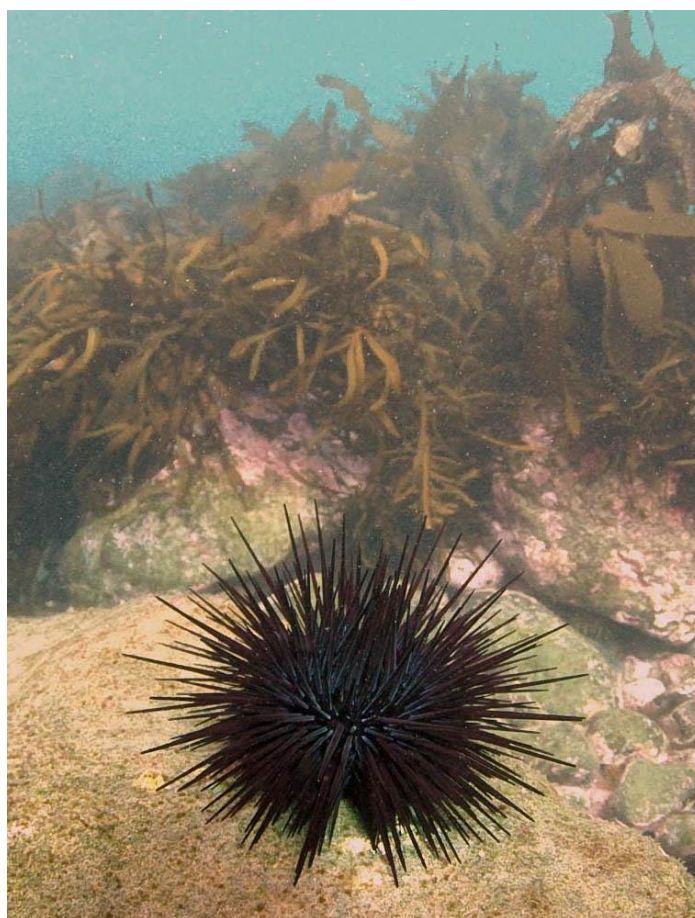
4.3.2.2 Marine biodiversity

Global climate change is predicted to have major negative impacts on biodiversity, particularly if important habitat modifying species undergo range shifts. Changes to marine habitats and biodiversity are best understood for the east coast of Tasmania, where sea urchin-induced changes to sub-tidal habitat have received wide attention (Ling 2008; Ling et al. 2009a, 2009b). The sea urchin *Centrostephanus rodgersii* has recently undergone poleward range expansion to relatively cool, macroalgal-dominated rocky reefs of eastern Tasmania. In high densities, this species creates 'barrens' – habitat grazed free of macroalgae, which can impact on local fisheries productivity (Johnson et al. 2011). The faunal community of the barrens habitat is overwhelmingly impoverished.

Ling (2008) reported that only 72 surveyed species were present within incipient barrens, compared with 221 within intact macroalgal beds. Options for managing or reversing these impacts have been proposed, and include translocation of large predators (Casper et al. 2011; Green et al. 2010) and creation of marine reserves (Ling & Johnson 2012). Limited economic analysis shows that Tasmanian fisheries, particularly abalone, may be vulnerable without adaptation efforts (Norman-Lopez et al. 2011).

Marine tourism in Tasmania includes recreational fishing and diving opportunities, as well as limited iconic animal viewing (whales, seals, seabirds). Evidence elsewhere suggests that some of these iconic species will be winners and others losers as a result of climate change (see Marine Report Card by Poloczanska 2009, seabirds, mammals; Chambers et al. 2011).

Photo 7. Poleward range expansion of *Centrostephanus rodgersii* creates species 'barrens' Photo: Scott Ling



4.3.2.3 *Wild fisheries*

The target species in Tasmania's most valuable wild fishery, southern rock lobster, are potentially vulnerable to climate change due to their very long larval duration (up to 24 months) and thus to changes in currents, and to their dependence on a habitat type impacted by the range-extending urchin *Centrostephanus* (Johnson et al. 2011; Pecl et al. 2009). There is a negative correlation between observed larval settlement and rising temperatures, suggesting that stock size may be lower in future. There is also increased lobster mortality in traps due to octopus predation (Pecl et al. 2009) which is projected to increase in future as octopuses are advantaged by a warming ocean (Andre et al. 2010).

Risk assessment of a number of other Tasmanian fishery species (Pecl et al. 2011) is also guiding more detailed assessment of impacts and adaptation options (e.g. the SEAP NARP project noted in Table below).

4.3.2.4 *Aquaculture*

The Tasmanian aquaculture industry is dominated in volume and value by the cage-based Atlantic salmon industry, which has grown from establishment in 1984 to now represent Australia's most valuable seafood industry (ABARES 2011). Australian salmonid production increased from 14, 673 tonnes in 2000–01 to 31, 915 tonnes in 2009–10 (117% growth), almost entirely due to production in Tasmania. In 2009–10, Tasmania produced 30, 950 tonnes of salmonids, accounting for 97% of Australian total salmonid production. The remaining 965 tonnes were produced in New South Wales and Victoria. The value of salmonid production rose by 13% (\$43 million) in 2009–10 to \$369.1 million. This increase was driven mainly by a 14% (\$43.2 million) increase in the value of Tasmanian salmonids production, with Tasmania's total production accounting for 98% of the total value. Additional expansion in volume and farm sites is underway and planned over the next decade. In Tasmania, the salmonid industry is an important regional employer.

Salmon are produced in land-based hatcheries, grown in ponds for 6–12 months, and then moved to coastal sea cages for the final two years of production. These sea cages are located in sheltered embayments, and are influenced by open ocean conditions, terrestrial freshwater runoff and air temperatures. Fish health and growth are both strongly influenced by ocean temperatures, with salmon in some Tasmanian regions grown in waters approaching their upper critical temperature range (>20°C) in summer (Battaglione et al. 2008). High summer temperatures pose a significant risk to the production systems of these farms, and even more so in the future given projected temperature increases under climate change in this climate hotspot. Under climate change this upper thermal limit is predicted to be exceeded more frequently, particularly in south-east Australia (Hobday & Lough 2011), which could lead to degraded fish health, increased disease outbreaks and mortality (Battaglione et al. 2008).

Other aquaculture industries in Tasmania include land-based abalone farming and rack-based mussel and oyster production. The land-based abalone farms are considered less vulnerable to climate change (Doubleday et al. 2013), while the mussel and oyster farms are at risk from extreme rainfall events, which lead to sudden declines in salinity, and the warming and stratification of the surface waters which can lead to increased risk of harmful algal blooms (Hallegraeff 2010).



Photo 8. High summer temperatures pose significant risks to salmon production systems Photo: Alistair Hobday

4.3.3 Existing adaptation efforts

One of the eight National Climate Change Adaptation Research Facility (NCCARF) research networks is focussed on marine biodiversity and resources (<http://www.nccarf.edu.au/marine/>) and hosted at the University of Tasmania (convenor Neil Holbrook). While this is a national network, it has also been responsible for raising awareness of the rapid change in Tasmanian waters, and become an important vehicle for advancing some of the research responses and for delivering the research findings, in particular with a range of fact sheets and guidance documents (see www.nccarf.edu.au/marine/).

Table 5 sets out the on-going Tasmanian-relevant projects funded by the Fisheries Research and Development Corporation and the Department of Climate Change and Energy Efficiency on behalf of the Australian Government in respect of marine biodiversity and resources.

Table 5. Marine biodiversity and resources projects relating to Tasmania

Title	Objectives
<p>2010/532 FRDC-DCCEE Changing currents in marine biodiversity governance and management: responding to climate change Michael Lockwood September 2013</p>	<p>This project will identify adaptive governance and management arrangements for conserving marine biodiversity in the context of climate change. Case study areas have been selected as the Whitsunday region (Cth/Qld waters), Tweed-Moreton region (Cth/Qld/NSW waters) and Freycinet bioregion (Cth/Tas waters). Requirements for adaptive governance and management of marine biodiversity have been developed through analysis of the literature, consultations with our agency and technical advisory groups, and judgements of an expert panel.</p>
<p>2010/506 FRDC-DCCEE Adaptive management of temperate reefs to minimise effects of climate change: developing new effective approaches for ecological monitoring and predictive modelling Neville Barrett End date April 2014</p>	<p>This work builds on data collected from past surveys to determine shifts in distribution and abundance of species. It will suggest adaptation strategies for fishery and marine park managers. Based on a long-term database spanning over 20 years of the abundance of temperate reef biota in southern NSW and Tasmania, and another database of the abundance of reef taxa collected all around Australia (Reef Life Survey project), this project is developing adaptive management strategies from models of the changes of abundance distributions of organisms. These temporal changes relate to environmental parameters such as temperature, which will inform potential management decisions.</p>
<p>2010/533 FRDC-DCCEE Human adaptation options to increase resilience of conservation-dependent seabirds and marine mammals impacted by climate change Alistair Hobday End date January 2013</p>	<p>This work will provide an insight into the effects of climate change on a number of iconic species, develop adaptation options, and recommend best-practice monitoring.</p>
<p>2010/564 FRDC-DCCEE Preadapting a Tasmanian coastal ecosystem to ongoing climate change through reintroduction of a locally extinct species Nic Bax End date March 2013</p>	<p>Using highly valued species, including blue groper, the potential for translocating fish as an adaptation policy is being investigated.</p>

Title	Objectives
2010/542 FRDC-DCCEE A climate change adaptation blueprint for coastal regional communities Stewart Frusher and Nadine Marshal End date June 2013	The project aims to develop a blueprint for coastal regional communities that enables these communities to understand the biophysical, social and economic implications of climate change on marine resources (commercial and recreational fishing, tourism, aquaculture) and thus facilitate appropriate adaptation options.
2011/039 FRDC-DCCEE SEAP Case Studies Gretta Pecl and Tim Ward End date March 2014	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 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.

There has been rapid development of an adaptation-focussed research agenda in marine systems, which has occurred despite limited understanding of biological climate impacts (Frusher et al. in press). This shift in focus to research required to deliver adaptation outcomes has led to more multi-disciplinary teams involving stakeholders from the beginning of the research process. For example, the potential impacts of climate change on marine biodiversity conservation on the east coast of Australia, including Tasmania are variable, so engaging with stakeholders has been used to provide ongoing reference points for contemporary decision making and planning (Haward et al. 2012). Refinement of management and governance in the marine sector may also lead to improved outcomes under climate change (Lockwood et al. 2012).

There have been few examples of direct response by the marine sector to climate change, despite the overwhelming evidence to date. This is in part due to the range of other issues that require attention in the marine sphere, including fisheries management and aquaculture zoning, and the perceived time horizon for climate change impacts to become critical. Many marine resource users do recognise that an understanding of future environmental conditions can assist in planning activities, minimising risks due to adverse conditions, and maximising opportunities.

For several fisheries and aquaculture industries, knowledge of climate impacts has altered decision-making. For example, the rock lobster fisheries managers in south-east Australia have altered their assessment models to account for the decline in recruitment associated with warming waters. There is also overall industry acceptance of the implications of increasing water temperatures on the future harvest potential of the Tasmanian rock lobster fishery (DPIPWE 2010c). In the year following the release of the Pecl et al. (2009) case study, the rock lobster industry accepted reduction in the Total Allowable Catch (TAC) and linked decreases in catch rate on the East Coast of Tasmania to reduced larval settlement (DPIPWE

2010c). Other fisheries sectors are also considering the implication of climate change on their assessment processes (e.g. Wayte 2012).

In aquaculture, the salmon industry recognised warming waters as a potential threat and identified research initiatives to reduce risk, such as disease management, selective breeding, infrastructure development and improved climate forecasting (Battaglione et al. 2008). Short-term farm management is assisted by weather forecasts, whereas longer-term planning may be hampered by an absence of useful climate information at relevant spatial and temporal scales. Seasonal forecasts of water temperatures for south-east Tasmanian Atlantic salmon farm sites several months into the future are provided by CSIRO (Hobday et al. 2011). Information on future ocean conditions up to several months into the future for the salmon aquaculture industry will enhance environment-related decision making of marine managers and increase industry resilience to climate variability.

A range of adaptation options exist for marine species and fisheries (Koehn et al. 2011). For example, translocation of some marine species to more suitable habitats around Tasmania is an option under climate change, and pilot translocations have occurred for rock lobster (Green et al. 2010). Other options remain to be tested.

4.3.4 Understanding future options

Future fisheries productivity will be impacted by climate change, particularly if the nutrient-poor EAC continues to influence the East coast of Tasmania. Projections using an ecosystem model based on assumed increases and decreases in primary productivity show a range of outcomes for target and non-target species in Tasmania (Watson et al. 2012) that may constrain future adaptation options for some fisheries. Such models provide a useful starting point for discussing these options.

Ecosystem impacts as a result of range extension of habitat-modifying organisms will be heterogeneous in space, and based on evidence that marine systems with a more natural complement of functional predators, can reinstate size and habitat-specific predator–prey dynamics eroded by fishing, marine reserves have been proposed as important in reducing the impacts of some range changing species such as *Centrostephanus* (Ling & Johnson 2012).

As climate change is just one of several stressors on marine environments, adaptation strategies must complement current efforts to improve marine management. Thus, developing decision-support tools that integrate non-climate stressors and inform decisions about when, where and what adaptation action is appropriate are critical in future adaptation research. These tools and approaches (e.g. Koehn et al. 2011) should also seek to resolve how governance at all scales, from the individual through to jurisdictions, can be coordinated for better outcomes (Frusher et al. in press). Researchers must also work across these scales to support wise and timely decision making.

Research currently underway is seeking to test these approaches and support end-users. Simulation testing is critical to inform options and design appropriate monitoring, as proposed for the Tasmanian rock lobster fishery (e.g. Marzloff et al. 2011).

4.3.5 Research gaps and future opportunities

Knowledge regarding the primary impacts of climate change on species is limited to species of conservation or commercial importance, and is limited in the range of impacts that are understood. For example, while impacts of warming oceans are reasonably clear, resulting in changes in distribution, the impacts of ocean acidification on marine resources, particularly valuable fishery (e.g. abalone) and aquaculture (e.g. oyster) species is extremely limited. Experimental studies need to be completed for a range of species, across their life cycle, as vulnerability varies with life stage. These candidate species should be selected on the basis of economic value to Tasmania, and obvious candidates are abalone, rock lobster and oyster.

Where research on impacts is included as part of an adaptation research program, such research should also be guided by the prospect of intervention – for example, investigation of the impacts of ocean acidification on phytoplankton, while important, are not likely to improve adaptation options. Thus, research projects that can include consideration of adaptation options – e.g. what options will be available for aquaculture businesses that rely on species impacted by declining pH – should guide research providers.

There is recognition that some adaptation options will require considerable lead times, and hence research into the timeliness of adaptation interventions – such as cost-benefit studies – are needed. Should a business relocate before impacts are apparent, or will post-impact adaptation suffice?

In the case of changing species distributions, there may need to be development of policy positions that clarify the allocation of new resources to users – how to manage access to range-changing species that could form valuable new fisheries.

Integrated multi-disciplinary studies are also needed, particularly to evaluate the socio-economic impacts of climate change on marine species and resources. These studies can then support additional research, or focus efforts where socio-economic impacts will be greatest.

Traditionally, marine conservation management and marine resource management have been separate – in future, these research and management areas should overlap to a greater extent. Considerable focus should be on developing win-win options (Grafton 2010), where short-term benefit is also compatible with long-term sustainability, for both marine sectors.


‘... focus should be on developing win-win options, where short-term benefit is also compatible with long-term sustainability, for both marine conservation and marine resource management.’

Communication is a key priority identified by stakeholders (Holbrook 2011), and researchers should continue to develop tools, skills and products for communicating both climate impacts and adaptation options. For the marine conservation sector, communication and education was identified as being either uniquely most important, or at least equally most important, by government, NRM and NGO representatives. This represents a clear message by the sector of the need for improved communication and education to better facilitate marine conservation in a changing climate.

Leading examples from the marine sector include both Tasmanian and National products and include the two marine report cards (Poloczanska et al. 2009, 2012) which discussed observed and projected impacts, adaptation options and knowledge gaps (<http://www.oceanclimatechange.org.au>), and targeted Tasmanian seafood industry information (e.g. TSIC Seaing change – http://www.tsic.org.au/files/Projects/Seaing_Change_Optimised2.pdf). Tasmania has also been the home to the innovative citizen science program REDMAP (www.redmap.org). This web-based initiative sees marine users report their unusual species for verification and mapping by a team of scientists and has now been extended to provide national coverage.

Hotspot regions, such as on Tasmania's East coast, provide natural laboratories for considering the impacts of global warming and thus an opportunity to test approaches and methodologies (Frusher et al. in review; Hobday & Pecl in press). The identification of marine waters off south-east Australia as a hotspot location has seen this region become a central focus for marine climate change research in Australia – a review in 2011 identified some 40 active projects focussed on fisheries, aquaculture and biodiversity (Pecl & Hobday pers comm.). Lessons from this region can see early adaptation and lessons transferred to other regions warming less rapidly (Pecl et al. 2010). A range of adaptation options exist (Koehn et al. 2011), but effectiveness needs to be explored, tested and observed in practice, under an adaptive management philosophy; indeed, an adaptive management approach is likely to be required as there are still many unknowns in this hotspot region. As part of such an approach, monitoring will be critical to assess the effectiveness of adaptation actions. However, existing monitoring programs in this region of rapid change are sparse with regard to ecological components while social or economic indicators are almost entirely absent. Progress will only be enhanced with improved and targeted monitoring, and research to design cost-effective approaches, including use of new technologies, is needed.

4.4 Land use planning

 Key findings – Land use planning	
Climate change impacts	<ul style="list-style-type: none"> ◆ storm surge, coastal erosion and inundation are all projected to increase with sea level rise. Inundation and storm surge mapping is available for sea level rise at 0.2 m increments up to 1.2 m. Erosion maps are in preparation ◆ fire risk is also expected to increase
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ numerous values and assets are located within current or potential storm surge and SLR coastal hazard zones. ◆ land use planning can minimise or avoid the location of new settlements in vulnerable areas; reduce the exposure of and promote adaptation efforts in existing settlements
Current adaptation efforts	<ul style="list-style-type: none"> ◆ the state has introduced sea-level rise planning allowances and a Bushfire Planning Code ◆ regional land use strategies all refer to the need to minimise exposure of new and existing settlements to climate change hazards
Future options	<ul style="list-style-type: none"> ◆ transferring the lessons learned from numerous local and regional initiatives, such as the Tasmanian Coastal Adaptation Pathways project will facilitate state-wide improvements in planning ◆ the current ambit of land use planning will need to be extended to achieve adaptation for existing settlements and infrastructure
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ how best to apply and transfer adaptation planning insights across places and projects ◆ assessing the suitability of the current governance arrangements for planning in Tasmania for adaptation needs

Land use planning plays an important role in determining the scope, location and operating conditions for a range of sectors. . It affects development for human settlements in areas prone to bushfire, flood or coastal hazards, as well as the allocation of land for industry, agriculture, forestry, conservation, water catchment management, and hazard mitigation. . The way in which land use planning responds to the impacts of climate change therefore has a critical influence on the way other activities, sectors and business adapt. . To date, the primary

focus has been on planning responses to risks posed to urban development and the built environment.

The impacts of climate change will affect human settlements and the infrastructure that supports them in a range of ways. Coastal communities will face increased risks from hazards such as inundation, storm surge and coastal erosion. More intense precipitation events will cause flooding and increased bushfire conditions will expose communities to greater risk from bushfire. The expansion or establishment of new settlements in areas vulnerable to flooding, inundation, erosion or bushfire will exacerbate the risks posed by climate change. There is a significant body of literature nationally and internationally (see Macintosh et al et al 2013) to suggest that land use planning that considers these future risks and that ensures new development is located away from vulnerable areas will be a critical part of the adaptation challenge.

4.4.1 Understanding climate change impacts

The *Climate Futures for Tasmania* project has provided a significant research base for planning in respect of several climate change risks, notably flooding and extreme events (White et al. 2010a). State-based and national research has examined the likely impacts of projected sea level rise on coastal inundation in the form of increased frequency of high sea-level events (Hunter 2012). New estimates of historic coastal sea levels over the last few hundred years have been made based on examination of sedimentary records along the east coast of Tasmania (Gehrels et al. 2012). They confirm a significant acceleration in the rate of sea-level rise since the early 20th century.

Other research has considered the impacts of storm surge and erosion combined with sea-level rise (SLR). Sharples (2006) conducted a first pass assessment of the vulnerability of 84% of the Tasmanian coastline to storm surge inundation and shoreline erosion as a consequence of sea level rise. T

The study mapped the potential storm surge inundation zones based on historically recorded storm surge events, factoring in an increase in the hazard zone with projected sea-level rise. These zones corresponded to coastal areas potentially susceptible to flooding in a 0.01% exceedance (approximately 2 year return period) storm surge event. Further work to identify extreme sea-level exceedance levels for the state was undertaken by Hunter (2008).

Two additional phases of coastal inundation mapping have now been completed for Tasmania. Stage 1 (Mount et al. 2011) mapped:

- 1 locations potentially affected by sea level rise at 0.2 m increments up to 1.2 m, plus 1.6 and 2.0 m above a base tidal height; and
- 2 locations potentially affected by flooding associated with storm-tide exceedance events at exceedance probabilities of 25%, 50% and 75%, averaged for the periods 2010–2050 and 2010–2100, with and without sea level rise.

It also provided coastal reference heights in a 1 km grid for the Tasmanian coastline. These can be used to look up hazard threshold heights for a specific 1 km square area. Stage 2 mapped a set of sea level rise scenarios around the coast using allowances, based on the

A1FI SRES scenarios and regional SLR projections. The result of this phase was a set of coastal area inundation maps to inform future coastal planning (DPAC 2012b; Lacy et al. 2012).

A similar spatial mapping exercise is currently underway for coastal erosion. About half of Tasmania's coastline is rocky, which means that there is likely to be limited recession as a result of SLR (DCC 2009). Sandy coasts comprise the other half, with risks of shoreline recession dependent upon whether the sandy coast is backed by soft sediment or bedrock. Several sections of sandy coast are already subject to severe erosion.

Storm surge, coastal erosion and inundation are all projected to increase, as will their likely impacts on coastal infrastructure, ecosystems and lifestyles.'

4.4.2 Understanding sectoral vulnerabilities

An assessment of Tasmania's coastal vulnerability formed part of the 2009 National First Pass Coastal Vulnerability Assessment (DCC 2009). Like everywhere else in Australia, the impacts of coastal erosion and other coastal hazards have been exacerbated by coastal development occurring too close to the shoreline and with little regard for sea-level rise and the active shoreline (Church et al. 2012).

Tasmania's population is concentrated along the coast, with about 75% of the population and most industry located in coastal local government areas. There is already a moderate exposure to storm surge, erosion and other natural hazards (DCC 2009; TCCO 2012a).

An estimated 6,100 properties are located within 110m of sandy shorelines, and hence potentially exposed to future coastal erosion, and 240 square km of coastal land is currently vulnerable to storm surge flooding (DCC 2009).

Storm surge, coastal erosion and inundation are all projected to increase, as will their likely impacts on coastal infrastructure, ecosystems and lifestyles. Inundation analysis based on a 1.1 m SLR estimates that 8,700–11,600 residential buildings with a replacement value of \$2.4–3.3 billion are vulnerable to inundation, more than half of which are located in the local government areas of Clarence, Central Coast, Break O'Day and Waratah/Wynyard (DCC 2009).



Photo 9. Climate change will exacerbate existing exposure to coastal hazards Photo: Alistair Hobday

A DPIW (2008a) desktop audit showed that numerous values and assets are located within current or potential storm surge and SLR coastal hazard zones, based on a SLR of 0.84 m above 2004 levels by 2100, plus a 50 m buffer. Vulnerable assets and values include natural reserves and other public land, public buildings, public recreation areas, highways and roads, schools, service stations, emergency services buildings, sewage and wastewater treatment plants.

Detailed analysis of exposure to inundation, coastal erosion and flooding has been undertaken for Clarence Council (SGS Economics & UNSW WRL 2008), with more modest investigations having been prepared for three other councils under the Tasmanian Coastal Adaptation Decision Pathways project (SGS Economics 2012a & b).

Work is currently underway on the impacts of climate change on bushfire conditions in Tasmania. Fire risk is expected to increase under climate change (White et al. 2010b) with associated risks for existing and new settlements. The recovery effort following the 2013 bushfires will provide important insights into the operation of the new Bushfire Planning Code in hindering or aiding adaptation.

The exposure of current settlements, and the limited application of land-use planning to new development, highlights the need for a three-pronged approach to planning for future impacts:

1. the use of planning instruments to minimise or avoid the location of new settlements in vulnerable areas;
2. the use of planning instruments to reduce the exposure of existing settlements (or mitigate existing and emerging hazards or risks), through mechanisms controlling redevelopment and in some places, implementation of managed retreat policies; and
3. the use of broader spatial planning instruments such as information instruments, financial mechanisms, and regulation to direct adaptation efforts in existing settlements (Macintosh et al. 2013).

4.4.3 Existing adaptation efforts

A range of adaptation activities in relation to land use planning are in place or underway, many of which have either been informed by, or have themselves produced, research outputs.

4.4.3.1 Planning for hazards framework

The State Government has embarked on an important initiative that will influence law and policy in respect of planning for coastal and other hazards. The development of Principles for the Consideration of Natural Hazards in the Planning System (DPAC OSM 2012) is addressing a wide range of natural hazards with climate change dimensions, including coastal erosion and inundation, bushfire, flooding, storms, and landslide. These principles, together with implementation guides, will form the basis for a new planning code in respect of each hazard.

4.4.3.2 Planning for bushfire hazards

The first such planning code – relating to development in bushfire prone areas in Tasmania – was released in September 2012. *Planning Directive No. 5: Bushfire-Prone Areas Code* requires all new planning schemes and Interim Planning Schemes to contain the requirements specified in the *Bushfire Code*. The purpose of the Code is:

to ensure that use and development is appropriately designed, located, serviced, and constructed, to reduce the risk to human life and property, and the cost to the community, caused by bushfires (TPC 2012).

The Code makes no reference to climate change as an exacerbating influence on bushfire in the state, but is nonetheless a valuable element of adaptation planning for bushfire. The Code is the product of a 2010 *Review of Construction and Development Control in Bushfire Prone Areas* (DPAC OSM 2010) by the Office of Security and Emergency Management within the Department of Premier and Cabinet. That Review recommended statewide mapping of bushfire-prone areas, but the Code uses a definition to identify bushfire-prone areas, rather than a spatial mapping approach.

4.4.3.3 Planning for coastal hazards

As noted above, considerable research has focussed on the identification and mapping of areas vulnerable to coastal hazards under future SLR. Hunter (2012) developed the technique used by the Tasmanian Climate Change Office for setting the sea level rise allowances required for Tasmania in order to preserve current return periods for extreme sea-level events. TCCO (2012b) has outlined the derivation of the state's planning allowance of:

- 0.2 m above 2010 levels by 2050; and
- 0.8 m above 2010 levels by 2100.

This allowance will form the basis of the Coastal Hazards Planning Code currently under development, and the subsequent modification of local government planning schemes across the state. The State Government has also released coastal inundation maps for the state, based on the sea level rise planning allowances, and is in the process of completing coastal erosion maps (TCCO 2012b). The Coastal Hazards Planning Code will form part of a broader statewide coastal protection and planning framework, which is expected to include provisions regarding protection of existing assets and infrastructure, allocation of roles and responsibilities, and liability principles (TCCO 2012b).

The former Department of Primary Industries and Water produced a General Information Paper articulating its policy on coastal hazards in Tasmania, and a set of internal principles guiding its management of Crown Land (DPIW 2008b). It is understood that the following principles are articulated in that guidance document:

- risks associated with coastal hazards rest with the property owner, whether public or private;
- DPIW (now DPIPWE) has no future obligation to repair or reduce the impacts of coastal hazards on private property or assets sited on public land;
- an open, evidence-based, risk-based approach will be taken to land use planning and decision making in coastal risk areas that will consider both the short- and longer-term consequences of planning and land use decisions;
- on land managed by DPIPWE, intensification of uses will be avoided, considering both short- and longer-term consequences; and
- human-made protections will generally be avoided.

4.4.3.4 Regional planning initiatives

Tasmania is divided into three regions for the purposes of regional land use planning (see Figure 8). Recent regional planning initiatives have explicitly mentioned climate change adaptation. The *Southern Tasmania Regional Land Use Strategy 2010–2035* (STRLUS) specifically identifies the impacts of climate change as an overarching consideration (STRLUS 2011). Strategic Direction 6 relates to ‘Increasing Responsiveness to the natural environment’ (STRLUS 2011) and advises that settlement planning needs to recognise natural values and hazards, and factor the presence of hazards into the identification of suitable areas for future development. It commits to minimising inappropriate residential development in areas at risk from hazards, including sea level rise and bushfire.

The strategy sees land use planning that takes hazards and risks into account as the single most important mitigation measure in areas of new development. In addition, the *Southern Tasmania Regional Land Use Strategy 2010–2035* specifically addresses bushfire risk. The first priority of the ‘Regional Policy for Management Risks and Hazards’ is to: ‘Minimise the risk of loss of life and property from bushfires’. This goal is to be achieved by addressing the management and mitigation of bushfire issues at the rezoning or subdivision stages, including in relation to vegetation clearance and the provision of safe road exit points; by identifying and protecting buffer zones; and through site design and layout – measures that are now covered by the Bushfire Code (STRPP 2011).



Figure 8. Map of planning regions in Tasmania

Source: Australian Dept of Education, Employment and Workplace Relations, jobsearch.gov.au

The policies on land use contained in the *Cradle Coast Regional Land Use Strategy* (CCRPI 2011) recognise that land use planning needs to ‘monitor the effects of climate change on the Region and apply an integrated mitigation, adaptation and risk management approach taking into account all relevant knowledge and available information.’ (CCRPI 2011) New development or intensification of existing development should be avoided on land that is already exposed to or affected by natural hazards, including coastal inundation and erosion and bushfire. The CCRLUS also provides that current and future landowners should be put on notice of existing and future risks. The *Regional Land Use Strategy of Northern Tasmania* (NTRCA 2011) also supports a risk-avoidance approach for new development and requires all local planning schemes to include provisions for areas subject to high coastal hazard, through overlays or zones and to restrict development so as to minimise the long term risk to life and property and minimise its impact on the coastal process. The *Northern Regional Land Use Strategy* (NTRCA 2011) also contains a regional policy of ensuring that future land use and development minimises the risk to people and property resulting from bushfire hazard. The associated actions for achieving this policy are to ‘include controls in planning schemes based on current best practice to minimise risk to persons and property resulting from bushfire hazard’ and ‘ensure subdivision design responds to bushfire hazard risks by providing for alternative access, building setbacks and buffer distances based on current best practice.’ (NTRCA 2011) These actions are likely to be achieved via the introduction of the new Bushfire Code.

4.4.3.5 Local planning

At present, in the absence of clear guidance from the state, responsibility for introducing planning controls relating to coastal climate hazards rests with local authorities. The sophistication with which local planning schemes address coastal hazards is highly variable across the state (Gibbs & Hill 2011; Macintosh et al. 2013). Clarence City Council, for example, has conducted extensive research into the present risks facing its coastline and the likely future scenarios under climate change, and has amended its planning scheme to provide controls that reflect these risks.

4.4.3.6 Adaptation training for planning professionals

The training of future planning professionals in climate change adaptation should enhance the incorporation of climate change impacts into future planning initiatives (Lyth et al. 2007). A project funded by the Australian Government Climate Change Adaptation Skills for Professionals Program entitled 'Climate Change Adaptation Planning for Planners of Built and Natural Environments', trialled the mainstreaming of climate change adaptation into existing postgraduate environmental planning and management coursework (Davidson & Lyth 2012). The *Climate Change Adaptation Planning (CCAP) for Planners of Built and Natural Environments* project produced curriculum materials for a core introductory module and four content modules for on-campus and distance learning modes. The result of this project has been the establishment of the postgraduate course unit, *Planning and Managing for Climate Change*, within the UTAS Master of Environmental Planning and Masters of Environmental Management courses in which Tasmanian students are enrolled and Tasmanian specific case studies and problems are included.

4.4.4 Understanding future options

The research undertaken to date has allowed significant progress on reforms to the planning regime. Completion of this reform is likely to minimise the exposure of new settlements to future risks. The NCCARF project *Limp, leap or Learn: A socio-legal analysis of planning laws for adaptation to climate change in Australian coastal settlements and bushfire-prone areas* developed a framework of design criteria and considerations for use in selecting the best legal instruments by which to implement spatial planning policy objectives for adaptation.

Photo 10. The TCAP project involved significant engagement with the community at Lauderdale

Source: www.ccc.tas.gov.au



This project has reviewed the current planning framework for coastal and bushfire climate hazards across all Australian jurisdictions including Tasmania, and has conducted in-depth interviews with planners in State Government and two Tasmanian local councils (Kingborough and Clarence) (Macintosh et al. 2013). The project did not attempt to guide local government in making policy choices around retreat, protection or accommodate for *existing settlements*, but instead, outlined the pros and cons of each instrument for implementing policy objectives agreed through other processes.

The State Coastal Framework is seeking to establish the policy settings at a state level, but further research will be needed to help guide those policy decisions. SGS Economics (2012b) suggests that this type of research will have to be highly place-based and there will be limited scope for transferability or extrapolation from other locations or experiences (SGS Economics 2012b). Experimentation with applying the outputs from the TCAP project to new locations could test this claim.

‘The assumption that planning can provide certainty for future development may need to be re-evaluated ... and the current ambit of land use planning will need to be extended to achieve adaptation for existing settlements and infrastructure.’


4.4.5 Research gaps and future opportunities

The importance of land use planning as a tool for adaptation means that we are likely to see new policies, laws and approaches over the coming decades, and on-going modifications to existing frameworks. The assumption that planning can provide certainty for future development may need to be re-evaluated in a future of uncertain bio-physical change and the current ambit of land use planning will need to be extended to achieve adaptation for existing settlements and infrastructure. Much of this research can occur at a national level and will apply with equal relevance to Tasmania.

The following gaps and opportunities of particular relevance to Tasmania are distilled from TCCO (2012a), Booth et al. (2011) and Cox et al. (2012):

- How the planning framework, including regional planning, should accommodate the long-term impacts of climate change, the likely impacts of extreme events, and the cumulative impact of multiple extreme events?
- Improving the communication of climate change impacts and engaging communities in adaptive responses
- The evaluation of costs of various adaptation options for existing communities in a way that is itself efficient and cost-effective
- Enhancing the processes of adaptation of existing communities to ensure they are consultative, locally-driven and participatory, and cost-effective
- Design and mix of instruments and incentives to promoting private adaptation
- Exploiting the synergies between climate change adaptation and mitigation
- Transferring adaptation planning insights across places and projects
- Assessing the suitability of the current governance arrangements for planning in Tasmania for adaptation needs.

4.5 Infrastructure and essential services

 Key findings – Infrastructure and essential services	
Climate change impacts	<ul style="list-style-type: none"> ◆ Research into climate change impacts on Tasmanian infrastructure and essential services has focussed on the implications of sea level rise. ◆ Increases in inundation, storm surge, flooding and bushfire as a result of climate change are likely to have impacts on infrastructure and essential services.
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ The degree of vulnerability of infrastructure to climate change depends on <i>the severity of climate change impacts, the adaptive capacity of the local community, and the location, age, design and construction method of the physical infrastructure.</i> ◆ Little is known about the flow-on effects to communities and economies from disruption or damage to infrastructure or essential services.
Current adaptation efforts	<ul style="list-style-type: none"> ◆ Several recent local projects and assessment tools reflect best-practice for climate change risk assessments for infrastructure. ◆ Climate change is being reflected in the management documents for several departments and organizations, including the Department of Primary Industries, Water, and Environment, and Hydro-Tasmania.
Future options	<ul style="list-style-type: none"> ◆ Where location or relocation to hazard-free areas is not feasible, new technologies, design and construction standards, and management, operating and maintenance protocols will be required to minimise risks to infrastructure.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ Use the 2013 bushfires as a case study to understand the full costs of infrastructure disruption and how to avoid these costs through design, modification, re-engineering of processes or other techniques.

Infrastructure and essential services encompasses public and private roads, rail routes and stock, power, water and sewerage utilities, waste disposal sites and an array of other less obvious but nonetheless significant infrastructure important to the functioning of communities and local economies. The physical impacts of climate change are likely to cause disruption and damage to, or loss of such infrastructure. The impacts generically and commonly mentioned include sea level rise, storm surge, wind and heavy rain damage, flooding, bushfire and heat stress. Examples of specific direct impacts include inundation or intermittent flooding

of transport routes and bridges (including major roads and local access routes serving industry, towns or communities), wind and heavy rain damage to power utility infrastructure, storm damage or flooding of water and sewerage plants. For Tasmania, most of these are relevant, although there has been a distinct focus on the impacts for infrastructure in coastal regions and the physical climate factors relevant to coasts. There has been some work undertaken on the indirect implications of climate change on river catchments and river flows important for Tasmania's hydro-electric power generation and future hydro-electricity infrastructure investment.

4.5.1 Understanding climate change impacts

Research into climate change impacts on Tasmanian infrastructure and essential services has focussed on the implications of sea level rise, although there has also been more limited attention to impacts from extreme weather events such as storms, flooding, and bushfire.

Sea level rise and coastal weather events have the potential for significant impacts in Tasmania. The majority of Tasmania's population lives in coastal areas (Steffen & Hughes 2011), with some 75% living in coastal councils (ABS 2012; TCCO 2012b), and key major industries and infrastructure assets located on or near the coast. Coastal regions have high social and economic significance (DCC, 2010). Tasmania is included in recent national assessments of climate change impacts relevant to infrastructure and essential services (e.g. DCC 2010; DCCEE 2011), and multi-sectoral adaptation responses (Gurren et al. 2011; Booth & Cox 2012). There are also a number of comprehensive state-based studies focussed only on Tasmania and the impact of sea level extremes (DPIW 2008a; DPIW 2008b).

In recent years, local government-driven projects have produced studies that explore vulnerability, risk and adaptation options associated with sea level rise and extreme coastal weather events such as storm surges (Clarence City Council see SGS Economics & Planning 2009); and vulnerability and adaptation issues for flood prone towns and communities in the Break O'Day Council (LGAT 2010). The first study was supported by the State Emergency Service and the Australian Department of Climate Change, the second by the Australian Government's Natural Disaster Mitigation Program.

Indirect effects on infrastructure and essential services through biophysical changes to the environment are mentioned in the literature. Climate Futures for Tasmania and the CSIRO Tasmanian Sustainable Yields project consider the future capacity for hydro-electric power generation given a likely reduction by 2100 of inflows to water catchments used for hydroelectric power generation (Bennett et al. 2010; CSIRO 2009). Other indirect effects on infrastructure and essential services do not appear to be a significant concern. For instance, a climate change impacts study for Clarence City Council (on Hobart's eastern shore) discusses salt-water intrusion into fresh groundwater and its potential impact on water supplies, but concludes that

Infrastructure and essential services

- Public and private roads
- Rail routes and stock
- Power, water and sewerage utilities
- Waste disposal sites
- Schools
- Parks and recreational assets

the short to medium term danger to health or property is likely to be minimal (SGS Economics & Planning 2009). There is also brief mention of contamination or pollution issues emerging as a result of sea level rise and flooding of coastal infrastructure such as service stations (DCC 2010).

4.5.2 Understanding sectoral vulnerabilities

Vulnerabilities are predominantly discussed in the context of how infrastructure and essential services:

1. might be damaged or altered by changing climatic conditions affecting both the service delivery capacity of the infrastructure and essential service; or
2. where infrastructure components may need to be more regularly serviced or replaced.

There is little research into the flow-on effects to communities and economies and the adaptive capacity of these in the face of disruption or damage to infrastructure or essential service. The State Government's *Adapting to Climate Change in Tasmania Issues Paper 2012* acknowledges that the vulnerability of human settlements and infrastructure to climate change varies across the state and the degree of vulnerability depends on a range of factors:

including the severity of climate change impacts, the adaptive capacity of the local community, and the location, age, design and construction method of the physical infrastructure (TCCO 2012a: 10).

The same paper also acknowledges that essential infrastructure and services across the state are vulnerable to long-term impacts of climate change but that low-lying coastal settlements will be particularly vulnerable in the future (TCCO 2012a).

4.5.2.1 Assessing the extent and cost of 'at risk' infrastructure and essential services

Assessments of infrastructure and essential services that may be affected by climate change, in particular impacts associated with sea level rise, storms, or floods have been undertaken in projects led at the national, state and local levels. For example the Australian Department of Climate Change *Climate Change Risks to Australia's Coast: A first pass national assessment* (DCC 2010) assessed the potential extent of 'at risk' infrastructure for each state and territory, although most of its Tasmania-specific conclusions were based on work by the former Tasmanian Department of Primary Industries and Water, *Climate Change and Coastal Asset Vulnerability: An audit of Tasmania's coastal assets potentially vulnerable to flooding and sea-level rise* (DPIW 2008a).

This audit identified the following infrastructure as being at risk: schools, emergency services (primarily their capability to function and respond), service stations, sewerage and wastewater facilities, major roads and bridges, important local roads, parks and wildlife infrastructure, waste disposal sites and storage tanks or facilities (DPIW 2008a). Some 12 school sites were identified as being at risk, with these difficult to move in the short and medium term. Some 22 sewerage and wastewater treatment plants are exposed; and some 140 km of highway

sections and 706 km of local access roads are at risk (DPIW 2008a, DCC, 2010). The Clarence City Council and Break O'Day Council projects (SGS Economics and Planning 2009; LGAT 2012) mentioned above also make some assessments of infrastructure most at risk for their areas.

An NCCARF-funded study of climate change adaptation issues for country towns (including relevance to Tasmania) raised issues about the vulnerability of small country towns and communities, including the implications of the cost of damaged infrastructure and their capacity to pay for maintenance, mitigation of risk, or replacement. It also highlights the potentially significant social (e.g. community health impacts) and economic loss (e.g. loss of business and personal income) associated with disruption to infrastructure and essential services (Beer et al. 2012).

4.5.2.2 Understanding effects on resilience and adaptive capacity

There has been little Tasmanian-specific work on the flow-on effects of infrastructure damage or disruption to communities or economies. A national study of the vulnerability of community sector organisations under climate change is currently underway, led by the Australian Council of Social Services (ACOSS) and funded by NCCARF (NCCARF 2012c). The project, *Climate Change and the Community Welfare Sector* has surveyed almost 300 organisations nationally, including Tasmanian community sector organisations. The survey investigates the implications of a range of climate change factors on the delivery of services by these organisations, and the implications of this for adaptive and resilient communities. The survey included specific questions about the organisation's vulnerability associated with disruption of essential services such as power, water, telecommunications and transport. Project results should help guide Tasmanian organisations in prioritising the complexity of inputs required for to building resilient communities and adaptive capacity (Mallon et al. 2013).

4.5.3 Existing adaptation efforts

A limited number of Tasmanian projects have been cited as positive initiatives and best practice approaches to planning for and managing the implications of climate change on infrastructure and essential services in the national literature. For example, the NCCARF Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNIS) project, *Case Studies of Climate Change Adaptation Tools and Application Processes Used by Local Government Practitioners* (Booth & Cox 2012) notes the following Tasmanian initiatives and approaches:

- Launceston City Council: Local Adaptation Pathways Program (LAPP) funded risk assessment
- Devonport City Council and Cradle Coast Authority: coastal and regional risk assessments and adaptation action plans
- Clarence City Council: comprehensive coastal vulnerability study of climate change impacts and adaptive responses (includes the use of integrated spatial mapping, assessments of social and economic impacts, cost benefit analyses and risk communication strategies)
- Developments in spatial mapping tools that have since been used elsewhere in Australia.

The Booth and Cox study (2012) notes the lack of in-house expertise of local councils in adaptation planning. Tasmanian councils reported that council employees provided vital local context but this element also constitutes a potential weakness, and that local knowledge may not constitute the necessary expertise required to identify and assess risks.

The report refers to the difficulties of risk assessment experienced by Tasmanian councils, for example:

at Devonport and Launceston, the lack of in-house technical knowledge 'up-front' made it an onerous task for staff to source expert advice, conduct research, and apply high-level knowledge to [...] generate risk ratings (Booth & Cox 2012: 26).

Booth and Cox also evaluate the benefits and lessons from the Clarence City Council integrated coastal impacts study (SGS Economics 2009), including different ways of thinking and doing things in council, especially in conducting an iterative learning process (Booth & Cox 2012). Tasmanian projects funded by the Local Adaptation Pathways Program (LAPP) are also noted in a report to the National Sea Change Taskforce (see Gurren et al. 2011).

Other adaptation efforts in this sector relate to the development of tools for risk assessment for certain sectors (such as transport infrastructure) or use by local government. An example of the former is the acknowledged need for climate risk assessment in infrastructure, planning and assessment especially for roads. For example sea level rise is identified as a particular risk to the Bridgewater Bridge due to its location in the Derwent Estuary and past experience of flooding during extreme sea level events. The replacement bridge currently being planned will take into account climate change risks recognising that the majority of the risks associated with service quality and public safety may be avoided by building the replacement bridge in a location which is not prone to erosion from sea level rise or extreme events (DIER 2012; DIER n.d).

An example of the latter is the 'Climate-Asyst' tool developed by the Tasmanian-based engineering firm Pitt & Sherry. Climate-Asyst is a climate change decision-support tool providing resources to assist infrastructure owners, managers and planners to help determine the effect that projected changes in climate will have on services and infrastructure assets. (Pitt & Sherry n.d.). It was developed using CFT data and descriptions of the physical impacts of a warming climate in local government areas.

The former Department of Primary Industries and Water also produced a range of reports and tools to support adaptation. The 2008 desktop audit of infrastructure vulnerable to coastal hazards included suggestions on possible adaptation options (DPIW 2008a). These include a template coastal risk management plan (DPIW 2009a), for use by state agencies and local governments to manage risks to specific assets from coastal flooding and erosion, or discrete local areas where a number of particular assets at risk occur together. It has also populated the template using two 'amalgam' case study locations (DPIW 2009b). DPIW has also produced a Coastal Works Manual for local government and other land managers and contractors (Page & Thorp 2010). The Manual sets out best practice guidelines for small-scale works in coastal areas, taking into account likely changes to coastal processes under climate

change. Hydro Tasmania has also explored the impacts and risks for its hydro electricity generation capacity (see Bennett et al. 2010). Climate change opportunities, risks and adaptation are embedded into its organisational strategic planning processes and frameworks (Hydro Tasmania 2012).



Photo 11. Hydro Tasmania has explored the impacts and risks for its hydro electricity generation capacity Photo: Anna Lyth

4.5.4 Understanding future options

Future options for new infrastructure must be understood in the context of adaptation in land use planning. A logical response is simply to locate new infrastructure in locations that are not vulnerable to the impacts of future climate change (see Section 6.4 above). This is not always possible, however, so new technologies, design and construction standards, and management, operating and maintenance protocols will be required to minimise risks to infrastructure.

For existing infrastructure, replacement may provide opportunities for changes in technologies and materials, or relocation, if necessary, for critical infrastructure located in vulnerable areas. For existing infrastructure that is still fully functional, further understanding is required about how to re-engineer processes so as to minimise service disruption, and to understand the flow-on effects of infrastructure disruption and damage on community and economic resilience and adaptive capacity.

Both new and existing infrastructure will benefit from further development and trialling of new assessment and decision support tools, including integrated spatial mapping, and

technological innovations in data collection. It will also require new financing models. At the national level, it has been noted that regulatory barriers such as fixed pricing deters power utilities and transport infrastructure companies from investing in adaptation (Kiem et al. 2010b).

4.5.5 Research gaps and future opportunities


Recent summer (January 2013) bushfires in the southeast of Tasmania have confirmed thinking about research gaps and future research opportunities for a range of climate-related events. During these fires, the Tasman and Forestier Peninsulas lost road transport access and energy supply, isolating and affecting both resident and visiting populations (such as restricting access to local food, electricity, fuel, water supply and health services). Future research might include a case study of these events, their impacts on Tasmanian communities and their infrastructure and essential services, in order to understand:

- the full costs of infrastructure disruption, whether associated with bushfire or other climate associated events (including downstream or cascading impacts) on: communities; utility providers (such as energy, telecommunications and water utilities); property damage; and maintenance or replacement costs (especially those local government authorities that are resource poor);
- how to avoid these costs through design, modification, re-engineering of processes or other techniques;
- what the design options and principles should be for adapting new and existing infrastructure and buildings to climate change in Tasmania, and how these might be implemented;
- how to distribute the future costs of infrastructure upgrade and increased risk;
- approaches to, and development of, Tasmanian professional capabilities (knowledge and practical skills) to more confidently and effectively assess, plan and manage climate risks in the future. This includes education of engineers, trade workers, planners, designers, and local government practitioners; and strategies for community coping and response to loss in infrastructure and essential services.



Photo 12. The 2013 bushfires highlighted the potential impacts of climate-related events on infrastructure. Photo: Sarah Brabazon

4.6 Human health and community wellbeing

 Key findings – Human health and community wellbeing	
Climate change impacts	<ul style="list-style-type: none"> ◆ The direct adverse impacts on human health from extreme climate related events or conditions that face other parts of Australia may be less relevant in Tasmania and the state may even derive positive health benefits, for example through warmer winters. ◆ Climate change impacts are likely to be felt more through indirect impacts than direct impacts.
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ The health impacts of climate change include the implications for respiratory illness of changes in pollen allergens and bushfire smoke; infectious diseases; and mental health and overall community wellbeing issues associated with direct climate impacts, including disruption from extreme events and prolonged conditions, such as drought.
Current adaptation efforts	<ul style="list-style-type: none"> ◆ There is virtually no adaptation activity occurring in respect of human health, but research is examining impact assessment tools and early warning techniques for dangerous weather conditions. ◆ Assessments of risk, vulnerability and adaptive capacity have been conducted for Ross River virus.
Future options	<ul style="list-style-type: none"> ◆ A deeper understanding is needed at regional and community levels of indirect impacts from biophysical changes and the risks and social vulnerability associated with these.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ Regionally-focussed vulnerability and risk assessment and monitoring. ◆ Techniques for improving the responsiveness and management of health impacts or events as they arise, as well as preparing communities for longer term adjustment to changing environmental and health conditions.

The impacts of climate change on the health and wellbeing of the Tasmanian population remains largely unstudied, despite reference to potential impacts in some work (Steffen & Hughes 2011). As a consequence, there is equally little research about adaptive options and approaches.

Climate change adaptation and human health research undertaken at the national level has been guided by the *National Climate Change Adaptation Research Plan for Human Health* (McMichael et al. 2009). The Research Plan identifies key research questions within sub-themes – heat, extreme weather events, vector-borne diseases, food safety and quality, air quality, water quality, mental health, community and Indigenous health, and health care services and infrastructure. Tasmania’s temperate climate and more subtle climate change projections relative to other parts of Australia mean that Tasmania has tended to be on the periphery of national research activity in this field. This does not mean that Tasmania should not be concerned or complacent about the health effects of climate change on its population. Instead the national focus to date may, in fact, reflect the incremental and iterative nature of impacts and adaptation research over time, especially where indirect health issues are concerned.

4.6.1 Understanding climate change impacts

There is no published research into the impacts of climate change on human health and community wellbeing in Tasmania. The *Climate Futures for Tasmania* (CFT)’s downscaled modelling provides a useful foundation for future regional and local analysis of impact and adaptation research in relation to human health. Much of the relevant Australian literature discusses the implications for human health in a very generic way: that is, not specifically relating to an assessment of a Tasmanian region or community. For example, the health effects of bushfire smoke with the likelihood of increasing risk of bushfire (see Johnston 2009); rural community health, including mental health impacts, and community social and economic costs associated with drought periods and climate associated extreme weather events (see Hanna et al. 2011; Steffen & Hughes 2011);

There is growing understanding of the climate factors contributing to the ecological drivers of the vector borne disease, Ross River virus, specific to Tasmanian regions (see Werner et al. 2011). While this work is not specifically focussed on climate change impact assessment, it does look at the significance of climate variables and the findings from the research are important inputs to current and future risk assessment and adaptation efforts in this area. This kind of research also suggests that there are probably other studies investigating the impacts of climate and climate change on a range of biophysical systems that may be important in contributing to health issues.

The direct impacts on human health from extreme climate related events or conditions that face other parts of Australia (such as heat waves) are considered in the literature as being of less relevance to Tasmania (see Bi et al. 2011), and there is even suggestion that Tasmania may receive some positive health benefits, for example warmer winters may lead to a reduction in cold-related illnesses (see Steffen & Hughes 2012). The relative vulnerability to changes in temperature and extreme heat events of other parts of Australia is largely assumed, however; there is nothing in the public or peer-reviewed literature that more deeply understands the impacts of social vulnerability. The occurrence of more extreme events, including storms, floods and bushfire are, nonetheless,

The occurrence of more extreme events, including storms, floods and bushfire are likely to pose direct threats, including death and injury, to Tasmanian communities, visitors and tourists.

likely to pose direct threats, including death and injury, to Tasmanian communities, visitors and tourists (TCCO 2012a).

Reviewing the potential impacts of climate change on human health Australia-wide, McMichael et al. (2006) suggest that the risks for Tasmania may be more subtle consequences of indirect climatic influences on the ecological and social systems that have implications for human health. These include:

- The impacts of climate change on bushfire hazard risk where this may affect rural and urban communities. Issues for human health in Tasmania are specifically focussed on respiratory illnesses associated with bushfire smoke and the sensitivity of some sectors of the community to this (see Johnston 2009).
- The impacts of climate change on the incidence and severity of drought in Tasmanian rural areas. Issues in the literature focus on the multi-faceted effects on rural communities including mental health, and community and regional social and economic wellbeing and resilience issues (see Hanna et al. 2011).
- The impact of climate change on ecological systems and components that are significant for the transmission to humans of vector borne diseases such as Ross River virus (Werner et al. 2012; Lyth et al. 2013) and the occurrence and severity of respiratory illnesses associated with the distribution and seasonality of plant allergens (Steffen & Hughes 2011).

Despite the absence of Tasmanian specific work on human health impacts, there is evidence of emerging interest and activity in understanding the indirect or more complex human health implications of climate change associated with biophysical changes, and the specific risks and adaptation challenges for Tasmanian regions, communities or groups. The Tasmanian Government's *Adapting to Climate Change in Tasmania Issues Paper* (TCCO 2012a: 29) acknowledge the importance of better understanding the health risks faced by vulnerable groups in the community (including the elderly, people with disability or chronic illnesses, remote communities, children and the poor), and the consequences of both direct and indirect impacts on health and health services, other services and critical infrastructure.

4.6.2 Understanding sectoral vulnerabilities

While health issues are largely recognised to be a consequence of the biophysical impacts of climate change, the human health and community wellbeing effects will be mediated by social factors, such as the characteristics of populations and indicators of their adaptive capacity. These include population vulnerability linked to socio-economic resources, the capacity of on-the-ground health services, monitoring and management systems (Bell 2011; Black et al. 2013). Understanding the socio-economic context of a region, community, or potentially vulnerable group is imperative, as is the need to engage with the agents in the system that contribute to the baseline and potential future adaptive capacity, for example, on the ground health services, monitoring and management systems. This is particularly significant for Tasmania for a range of health implications (see Johnston 2009; Bell & Towle 2011), because of the state's demographic, and socio-economic profiles (Bell 2011; Bell & Towle 2011; Lyth et al. 2013) and the poor health outcomes of its population, which are largely a function of socio-economic disadvantage and the ageing population (ABS 2011).

Steffen and Hughes (2011: 9) mention the potentially vulnerable members of the Tasmanian community as being 'the elderly, the very young, those with existing medical problems, those in rural communities and those in lower socio-economic groups'. They also refer to tourists as being at risk due to their lack of familiarity with the local climate, resources, local hazard or emergency resources and processes, such as emergency evacuation routes in the case of bushfire.

There is broad agreement (Steffen & Hughes 2012; TCCO 2012a) on the health issues that may affect Tasmania, including:

- the implications for respiratory illness of changes in pollen allergens and bushfire smoke;
- infectious diseases; and
- mental health and overall community wellbeing issues associated with a range of impacts, including disruption from extreme events and prolonged conditions, such as drought.

It is likely that there will be other issues and cumulative health and wellbeing implications that have not yet been considered because of the overall lack of attention and investment in climate change and human health research or practical studies in Tasmania. For example, Mallon et al. conclude that many community service organisations are vulnerable to extreme events. Temporary closure of such organisations will have serious flow-on effects for individuals who rely on such organisations to overcome difficulties faced by existing vulnerabilities (Mallon et al. 2013).

Beyond these broad statements about possible health futures in a changing climate and those potentially most at risk there is little evidence of any deeper assessment of social vulnerability as it relates to climate change in Tasmania, although there is work emerging in this area funded by the Tasmanian Government, for example Lyth et al. (2013) explore socio-economic and geographical vulnerability indicators most relevant to Ross River virus risk in Tasmania, as well as preliminary assessment of the adaptive capacity of the professional communities of practice likely to be involved in local risk assessment, hazard management and health service response.

4.6.3 Existing adaptation efforts

There is virtually no research into existing adaptation efforts in relation to human health in Tasmania, nor is there any current government policy addressing climate change-health issues. Work that has been done has been initiated by researchers, but undertaken with support from the State Government and either the local government association or regional natural resource management organisations. These projects fall into four categories:

1. Improved techniques for monitoring weather variables to allow for improved early warning of dangerous conditions. For example, Johnston et al. (2010) reviewed approaches to monitoring smoke from vegetation fires for public health monitoring

- systems, explaining that the availability of more precise temporal and spatial air quality data will improve the ability to issue health alerts for those most vulnerable.
2. Health impact assessment tools. For example, Bell and Towle (2011) discuss the need for, and approaches to, regional and community health risk assessments in Tasmania, using community and primary health carer involvement to better understand local social vulnerability and adaptive capacity contexts. Bell et al. (2012) piloted an online climate change health impact and risk assessment tool for use by local government.
 3. Risk and vulnerability assessments. For example, Lyth et al. (2013) explore the risk and vulnerability (including adaptive capacity) of Tasmanian regions to the vector borne disease Ross River virus.
 4. Developing adaptation options. Lyth et al. (2013) investigate adaptation options for managing the risk of Ross River virus, including preliminary assessment of the adaptive capacity of the professional communities of practice likely to be involved in local risk assessment, hazard management and health service response. At a systemic level, Bell et al. (2012) reflect on the type of adaptation responses required to tackle the health implications of climate change through addressing health services in particular and the professional education of health practitioners and workforce across the sector.

Research supported by the Bushfire CRC is examining psychological factors associated with community preparedness for bushfires in order to inform adaptation and emergency management responses in Tasmania and around Australia (see McNeill et al. 2013). The Tasmanian Fire Service has also commissioned research relating to the January 2013 Tasmanian bushfires.

4.6.4 Understanding future options

Hanna and Spickett (2011:12) state that:

Australia [including Tasmania] still requires much work to guide the development of a comprehensive strategy to underpin the adaptation of its health system. Adaptation will be an evolving process as impacts emerge.

Some emerging evidence (Lyth et al. forthcoming 2013) suggests that small or subtle changes in climate could have significant health effects on already vulnerable populations or the capacity of health services in Tasmania. The case of pollen allergens, bushfire smoke and Ross River virus are initial examples. A deeper understanding is required of indirect impacts from biophysical changes and the elements of risk and social vulnerability associated with these. This research must occur at the regional and community levels (Bell & Towle 2011).

McMichael et al. (2006: 866) talk about the potential for many communities to buffer themselves, at least temporarily, against some of the effects of climate change and so refer to the need for understanding the 'buffering capacity' of regions and communities where there are differences in geography, technological resources, governance, and wealth.

4.6.5 Research gaps and future opportunities

Bell (2011: 811) explains that climate change literature needs to extend to provide an evidence base for managing the specific challenges of regional policy and health service development that is responsive to climate change. Currently the climate change literature informs policymakers of the likely bigger picture health implications but does not offer the more nuanced region-specific information required as referred to by McMichael et al. (2006) in the global and national context. In Tasmania it particularly includes the need for:


- Understanding the social, environmental and institutional determinants of vulnerability in a given region (groups and areas most vulnerable to what under what circumstances), including rural communities and cumulative health and well-being vulnerabilities (Bell 2013).
- Community-based vulnerability and health risk assessments (Bell & Towle, 2011).
- Improvements in regional and local monitoring of: bushfire smoke (Johnston et al. 2012), aero allergen (pollen allergen) concentrations and seasonality (Beggs 2010), vector (mosquito) densities in highest risk areas with respect to Ross River virus (Carver et al. 2011) or other vector borne diseases that may emerge as a threat.

In addition to regionally-focussed vulnerability and risk assessment and monitoring and research identifying gaps in understanding, adaptation options to manage health vulnerability and community well-being need to be formulated, evaluated, costed, and tested (McMichael et al. 2006). This includes how we can improve responsiveness and management of health impacts or events as they arise, as well as preparing communities for longer-term adjustment to changing environmental and health conditions.

This will require:

- raising community awareness of health risks and approaches to assessing and mitigating local and individual risks (Bell & Towle 2011). Communication and public education about impacts and adaptation should be targeted to specific populations, including older people, low income groups, people with disabilities, people from culturally and linguistically diverse backgrounds and newly-arrived migrants and Indigenous communities (Fritze et al. 2009; Reser et al. 2012; Boon et al. 2012; Hansen et al. 2012);
- building community-wide resilience, particularly in rural communities (Hannah et al. 2011);
- adjusting and improving how professional education, practitioner and health service capacity is developed (e.g. Bell et al. 2012; Bell 2011); and
- raising awareness and response-capacity within the community support and services sector about the needs of regions, communities or groups most at risks that are relevant to them (Mallon et al. 2013).

4.7 Business and industry

 Key findings – Business and industry	
Climate change impacts	<ul style="list-style-type: none"> ◆ the implications of temperature increases, regional changes in rainfall patterns, and increased frequency and intensity of extreme weather events have not yet been assessed for business and industry sectors ◆ sea-level rise and associated impacts will affect business and industry in vulnerable coastal locations
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ there will be direct physical disruptions to business operations from extreme events, and indirect impacts on the production and supply chains of Tasmanian businesses resulting from the effects of climate change elsewhere. ◆ there may be opportunities flowing from business relocations and shifts in consumer preference
Current adaptation efforts	<ul style="list-style-type: none"> ◆ there is very little evidence of businesses or industry addressing climate change impacts
Future options	<ul style="list-style-type: none"> ◆ limited adaptation research and practice relating to Tasmanian businesses suggests that businesses are likely to respond reactively rather than proactively to climate change impacts as they occur. ◆ a key challenge will be to change the attitudes of businesses to medium-to-longer term climate-related threats.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ business- and industry-specific research into climate change impacts and adaptation options at temporal and spatial scales suited to their planning and decision-making processes.

The *Tasmanian Framework for Action on Climate Change* (TCCO 2008: 11) noted that ‘many sectors of Tasmania’s economy will need to adapt to the environmental impacts of climate change as well as adjusting to the requirements of a carbon-constrained economy’. While there has been considerable research relating to primary industries and natural resource management, there has been very little climate change adaptation research explicitly focussed on the impacts of a changing climate for other Tasmanian businesses such as tourism, mining, retailing, construction and manufacturing.

The vast majority of businesses operating within Tasmania are either non-employing micro-businesses (58.8%), small enterprises of less than 20 staff (36%) or medium enterprises of between 20 and 199 staff (4.9%) (DEDTA 2011). Hence, notwithstanding the economic importance of major enterprises such as mineral processing, a diverse mix of small and medium enterprises (SMEs) comprise around 99.7% of all businesses in the state and are especially important in terms of supporting Tasmania's decentralised population. There is likely to be great diversity in the vulnerability and risk profiles of different SMEs to the impacts of climate change. Likewise, national research (Chong et al. 2012; Murta et al. 2012) suggests that SMEs are also likely to differ markedly in their adaptive capacities.

4.7.1 Understanding climate change impacts

The *Climate Futures for Tasmania* (CFT) project (Grose et al. 2010) provides Tasmanian businesses with a high quality information basis from which to understand the likely physical impacts of climate change. It has provided fine-scale information on a number of key climate variables anticipated to change as a result of global climate change. The implications of temperature increases, regional changes in seasonal rainfall patterns, and increased frequency and intensity of extreme weather events for the sectors of agriculture and water resources have been elaborated in related CFT reports (ACE CRC 2010a; Bennett et al. 2010) but this information is yet to be applied to other industry sectors.

The concentration of most business and industry along the coast means that research at national, state and local levels into the impact of sea-level rise and coastal inundation is also directly relevant to Tasmanian businesses and industries (DCC 2009; TCCO 2012a). A 1.1 m sea level rise would threaten significant transport infrastructure and up to 300 commercial buildings (Steffen & Hughes 2011; DCCEE 2011). Disruption, loss or damage to transport and telecommunication infrastructure and limited access to fuel supplies through damage or inaccessibility to service stations can have far reaching impacts on the operation of businesses and services of all sizes, and as a consequence on the vulnerability and resilience of communities, local and state economies. While national and Tasmanian research has identified the broad extent of risk to infrastructure and essential services and noted the social and economic implications (DCCEE 2011; DPIW 2008a), the extent and cost of sea-level rise to Tasmanian businesses and industries remains largely unknown.

4.7.2 Understanding sectoral vulnerabilities

There is limited peer-reviewed research on the implications of the biophysical impacts of climate change on key industry sectors and businesses in Tasmania.

There appears to have been very little peer-reviewed research into the vulnerabilities of Tasmanian businesses and industries as a result of climate change. Beer et al. (2012) examined the vulnerability of some Tasmanian non-coastal settlements to the impacts of climate change, but this report was primarily focussed on primary production industries, and did not extend to assessing the vulnerability of communities dependent on other industries and businesses. Based on national research (e.g. Linnenluecke et al. 2011), it can be expected that there will be direct physical disruptions to business operations from extreme events, and indirect impacts on the production and supply chains of Tasmanian businesses

resulting from the effects of climate change elsewhere. Steffen and Hughes (2011) have suggested that there may be benefits for Tasmanian businesses and industries as a result of climate change impacting mainland Australia more severely relative to Tasmania, resulting in firm relocations (Galbreath 2011; see also Linnenluecke et al. 2011; Tasmanian Department of Treasury and Finance 2012) or shifts in consumer preferences southward.



Photo 13. Storm damage to world heritage listed Port Arthur Historic Site, 2011, Photo: Port Arthur Historic Site Management Authority

A sector of particular interest is tourism. It is anticipated that the tourism industry in Tasmania will be affected by climate change, especially in terms of risks to the status of iconic natural and cultural drawcards, such as the biodiversity of Tasmania's world heritage areas (DPIPWE 2010a; Rudman et al. 2008) and significant Indigenous and colonial cultural heritage sites (see Section 5.1). Detailed research into the impacts of climate change on the Tasmanian tourism industry is yet to be undertaken, but national-level research (e.g. STCRC 2009; Turton et al. 2010; see also summary by Carter in Poloczanska et al. 2012b) points to impacts arising from:

- direct physical changes associated with sea-level rise and coastal hazards. For example, the Port Arthur Historic site has already experienced significant damage from storm surge events (ABC News 2011)
- regional impacts, such as localised water shortages and increased frequency of extreme weather events, are also likely to impact on businesses. For example, in early January 2013 communities located south-east of Hobart experienced a severe bushfire. The bushfire cut off access to the Tasman Peninsula and the iconic Port Arthur Historic site. A representative from the Tourism Industry Council of Tasmania noted in an article in *The Mercury* early February 2013 that 'it was too early to tell just how much the bushfires would cost the state's tourism industry' (Martin 2013)

- indirect impacts resulting from changes to ecosystem services, and threats to the biodiversity and geodiversity that underpin much of the island's nature-based tourism
- opportunities for increased visitation to Tasmania, as tourists seek out experiences in cooler climatic zones and avoid destinations that are more prone to extreme weather events (Hadwen et al. 2011a; Mair 2011; Steffen & Hughes 2011; TCCO 2012a). Hadwen et al. (2011a) identified climatic variables as significant determinants of destination choice among tourists, one implication being that climate changes will positively affect destination choice for Tasmanian tourism. With this may arise opportunities for business and industry, but also pressures on the places and infrastructure most attractive to tourists and seasonal visitors. Moreover, Steffen and Hughes (2011) query whether tourists constitute a potentially vulnerable group, as they are unfamiliar with the location, local services and emergency response messages

Climate change risk assessments have tended to focus on the impacts of shifting to a low-carbon economy, including issues of energy efficiency and mitigation of carbon emissions. A report conducted for the Tasmanian Government by Pitt & Sherry (Harrington et al. 2008) into the *Impact of Climate Change on Tasmania's Food and Beverage Industry* investigated how climate change will affect aspects of the supply chain (production, manufacture and processing, transportation and retailing) of Tasmanian food and beverage products. While acknowledging the importance of adaptation research, and recommending that state and federal governments maintain adaptation research funding (Harrington et al. 2008: 4), the report concentrated on the opportunities for businesses to reduce their exposure to the risks presented by national carbon policies. Likewise, within the tourism industry the focus has been shared between energy efficiency and carbon reduction, often cohering around industry desire to meet consumer demands for environmentally friendly businesses or to protect the 'clean and green' brand values of the island-state.

4.7.3 Existing adaptation efforts

There is institutional recognition that Tasmanian businesses and industries will face added risks as a result of climate change, and a number of risk management assessment projects have been undertaken directed towards the identification of vulnerabilities. As noted above, however, these risk assessments have primarily focussed on actions designed to reduce GHG emissions and implement more energy efficient processes and practices (Gardner 2010; DPAC 2012e). Reflecting broader national trends (West & Brereton 2013) the primary focus of business and industry to date has been adapting to changes in policy (especially energy policy).

There is very little documented research into the adaptive efforts of Tasmanian businesses and industries. A national study by Zeppel (2011) noted Tourism Tasmania's intent to "market Tasmania as a climate friendly destination" (TICT 2007 cited by Zeppel 2011: 612). Booth and Williams (2012) contributed to an NCCARF-funded study (King et al. 2012) by examining what role insurance might play as an adaptive response to the impacts of climate change by focussing on bushfire management in Tasmania.

At a national level, research shows that the effectiveness of assistance for small and medium enterprises (SMEs) was limited by the short duration of business recovery programs, the lack

of specific support in responding to climate hazards, and a lack of consideration for the psychological impacts of such events (Kuruppu 2013).

There is some evidence that businesses have used the framework provided by the Australian Greenhouse Office's (2006) *Climate Change Impacts & Risk Management Guide for Business and Government* to undertake risk assessments (Materia 2008). Additionally, one significant outcome of the CFT project was a tool to assess the susceptibility of Tasmanian infrastructure to climate change impacts. Developed by Pitt & Sherry, a private engineering consulting firm, in partnership with the Antarctic Climate & Ecosystems Cooperative Research Centre (ACE CRC), ClimateAsyst® is likely to be of relevance to some major Tasmanian businesses and industries as a means of assisting them to assess their exposure to the impacts of climate change.

Table 6. sets out the national NCCARF projects of potential broad significance to Tasmanian business and industry (NCCARF 2012).

Table 6. NCCARF projects of likely significance to Tasmanian business and industry

Title	Objectives
<p>Climate change adaptation for Australian minerals industry professionals – Best practice guidelines</p> <p>Damien Giurco (University of Technology, Sydney)</p>	<p>The minerals industry generates 50% of Australia’s export earnings, yet research into its ability to adapt to climate change is limited. In a recent study, stakeholders identified the major challenges as use of scarce resources such as water and energy; impacts on the environment and community; hazards and workforce issues; impacts on infrastructure; and mine planning and design. This project will evaluate industry awareness, and existing strategies, and develop best practice guidelines for climate change adaptation and planning by minerals industry professionals.</p>
<p>Assessing the potential for, and limits to, insurance and market-based mechanisms for encouraging climate change adaptation</p> <p>John McAnaney (Macquarie University)</p>	<p>Insurance provides a means of helping communities recover from natural disasters. It is clear, however, that many people afflicted by flooding in southern Queensland in 2011 lacked suitable insurance cover, making recovery difficult and prolonged. This project seeks to understand why cover for riverine flood was so limited when damage from other natural hazards like bushfire, earthquake, tropical cyclone and hail storm are explicitly covered and routinely dealt with in home and contents policies. This project will propose solutions to align the incentives necessary at various levels of government to reduce the risk to Australian communities.</p>
<p>Climate change adaptation – Building community and industry knowledge</p> <p>Jenny Shaw (WA Marine Science Institute)</p>	<p>This project will increase knowledge and understanding of likely climate change and adaptation measures open to local communities. It will support a Case Study for Australia in adaptive management that cross-correlates regional needs with Australia-wide management policies. Key climate change information will be synthesised, analysed and adapted for marine biodiversity and fisheries businesses, and extension and knowledge sharing activities tailored for regional needs.</p>

4.7.4 Understanding future options

Climate change may well afford positive opportunities for Tasmanian businesses and industries. For example, Hodgkinson et al. (2010) suggested that there may be opportunities to export Tasmanian mining expertise and practice to areas of mainland Australia as an adaptive response for mines affected by higher rainfall. Without further research, however, it is impossible to assess the magnitude of these opportunities relative to potential risks.

Current limited research and practice suggests that businesses are likely to respond reactively rather than proactively to climate change impacts as they occur. Summarising a national report, Johnston et al. (2013: v) noted that ‘most Australian companies appear to be struggling to move forward in responding to climate change impacts, apparently paralysed by short-term profit-first thinking, uncertain political risks and a corporate culture unused to volatility and

disruption'. A key challenge will be to change the attitudes of businesses to medium-to-longer term climate-related threats.

4.7.5 Research gaps and future opportunities

In its submission to the Productivity Commission's inquiry into the barriers to adaptation, the Tasmanian Government (2011: 6) argued that:

Adaptation policy responses are limited by the depth of understanding of how information pertaining to climate change impacts relates to different end users, sectors and purposes. Across a number of industry sectors in Tasmania, imperfect information on how climate change may impact economic performance has been identified as a barrier to adaptation.

Interview and workshop participants reinforced the view that quality information on climate change impacts and adaptation needs to be relevant to business and industry end users, at temporal and spatial scales suited to their planning and decision-making processes. Such research needs to be cognisant of the myriad factors that will influence any business' ability to identify, develop and act upon adaptation decisions. Such information will be critical in order to identify and assess the adaptive capacity of individual businesses and industry sectors, as it is likely to be highly variable and dependent on a range of factors that will often take precedence over adaptation per se. Accordingly, business and industry sectors need to be engaged in the process of adaptation research for adaptation options to be incorporated into business and industry strategic planning.

'While the new climate simulations are invaluable, their full potential is not realised unless researchers and policy makers use them in their research, business planning and decision making processes.'


(ACE CRC 2012b)

At present, a significant information gap exists in terms of business and industry preparedness, expertise and knowledge about climate change impacts and adaptation options. This information gap is not unique to Tasmania (e.g. Johnston et al. 2013; West & Brereton 2013).

The CFT project has set a high standard in terms of researcher-industry collaboration, and could form the basis for further Tasmanian industry-specific studies. As noted by the ACE CRC (2010b: 13):

While the new climate simulations are invaluable, their full potential is not realised unless researchers and policy makers use them in their research, business planning and decision making processes. Therefore, to make sense of the mathematically complex simulations, an intermediate step is required to extract and interpret the simulations for particular geographic areas, industry sectors or applications.

4.8 Emergency management

 Key findings – Emergency management	
Climate change impacts	<ul style="list-style-type: none"> ◆ Tasmania is likely to experience more extreme weather, with increases in rainfall intensity and temperature extremes ◆ there will also be more dry days, with an associated increase in bushfire conditions
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ there are likely to be longer fire seasons with more frequent and more intense fires. ◆ there will be more storms, with increased flooding, coastal inundation and estuarine flooding
Current adaptation efforts	<ul style="list-style-type: none"> ◆ emergency management issues are being reflected in new planning reforms, such as the bushfire code ◆ the State Natural Hazards Policy Framework provides a foundation for refining and implementing reforms in the emergency management sector
Future options	<ul style="list-style-type: none"> ◆ the cost of future extremes and options for resourcing emergency responses is being examined at the national level, but requires state-specific analysis ◆ future efforts will involve a combination of householder and community education, land use planning measures, and enhanced resourcing and capacity building the emergency management organisations
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ the uncertainty associated with extreme events is unlikely to be reduced by further modelling work, so future research should focus on aspects of community resilience, community and organisational preparedness and adaptive capacity

4.8.1 Understanding climate change impacts

The *Climate Futures for Tasmania: Extreme Events* study shows that the state is moving towards a pattern of more extreme conditions (White et al. 2010a). This is consistent with research at the national and international levels (AFAC 2009b; IPCC 2012). The CFT project examined a range of extreme temperature, rainfall, and bushfire conditions to assess the likely impacts of climate change on the characteristics of these events this century.

The study projects an increase of up to 60% in peak intensity rainfall events across the state. Extreme rainfall events are likely to become more frequent, with associated flooding issues, but with an overall decrease in the number of rain days that will affect bushfire conditions (White et al. 2010a). The report concludes that:

the emerging pattern of change represents a consistent and progressive adjustment of the current climate and its weather patterns to a new climate where there will be more hot days and warm nights, more extreme wet days, an increase in the size of heavy downpours, and more dry days. The intensifying of rainfall events also leads to a tendency for increased drier and wetter conditions on seasonal and annual bases and the reduced occurrence of normal conditions (White et al. 2010a: executive summary).

Work on climate change and emergency management conducted at the national level suggests the following impacts of these projected changes to extreme events relevant to Tasmania:

- longer fire seasons;
- greater frequency and higher average intensity of bushfires;
- more storms and higher winds, with resulting vegetation and infrastructure damage; and
- increased flooding, coastal inundation and estuarine flooding (AFAC 2009b).

In addition to the statewide modelling of coastal inundation and storm surge that has been undertaken (see section 5, bushfire modelling for the southern region of Tasmania has been conducted as part of the Regional Councils Climate Adaptation Project. The modelling used the Tasmanian Bushfire Risk Assessment Model (BRAM) (Graham et al. 2012) and the A2 scenario to model bushfire scenarios over near-future, mid-century and end-of-century time scales. It showed increased bushfire risk across Tasmania, but especially in the central plateau (Graham et al. 2012).

The *Climate Futures for Tasmania* project and other work has provided Tasmanian decision-makers with detailed and comprehensive fine-scale climate change modelling. It is especially valuable in adaptation planning for gradual, iterative change. Despite the rigour of this work, however, uncertainty remains over factors such as the timing, frequency and severity of extreme events. The uncertainty associated with extreme events is unlikely to be reduced by further modelling work, so future research is likely to focus on aspects of community resilience, community and organisational preparedness and adaptive capacity.

4.8.2 Understanding sectoral vulnerabilities

The shift towards more extreme weather conditions and more bushfire conditions has major implications for the emergency management sector. Handmer et al. (2012) see the broader societal consequences of weather-related disasters as a function of the effectiveness of disaster reduction efforts, emergency services activities, and the social and economic resilience of the affected community. These impacts will be exacerbated or responses made more complicated by virtue of demographic and socioeconomic trends such as ageing

populations, work patterns, land-use change, migration to and from rural areas and changed volunteering levels.

A national assessment of the impact of climate change specifically on the bushfire and the emergency services sector (AFAC 2009a, 2009b) concluded that the impacts on the sector will be influenced by changes in the frequency and intensity of emergencies and the exposure of the community (e.g. increased fire or flooding risk); and indirect impacts on the capacity of the service providers to deliver services (cost and security of supply of energy and water). Not only will the emergency services sector have to deal with extreme events and the uncertainty around projected changes over the long term, it will also have to modify the way it does business in response to changes in event profiles, and community resilience and exposure and in response to increased demand for services across sectors/events, regions, and even internationally (AFAC 2009b).

The Australasian Fire and Emergency Service Authorities Council (AFAC 2009b) identifies important roles for emergency services managers in providing input on infrastructure design, land use planning and building standards, negotiating new allocations of responsibility and expectations between the sector and the community. The AFAC (2009b) also warns that the sector needs to monitor demographic and socio-economic trends, and engage in on-going community education and awareness.

There are several research initiatives underway at the national level considering the impacts of climate change on extreme events. Loughnan et al. (2012) have identified threshold weather conditions for mortality in Australian capital cities; described spatial distributions of human vulnerability to extreme heat; and provided information to target emergency responses during heat waves. It developed an index for each capital city that describes baseline (current) risk and predicted changes in risk in relation to climate change impacts for 2030, taking into account altered risk profiles from age, population density (as a surrogate for urban heat island), and wealth. Others have focussed on various aspects of the Prevention-Preparedness-Response-Recovery (PPRR) emergency management framework (Handmer et al. 2012). These are directly relevant to adaptation insofar as both focus on risk and vulnerability reduction (Gero et al. 2010).

4.8.3 Existing adaptation efforts

A significant body of research exists to inform the emergency management sector's response to the current climate, and a growing body of literature about the likely changes to extreme events in the future. There are some major policy documents relating to climate change adaptation and emergency management (Ministerial Council for Police and Emergency Management 2009, COAG 2011), but there is relatively little research that explores the implications of future climatic conditions for emergency management (Handmer et al. 2012).

Considering the first element of the PPRR emergency management spectrum, preventing the effects of extreme events falls largely outside the domain of emergency management agencies and relates principally to planning and building standards. The National Strategy for Disaster Resilience (AEMI 2011) highlights land use planning as a critical way of strengthening climate-related disasters, although Handmer et al. (2012) note the trend across Australia to deal with increased risks by using greater reliance on emergency

management responses rather than tighter land use planning. The tension between planning imperatives and emergency management considerations has also been observed in Macintosh et al. (2013), in the context of approaches to land use planning for bushfire hazard in Tasmania and nationally.

The Tasmanian State Government has developed a policy framework for natural hazards and policy responses (DPAC 2012d). On the basis of this framework, it has reviewed arrangements for land use and development in bushfire prone areas and produced a new Planning Code for Development in Bushfire Prone Areas (discussed in more detail in Section 6.4.3.). Neither the Bushfire Code nor the hazards framework specifically addresses the exacerbating influences of climate change on hazards. Macintosh et al. (2013) suggest that climate change is being actively considered in planning for coastal hazards, but not for bushfire. The exacerbating effect of climate change on bushfire threat is likely to be considered by altering the bushfire attack level (BAL) that influences the building standards to which new buildings must conform, rather than in any explicit adjustment to the planning framework (Macintosh et al. 2013). Additional policy statements outlining the State Government's approach to managing the risks of coastal erosion and inundation and severe weather in land use planning are under development (DPAC 2012c).

Several local government climate change adaptation projects have also considered emergency management dimensions. Each local council in the Southern Tasmanian Region has recently prepared a climate change risk assessment as part of the Southern Tasmanian Councils Climate Change Adaptation Project (RCCCAP) and is completing a Climate Change Adaptation Action Plan. A toolkit for local government to promote community adaptation to bushfire in a climate change context has been developed for the Southern Tasmanian Councils Authority, based on research in Kingborough and Huon Councils (Chaplin & Fairbrother 2012). In 2010, LGAT produced a series of climate change studies addressing particular climate risks in specific local government areas around the state (LGAT 2010).

4.8.4 Understanding future options

Research for the Southern Tasmanian Councils Authority identified important barriers or impediments to bushfire preparedness, including:

- urban expansion leading to new residents with little understanding of risks;
- lifestyle choices leading to gaps between awareness of risk and actual householder preparedness; and
- an ageing population, leading to greater reliance on emergency services (Chaplin & Fairbrother 2012).

The resource constraints of the emergency services agencies will also be major factors in future. It is clear that the future financial and social costs of extreme events are likely to increase with the severity of these events. Governments across the country are recognising the limits to their ability to fund emergency management resources. Greater emphasis is being placed on the importance of prevention over response and recovery, and sharing of responsibility and cost across government, the community and private actors (Climate Commission 2011; NCDR 2011).

Support for those who experience climate-related emergencies also requires closer investigation. Current approaches to disaster relief funding may be either inefficient or maladaptive (Bird et al. 2011; Vernon-Kidd et al. 2010; Wenger 2012; Kuruppu 2013). Research by the insurance industry has modelled that removing premium-based taxes would reduce the number of households without contents insurance in Tasmania from 47,000 to 2,600, and without building insurance from 7,000 to 800 (Productivity Commission 2012). Other national research shows that the potential for insurers to drive adaptation by incentivising actions that reduce or avoid future risks associated with climate change is currently under-utilised (Bird et al. 2011).

4.8.5 Research gaps and future opportunities


The January 2013 bushfires have triggered further research into bushfire prevention, preparedness and response. At the same time, they have launched a broader community conversation about roles and responsibilities in respect of mitigating, preparing for, responding to, and recovering from extreme events. At the same time, extreme events on the mainland such as the Queensland floods offer important lessons for emergency management agencies in Tasmania.

The uncertainty associated with extreme events is unlikely to be reduced by further modelling work, so future research is likely to focus on aspects of community resilience, community and organisational preparedness and adaptive capacity. At the national level, Handmer et al. (2012) have identified a range of national information needs for the emergency management sector. The following list represents those research priorities for which Tasmania-specific research would be particularly beneficial:

- changes to community vulnerability resulting from demographic and other processes;
- how the capacity of communities to respond to projected climate impacts can be enhanced;
- institutional responses to changed climate conditions and consequential demands on emergency services;
- how communication tools can manage emerging climate change induced emergency service demands;
- compounding effects of climate-change derived climate conditions and weather events, such as drought and heat waves; and
- trade-offs between prevention and other values, such as native vegetation conservation.

Given the paucity of research on these issues that is specific to Tasmania's social, demographic and economic and institutional context, further exploration of these issues from a specifically Tasmanian perspective should yield valuable insights.

4.9 Policy and governance

 Key findings – Policy and governance	
Climate change impacts	<ul style="list-style-type: none"> ◆ local climate profiles have been developed for Tasmania’s 29 local government areas ◆ the impacts of climate change on coastal hazards are the major focus on current adaptation policy
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ there is growing recognition that climate change impacts are likely to place pressure on existing governance arrangements, and on the allocation of roles, responsibilities and resources between level of government, and between government and private actors.
Current adaptation efforts	<ul style="list-style-type: none"> ◆ advances have been made in coastal adaptation policy in Tasmania recently and further initiatives are underway ◆ the Regional Councils Climate Adaptation Project has enabled climate change impacts and adaptation options to be considered for Tasmania’s Southern region and incorporated into a regional adaption strategy and council adaptation plans
Future options	<ul style="list-style-type: none"> ◆ there is a growing consensus that transformative change is necessary to successfully transition to a climate change adapted society ◆ the barriers to both incremental and transformative change require close attention ◆ research emphasises the need for attenuated engagement processes that recognise and respond to characteristics of individual communities rather than attempting to impose uniform, top-down policy responses.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ research opportunities should focus on maximising the transformative potential of medium-term adaptation responses, and practical approaches to improving policy, planning and governance frameworks. ◆ approaches that align bottom-up initiatives with top-down framework and policy development are required as a priority

The implications of climate change impacts and adaptation for policy and governance in Australia have been explored across a range of sectors, with particular attention given to coastal zone management. More generally, the roles and responsibilities of different levels of

government in managing risks, raising awareness and creating the circumstances in which adaptation may occur efficiently and effectively have been the focus of recent research.

4.9.1 Understanding climate change impacts

As detailed in previous sections of this report, the CFT project and subsequent work based on CFT data have provided the basis for much of the Tasmania-specific work focussed on understanding climate change impacts at a scale relevant to decision-making and policy formulation. This includes a series of research reports tailored to particular sectors (e.g. Holz et al. 2010; White et al. 2010a) and *Local Climate Profiles for Tasmania's 29 Local Government Areas* (DPAC 2012a). These reports have been useful in policy development, providing a basis for further investigations such as the Tasmanian Coastal Adaptation Decision Pathways project (LGAT 2012), and the development of the *Adapting to Climate Change in Tasmania: Issues Paper* (DPAC 2012a), which will inform the development of the Tasmanian 2020 Climate Change Strategy, due for completion in 2013.

Emerging hazards associated with sea level rise in the coastal zone have been the focus of Tasmania-specific research effort since at least 2004 (DPIW 2004), owing to the importance of the coast to our society and the fact that these hazards are presenting current day management challenges to community and all levels of government (e.g. Carley et al. 2008). For 'the Island State', coastal hazards are an immediate priority for policy development, and an ongoing challenge for the state government and 25 of the 29 local governments with responsibilities for coastal areas.

4.9.2 Understanding sectoral vulnerabilities

Recent work in the Tasmanian context has focussed on understanding sea level rise and coastal hazards (Hunter 2012, DPAC 2012b) and translating this understanding into effective policy responses. As noted in section 6.4.3 the Tasmanian Government has established a sea level rise planning allowance and released a second stage of coastal inundation mapping (Lacey et al. 2012), which incorporates the sea level rise planning allowance (see DPAC 2012c) and coastal erosion mapping is due to be completed by early 2013.

General (as distinct from coastal) climate change impacts and options for adaptation have been examined at a national level (DCCEE 2010) and more recently via an in-depth examination in Southern Tasmania through the Regional Councils Climate Adaptation Project (STCA 2012).

Traditional policy development approaches in rural and primary industries settings have been assessed as inadequate to deal with the complex and multi-faceted impacts of climate change (Nelson et al. 2010a). Demographics of rural and regional communities have attracted a particular research focus, as the barriers to adaptation in these communities may require specific strategies and policy approaches in order to progress effective responses (Nelson et al. 2010b). These findings are of particular relevance to Tasmania, given the

'...many climate change impacts are likely to place pressure on existing governance arrangements, and on the allocation of roles, responsibilities and resources between level of government, and between government and private sectors.'

preponderance of rural and regional communities and older mean age relative to the overall population.

There is growing recognition that many climate change impacts are likely to place pressure on existing governance arrangements, and on the allocation of roles, responsibilities and resources between level of government, and between government and private actors. National studies have identified the need of reform in relation to coastal governance arrangements for adaptation (ALGA 2011; Forbes 2009; Gibbs & Hill 2011; Good 2011; Gurran et al. 2011; House of Representatives 2010). Coastal climate change policies have been found to be particularly lacking in Tasmania, in comparison to other states (Gibbs & Hill 2011).

The Royal Commissions following both the Victorian bushfires and Queensland floods have also highlighted legal, policy and institutional failures. Several studies have concluded that collaborative approaches to address weaknesses in areas crucial to policy and governance are required (e.g. knowledge management, legislative frameworks) (ALGA 2011; DCCEE 2010).

4.9.3 Existing adaptation efforts

State, territory and national governments have started to articulate the appropriate allocation of roles and responsibilities for adaptation – across levels of government and between government and private interests (COAG 2012; DPAC 2012c; TCCO 2012a). The Tasmanian Government (TCCO 2012a) identifies four roles for government in adaptation:

1. providing sound public information at the regional and local level;
2. taking climate change risks and opportunities into account in public policy, planning and regulation;
3. managing climate change risks and impacts to state-owned and managed infrastructure, assets and services; and
4. assisting vulnerable communities to build climate resilience and adaptive capacity.

These draft statements of policy have yet to be thoroughly tested or validated in either practice or adaptation theory.

Considerable advances have been made in coastal adaptation policy in Tasmania in very recent times, and a number of initiatives are underway at the time of writing. As noted above, the announcement of a sea level rise planning allowance and the development of a state coastal framework will significantly enhance the state's response to coastal climate hazards.

Some recent coastal adaptation projects have contained significant research components of significance to policy and governance arrangements. This research can be classified as either technical modelling and mapping of vulnerable areas, or 'action research' that focuses on the decision-making and community engagement processes. Work in Clarence Council and under the Tasmanian Coastal Adaptation Pathways Project has identified a 15-step decision pathway for assisting in coastal adaptation that involved two parallel processes – a community process and a policy and planning process (SGS 2012), set out in Figure 9.

Community process

Policy and planning process

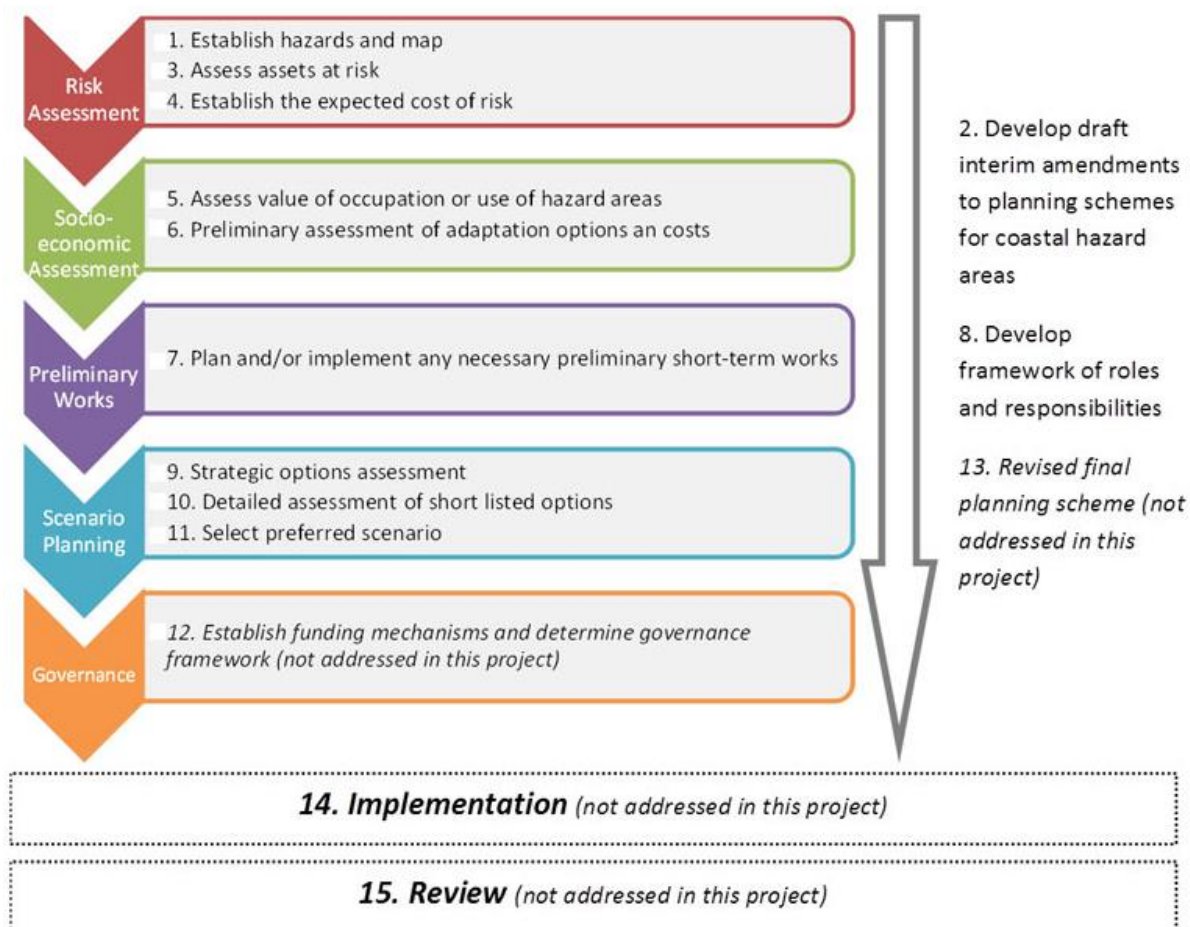


Figure 9. TCAP Pathway process

Source: SGS Economics 2012, www.dpac.tas.gov.au

Studies covering steps 1-9 have been undertaken in Kingston (Kingborough Council), St Helens/Georges Bay (Break O'Day Council), and Port Sorell (Latrobe Council). For Lauderdale in Clarence City Council, step 12 was reached (SGS 2012a). In addition to these projects, a pilot study of the township of Snug in Kingborough explored community interest in, and capacity to adapt to, coastal hazards and sea level rise (Leith et al. 2012). Leith et al. recommended the development of community-based approaches to managing current and future coastal hazards that integrate the efforts of Council, community and science; improvement in Council's level and quality of consultation and communication with the community in coastal hazards management; and development of a citizen science program to collect information about coastal hazards and risks.

Twelve other projects funded through the Australian Government's *Coastal Adaptation Decision Pathways Program* will release findings and reports early in 2013. These projects from across the country have been funded 'to develop leading practice approaches to better manage future climate risk to coastal assets and communities' (DCCEE 2012). They will provide valuable insights into a range of process issues relating to the way adaptation can and should occur in the coastal zone, as well as economic valuation approaches.

Hadwen et al. (2011b) have undertaken research into adaptation pathways for coastal ecosystems and recommend the following principles for coastal zone adaptation (Hadwen et al. 2011b):

1. Adaptation needs clearly defined goals
2. Decision-making must include stakeholders from environmental, social and economic realms
3. Decision-making requires data to be easily available and shared
4. Adaptation demands a drastic re-think of existing policy and planning constraints
5. Adaptation requires a thorough understanding of connectivity within and between ecosystems
6. While adaptation must occur at the local or regional scale, broader perspectives are also important
7. Climate change adaptation should not be considered in isolation of non-climate threats coastal environments already face.

The Regional Councils Climate Adaptation Project has enabled climate change impacts and adaptation options to be considered for Tasmania's Southern region and incorporated into a regional adaption strategy and council adaptation plans which are expected to be published in 2013 (STCA 2012).

4.9.4 *Understanding future options*

Recognition of barriers to effective adaptation at a range of spatial and temporal scales is of key importance in policy development (Gero et al. 2012; Barnett and Waters 2013). Development and implementation of effective strategies to overcome these barriers must be responsive to the scale at which the barrier is occurring. They must also recognise the limited impact of relatively straightforward short-term 'no-regrets' actions aimed at helping communities and organisations to deal with current climate variability and extreme events (Productivity Commission 2012).

In the longer term, it is important to ensure that policy responses are grounded in paradigms that recognise the game-changing nature of climate change and avoid maladaptation (Herriman et al. 2012; Mukheibir et al. 2012a). There is a growing consensus that transformative change is necessary to successfully transition to a climate change adapted society (including economy, polity) (Moser & Ekstrom 2010). Research focussing on the preconditions for transformative change is highlighting limitations in our legislative and regulatory frameworks (Macintosh et al. 2013) and urban planning (Matthews 2012). Key themes emerging in this research focus on social, economic and institutional circumstances that either hinder or facilitate adaptation initiatives in terrestrial management (Gilfedder et al. 2012; Hughes et al. 2010; Jones in progress), as well as marine systems (Haward et al. 2012; Lockwood et al. 2011). Research also emphasises the need for attenuated engagement processes that recognise and respond to characteristics of individual communities (Leith et al. 2012; SGS Economics 2012b) rather than attempting to impose uniform, top-down policy responses.


Valuation of environmental assets may enable objective prioritisation of adaptive actions designed to manage impacts of climate change on particular natural systems. The current state of knowledge in this field is improving and in time may become consistent enough for policy makers to confidently apply a benefit-cost methodology to underpin decision making for natural systems (Bennett 2011).

4.9.5 *Research gaps and future opportunities*

Governance arrangements, especially those that clarify the roles and responsibilities of public and private sector actors, and different tiers of government, are increasingly being recognised as enablers of adaptation. Conversely, the absence of supportive governance arrangements is a key barrier to adaptation (Barnet et al. 2013). While some additional research may be required to inform governance choices, much of this information is already available and decisions over which option to select will depend upon political preference.

Key research opportunities will focus on maximising the transformative potential of medium-term adaptation responses, and practical approaches to improving policy, planning and governance frameworks to better recognise the dynamic circumstances that climate change creates. Although much of this work will necessarily be conducted on a sector-by-sector basis, and work will continue at a local and community basis, approaches that align bottom-up initiatives with top-down framework and policy development are required as a priority.

4.10 Indigenous issues

 Key findings – Indigenous issues	
Climate change impacts	<ul style="list-style-type: none"> information about projected climate change impacts has yet to be translated into specific understandings of how physical and biophysical impacts will affect Indigenous Tasmanian communities
Sector-specific vulnerabilities	<ul style="list-style-type: none"> Tasmanian Aboriginal cultural heritage is particularly at risk from sea level rise and associated impacts, since many sites are located in intertidal and subtidal areas there has been no specific assessment of the vulnerability of Indigenous communities in Tasmania to the direct or indirect impacts of climate change, based on socio-economic, geographical, or cultural differences
Current adaptation efforts	<ul style="list-style-type: none"> no evidence of any research detailing current climate change adaptation efforts relating to Tasmanian Aboriginal communities or heritage values was identified
Future options	<ul style="list-style-type: none"> a clearer understanding of impacts and vulnerabilities is needed before future options can be considered
Research gaps and opportunities	<ul style="list-style-type: none"> a proper assessment of the impacts of climate change on Tasmanian Indigenous communities, taking into account the vulnerability and adaptive capacity of Indigenous individuals, households, communities, businesses and institutions

4.10.1 Understanding climate change impacts

The *Climate Futures for Tasmania* (CFT) project provides a substantial baseline of research identifying the physical changes that Tasmania will experience as a result of climate change. While much of the detailed climate change information presented in the CFT project is relevant to Tasmania's Indigenous communities and heritage values, this information has yet to be translated into specific understandings of how physical and biophysical impacts will affect Indigenous Tasmanian communities. One physical change already identified as critical for Indigenous communities is sea-level rise. Sea-levels have already risen around Tasmania over the last century (Church et al. 2012; Gehrels 2012), and will continue to rise throughout the 21st century. The TCCO suggest an allowance of 0.8m above 1990 levels by 2100 (TCCO 2012). Sea-level rise, increased flooding and storm surge events are already affecting Tasmania's coasts (Sharples 2004, 2006). These processes threaten Tasmanian Aboriginal heritage, including coastal rock art, middens, burials, sacred and ceremonial sites, hut depressions, stone and ochre resources. It is anticipated that significant Aboriginal cultural

heritage will be destroyed and removed from context by these forces. Tasmanian Aboriginal cultural heritage is particularly at risk since many sites are already located in intertidal and subtidal areas (Page & Thorp 2010).

4.10.2 Understanding sectoral vulnerabilities

There has been no peer-reviewed research into climate change impacts or adaptation specific to Indigenous Tasmanian communities and associated heritage values, practices, landscapes and seascapes. At the national level, Indigenous communities have been identified as particularly vulnerable to the impacts of climate change (Langton et al. 2012), especially in the areas of physical and mental health, because of their remoteness, socio-economic conditions, and exposure to extreme events and natural disasters (House of Representatives 2009). There is also recognition at state government level that Indigenous heritage and culture is under threat from the impacts of climate change (TCCO 2012a; Tasmanian Planning Commission 2009).

This recognition is often focussed on the detrimental impacts of sea-level rise, coastal erosion and inundation on Tasmania's Aboriginal cultural heritage. Sea-level rise is likely to profoundly transform Tasmania's coastal landscapes (DCC 2009); environments economically, culturally and spiritually significant for Aboriginal Tasmanians, providing numerous natural resources upon which many traditional cultural practices are based, but also aesthetic and geographic landscapes important to delineate country. A report into the impact of sea-level rise on the Circular Head region of the North-West coast noted that 'Aboriginal people have identified the Circular Head region as being especially significant for education in traditional use of the land and sea' (Tilden 2011: 2), highlighting the interlinked connections between natural, economic and social values impacted by climate change.



Photo 14. Circular Head is significant for education in traditional use of land and sea
Photo: DCCXLIX, Flickr

While there is awareness that sea-level rise will have ‘catastrophic consequences for the survival of important elements of Tasmania’s Aboriginal heritage’ (Aboriginal Heritage Tasmania 2012: np), no research was identified as specifically focussed on ascertaining site vulnerability or detailing the extent of anticipated impacts. A study into the vulnerability of Tasmanian coastal assets could not assess the extent of Aboriginal heritage likely to be affected since relevant datasets were not available or accessible for Aboriginal cultural heritage sites (DPIW 2008).

It may be speculated that climate change induced impacts on Tasmanian landscapes will have profound consequences for Indigenous physical and spiritual associations to country (Langton et al. 2012), including changes to hunting, fishing and cultural practices. The Tasmanian Planning Commission (2009: np) has noted that:

There is concern about the implications of changes in traditional recreational activities such as mutton-birding due to species population changes. A decline in the productivity of Tasmania’s coastal and marine environment due to increases in sea-surface temperatures and other climate related changes may have implications for traditional recreational activities.... Changes in the timing of plant and animal life cycle events may have implications for traditional Aboriginal activities.

While there is published research relating to some of these biophysical impacts, how they will affect Indigenous communities remains undocumented. A number of areas within Tasmania are administered by Indigenous land management agencies, such as the Tasmanian Aboriginal Centre (TAC), the Aboriginal Land Council of Tasmania (ALCT) and the Tasmanian Aboriginal Land and Sea Council (TALSC), and these organisations are likely to require access to information about the biophysical impacts resulting from climate change to inform their decision-making, planning and management activities.

There has not been any specific assessment of the vulnerability of Indigenous communities in Tasmania, based on socio-economic, geographical, or cultural differences, to the impacts of climate change. Nor has there been any research into indirect effects from changes to Tasmania’s natural environments (for example, changes to fishing, hunting and cultural practices). Research of potential relevance to Indigenous Tasmanian communities has been conducted either generically at a national level, is embedded in studies of Indigenous communities from other parts of Australia, or derives from Tasmanian-specific research related to other sectors.

Given the dearth of research relating specifically to Indigenous Tasmanians, research projects undertaken in furtherance of the *National Adaptation Research Plan for Indigenous Communities* (Langton et al. 2012) could form the basis for future inquiries into the impacts, vulnerabilities, adaptation options and future opportunities relating to Indigenous communities in Tasmania. Potentially relevant projects are listed in Table .

Table 7. NCCARF projects of potential significance to Tasmanian Indigenous communities

Title	Objectives
<p>Health impacts of climate change on Indigenous Australians: identifying climate thresholds to enable the development of informed adaptation strategies</p> <p>Donna Green (University of New South Wales)</p>	<p>This project aims to provide decision-makers with clear and robust policy-relevant evidence that identifies the connections between climate, and the health and well-being of Indigenous people in the tropical north of Australia. It is the first major comparative study to test the hypothesis of disproportionate climate impacts on health, through two separate but related projects in urban and remote Indigenous communities. The study disaggregates data by indigeneity for past climate-morbidity and mortality relationships in order to identify thresholds in the urban setting. These identified thresholds would then be used to project mortality and morbidity of Indigenous people to future climate change, assuming no acclimatisation or adaptive strategies occur.</p> <p>In the remote community sites, in addition to the quantitative analysis, the project will also perform a qualitative study to assess the psychosocial impacts of climate change through the use of semi-structured interviews. Overall, we anticipate this research will better enable policy-makers to develop effective adaptation strategies to increase the resilience of Indigenous Australians to the health impacts of climate change.</p> <p>(http://www.nccarf.edu.au/content/health-impacts-climate-change-indigenous-australians-identifying-climate-thresholds-enable)</p>
<p>Changes to Country and Culture, Changes to Climate: strengthening institutions for Indigenous resilience and adaptation</p> <p>Jessica Weir (Australian Institute of Aboriginal and Torres Strait Islander Studies)</p>	<p>To understand the barriers to and enablers of Registered Native Title Bodies Corporate (RNTBCs) in facilitating community driven adaptation on native title lands and develop best practice for participatory climate change decision-making, specifically through:</p> <ol style="list-style-type: none"> 1. analysing and documenting the role and capacity of RNTBCs in climate change adaptation, through collaborative research partnerships; and 2. providing relevant stakeholders with knowledge to develop effective working relationships with RNTBCs, based upon an appreciation of their unique systems of communal land ownership and governance circumstances <p>(http://www.nccarf.edu.au/content/changes-country-and-culture-changes-climate-strengthening-institutions-indigenous-resilience)</p>

Title	Objectives
<p>Learning from the past, adapting in the future: identifying pathways to successful adaptation in Indigenous communities</p> <p>Meg Parsons (University of Melbourne)</p>	<p>This project will examine how Indigenous individuals, households, communities, business, and institutions perceive and respond to climate variability and extreme weather events. It will explore the importance of climate events and climate change relative to other risks facing Indigenous communities. It will identify entry points for the development and implementation of equitable, efficient and appropriate climate change adaptation plans and policies for Australian Indigenous communities. Using case studies, and a systematic review of experiences and cases from across Australia and internationally, it will produce information to assist Indigenous communities and decision makers to engage in and develop community level adaptation strategies, and suggest strategies to enhance adaptive capacity within the communities.</p> <p>(http://www.nccarf.edu.au/content/learning-past-adapting-future-identifying-pathways-successful-adaptation-indigenous)</p>
<p>Understanding Urban and Peri-urban Indigenous People's vulnerability and adaptive capacity to Climate Change</p> <p>Daryl Low Choy (Griffith University)</p>	<p>The challenges facing coastal communities in Australia are potentially immense, and while community and stakeholders generally accept that change is occurring, the degree of change remains disputed, and the visual picture of what settlements might have to adapt to and address is very unclear. Using case study areas in Queensland, South Australia and Victoria, this project will investigate the long-accumulated knowledge of Australia's Indigenous community regarding the challenges of climate change for coastal communities.</p> <p>(http://www.nccarf.edu.au/content/understanding-urban-and-peri-urban-indigenous-peoples-vulnerability-and-adaptive-capacity)</p>

4.10.3 Existing adaptation efforts

No evidence of any research detailing current climate change adaptation efforts relating to Tasmanian Aboriginal communities or heritage values was identified in this review. A conference abstract by Prince (2007) and report by Rao et al. (2008) mention efforts by the Parks and Wildlife Service and the TALSC to stabilise and revegetate eroding middens located within the Tasmanian Wilderness World Heritage Area (see also unpublished reports mentioned by the Tasmanian Planning Commission 2009). The *Tasmanian Coastal Works Manual* (Page & Thorp 2010: 11) notes rising sea-levels as an added impetus for protection of 'Aboriginal sites and values from human impacts such as works activities' and suggests that 'land managers should monitor sites carefully for any changes or potential impact and undertake risk assessments to determine the best strategies for mitigation and protection of heritage values where appropriate'.

4.10.4 Understanding future options

In light of the limited research, it is hard to assess the extent to which climate change poses significant threats to Tasmania's Indigenous communities. Without an assessment of potential risks, it is difficult to identify and evaluate future options.

4.10.5 Research gaps and future opportunities

The absence of research into the impacts of climate change on Indigenous communities and cultural heritage values in Tasmania is potentially a significant gap. Hence, it is difficult to identify specific research gaps and opportunities other than to speculate that they echo those existing nationally. According to Langton et al. (2012: 4), research should prioritise the vulnerability and adaptive capacity of Indigenous individuals, households, communities, businesses and institutions.

Whatever research is done must be cognisant of cultural issues and perspectives. For example, Thom et al. (2009: 15) have noted that the 'cultural links of Indigenous communities to sea country create some highly sensitive issues when examining potential adaptation strategies to climate change'. A paper by O'Neill et al. (2012: 1107) on local Indigenous resistance to research on the impacts of climate change in Torres Strait highlighted that 'adaptation responses are likely to be prioritised differently' for Indigenous communities.

5 SYNTHESIS AND CROSS-CUTTING THEMES

This section examines challenges and future directions for Tasmanian policy-makers, researchers and practitioners considering adaptation futures. We first examine the common drivers of adaptation in order to understand better where the entry points for enhancing adaptation actions might be. We then explore common themes and issues that emerged in our exploration of what short- and medium-term vision researchers and stakeholders held for adaptation in their sectors or fields. The barriers to progressing these visions are identified, followed by a discussion of the sectoral dependencies and relationships that may influence future adaptation pathways.

Given the lack of Tasmania-specific research on these cross-cutting issues, the discussion synthesises findings from interviews with researchers and stakeholders, and discussions during the project workshop held in December 2012. Where relevant, literature is cited in support of these findings.

5.1 Drivers of adaptation

Summary – Drivers of adaptation in Tasmania

- ◆ funding and resources (may be a mechanism driving adaptation or lack of funding may be barrier)
- ◆ past events (e.g. extremes, climatic impacts), knowledge of likely physical impact that will result in cost
- ◆ changes in market supply & demand
- ◆ changes in policy and political environment
- ◆ community or public pressure, general awareness and community attitudes
- ◆ developments in research and understanding, capacity and know-how
- ◆ desire to seize new opportunities
- ◆ risk management, avoiding catastrophic change, mitigating discomfort of change and transformation, avoiding legal liability
- ◆ moral impetus, intergenerational equity
- ◆ loss of goods/services etc including personal loss

There are very few published case studies of adaptation in Tasmania. Conclusions about what might be driving adaptation have therefore been drawn through inference from available literature as well as feedback from interviews and the project workshop. Workshop participants were each asked to identify what they thought were the most significant drivers (or motivators) of adaptation for their sector. Examples such as changes in production or market conditions, changes in the policy environment, or changes to supply chains were given as examples, to serve as thought-starters. Participants were asked to write their responses clearly and concisely on sticky notes. These notes were then posted on the wall for all to view, and grouped into themes.

Grouping occurred immediately after all participants had completed their notes, and was done in consultation with workshop participants to verify that the choice of category captured their original intent. Ten emerging themes are outlined in Table 8, below. Against each theme heading is the group of responses provided. While the theme categorisations and rankings are indicative only, based on a snapshot of professional opinions, the findings do largely correspond to those from the larger body of Australian and international literature on the motivations for adaptation (see, for example, Kiem et al. 2012, King et al. 2012).



Photo 15 Workshop participants were asked to identify significant drivers of adaptation. Photo: Holger Meinke

Table 8. Workshop participant opinions on drivers of climate change adaptation interest and action

Driver	Examples of comments	
Funding and resources (may be a mechanism driving adaptation or lack of funding hindering adaptation innovation)	<p>'Money!'</p> <p>'Changing financing mechanisms [for infrastructure](e.g public-private partnerships)'</p>	<p>'Lack of funding /resources....'</p> <p>'Future access to funds and insurance [infrastructure]'</p>
Past events (e.g. extremes, climatic impacts), knowledge of likely physical impact that will result in cost	<p>'Shifting species distribution'</p> <p>'Changes in environmental health condition'</p> <p>'Response (or lack of) to extreme event'</p> <p>'Past events and current variability'</p>	<p>'Warming & drying of wetter uplands (Tasmanian Central Plateau)'</p> <p>'Response to extreme event'</p> <p>'A need to respond to an extreme event – particularly one that is likely to occur again and again (flooding, bushfire, sea level rise, drought etc)'</p>
Changes in market supply & demand	<p>'Changes in markets – demand & supply – across state, national, international scales'</p> <p>'Marine resources – markets & demand'</p> <p>'Changes in other sectors (affecting food supply, production, employment, markets, fiscal environments .'</p> <p>'Changes in water demand and patterns of use'</p> <p>'Shifts in availability of skilled & unskilled labour'</p>	<p>'Economic downturn –profitability of businesses related to climate change impacts'</p> <p>'Changes in markets – as population awareness changes the demand for greener products will drive adaptation. Climate change will limit or create opportunities'</p> <p>'...industry concern/pressures e.g. tourism'</p>
Changes in policy and political environment (not necessarily related to adaptation)	<p>'Water law and policy changes (biodiversity)'</p> <p>'Governance'</p> <p>'Changes in land-use'</p> <p>'National policy (e.g. carbon/energy)'</p> <p>'Climate change as critical external factor in policy setting'</p> <p>'lack of political will'</p> <p>'Broader planning reforms'</p>	<p>'Political will – governments prepared to act'</p> <p>'Changes in policy environment enabling adaptation'</p> <p>'Changes in policy affecting communities (industries, employment, education, housing etc) Biodiversity adaptation responses (e.g. Marine Park Areas)'</p>

Driver	Examples of comments	
Community or public pressure, general awareness and community attitudes	<p>'Increased levels of demand from community & industry for certainty in planning'</p> <p>'Land use planning - changes in community values'</p> <p>'Knowledge & awareness of impacts, adaptation approaches and opportunities'</p> <p>'Changes in community awareness around disaster response and recovery'</p>	<p>'Public awareness'</p> <p>'Changes in community expectations around disaster response & recovery (emergency management)'</p> <p>'Societal values and attitudes'</p> <p>'Community knowledge and awareness'</p> <p>'Increased community acceptance'</p> <p>'Community concern/support'</p>
Developments in research and understanding, capacity and know-how	<p>'New developments in research – climate impacts – adaptation opportunities & options'</p>	<p>'Know-how'</p> <p>'Understanding the most effective scales to operate at'</p> <p>'Projections – for emergency planning'</p>
Desire to seize new opportunities	<p>'Creating/acting on opportunities – ensuring policy settings are appropriate'</p>	<p>'Tourism opportunities'</p>
Risk management, avoiding catastrophic change, mitigating discomfort of change and transformation, avoiding legal liability	<p>'Changes in settlement patterns (density, demographics etc)[risk management]</p> <p>'...implications for liability ...access to insurance'</p> <p>'Concern about future liability'</p> <p>'Minimising exposure to risk'</p>	<p>'Risk management approach across many emergencies'</p> <p>'Risk management – social, economic, environmental'</p> <p>'Awareness of risk and vulnerability (industry specific)'</p>

Driver	Examples of comments	
Moral impetus, intergenerational equity	'Moral impetus' 'Avoidance of major change – adaptation is a minimalist approach'	'Human desire for preservation'
Loss of goods/services etc including personal loss	'Potential threats to people and assets and desire to avoid these threats' 'Reduce risk to natural assets to reduce risks to life and property from increased frequency and severity of fire'	'Balance between risk & opportunity in coastal areas (enjoy it while it is 'safe' to do so)'

From these ten major themes, participants were asked to rank the drivers in order of importance to them using Turning Point® real-time polling software.

Participants could rank up to ten drivers, in descending order of perceived importance. Figure 10 shows the aggregated scores of the ten themes. Of these, the risk management theme (*risk management, avoidance of catastrophe or transformation and legal liability*) received the highest score, followed by the *threat of loss of goods and services* (such as personal loss), and then *developments in research and understanding*. *Changes in policy and political environments* not necessarily related directly to climate change adaptation, and changes in public environments (*community pressure, awareness and community attitudes* around climate change) scored similarly.

The mid-ranking themes were *changes to markets* (factors contributing to supply and demand of goods and services), availability of *funding and resources* for adaptation work, and the impetus of responding to *past events*, particularly extreme weather events. The final two themes (the *moral impetus and intergenerational equity*, and the *desire to seize new opportunities*) ranked the lowest but were still considered important drivers for a number of participants in some form or another. While this ranking process is obviously only indicative, 83% of participants indicated that they were happy with the overall scoring.

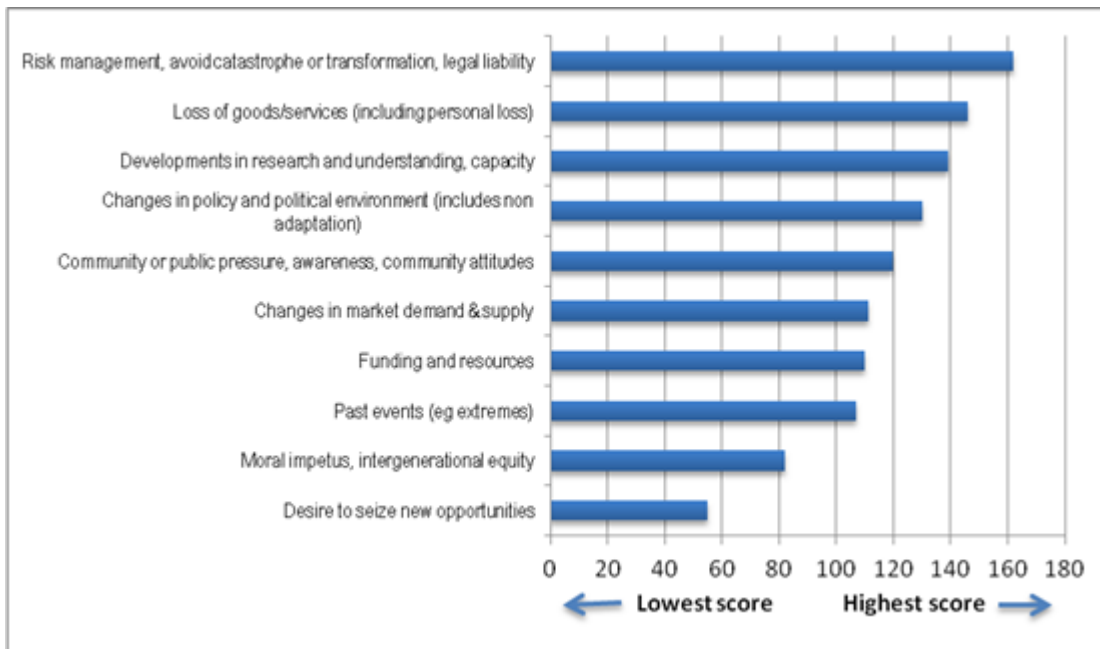


Figure 10. Top 10 drivers of climate change adaptation interest and activity

These results suggest that a high level of direct or private interest is necessary in order to drive adaptation. In many situations, people are having to experience an event first-hand before being able to imagine its potential impact on them. At a policy level, this is evident in significant reforms coming on the back of major extreme events and natural disasters that involve significant losses for governments as well as for private individuals, such as the 2011 and 2013 Queensland floods or 2009 Victorian bushfires. Research elsewhere suggests that the window for action following events may be relatively brief (Helman et al. 2010). Adaptation is more likely to occur where it can be articulated as part of a broader risk management strategy and this assumes that the risk of some adverse outcome has already been identified. The high ranking of *fear of loss* (in the form of business opportunities, property damage or legal liability) also reflects the economics and decision theory literature relating to loss aversion – that is, people are motivated more by a desire to avoid loss than by an expectation of gain (Kahneman & Tversky 1984).

The results also point to the importance of research and research funding programs as a driver of adaptation in its own right. Indeed, the fact that risk assessment was ranked highest may well reflect the importance given to risk-assessments over the first ‘phase’ of adaptation research in Australia between about 2004-2012. While we did not explore the issue in more depth, we suggest that better understandings of both the need for adaptation (for example, through the CFT, sea-level rise, and other sector-specific work) *and* the feasibility of potential adaptation options are driving adaptation planning and action in many sectors in Tasmania.

The lower importance of market influences probably indicates that climate change impacts have not yet penetrated the supply chain or customer demand. One can only assume that this will assume higher importance over time, as prudent risk management interventions give way to more pressing economic or business imperatives that are reactions to external pressures.

The fact that concern for future generations and moral impetus ranked relatively low may also reflect the current stage of adaptation action in Australia more broadly. There are, however,

significant risks that decisions taken now will create path dependencies that limit future scope to protect non-human values or future generations. This reinforces the need, emerging from the limited literature on this issue, for mechanisms by which to ensure that these interests are adequately represented and valued in present-day adaptation decision-making. This will be increasingly important in the future, as decisions are made involving difficult trade-offs between current and future interests/generations, and between protection of human versus environmental values. The precise mechanism by which to capture or represent these views will depend upon the interests to be traded-off and the benefits that might flow.

The low ranking of the driver relating to new opportunities is noteworthy, if not entirely surprising. We suggest that it reflects the level of understanding of climate change impacts, the extent of those impacts on current operations and the relative primacy of non-climate drivers in current business decision-making and policy-making.

5.2 Future visions: common elements and themes

Summary – Future visions

- ◆ Climate change adaptation needs to be mainstreamed into government and industry's core business.
- ◆ A more holistic approach to funding recognising the multi-faceted, trans-disciplinary nature of adaptation and adaptation science is required to truly mainstream adaptation.
- ◆ Improvements in governance arrangements will improve adaptation efforts. This includes: the need for clear adaptation plans and policies; roles, responsibilities and leadership); the need for holistic approaches; legal and policy reform; and more adaptive institutional arrangements.
- ◆ Enhancing adaptive capacity and resilience and reducing non-climate stressors is a no-regrets strategy for dealing with climate change.
- ◆ Resourcing is needed for effective adaptation, including adequate training or re-training of personnel, education programs, investment in new processes, and the funding of specific policies and programs.
- ◆ Local government currently lacks the resources required to deliver adaptation policies and actions.
- ◆ The effectiveness of adaptation actions requires ongoing monitoring and evaluation.
- ◆ Achieving required attitudinal shifts requires sector-specific and targeted public education programs.

Adaptation means different things across sectors and between actors. As with other parts of Australia, it is impossible to articulate a single vision for adaptation in a given sector in Tasmania, let alone for the entire state. Not surprisingly, the literature makes very little explicit reference to what adaptation needs to 'look like', but both stakeholder interviews and workshop discussions revealed a remarkably consistent, sector-neutral set of recurring themes that also find reflection in published research.

Workshop participants were asked to identify a vision for adaptation in their sector by 2040, and what steps would be needed over the next 5–10 years in order to achieve this. The exercise was undertaken for the following sectors: governance, land use planning, marine biodiversity and resources, terrestrial biodiversity, agriculture, and business and industry.

While the results of this visioning exercise cannot be taken to be authoritative for any sector, the common issues that emerged are important guides to future adaptation policy, planning, research and implementation. They should be read in conjunction with the discussion in 5.3 of barriers to adaptation, since the elements of 'good adaptation' identified often involve the removal or reduction of barriers.

5.2.1 Mainstreaming adaptation

The need for climate change adaptation to be mainstreamed into government and industry's core business was a powerful, persistent theme. There was a view that the time for 'pilot' projects addressing adaptation was past and there was now a need for adaptation to assume a more central role and become part of 'business as usual'. For government policy, this meant integrating adaptation considerations into all government departments, not just those relating to climate change: 'ideally, every government department would have a climate change adaptation strategy' (Interview 005). It also means ensuring that adaptation goes beyond merely developing a strategy and required training and resourcing within agencies and decision-making processes. From a business perspective, the priority was seen to have adaptation reflected in business plans. The call for mainstreaming also extended to budgetary arrangements: 'everyone has to do it! All budgets should have an allocation for adaptation planning' (Interview 006).

While the call for mainstreaming holds undeniable appeal, it is notoriously hard to deliver in practice. Similar calls have been made in respect of climate change mitigation, environmental protection more generally, as well as a range of other social policy objectives (such as gender and health). Fundamentally, mainstreaming requires a significant change to the way we govern. It requires the dismantling of sectoral 'silos' and a more integrated approach to the range of sectoral dependencies we discuss. Attention to the way governance arrangements support or impede adaptation is a related recurring issue addressed below. In addition, the tendency of governments to allocate funds for specific programs constrains the capacity of agencies and individuals seeking to resource broad-based initiatives that do not fit a linear model of program delivery. A more holistic approach to funding that recognises the multi-faceted, trans-disciplinary nature of adaptation and adaptation science would be required to truly 'mainstream' adaptation.

Moreover, there may be some circumstances in which mainstreaming of adaptation may itself act as a barrier. By definition, mainstreaming presupposes that existing policies and institutional arrangements can accommodate adaptation imperatives. The call for mainstreaming by stakeholders may reflect the fact that virtually all stakeholder insights are constrained by prevailing economic, business, and policy contexts. This may be appropriate in sectors where incremental change will work, but may actually serve to limit the potential for transformative change where this is needed. Our investigations revealed a profound absence of discussion of the potential for transformation, which may reflect either the entrenchment of existing path dependencies or the perceived lack of urgency or need for more fundamental changes.

5.2.2 Governance

The need for enhanced governance arrangements to support adaptation underpinned all 'visions', and was also reflected in most stakeholder interviews. Concerns over governance encompassed a wide range of issues, including: the need for clear adaptation plans and policies; roles and responsibilities (including the need for leadership); the need for holistic approaches; legal and policy reform; and more adaptive institutional arrangements.

While there is a significant body of literature characterising autonomous or reactive adaptation, there was wide agreement among participants that effective adaptation needed to be explicitly planned for. Some described this as a 'clarity of purpose', or 'policy certainty', while others simply expressed the view that we needed to 'have a plan!' or leadership (Hobson and Neimeyer 2011). While the content of these plans was discussed less than the need for the plan itself, implicit in all discussions was the importance of plans taking a pro-active, preventive approach to avoiding climate change risks.

There is broad recognition of the need for governance arrangements to clearly articulate the distribution of roles and responsibilities (Barnett & Waters 2013), and to reflect the multiple spatial and temporal scales at which adaptation needs to occur ((Kellett et al. 2011). A related issue was the importance of ensuring that governance arrangements give effect to the principle of subsidiarity – allowing decisions and actions to be taken at the level at which both scale efficiencies and accommodation of local differences can best be realised (Hadwen et al. 2011b; Robson et al. 2013).

Recognising adaptation's broad reach also means developing mechanisms by which to coordinate and share planning and implementation vertically across tiers of government and horizontally across agencies and organisations (King et al. 2012).

Some sectors foreshadowed the need for legal reform, although there was little detail about what kinds of change might be needed. An exception to this was for the marine sector, which indicated the need for a policy, backed by law, for zoning to achieve a vision of 'increased sustainable production of seafood (both fisheries and aquaculture) under a system that maintains and improves biodiversity services'. Some sectors may also require a fundamental re-think of the current institutional arrangements. For example, land use planning may require reforms to the system of merits review of local government planning decisions, reflecting concern that precautionary planning decisions aimed at minimising future exposure may be overturned by a planning tribunal. Some even suggest the need for a review of the decision-making arrangements themselves, including the role of the Tasmanian Planning Commission and local governments.

Another common theme was the importance of addressing adaptive capacity and resilience (Kiem 2010a and 2010b; Boon et al. 2012). Redoubling our efforts to manage non-climate stressors and enhancing natural resource management governance arrangements is a no-regrets strategy would go far in delivering adaptation benefits. Addressing deficiencies in the way we currently handle non-climate stressors requires attention to deficiencies in current governance regimes.

There was widespread agreement that the improvements in governance needed for adaptation are no different from broader good governance principles in relation to biodiversity, resource management, health and a range of other policy spheres. For example, in the context of biodiversity conservation, this would involve harmonising conservation objectives across agencies with conservation, land use management and resource exploitation responsibilities; and resourcing policies and programs over long timeframes – elements that have hitherto proven very difficult to achieve.

Connecting the related themes of mainstreaming and governance of adaptation is the need for more holistic approaches, requiring integration of policy content and institutional arrangements. In a biodiversity context, it involves an expanded focus to ecosystem services, away from purely species-based approaches (Hadwen et al. 2011b). From a business perspective, a more holistic approach may require diversification of business activities and profiles in order to minimise risks and pursue opportunities from adaptation. In relation to land use planning, it requires that decisions about whether to protect, defend, accommodate or retreat from vulnerable settlements need to consider the needs of other land uses, particularly ecosystem needs in coastal and bushfire-prone areas. In health, a focus on sustainable and resilient communities will demand contributions from sectors beyond health services. As part of this focus on holistic decision-making, some stakeholders also saw significant benefits in more integrated and multi-disciplinary research (Interview 012).

Achieving the changes in governance outlined above will demand new models of collaboration and public participation. In biodiversity conservation, this will include the need for more citizen science (natural and social) to inform adaptation priorities. In land use planning, adaptation requires community agreement on acceptable levels of risk, particularly in a bushfire, flooding, or coastal context. Principles of collaborative governance can enhance the processes by which adaptation is achieved.

5.2.3 Resourcing

Planning and implementation of adaptation will need to be adequately resourced. This involves adequate training or re-training of existing personnel, broader community education programs, investment in new agricultural or business processes, and the funding of specific policies and programs. A recurring theme is the limited capacity of local government to deliver the adaptation policies and actions expected of them by the community and devolved to them by State government (Mukheiber et al. 2012b). Another issue emerging from the national literature is the inefficiency and ineffectiveness of emergency funding as a means of financing adaptation (Crompton et al. 2012; Wenger et al. 2012; Boon et al. 2012).

In both business and agriculture it was recognised that incentives may be needed in order to drive private adaptation and stimulate market demand. Transitional support in the form of subsidies and tax breaks and increased training for new and transitional industries could be considered, although the long-term sustainability of such measures needs to ensure that they do not create new dependencies or entitlement mentalities.

5.2.4 Implementation, monitoring and evaluation

A key correction to current governance arrangements that was identified across sectors was the need for better and ongoing monitoring and evaluation of adaptation policies and actions. As part of the critique that the time for pilot projects had passed, it was recognised that we need to start ‘doing’ adaptation, even if it means doing so imperfectly. While some participants suggested that more baseline information is required, this was not understood to imply that such data collection should occur *before* action begins, rather that existing baselines should be used as a starting point and that such information was crucial for effective monitoring and ongoing adaptive responses. There was widespread support for more adaptive governance models – that implement measures, rigorously monitor their effectiveness, evaluate unforeseen impacts, and then make adjustments to enhance their operation. Across sectors, the importance of program longevity was emphasised, even though the precise elements of the program may change over time.

A few stakeholders – particularly those in the primary industries sector – explored implementation through the lens of the ‘research-to-action’ interface, arguing for more extension work (Interview 003) and boundary organisations to bring new research to the hands of end-users.

5.2.5 Attitudinal change

While information, resources, and policy interventions are essential for successful adaptation, they are unlikely to be sufficient. Some profound shifts in attitude will be required too. Achieving these shifts will require sector-specific and public education programs (QUT 2010). In business, the focus needs to broaden, from impacts and vulnerability towards adaptation planning and implementation. To some extent, this requires increased acceptance of the inevitability and likely future shape of climate change impacts, but it also involves looking beyond climate risks to exploring business opportunities. In a biodiversity context, both the community and policy-makers will have to accept the inevitability of new losses and trade-offs such as species loss, and shift to a policy of conservation triage. At the same time, however, broader community understanding and appreciation of the value of biodiversity and its role in adaptation will need to be engendered. In relation to land use planning, Tasmanians will need to change their views about acceptable levels of risk and the balance of risks and benefits associated with living in vulnerable coastal or bushfire-prone areas.

5.2.6 Opportunities

Very few of the workshop ‘visions’ considered the opportunities that may flow from adaptation imperatives, but opportunities emerged in a few stakeholder interviews. The decision-support tools that are being developed to inform adaptation had potential to result in better risk management more generally. Primary industries and tourism saw potential to exploit the state’s ‘clean, green’ image, while the state’s small size, tight networks, and skilled climate change research base fostered trusted research partnerships (Interview 009; Interview 010).

5.2.7 Research-to-practice translation

Stakeholder participants generally indicated a high level of satisfaction with the impacts and adaptation research completed or currently underway in Tasmania: 'I think the state of adaptation research in Tasmania is really good. We are certainly leading the way in that regard. I am very confident in the adaptation research being done' (Interview 014). For some, however, there was scope to improve the dissemination of research outcomes. There is a desire for information about best-practice experiences from elsewhere in Tasmania, Australia and internationally. In some sectors, particularly primary industries, traditional extension and engagement activities are needed to bring these insights to the level of the local operator:

The best way to improve dissemination of climate change adaptation research would be to rely less on a package of information in the mail and instead return to the old-fashioned approach of someone actually coming and seeing you. (Interview 013)

In the same way that significant gains could be made by applying good-governance principles to current stressors and problems, participants saw considerable untapped potential in current data and tools. In the biodiversity context, consolidation and tweaking of tools that already exist, such as Conservation of Freshwater Ecosystem Values (CFEV), Conservation Information Systems (CIS), and the Natural Values Atlas (NVA) could considerably enhance the information base upon which adaptation decisions are made.

5.3 Barriers to adaptation

Summary – Barriers to adaptation

- ◆ barriers exist across the three phases of understanding, planning and managing adaptation
- ◆ understanding the nature of the climate impact is not enough for effective adaptation: both the planning phase and the managing phase also represent potential barriers.
- ◆ more detailed sector-specific analysis could identify specific barriers for each sector and develop strategies to overcome the potential barriers.

An understanding of the limits and potential barriers to adaptation can enhance the objectives, design and implementation of adaptation efforts (Morrison and Pickering 2011). The concepts of barriers and limits are often used interchangeably in adaptation planning. Limits to adaptation consist of thresholds beyond which activities, land uses, ecosystems, species, or other system states can no longer be maintained, even in a modified form (Moser & Ekstrom 2010). Beyond such limits, irreversible loss occurs unless radical system shifts, known as transformations, can occur. Limits are common in physical and ecological systems in their natural state, but, in some instances, physical and ecological limits have been stretched or overcome with technological innovations (IPCC 2007b). Limits are more likely to be encountered in natural systems than in social, industry or political contexts. Whether Tasmania faces limits to adaptation depends on how adaptation is defined. It will be specific to each sector and place, and to the values of those seeking to adapt. That said, the exceedence of natural limits is likely to result in irreversible loss of places, identities, species and ecosystems comprising Tasmania's unique terrestrial biodiversity and marine ecosystems.

Apparent limits that can be avoided or pushed back through technological or other means are better understood to be barriers to adaptation. Barriers are obstacles that can be overcome through changes in attitude, priorities, values, resources, land use or institutions (Moser & Ekstrom 2010), although these changes may well be extremely hard to achieve. What may first seem to be 'limits', especially social ones, are in fact barriers that can be overcome with sufficient political will, social support, resources, and effort (Adger et al. 2009). However, many barriers will make adaptation less efficient or effective, or may require costly changes that lead to missed opportunities or higher costs.

The barriers to adaptation will be more nuanced and diverse than limits. Even within a specific sector or location, individuals and groups are likely to face difficulties at different stages of the adaptation cycle – some in identifying the need for adaptation, some in developing responses. These differences mean that the processes of adaptation decision-making must be inclusive and pluralist.

Barriers are sometimes perceived to be more problematic than they are in reality, so understanding potential barriers is an important part of adaptation planning (Moser & Ekstrom 2010). Despite this, the complex interrelationships between barriers may make it difficult to distil or prioritise individual barriers (Evans et al. 2011).

This section reports stakeholder perceptions regarding barriers to adaptation drawn from both interviews and workshops techniques, with reference to supporting literature where relevant. The workshop used a high-level structure to consider 'where' barriers can arise in adaptation development, while the interviews showed in more detail 'what' barriers were encountered. Although the interviews were the more comprehensive, we first present the barriers framework, as this high-level overview provides a structure for organising the interviewee perspectives, and also identifies where no apparent barriers exist.

The project workshop used the framework developed by Moser and Ekstrom (2010) to explore where potential 'institutional' barriers in the process of undertaking adaptation for each sector might lie. This framework differs from the interview-based description of barriers, as it focuses on why barriers arise, rather than what barriers exist. The potential barriers are divided into three stages (understanding, planning and managing), each with three elements (Figure 11).

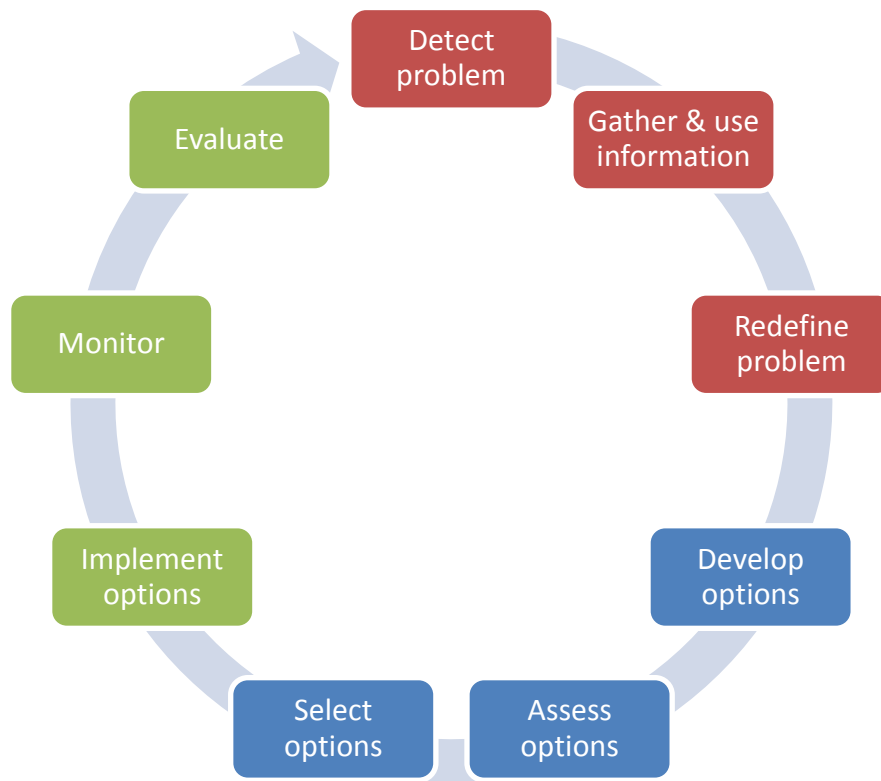


Figure 11. Barriers framework used in the project to evaluate stakeholder perceptions about sectoral barriers

Source: Barmuta et al 2012, adapted from Moser and Ekstrom (2010)

Each of the nine elements in the framework was scored using TurningPoint® software on a Likert Scale from 1-5, where 5 represented a strong barrier for the option, and 1 represented no barrier. Workshop participants ranked general adaptation barriers from the perspective of their sector, according to the following guidance:

Please rate how well your sector (and institutions responsible for that sector) will cope with each of the potential barriers to successful adaptation.

The specific questions for each element were:

- Detecting a signal will be a barrier for adaptation in this sector
- Gathering/using information will be a barrier for adaptation in this sector
- Defining the problem will be a barrier for adaptation in this sector
- Developing options will be a barrier for adaptation in this sector
- Managing the process will be a barrier for adaptation in this sector
- Selecting options will be a barrier for adaptation in this sector
- Implementation will be a barrier for adaptation in this sector
- Monitoring the outcomes will be a barrier for adaptation in this sector
- Evaluating effectiveness will be a barrier for adaptation in this sector



Photo 16. Workshop participants assessed barriers to adaptation using TurningPoint® software. Photo: Holger Meinke

Additional descriptions of each element were provided to participants and discussed on each TurningPoint® PowerPoint slide prior to scoring. The scores for each element were averaged for analysis. As the number of representatives varied from zero to four per sector (see Figure 3, above) rather than analysing the results by sector, and risking unrepresentative views, we instead illustrate the perceived barriers across all participants and sectors. To be representative of each sector, we feel that ten or more representatives should be consulted, and more detail on the types of adaptation being proposed would need to be provided. The coarse result is informative as an example of barrier analysis.

After scoring, results for each question were reviewed and discussed by the workshop participants to clarify and elucidate issues. An example of the scoring is shown in Figure 10. In this case, in response to the element regarding detection of signals, 55% of the group 'agreed' (score of 2) that this would be a barrier to adaptation, with the remainder scoring the other options. Scores of 1 or 2 signify a barrier; while scores above 3 show the participants do not consider this element to be a barrier. The average of all the scores for this question was 2.68, showing that on average, detecting clear signals that would trigger adaptation was considered a barrier for these Tasmanian sectors (score <3, which would be neutral).

Detecting signals will be a barrier

Detecting a response in an indicator for your sector (e.g. fish catch), and knowing likely cause (i.e. climate change)

- Threshold of concern (initial framing as problem)
- Threshold of response need and feasibility (Initial framing of response)

1. Strongly Agree (barrier)
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree (no barrier)

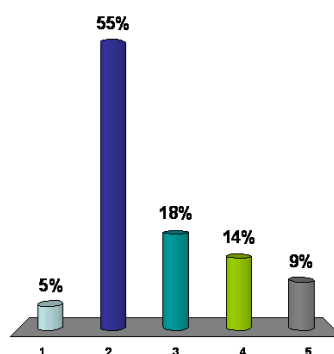


Figure 12. Example of scoring for the barrier analysis, for the first element in the framework

While individual scores spanned the full range of scores (1-5), all of the 9 elements of the Moser and Ekstrom (2010) framework were seen as potential barriers (average score <3; Figure 13).

The elements in the understanding stage were seen as slightly less problematic than the planning and managing stages (scores closer to 1). Interestingly, while researchers were a little more optimistic than the non-researchers (end users and managers), both groups were very similar, and the averages for the three stages showed that the managing phase was likely to be the most significant barrier to successful adaptation (Figure 14). This is borne out in national adaptation literature which identifies a lack of community support and a lack of consensus on adaptation options as barriers to implementing adaptation (Haynes et al. 2011; Poloczanska et al. 2012b; Petheram et al. 2010; Gross et al. 2011; Evans et al. 2011).

While research can contribute to reducing barriers in the understanding phase, it is institutional arrangements that need attention to reduce barriers in the planning phase, and resourcing (financial and people) is needed to see the managing phase occur successfully. From these results, it is clear that more attention needs to be paid to these last two stages, a conclusion reinforced by participants' identifying resourcing and governance as priority areas for reform as part of the visioning exercise.

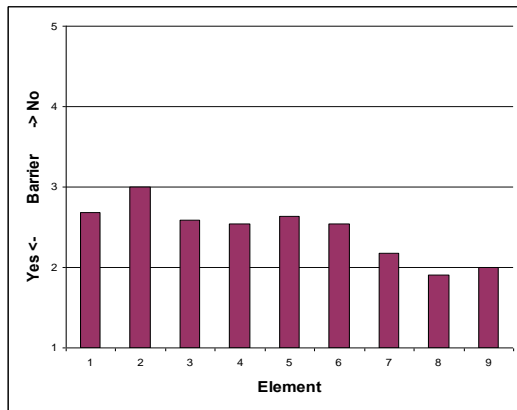


Figure 13. Average scores for each of the nine elements in the barriers framework

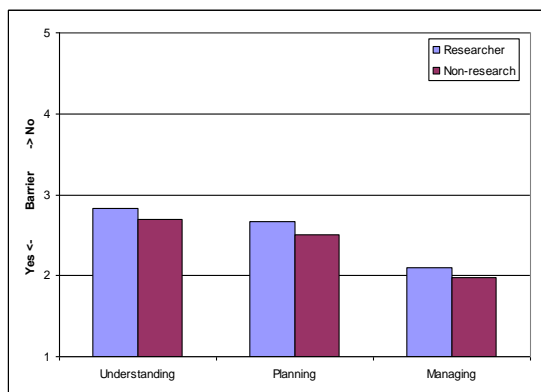


Figure 14. Average scores for each of the three stages (each composed of three elements) for researchers and non-researchers

Interviews with Tasmanian sectoral representatives and research scientists identified common barriers and these barriers all fell within the three main stages of Moser and Ekstrom (2010): understanding of climate change and adaptation options, planning, and managing. Across the set of interviewees as a whole, most barriers were discussed (Table 9).

Interestingly, only one of the nine potential elements in the Moser and Ekstrom framework (#1: Detecting a signal will be a barrier for adaptation) was not identified as a barrier in interviews. Consistent with this, when this element was scored in the workshop, it was the second least ‘problematic element’, after gathering and using information (#2). A possible explanation for this is researchers’ and stakeholders’ widespread satisfaction with the Climate Future for Tasmania work in providing this scientific foundation.

Overall, this analysis confirms that barriers to adaptation planning and action exist, and should be a focus when developing strategies. It also provides further empirical support for the importance of barriers identified in the national literature (Barnett & Waters 2013). Importantly, it suggests that it is not sufficient just to understand the nature of the climate impact; both the planning phase and the managing phase also represent potential barriers. Sectors could undertake more detailed analysis using these methods to develop strategies to overcome the potential barriers.

Table 9. Barriers to adaptation identified by interviewees, categorised against the elements of the Moser and Ekstrom (2010) framework

Element in Moser and Ekstrom framework	Examples of barriers discussed in interviews with stakeholders
Stage in Moser & Ekstrom Framework: <i>Understanding</i>	
1) Detecting a signal will be a barrier for adaptation	none identified.
2) Gathering/using information will be a barrier for adaptation	<p>Information</p> <ul style="list-style-type: none"> • the confusion/uncertainty that surrounds CC science results in confusion in how to respond (Interview 007) • key barriers exist in terms of the ability to know what information to gather and the competency to assess it, and the ability to critically evaluate information and then apply it (Interview 015) • problem in accessing most relevant information (Interview 013A) • plethora of CC research, but much not relevant to Tas and it needs to be presented at temporal and spatial scales that people can relate to. There is lots of info relating to high level principles, but there is a need to bring it down to site scale – what need to do and when and with what priority? I.e., there exists a need to convert principles into tools, systems, frameworks that help decision makers and land managers (Interview 013; Interview 013A) • expectation of the power of projection capability: ‘The state is compact and small, events discrete, we should be able to do exquisite scenario modelling’ (Interview 015)
3) Defining the problem will be a barrier for adaptation	<p>Climate change is only one issue among many:</p> <ul style="list-style-type: none"> • sectors are dealing with a whole range of threats and issues, not just adaptation (Interview 009; Interview 017) • CCA not considered high priority for tourism (ranked 20th out of 20 issues) and for those that want to do something, don’t know what to do (Interview 010). • key barrier to CCA is making it relevant to businesses and that will inevitably be a struggle as it is not the highest priority issue. I am sure it matters to them, but it is a long way down the list when it comes to day-to-day issues (Interview 010) <p>Disincentives for adaptation</p> <ul style="list-style-type: none"> • early adaptors may well experience perverse effects resulting from their response to CC risks (Interview 004) • CCA research needs to adopt time horizons that fit with industry planning horizons (5 to 10 years at most): ‘2050 not on radar’ (Interview 003; Interview 017)
Stage in Moser & Ekstrom Framework: <i>Planning</i>	
4) Developing options will be a barrier for adaptation	<p>Adaptation planning is really hard</p> <p>‘key barrier exists in terms of actually developing viable adaptation options that are not based on reductionist science, but instead engage with the cultural, social and economic aspects’ (Interview 016)</p>
5) Managing the process will be a barrier for adaptation	<p>Policy and governance issues</p> <ul style="list-style-type: none"> • short-sighted political imperatives and anti-policy frame of mind of all political parties key barriers to CCA (Interview 013)

Element in Moser and Ekstrom framework	Examples of barriers discussed in interviews with stakeholders
	<ul style="list-style-type: none"> • legal liability a big issue (Interview 005; Interview 006; Interview 008) • policy settings critical – lack of clear policy direction from State Government and slow pace of policy reform (Interview 005; Interview 019; Interview 009) • need for consistency and clarity in government policy (Interview 011) • lack of clarity in roles/responsibilities critical barrier in CCA planning (Interview 002; Interview 008) • key barrier is for elected reps to develop agreed understanding of the issues – feeds through to everything else (Interview 006) • hesitation by govt to make info available to community in timely manner (Interview 005) • competing policy objectives (Interview 012) <p>hard to constantly update positions and policies in light of new information (Interview 015)</p>
6) Selecting options will be a barrier for adaptation	<p>Selecting options</p> <ul style="list-style-type: none"> • worried about the capacity of govt agencies in Tas to respond to science and review their own goals and objectives – need to look at relevant legislation to ensure that it facilitates change (Interview 013) • major barrier is the cost of exploring adaptation options in practice (not just theoretically) (Interview 007) <p>assessing adaptation options (Interview 016)</p>
Stage in Moser & Ekstrom Framework: <i>Managing</i>	
7) Implementation will be a barrier for adaptation	<p>Resources</p> <ul style="list-style-type: none"> • lack of resources (financial and legislative commitment) at state (Interview 005); local government (Interview 006; Interview 017); or in sector (Interview 014) • differential capacity of local governments (Interview 005) <p>very hard to develop proactive rather than reactive approach (mainly to do with lack of resources) (Interview 012)</p>
8) Monitoring the outcomes will be a barrier for adaptation	<p>Monitoring and evaluation</p> <ul style="list-style-type: none"> • lack of monitoring and evaluation (Interview 005). <p>monitoring and evaluation never get done well (Interview 005; Interview 006; Interview 021)</p>
9) Evaluating effectiveness will be a barrier for adaptation	<p>Monitoring and evaluation (same as previous element)</p> <ul style="list-style-type: none"> • lack of monitoring and evaluation (Interview 005). <p>monitoring and evaluation never get done well (Interview 005; Interview 006; Interview 021)</p>

5.4 Sectoral dependencies

Summary – Sectoral dependencies

- ◆ understanding sectoral dependencies is vital to ensure that adaptation efforts consider the full range of potential influences
- ◆ sectoral dependencies were identified at all scales, including the national and international scales.
- ◆ the high level of connectedness identified by workshop participants (especially at the state scale) might reflect the close relationships in a relatively small polity such as Tasmania, but may also reflect existing efforts to identify sectoral linkages, starting with participants' own networks and communities of interest.
- ◆ a high level of sectoral interconnectedness means that the effects of climate change and adaptation efforts will be complex and multi-layered. It will be important for sectors to remain aware of developments in other sectors, as what one sector is doing will have ramifications for other sectors. Approaches to climate change adaptation based exclusively around individual sectors will not be optimal

The literature review and interviews undertaken for this project show that adaptation planning in Tasmania has been largely sectoral in focus. Despite this sectoral approach, however, there are likely to be a range of interrelationships that affect the effectiveness of adaptation efforts in one sector. These relationships may be supportive or facilitative across sectors, or they may undermine adaptation efforts in other sectors. Understanding sectoral dependencies is therefore vital in order to ensure that adaptation efforts consider the full range of potential influences. Accordingly, we explored the dependencies between and across sectors, which we defined to refer to 'strong linkages'.

5.4.1 Methods and data limitations

Information regarding sectoral dependencies was obtained by canvassing the perceptions of workshop participants. Participants were asked to form sector-specific groups based upon self-identification of the sector they felt captured their primary research or stakeholder interests. A small number of participants with expertise in more than one sector were allocated to sectors in order to balance group size and to ensure representation across sectors. Nine groups were formed based on the sectors examined in Section 5 of this report. In the absence of workshop participants from the Tasmanian Aboriginal community, a decision was made not to anticipate dependencies specific to this sector. Indigenous perspectives on dependencies were identified as an issue for possible future follow-up with interview participants.

Participants were asked to map the influences on their sector's adaptation efforts, and their sector's adaptation influences on other sectors. Each sectoral-group was provided with six A3-sized sheets of paper upon which was printed the diagram in Figure 15. The ten circles represented the ten sectors used throughout the report, and three additional blank circles were included so that participants could identify additional relevant sectors. Each group was asked to draw lines from their sector to others for each of six situations – covering three spatial scales and two 'pathways' of dependence:

1. Within Tasmania, we have influence on these sectors
2. Within Tasmania, we are influenced by these sectors
3. Nationally, we have influence on these sectors
4. Nationally, we are influenced by these sectors
5. Internationally, we have influence on these sectors
6. Internationally, we are influenced by these sectors.

The three spatial scales of analysis (state, national and international) were chosen on the basis that they were likely to reflect relevant geographical, governmental, legislative and social differences. A few workshop participants (e.g., those representing the Primary Industries and Human Health & Community Wellbeing sectors) noted the importance of dependencies operating at finer scales, especially regional, local, family and even enterprise scales. Some groups also identified intra-sectoral dependencies as important, and mapped these by drawing lines that looped from their sector back to that same sector. This was particularly the case when the sector was aggregated (e.g. Marine Biodiversity & Resources contains both conservation and exploitation, Primary Industries contains both grazing and cropping), as there are interactions between these sub-sectors.

Participants were also encouraged to provide additional information about the type and form of dependencies by writing accompanying notes to the links.

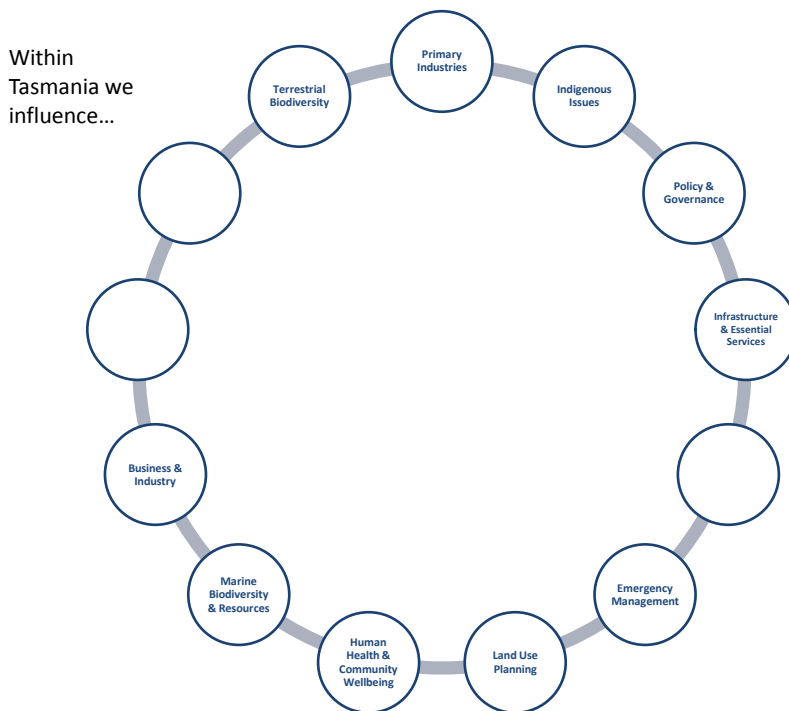


Figure 15. A worksheet used by workshop participants to identify sectoral dependencies

The nine workshop groups were asked to identify the relationships most critical to their sector, and the time allocated to complete the exercise was restricted in order to minimise the masking of significant dependencies by identification of minor linkages. Each sectoral group

completed six worksheets (three spatial scales by two directions for dependencies) indicative of their sector's relationship to other sectors. In total, 54 'dependency maps' were produced.

After the groups completed the exercise, display and discussion of results provided an opportunity for feedback from workshop participants from other groups. Figure 16 reproduces one such dependency diagram, in this case showing the influence of the Marine Biodiversity and Resources sector on other sectors at the national scale.

While information on sector dependencies was collected from sector-specific groups, data has been aggregated for discussion. This decision reflects the small number of participants constituting some sectoral-groups (in some cases, only two 'representatives'), qualitative differences in interpretation of the exercise from sectoral groups, as well as feedback provided by some workshop participants that 'not too much be made of differences between individual sectors'. Hence, data from the dependency diagrams have been aggregated and the results treated as indicative of broad trends, rather than being quantitatively representative of individual sectors. As such, the results provide a broad-brush view of Tasmanian sectoral dependencies at three spatial scales.

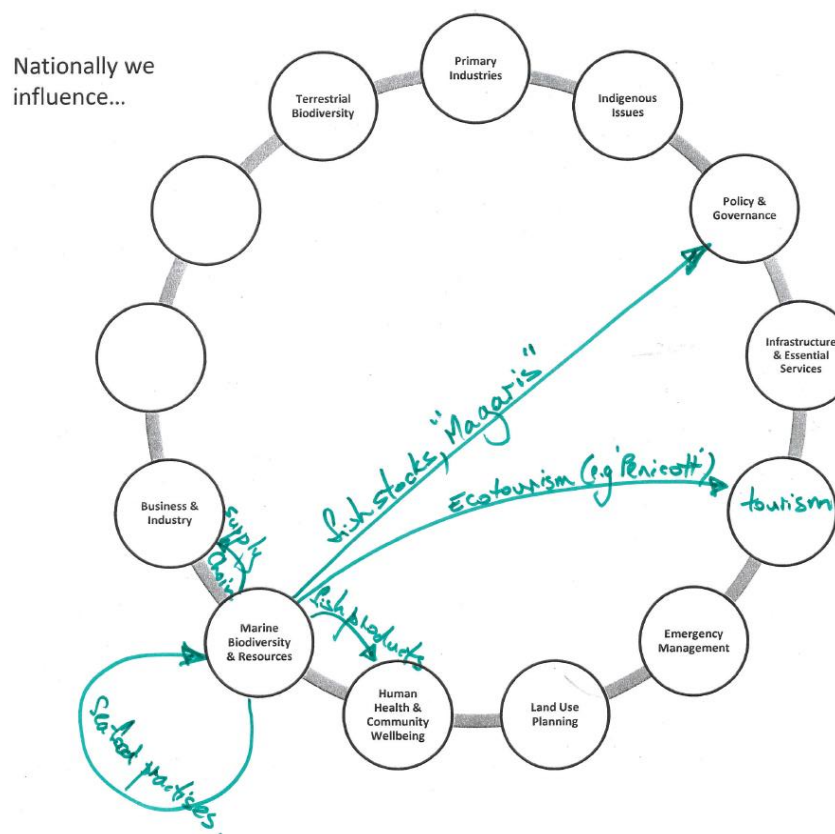


Figure 16. Dependency diagram: Influence of Marine biodiversity & resources on other sectors, national scale

5.4.2 Results

During the identification of dependencies, another eight 'sectors' (e.g. 'water resources') were volunteered by participants. These additional sectors attracted 20 links across all identified sectors, representing 7% of all links described. This suggests either that the groups were constrained by the choices presented on their worksheets and therefore didn't identify other sectors, or that the pre-identified sectors captured the majority of the potential linkages. In discussion with participants during a feedback session, there seemed to be general satisfaction with the sectors identified.

Overall, 279 linkages were identified. The number of links (dependencies) decreased as the spatial scale of analysis increased. At the Tasmanian or state scale, between four and 12 dependencies were identified by each sector for an overall average of 7.6 links, indicating a high degree of interconnectedness. Sectors were influenced by an average of 8.2 other sectors, and considered themselves as influencing 7.0 other sectors. At the national scale between two and ten dependencies were identified, an overall average of 4.8, with influence by other sectors greater than the influence on other sectors (influenced by = 5.6; influence on = 4.0). Finally, at the largest scale – international – between zero to eight dependencies were identified (after removing three combinations that were not completed), for an overall average of 3.7 links, with influenced by (average 4.7 links) greater than influence on (average 2.9 links). Figure 17 summarises these results.

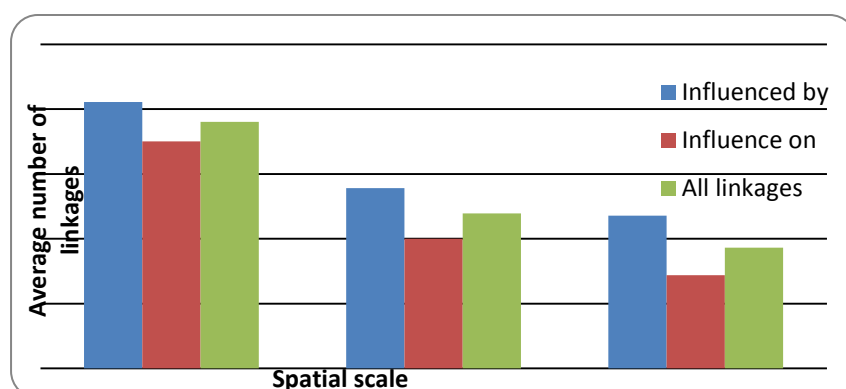


Figure 17. Average number of linkages identified by workshop participants at three spatial scales

Figure 18 summarises the aggregated number of sectoral linkages across all scales identified by workshop participants. Not surprisingly, the most 'connected' sector was Policy & Governance (42 links). The least connected was Indigenous (15 links), although it must again be emphasised that this sector was only represented in other sector's mapping, since the sector was not represented in the exercise of drawing links. The Terrestrial Biodiversity (20 links) and Marine Biodiversity & Resources (21 links) also had low levels of inter-dependency. Of the ten core sectors, the overall average was 25.9 links. The influenced by average was 14.2 links per sector (Policy & Governance highest number of links), while the influence on average was 11.7 links per sector (Policy & Governance highest number of links).

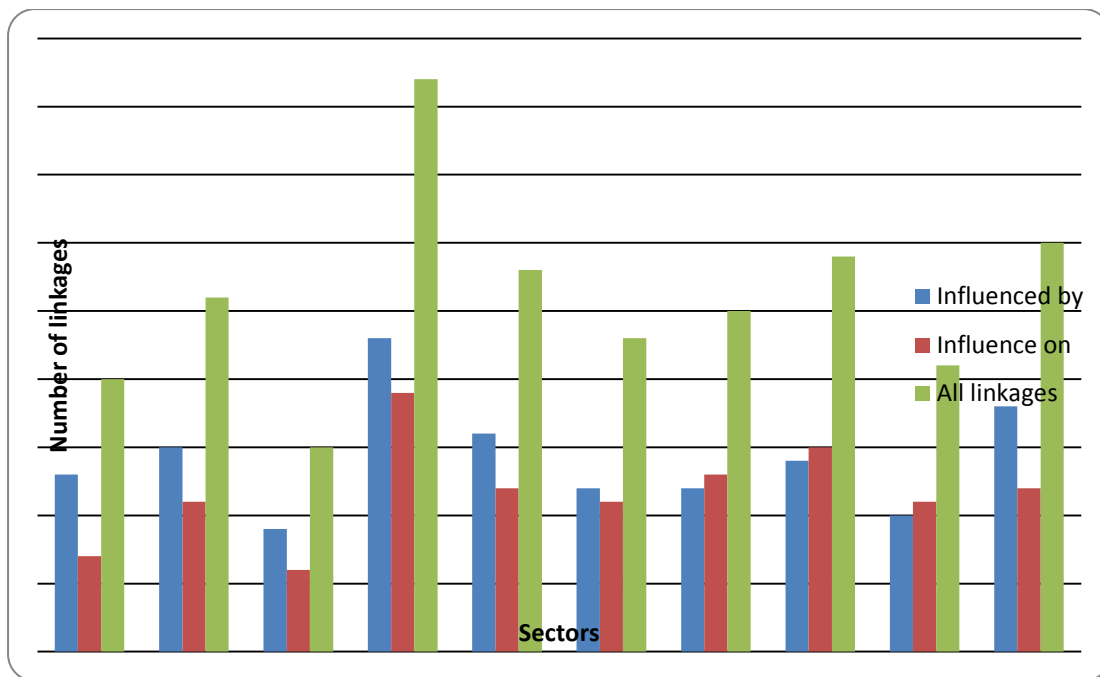


Figure 18. Aggregated sectoral linkages identified by workshop participants

There was a consistent disparity between the number of links influenced by and influence on across all scales. Of the 24 possible sector-scale combinations for which data was completed (3 were not completed), only two sectors identified themselves as stronger at influencing other sectors than they were influenced by other sectors. Ten combinations rated themselves as equally influencing and influencing by; and the remaining 12 combinations saw themselves as more influenced by than influencing other sectors (see Figure 19). This may be a true pattern, although it may also suggest that sectoral representatives were more able to identify what they are influenced by than what they have influence on – more detailed investigation is needed to resolve this issue.

5.4.3 Discussion

The form, type and nature of relationships between sectors are likely to have crucial implications for future climate change adaptation efforts. While the mapping exercise could not provide detailed information that is representative of individual sectors, the aggregated results of perceived linkages raise a number of important issues:

The high level of connectedness identified by workshop participants (especially at the state scale) might reflect the close relationships often taken as typical of small communities like Tasmania. It is also likely, however, to reflect existing efforts made by stakeholders and researchers in identifying sectoral linkages, starting with their own networks and communities of interest.

The high number of linkages identified by workshop participants also suggests that it will be important for sectors to remain aware of developments in other sectors, as what one sector is doing will have ramifications for other sectors. A high level of sectoral interconnectedness means that the effects of climate change and adaptation efforts will be complex and multi-layered. Approaches to climate change adaptation based exclusively around individual sectors

will not be optimal, an issue which harks back to the widespread support for more 'mainstreaming' and integration of adaptation activities. The processes by which these relationships are recognised and explored in adaptation planning are still emerging.

Sectoral dependencies were identified at all scales, including the national and international scales. We anticipated that the disparity between being influenced by and having influence on would increase as the scale of analysis increased, and this general trend was borne out, though the main shift appears to occur when moving from the national to the international, rather than from the state to the national scale. While Tasmania may appear vulnerable to international influences, comparisons with other Australian states and/or regions would be required to contextualise these findings.

The exercise of stakeholders and researchers mapping linkages between sectors was a first-step at developing a tool that can be used to better understand sectoral dependencies in adaptation. In completing the task, participants recognised both climate adaptation issues as well as more general issues in their identification of linkages. A distinction could be made between these types of relationships depending on the requirements of those completing the task. Climate change adaptation planning often requires a high level of detail and the task could also be undertaken with a greater focus on describing the qualities of linkages, rather than just mapping their existence. An example of how these dependency diagrams might highlight key issues for adaptation planning is drawn from the Marine Biodiversity & Natural Resources sector and displayed in Box 1. Future development of this work could examine dependencies identified in light of adaptation research, and adaptation research might begin to factor in such sectoral connections and dependencies in order to maximise opportunities and minimising the risk of maladaptation.

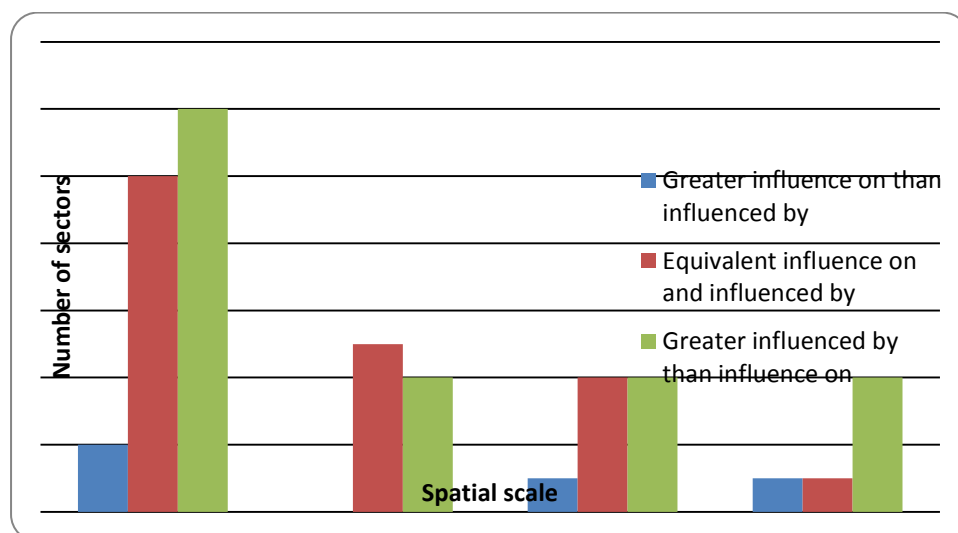


Figure 19. Proportion of 'influenced by' and 'influence on' linkages

Box 1. Example of dependencies identified for the marine biodiversity and resources sector

Tasmania

- influenced by
 - within Tasmania, there are influences within sub-sections of this sector, e.g., commercial fishing and conservation management – intra-sectoral influences/dependencies
- influence on
 - one of the eight linkages identified was with community health and wellbeing. The type of linkage envisaged here was through access to recreational and aesthetic opportunities that arise from a well-managed marine estate

National

- influenced by
 - nationally we are influenced by availability of efficient transport networks (business and industry sector) to deliver seafood and aquacultural products to mainland markets
- influence on
 - approaches to marine tourism in Tasmania have been seen as leading examples nationally and led to similar tourism enterprises in other regions of Australia

International

- influenced by
 - at an international level, international conventions (policy and governance sector), e.g., RAMSAR, WHA influence the management of marine biodiversity and resources in Tasmania
 - one of three linkages identified
- influence on
 - internationally, Tasmanian marine research has influenced international policy and governance through best-practice guidelines resulting from long-term studies on MPAs

An example of an adaption perspective on these dependencies/the significance of these sorts of sectoral dependencies for future adaptation efforts:

6 CONCLUSIONS

6.1 The state of adaptation activity and research

This project assessed the current state of climate change adaptation knowledge in Tasmania, based on published and on-going research, extensive interviews with researchers and stakeholders, and a project workshop. It aimed to determine the awareness and uptake of successful adaptation approaches by stakeholders and sectors, namely:

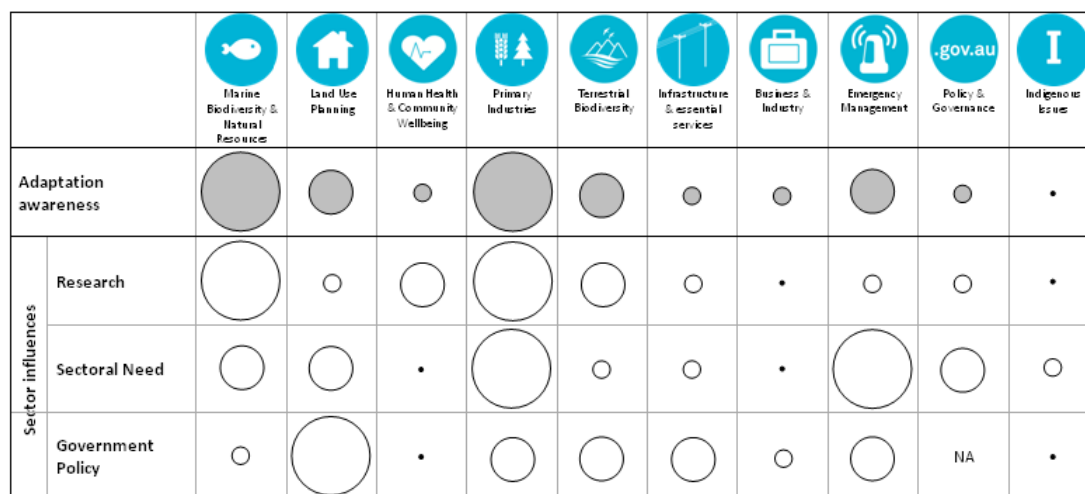
- primary industries
- terrestrial biodiversity
- marine biodiversity and resources
- land use planning
- infrastructure and emergency services
- human health and community well-being
- business and industry
- emergency management
- policy and governance
- Indigenous issues.

We found differences between the sectors in terms of their perceptions of climate change impacts and the need for response. For each sector, we have made a subjective assessment of the state of adaptation, based on the synthesis of literature and stakeholder consultation information (Figure 20). Awareness and motivation for adaptation is highest in the marine, primary industries, and emergency management sectors. This awareness and motivation for all sectors was reported to the project team as linked, in part, to one or more of three main influences on adaptation: research, sectoral needs, and/or government policies (Figure 20). In some sectors, such as marine and primary industries, research has played a major role, while in others any adaptation that has occurred has been driven almost entirely by issues relating specifically to the sector (e.g. emergency management), or to policy-related drivers (e.g. land use planning).

The project has highlighted areas of significant research strength in Tasmania, and others where there is little or no research specific to the state (Figure 20). Research is strongest in marine biodiversity and resources, and to a lesser extent primary industries and terrestrial and freshwater biodiversity. There is no Tasmania-specific work relating to the impacts of climate change on Indigenous Tasmanians, and very little coverage of health and community well-being issues or business and industry perspectives (other than the primary industries). Some major recent projects of relevance to coastal adaptation, land use planning and (to a lesser

extent) infrastructure and emergency management have started to fill significant policy gaps in these areas.

Given the qualitative relationship between research strength and sectors with greatest climate adaptation awareness, investment in research is clearly important to develop climate impact and adaptation strategies in Tasmania. Thus, strategies for increasing and maintaining high quality research should be a government priority.



Legend





				NA
High	Moderate	Minimal	None or virtually none	Not applicable

Figure 20. The state of adaptation activity and awareness for 10 Tasmanian sectors and the degree to which research, sectoral needs, and government policy influence

The size of the circles indicates the relative influence for each category.

The *Climate Futures for Tasmania* (CFT) projections and the subsequent publications are widely regarded as providing an excellent foundation upon which to undertake more detailed adaptation planning at the enterprise-, sector- or region-specific level. These projections have allowed most Tasmanian sectors considerable advantage in terms of understanding future environmental risk, and there are several projects that have since used these projections to further inform sectoral adaptation plans (e.g. freshwater biodiversity, Barmuta et al. 2012). While the marine sector did not benefit in particular from CFT, as the coverage did not extend to marine environment, a strong history and expertise base in Tasmania at CSIRO and the ACE CRC also allows access to state of the art climate projections.

6.2 Research gaps and priorities

Significant gaps remain in our understanding across all sectors, and the report has identified a range of research priorities that seek to clarify the application of national or international research in Tasmania or further develop earlier findings of Tasmanian projects, including action research such as the Coastal Adaptation Pathways Projects. Table 10 presents the research priorities identified for each sector. We note that these priorities fall into one of three general categories, including climate and system understanding (n=13), evaluating adaptation

options (n=15) and resolving societal issues around adaptation (n=20). While some priorities might also be placed in more than one category, this summary shows that research investment is needed in all three areas. Future research endeavours should engage stakeholders and end-users in the earliest stages of research design, including the refinement of research objectives and questions. Wherever possible, opportunities for multi-sectoral synergies and relevance should be maximised as the dependencies mapped for this project showed strong connectivity in Tasmania.

Table 10. Summary of sectoral adaptation research priorities

Each priority is classified into one of three broad categories.

	Improving climate and system understanding	Evaluating adaptation options	Resolving societal issues
Primary industries			
Better understanding of cross-cutting, multi-level and indirect impacts	X		
Enhanced understanding of trends in variability and the impact and frequency of extreme events	X		
Evaluating alternative cropping options for a wide range of locations throughout Tasmania		X	
Understanding the likely socio-economic and environmental consequences of adaptation options		X	
Terrestrial and freshwater biodiversity			
Ecosystem-level analyses of impacts and adaptation options		X	
Determining the advantage of reducing the non-climate stressors on species and landscapes.		X	
The management of agricultural practices (such as wind breaks) and rotation of livestock to increase biodiversity outcomes.		X	
The impacts of fire management practices on biodiversity.	X		
Whether Tasmania should become a refuge for mainland species, and if so, which ones?			X
Social research into where extension and education will be needed to overcome barriers to some adaptation options.			X
Marine biodiversity			
Impacts of ocean acidification on, and adaptation options for, marine resources, especially commercially valuable and aquaculture species (especially abalone, rock lobster, and oyster)	X		
Cost-benefit and other analyses of the timing of adaptation interventions for key industries, especially those requiring long lead-times		X	
How to manage access to range-changing species that could form valuable new fisheries.			X
Integrated multi-disciplinary studies into the socio-economic impacts of climate change on marine species and resources			X

	Improving climate and system understanding	Evaluating adaptation options	Resolving societal issues
Win-win adaptation options for marine conservation management and marine resource management, where short-term benefit is also compatible with long-term sustainability		X	
Assessing the effectiveness of adaptation actions in Tasmania's hotspots based on ecological, social and economic indicators		X	X
Land use planning			
How the planning framework, including regional planning, should accommodate the long-term impacts of climate change, the likely impacts of extreme events, and the cumulative impact of multiple extreme events?			X
Improving the communication of climate change impacts and engaging communities in adaptive responses			X
The evaluation of costs of various adaptation options for existing communities in a way that is itself efficient and cost-effective		X	
Enhancing the processes of adaptation of existing communities to ensure they are consultative, locally-driven and participatory, and cost-effective			X
Design and mix of instruments and incentives to promoting private adaptation		X	
Exploiting the synergies between climate change adaptation and mitigation		X	
Transferring adaptation planning insights across places and projects			X
Assessing the suitability of the current governance arrangements for planning in Tasmania for adaptation needs?			X
Infrastructure and essential services			
Understanding the full costs of infrastructure disruption, from extreme events (including downstream or cascading impacts) on: communities; utility providers (such as energy, telecommunications and water utilities); property damage; and maintenance or replacement costs	X		
How to avoid these costs through design, modification, re-engineering of processes or other techniques		X	
The design options and principles for adapting new and existing infrastructure and buildings		X	
How to distribute the future costs of infrastructure upgrade and increased risk			X
Approaches to, and development of, Tasmanian professional capabilities (knowledge and practical skills) to more confidently and effectively assess, plan and manage climate risks in the future			X
Strategies for community coping and response to loss in infrastructure and essential services			X
Human health and community well-being			
Understanding the social, environmental and institutional determinants of vulnerability in a given region, including rural communities and cumulative health and well-being vulnerabilities	X		

	Improving climate and system understanding	Evaluating adaptation options	Resolving societal issues
Community-based vulnerability and health risk assessments.	X		
Improvements in regional and local monitoring of: bushfire smoke, aero allergen concentrations and seasonality, vector (mosquito) densities in highest risk areas with respect to Ross River virus or other vector borne diseases that may emerge as a threat.	X		
How to improve responsiveness and management of health impacts or events as they arise, as well as preparing communities for longer term adjustment to changing environmental and health conditions.			X
Business and industry			
Enhanced understanding of business and industry preparedness, expertise and knowledge about climate change impacts and adaptation options	X		
Ensuring that cross-cutting adaptation research is presented at temporal and spatial scales suited to the planning and decision-making processes of businesses and industry	X		
Longer-term engagement with specific business and industry sectors to identify specific sectoral needs			X
Emergency management			
Changes to community vulnerability resulting from demographic and other processes	X		
How to enhance the capacity of communities to respond to projected climate impacts	X		
Institutional responses to changed climate conditions and consequential demands on emergency services			X
How communication tools can manage emerging climate change induced emergency service demands			X
Understanding the compounding effects of climate-change derived conditions and extreme weather events, such as drought and heat waves	X		
Trade-offs between prevention/hazard mitigation and other values, such as native vegetation conservation.		X	
Policy and governance			
How to maximise the transformative potential of medium-term adaptation responses		X	
Practical approaches to improving policy, planning and governance frameworks to better recognise the dynamic circumstances that climate change creates			X
Approaches that align bottom-up initiatives with top-down framework and policy development			X
Indigenous issues			
State specific adaptation research priorities need to be identified and developed either by, or in conjunction with, indigenous people, communities and representatives			X

6.3 Future directions

Our findings suggest that there is surprising commonality across sectors in relation to the key drivers and barriers to adaptation and the elements of a climate-adapted future. Risk management principles and fear of losses, including legal liability, are the primary drivers of adaptation at a broad level. Ethical considerations and the pursuit of new opportunities are least important. There is very little evidence of transformative change or even discussion of the need for such change in the near- or medium-term future. To the extent that any industry is currently undertaking adaptation measures, they are driven by understandings of short-term changes that are likely to affect profitability within budgetary planning horizons.

While it was impossible to articulate a single vision, or even a set of visions, for adaptation in Tasmania, several themes emerged strongly. They were:

- the need for adaptation to become more integrated and mainstreamed into core business decision-making and policy-making;
- improved governance for adaptation, including better cross-sectoral arrangements and processes;
- better resourcing and training for adaptation;
- moving from planning to implementation; and the need for monitoring and evaluation of adaptation strategies.

The analysis of barriers to adaptation showed that barriers exist at all three stages of adaptation: understanding, planning and managing. Higher barriers were recognised at the planning stage than at the earlier understanding stage, while the barriers were higher again at the implementation stage. Overcoming these barriers would go far in delivering the common elements of the adaptation visions identified in this report.

As a geographically small state with a small population, the activities of, and issues facing, one sector have a significant impact on others. While some may view these sectoral dependencies as a barrier to adaptation, they also create opportunities for more embedded and holistic approaches that achieve efficiencies across the entire community, economy and environment. Developing consultation, policy- and decision-making processes that reflect these interdependencies will be challenging, but could have spin-off benefits for good governance more generally.

There is an emerging preference in the Australian policy literature for mechanisms that promote private and autonomous adaptation (Productivity Commission 2012; SCCC 2012; TCCO 2012a). Local and small-scale adaptation decision-making is more likely to promote autonomy and resolve trade-offs between competing values, but care will be required to ensure that processes and institutions still ensure the recognition and protection of public goods (SGS Economics 2012b). There will also need to be mechanisms by which to resolve conflicts between competing adaptation priorities within and between sectors. Systemic changes in attitude are likely to require more profound cultural shifts.

The experience of adaptation in Tasmania presents us with a unique opportunity to understand 'system-wide' relationships, influences and constraints. There is neither the time nor the resources to undertake state-specific research for every priority area across every sector. This means that many adaptation challenges must be met through the transfer of lessons learned elsewhere. With careful monitoring and evaluation of the effectiveness, equity and efficiency of adaptation interventions, understanding this unique Tasmanian context will aid in the transfer and adoption of insights drawn from adaptation research across sectors and across jurisdictions.

BIBLIOGRAPHY

- (ABARES) Australian Bureau of Agricultural and Resource Economics and Sciences (2011) *Australian fisheries statistics 2010* (ABARES: Canberra, ACT).
- (ABC News) Australian Broadcasting Corporation News (2011) *Port Arthur climate risk*, available from: <http://www.abc.net.au/news/2011-07-20/20110720-port-arthur-storm-damage/2803354>.
- (ABS) Australian Bureau of Statistics (2011) *1304.6 – Tasmanian Key Indicators, March 2011* (ABS: Canberra, ACT).
- (ABS) Australian Bureau of Statistics (2012) *3218.0 – Regional Population Growth, Australia, 2011* (ABS: Canberra, ACT).
- (ACE CRC) Antarctic Climate & Ecosystems Cooperative Research Centre (2010d) *Climate Futures for Tasmania: General Climate Impacts: The Summary* (ACE CRC: Hobart, Tasmania).
- (ACE CRC) Antarctic Climate & Ecosystems Cooperative Research Centre (2010c) *Climate Futures for Tasmania: Impacts on Agriculture: The Summary* (ACE CRC: Hobart, Tasmania).
- (ACE CRC) Antarctic Climate & Ecosystems Cooperative Research Centre (2008) *Position Analysis: Climate Change, Sea-level Rise and Extreme Events: Impacts and Adaptation Issues* (ACE CRC: Hobart, Tasmania), available from: http://www.cmar.csiro.au/sealevel/downloads/SLR_PA.pdf.
- (ACE CRC) Antarctic Climate and Ecosystems Cooperative Research Centre (2010a) *Climate Futures for Tasmania: Impacts on Agriculture Technical Report* (ACE CRC: Hobart, Tasmania).
- (ACE CRC) Antarctic Climate and Ecosystems Cooperative Research Centre (2010b) *Climate Futures for Tasmania Climate Modelling: The Summary* (ACE CRC: Hobart, Tasmania).
- (AEMI) Australian Emergency Management Institute (2011) *National Strategy for Disaster Resilience*, available at: <http://www.em.gov.au/Publications/Program%20publications/Pages/NationalStrategyforDisasterResilience.aspx>
- (AFAC) Australasian Fire and Emergency Service Authorities Council (2012) *Climate Change and the Fire and Emergency Services Sector* (AFAC: East Melbourne, Victoria).
- (AFAC) Australasian Fire and Emergency Service Authorities Council (2009b) *Climate Change and the Fire and Emergency Services Sector Position* (AFAC: East Melbourne, Victoria).
- (AFAC) Australasian Fire and Emergency Service Authorities Council (2012) *Climate Change and the Fire and Emergency Services Sector* (AFAC: East Melbourne, Victoria).
- (AFAC) Australasian Fire and Emergency Service Authorities Council (2009a) *Climate Change and the Fire and Emergency Services Sector: Discussion Paper* (AFAC: East Melbourne, Victoria).
- (ALGA) Australian Local Government Association (2011) *Local Council Risk of Liability in the Face of Climate Change – Resolving Uncertainties - A Report for the Australian Local Government Association*, available from: http://www.climatechange.gov.au/~/_/media/publications/local-govt/alga-report-final-pdf.pdf.

- (CCRPI) Cradle Coast Regional Planning Initiative (2011) *Living on the Coast: the Cradle Coast Regional Land Use Planning Framework*.
- (COAG) Council of Australian Governments (2011) *National Strategy for Disaster Resilience: Building the Resilience of Our Nation to Disasters* (Commonwealth of Australia: Canberra, ACT).
- (COAG) Council of Australian Governments, Standing Committee on Climate Change (2012) *Roles and Responsibilities for Climate Change Adaptation (Draft)*, available from: www.climatechange.gov.au/.../sccc/.../sccc/20150504-sccc-communicue-pdf.pdf.
- (CSIRO) Commonwealth Scientific and Industrial Research Organisation (2009) *Water availability for Tasmania*, Report one of seven to the Australian Government from the CSIRO Tasmania Sustainable Yields Project (CSIRO Water for a Healthy Country Flagship: Australia), available from: <http://www.csiro.au/Organisation-Structure/Flagships/Water-for-a-Healthy-Country-Flagship/Sustainable-Yields-Projects/TASSY.aspx>.
- (DCC) Commonwealth Department of Climate Change (2009) *Climate Change Risks to Australia's Coasts: A First Pass National Assessment* (DCC: Canberra, ACT).
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2011) *Climate Change Risks to Coastal Buildings and Infrastructure: A Supplement to the First Pass National Assessment* (DCCEE: Canberra, ACT).
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2011) *The Critical Decade – Climate Science, Risks and Responses* (Climate Commission Secretariat: Canberra, ACT).
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2010) *Adapting to Climate Change in Australia: an Australian Government Position Paper*, available from: <http://www.climatechange.gov.au/~media/publications/adaptation/gov-adapt-climate-change-position-paper.pdf>.
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2010) *Climate Change Adaptation Actions for Local Government*, available from: http://www.climatechange.gov.au/what-you-can-do/~media/publications/local-govt/localadaption_localgovernment.pdf.
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2012) *Coastal Adaptation Pathways Projects*, available from: <http://www.climatechange.gov.au/en/government/initiatives/coastal-adaptation-decision-pathways.aspx>.
- (DEDTA) Department of Economic Development, Tourism and the Arts (2011) *Businesses in Tasmania*, available from: http://www.development.tas.gov.au/economic/economic_development_plan/achieving_our_vision/supporting_business/businesses_in_tasmania.
- (DIER) Department of Infrastructure, Energy and Resources (2012) *Tasmanian Government 2012 Transport Submission to Infrastructure Australia New Bridgewater Bridge*, Submission to Infrastructure Australia, available from: http://www.dier.tas.gov.au/__data/assets/pdf_file/0010/81946/Burnie_to_Hobart_Freight_Corridor_New_Bridgewater_Bridge.pdf.
- (DIER) Department of Infrastructure, Energy and Resources (n.d) *Australian Government National Building Program Information flyer: The Bridgewater Bridge Replacement*.

- (DPAC OSM) Department of Premier and Cabinet, Office of Security and Emergency Management (2010) *Review of Construction and Development Control in Bushfire Prone Areas* (DPAC: Tasmania).
- (DPAC OSM) Department of Premier and Cabinet, Office of Security and Emergency Management (2012) *Principles for the Consideration of Natural Hazards in the Planning System* (DPAC: Tasmania).
- (DPAC) Department of Premier and Cabinet (2012a) *Local Climate Profiles for Tasmania's 29 LGAs* (DPAC: Tasmania), available from:
http://www.dpac.tas.gov.au/divisions/climatechange/adapting/climate_futures/local_government_area_climate_profiles.
- (DPAC) Department of Premier and Cabinet (2012b) *Derivation of the Tasmanian Sea Level Rise Planning Allowances* (DPAC: Tasmania), available from:
http://www.dpac.tas.gov.au/_data/assets/pdf_file/0003/176331/Tasmanian_SeaLevelRisePlanningAllowance_TechPaper_August2012.pdf.
- (DPAC) Department of Premier and Cabinet (2012c) *Tools* (DPAC: Tasmania), available from:
http://www.dpac.tas.gov.au/divisions/climatechange/what_the_government_is_doing/new_tools_to_improve_planning_for_sea_level_rise_and_coastal_hazards.
- (DPAC) Department of Premier and Cabinet (2012d) *Principles for the Consideration of Natural Hazards in the Planning System (Draft)* (DPAC: Hobart, Tasmania).
- (DPAC) Department of Premier and Cabinet (2012e) *ClimateConnect Grant Program*, available from:
http://www.climatechange.tas.gov.au/grants/climateconnect_grants.
- (DPIPWE) Department of Primary Industries, Parks, Water & Environment Resource Management & Conservation Division (2010a) *Vulnerability of Tasmania's Natural Environment to Climate Change: An Overview* (Unpublished Report) (DPIPWE: Hobart, Tasmania).
- (DPIPWE) Department of Primary industries, Parks, Water and Environment (2010c) *Rock Lobster Management Plan Review Report on Discussion Paper* (DPIPWE: Tasmania), available from:
[http://www.dpiw.tas.gov.au/inter-nsf/Attachments/JPAN-89X76Q/\\$FILE/Report%20on%20the%20Second%20Consultation%20Phase.pdf](http://www.dpiw.tas.gov.au/inter-nsf/Attachments/JPAN-89X76Q/$FILE/Report%20on%20the%20Second%20Consultation%20Phase.pdf).
- (DPIW) Department of Primary Industries and Water (2004) *Information Paper: Sea-Level Change Around Tasmania*, available from: <http://www.dpiw.tas.gov.au/inter,nsf/Publications/PMAS-63K6W5?open>.
- (DPIW) Department of Primary Industries and Water (2008a) *Climate Change and Coastal Asset Vulnerability: an Audit of Tasmania's Coastal Assets Potentially Vulnerable to Flooding and Sea Level Rise* (DPIW: Tasmania).
- (DPIW) Department of Primary Industries and Water (2008b) *Coastal Hazards in Tasmania General Information Paper* (DPIW: Tasmania).
- (DPIW) Department of Primary Industries and Water (2008c) *Sea-level Extremes in Tasmania: Summary and Practical Guide for Planners and Managers* (DPIW: Tasmania).
- (DPIW) Department of Primary Industries and Water (2009a) *Coastal Risk Management Plan: Template and Guidelines, Department of Primary Industries and Water* (DPIW: Tasmania).
- (DPIW) Department of Primary Industries and Water (2009b) *Coastal Risk Management Plan: Case Study* (DPIW: Tasmania).

- (DTF) Department of Treasury and Finance (2012) *Submission to the review of the Tasmanian Climate Change (State Action) Act (2008)*.
- (IPCC) Intergovernmental Panel on Climate Change, 'Summary for Policymakers' in Field C B, Barros V, Stocker T F, Qin D, Dokken D J, Ebi K L, Mastrandrea M D, Mach K J, Plattner G K, Allen S K, Tignor M & Midgley P M (eds.) (2012) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (Cambridge University Press: Cambridge, UK & New York, USA) 1-19.
- (IPCC) Intergovernmental Panel on Climate Change, 'Summary for Policymakers' in Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K B, Tignor M & Miller H L (eds.) (2007b) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press: Cambridge, United Kingdom & New York, USA).
- (IPCC) Intergovernmental Panel on Climate Change, Parry M L, Canziani O F, Palutikof J P, Van Der Linden P J & Hanson C E (eds.) (2007a) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge University Press: Cambridge, UK).
- (LGAT) Local Government Association of Tasmania (2010) *Tasmanian Local Council Climate Change Case Studies: Lower George River Flood Risk Project*, available from: http://www.lgat.tas.gov.au/webdata/resources/files/Climate_change_case_studies_-_break_o_day.pdf.
- (LGAT) Local Government Association of Tasmania (2010) *Tasmanian Local Council Climate Change Case Studies: Climate Change Impacts on the Clarence Coastal Area*, available from: http://www.lgat.tas.gov.au/webdata/resources/files/Climate_change_case_studies_-_Clarence.pdf.
- (LGAT) Local Government Association of Tasmania (2012), available from: <http://www.climatechange.tas.gov.au/>.
- (NCCARF) National Climate Change Adaptation Research Facility (2012c) *Project Descriptor: Climate Change and the Community Welfare Sector – Risks and Adaptation*, ACOSS project funded by NCCARF Settlements & Infrastructure Climate Change Adaptation Research Grants Program (NCCARF: Gold Coast, Queensland), available from: <http://www.nccarf.edu.au/content/climate-change-and-community-welfare-sector---risks-and-adaptation>.
- (NCCARF) National Climate Change Adaptation Research Facility (2012b) NCCARF Research Portfolio Factsheet 8: Business and Industry (NCCARF: Gold Coast, Queensland).
- (NCCARF) National Climate Change Adaptation Research Facility (2012a) *Climate Change Adaptation Research in Australia: An Overview of Research Funded by the National Climate Change Adaptation Research Facility* (NCCARF: Gold Coast, Queensland).
- (NCCARF) National Climate Change Adaptation Research Facility (2012b) *NCCARF Research Portfolio Factsheet 8: Business and Industry* (NCCARF: Gold Coast, Queensland).
- (NCCARF) National Climate Change Adaptation Research Facility, *Adaptation Research Network: Marine Biodiversity and Resources*, available from: www.nccarf.edu.au/marine/.
- (NTRCA) Northern Tasmania Regional Councils Authority (2011) *Regional Land Use Strategy of Northern Tasmania*.

- (QUT) Queensland University of Technology (2010) *Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- (RMC) Department of Primary Industries, Parks, Water and Environment, Resource Management & Conservation Division (2012) *Research and Monitoring in the Tasmanian Wilderness World Heritage Area* [Brochure] (DPIPWE: Hobart, Tasmania), available from: [http://www.dpiw.tas.gov.au/inter.nsf/Attachments/LJEM-8UWVPM/\\$FILE/WWHA%20reportweb.pdf](http://www.dpiw.tas.gov.au/inter.nsf/Attachments/LJEM-8UWVPM/$FILE/WWHA%20reportweb.pdf).
- (SCCC) Select Committee on Climate Change (2012) *Roles and responsibilities for climate change adaptation in Australia*, available from: <http://www.climatechange.gov.au/government/initiatives/sccc/discussion.aspx>.
- (STCA) Southern Tasmanian Councils Association (2012) available from: <http://stca.tas.gov.au/cc/>.
- (STCRC) Sustainable Tourism Cooperative Research Centre (2009) *The Impacts of Climate Change on Australian Tourism Destination: Developing Adaptation and Response Strategies*, (CRC for Sustainable Tourism: Gold Coast, Queensland).
- (STRPP) Southern Tasmania Regional Planning Project (2011) *Southern Tasmania Regional Land Use Strategy 2010-2035*. .
- (TCCO) Department of Premier and Cabinet, Tasmanian Climate Change Office (2008) *The Tasmanian Framework for Action on Climate Change* (TCCO: Hobart, Tasmania).
- (TCCO) Department of Premier and Cabinet, Tasmanian Climate Change Office (2012a) *Adapting to Climate Change in Tasmania – Issues Paper* (TCCO: Hobart, Tasmania), available from: http://www.dpac.tas.gov.au/__data/assets/pdf_file/0009/174834/Adapting_to_climate_change_in_Tasmania.pdf.
- (TCCO) Department of Premier and Cabinet, Tasmanian Climate Change Office (2012b) *Derivation of the Tasmanian Sea Level Rise Planning Allowance Technical Paper* (TCCO: Hobart, Tasmania).
- (TPC) Tasmanian Planning Commission (2009) *State of the Environment Report: Tasmania 2009* (TPC: Hobart, Tasmania), available from: <http://soer.justice.tas.gov.au/2009/>.
- (TPC) Tasmanian Planning Commission (2012) *Planning Directive No. 5: Bushfire-Prone Areas Code*.
- Aboriginal Heritage Tasmania (2012) *The Impacts of Climate Change* (DPIPWE: Tasmania), available from: <http://www.aboriginalheritage.tas.gov.au/editorials/Pages/The-impacts-of-climate-change.aspx>.
- Adger N, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson D R, Naess L O, Wolf J, Wreford A (2009) 'Are there social limits to adaptation to climate change?' *Climatic Change* 93: 335-354.
- Allenby B R & Sarewitz D (2011) *The Techno-Human Condition* (MIT Press: Cambridge, Massachusetts).
- Andre J, Haddon M & Pecl G T (2010) 'Modelling climate-change-induced nonlinear thresholds in cephalopod population dynamics' *Global Change Biology* 16: 2866-2875.
- Australian Greenhouse Office (2006) *Climate Change Impacts and Risk Management – a Guide for Business and Government* (Department of Environment and Heritage: Canberra, ACT).

- Barmuta L A, Davies P E, Watson A, Lacey M, Graham B, Reid M G, Carter S & Warfe D M (2012) *Joining the dots: integrating climate and hydrological projections with freshwater ecosystem values to develop adaptation options for conserving freshwater biodiversity*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Barnett J & Waters E (2013) *Barriers to Adaptation to Sea Level Rise*, Draft Final Research Report to the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Barnett J, Dovers S, Hatfield-Dodds S, McDonald J, Nelson R & Waller S (2011) *National Climate Change Adaptation Research Plan: Social, Economic and Institutional Dimensions* (NCCARF: Gold Coast, Queensland).
- Battaglione S C, Carter C, Hobday A J, Lyne V & Nowak B (2008) 'Scoping Study into Adaptation of the Tasmanian Salmonid Aquaculture Industry to Potential Impacts of Climate Change', *National Agriculture & Climate Change Action Plan: Implementation Programme report* (TAFI, UTAS & CSIRO: Hobart, Tasmania).
- Beer A, Tually S, Kroehn M & Law J (2012) *Australia's Country Towns 2050: What Will A Climate Adapted Settlement Pattern Look Like?* [Preliminary Report] (Centre for Housing, Urban and Regional Planning University of Adelaide: Adelaide, South Australia).
- Beggs P J (2010) 'Adaptation to Impacts of Climate Change on Aeroallergens and Allergic Respiratory Diseases' *International Journal of Environmental Research and Public Health* 7: 3006-3021.
- Bell E & Towle N (2011) 'Climate Change and Primary Health Care: Towards Better Regional Health Impact and Risk Assessments', Proceedings of the 11th National Rural Health Conference: *Rural and Remote Australia – The Heart of a Health Nation* (Perth, 13-16 March 2011), available from: <http://11nrhc.ruralhealth.org.au/plenary-and-concurrent-papers>.
- Bell E (2011) 'Making Health Services 'Climate-ready': A Policy Framework for Regional Development' *American Journal of Public Health* 101: 804-813, DOI 10.2105/AJPH.2010.202820.
- Bell E J (2013) 'Climate change and health research: has it served rural communities?' *Rural and Remote Health* 13: 2343, available online from: <http://www.rrh.org.au>.
- Bell E, Horton G, Blashki G & Seidel B M (2012) 'Climate Change: Could it Help Develop 'Adaptive Expertise'?' *Advances in Health Sciences Education* 17: 211–224.
- Bell E, Turner P & Sainsbury F (2012) *Climate Change Health Impact and Risk Assessment Tool: a Pilot Implementation Project*, Summary Report to the Tasmanian Government Climate Connect Community Grants Program.
- Bennett J (2011) *Estimating the Value of Australian Environmental Assets*, available from: <http://www.tandfonline.com/doi/pdf/10.1080/14486563.2011.566157>.
- Bennett J C, Ling F L N, Graham B, Corney S P, Holz G K, Grose M R, White C J, Gaynor S M & Bindoff N L (2010) *Climate Futures for Tasmania: Water and Catchments Technical Report* (ACE CRC: Hobart, Tasmania), available from: http://www.dpac.tas.gov.au/divisions/climatechange/adapting/climate_futures/climate_futures_f_or_tasmania_reports.
- Bird D, King D, Haynes K, Box P, Okada T & Nairn K (2011) *Impact of the 2010/11 Floods and the Factors That Inhibit and Enable Household Adaptation Strategies* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

- Black D A, Veitch C, Wilson L A & Hansen A (2013), *Heat-Ready: Heatwave awareness, preparedness and adaptive capacity in aged care facilities in three Australian states: New South Wales, Queensland and South Australia*, [Draft] Report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Boon H J, Millar J, Lake D, Cottrell A, King D (2012) *Recovery from Disaster: Resilience, Adaptability and Perceptions of Climate Change* (NCCARF: Gold Coast, Queensland).
- Booth K & Williams S (2012) 'Is Insurance an Under-Utilised Mechanism in Climate Change Adaptation? The Case of Bushfire Management in Tasmania', *Australian Journal of Emergency Management* 27 (4): 38-45.
- Booth P & Cox R (2012) *Case Studies of Climate Change Adaptation Tools and Application Processes Used by Local Government Practitioners*, final Stage 1 Report to the Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNSI) (NCCARF: Gold Coast, Queensland). .
- Booth P (2012) *Stage 1 Report: Case Studies of Climate Change Adaptation Tools and Application Processes Used by Local Government Practitioners*, Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNSI) (School of Civil and Environmental Engineering, University of New South Wales: Sydney, New South Wales). .
- Booth P, Graham P & Chen N (2011) *Framing a National Climate Change Adaptation Policy for the Built Environment*, Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNSI) Position Paper, available from: www.nccarf.edu.au/settlements-infrastructure/discussion_papers.
- Bridle K, Jones J, Kerlake F, Sanderson D, Phelan D, Parsons D, Prior S, Brown C & Mohammed C (2012b) *Projected Impact of Climate Change on Wine Grape Production – Opportunities for Growers*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8UT3EQ?open>.
- Bridle K, Lisson S, Parsons D, Phelan D, Prior S, Brown C & Mohammed C (2012c) *Projected Impact of Climate Change – Farmers Talk About Their Options*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8UT37X?open>.
- Bridle K, Phelan D, Parsons D, Prior S, Brown C & Mohammed C (2012a) *Projected Impact of Climate Change on Extensive Dryland Pastures – Opportunities for Graziers*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8UT2PF?open>.
- Cai W (2006) 'Antarctic ozone depletion causes an intensification of the Southern Ocean supergyre circulation', *Geophysical Research Letters* 33 DOI:10.1029/2005GL024911.
- Cai W, Shi G, Cowan T, Bi D & Ribbe J (2005) 'The response of the Southern Annular Mode, the East Australian Current, and the southern mid-latitude ocean circulation to global warming', *Geophysical Research Letters* 32 DOI:10.1029/2005GL024701.
- Carley J T, Blacka M J, Timms W A, Andersen M S, Mariania A, Rayney DS, McArthur J & Cox R J (2008) *Coastal Processes and Hazards for Preparation of a Coastal Management Strategy for Clarence City, Tasmania* (Water Research Laboratory, University of New South Wales: Manly Vale, New South Wales).
- Carver S, Goate S, Allen G R, Rowbottom R M, Fearnley E M & Weinstein P, (2011) 'Relationships of the Ross River virus (Togoviridae: Alphavirus) vector, *Aedes camptorhynchus* (Thomson)

- (Diptera: Culicidae), to biotic and abiotic factors in saltmarshes of south-eastern Tasmania, Australia: a preliminary study', *Australian Journal of Entomology* 50: 344–355.
- Casper R M, Barrett N S, Bax N & Hobday A J (2011) *Review of the Eastern Blue Groper*, Pre-adapting a Tasmanian coastal ecosystem to ongoing climate change through re-introduction of a locally extinct species, FRDC-DCCEE Project No: 2010/564.
- Chambers L E, Devney C A, Congdon B C, Dunlop N, Woehler E J & Dann P (2011) 'Observed and predicted effects of climate on Australian seabirds', *Emu* 111: 235-253.
- Chaplin S & Fairbrother P (2012) *Community Adaptation to Bushfire in a Changing Climate: A Toolkit for Local Government* (Centre for Sustainable Organisations and Work, RMIT: Melbourne, Victoria).
- Chong J, Asker S, O'Rourke A & White S (2012) *Green Chrysalis – Small and Medium-Sized Enterprises: Innovation and Transformation Towards Australia's Low-Carbon Economy*, Report prepared for the Australian Business Foundation (Institute for Sustainable Futures, University of Technology: Sydney, New South Wales).
- Church J A, White N J, Hunter J R & McInnes K L (2012) 'Sea Level', in Poloczanska E S, Hobday AJ & Richardson A J (eds.) *A Marine Climate Change Impacts and Adaptation Report Card for Australia 2012*, available from: <http://www.oceanclimatechange.org.au>.
- Cica N (2013) 'The cracks are how the light gets in', *Griffith Review* 38, available from: <https://griffithreview.com/edition-39-tasmania-the-tipping-point/the-cracks-are-how-the-light-gets-in>.
- ComSec (2013) *State of the States Report: April 2013*, available from: <http://www.investing.commsec.com.au/stateofstates>.
- Corney S P, Katzfey J K, McGregor J, Grose M, White C, Holz G, Bennett J, Gaynor S & Bindoff N L (2010) *Climate Futures for Tasmania: methods and results on climate modelling* (ACE CRC: Hobart, Tasmania).
- Cozzolino D, Cynkar W, Damberg R G, Gishen R G & Smith P (2010) 'Grape (*Vitis Vinifera*) compositional data spanning ten successive vintages in the context of abiotic growing parameters', *Agriculture, Ecosystems and Environment* 139(4): 565-570
DOI:10.1016/j.agee.2010.09.017.
- Cresswell G (2000) 'Currents of the continental shelf and upper slope of Tasmania' *Papers and Proceedings of the Royal Society of Tasmania* 133: 21-30.
- Crimp S, Gartmann A, DeVoi P, Gaydon D, Howden M & Odgers J (2008) *Adapting Australian Farming Systems to Climate Change: a Participatory Approach* [Final Report] (Australian Greenhouse Office: Canberra, ACT), available from: http://www.bcg.org.au/resources/Adapting_Australian_farming_systems_to_climate_change_final_report_web.pdf.
- Crompton R, McAneney D, McAneney J, Musulin R, Walker G & Jr R P (2012) *Market-Based Mechanisms for Climate Change Adaptation: Assessing the potential for and limits to insurance and market-based mechanisms for encouraging climate change adaptation*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Cubillos J C, Wright S W, Nash G, de Salas M F, Griffiths B, Tilbrook B, Poisson A & Hallegraeff G M (2007) 'Calcification morphotypes of the coccolithophorid *Emiliana huxleyi* in the Southern

Ocean: changes in 2001 to 2006 compared to historical data', *Marine Ecology Progress Series* 348: 47-54.

Davidson J & Lyth A (2012) 'Education for Climate Change Adaptation – Enhancing the Contemporary Relevance of Planning Education for a Range of Wicked Problems', *Journal for Education in the Built Environment* (7)2: 63-83, available online from: [http://cebe.cf.ac.uk/jebe/pdf/JulieDavidson7\(2\).pdf](http://cebe.cf.ac.uk/jebe/pdf/JulieDavidson7(2).pdf).

Dennis C (2002) 'Baiting plan to remove fox threat to Tasmanian wildlife', *Nature* 416: 357.

Doubleday Z A, Clarke S M, Li X, Pecl G T, Ward T, Battaglione S, Frusher S, Gibbs P J, Hobday A J, Hutchinson N, Jennings S M & Stoklosa R (2013) 'Assessing the risk of climate change to aquaculture: a case study from south-east Australia', *Aquaculture Environment Interactions* 3(2): 163-175 DOI: 10.3354/aei00058.

Dunlop M & Brown P R (2008) *Implications of climate change for Australia's National Reserve System: A preliminary assessment*, Report to the Department of Climate Change (DCC) (DCC: Canberra, ACT).

Evans L S, Fidelman P, Hicks C, Morgan C, Perry A L & Tobin R (2011) *Limits to climate change adaptation in the Great Barrier Reef: Scoping ecological, institutional and economic limits*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

Fitzgerald N (2011) *Establishment Report for Tasmanian Wilderness World Heritage Area Climate Change Monitoring Program: Montane Conifers*, Nature Conservation Report Series 11/06 (Resource Management and Conservation Division, DPIW: Hobart, Tasmania).

Fleming A & Vanclay F (2010) 'Farmer responses to climate change and sustainable agriculture: a Review', *Agronomy for Sustainable Development* 30: 11-19 DOI:10.1051/agro/2009028.

Folder S (2012) *Climate Ready Farms for the Future: Case Study, Regional NRM Strategy*, a report for Cradle Coast NRM by Pear Consulting (Cradle Coast Authority: Tasmania).

Forbes C (2009) 'The effects of climate change induced coastal inundation' National Environmental Law Review, available from: <http://www.austlii.edu.au/au/journals/NatEnvLawRw/2009/48.html>.

Fritze J, Williamson L & Wiseman J (2009) *Community Engagement and Climate Change: Benefits, Challenges and Strategies*, report for the Victorian Department of Planning and Community Development.

Frusher S & Marshall N (2012) *A Climate Change Adaptation Blueprint for Coastal Regional Communities* [Project synopsis], available from: http://www.nccarf.edu.au/sites/default/files/attached_files_research_projects/2010-542%20Website%20snippet%20Frisher-Marshall.pdf.

Frusher S D, Hobday A J, Jennings S M, Pecl G T, Haward M, Nursey-Bray M, Holbrook N J, van Putten E I, Crighton C & D'Silva D (in press) 'History of a hotspot – from anecdote to adaptation in south-east Australia', *Reviews in Fish Biology and Fisheries*.

Galbreath J (2011) 'To what extent is business responding to climate change? Evidence from a global wine producer', *Journal of Business Ethics* 104: 421-432 DOI 10.1007/s10551-011-0919-5.

Gale F (2013) 'No basket-case – Tasmania on the bumpy road to economic sustainability', *The Conversation*, 8 Feb 2013, available from: <http://theconversation.com/no-basket-case-tasmania-on-the-bumpy-road-to-economic-sustainability-11293>.

- Gardner J, Parsons R & Paxton G (2010) *Adaptation Benchmarking Survey: Initial Report*, CSIRO Climate Adaptation Flagship Working paper No. 4, available from: <http://www.csiro.au/Organisation-Structure/Flagships/Climate-Adaptation-Flagship/CAF-working-papers/CAF-working-paper-4.aspx>.
- Gaydon D S, Meinke H & Rodriguez D (2012) 'The best farm-level irrigation strategy changes seasonally with fluctuating water availability', *Agricultural Water Management: An International Journal* 103: 33-42 DOI:10.1016/j.agwat.2011.10.015.
- Gehrels W R, Callard S L, Moss P T, Marshall W A, Blaauw M, Hunter J, Milton A & Garnett M H (2012) 'Nineteenth and Twentieth Century Sea-level Changes in Tasmania and New Zealand' *Earth and Planetary Science Letters* 315–316: 94-102.
- Gehrels W R, Callard S L, Moss P T, Marshall W A, Blaauw M, Hunter J, Milton A & Garnett M H
- Gero A, Kuruppu N & Mukheibir P (2012) *Cross-scale barriers to climate change adaptation in local government, Australia - Draft background report*, prepared for NCCARF (Institute for Sustainable Futures, University of Technology: Sydney, New South Wales) 1-35.
- Gero A, Meheux K & Dominey-Howes D (2010) *Disaster risk reduction and climate change adaptation in the Pacific: The challenge of integration*, ATRC-NHRL Miscellaneous Report 4, available from:<http://www.nhrl.unsw.edu.au/downloads/UNSW%20DRR%20and%20CCA%20in%20the%20Pacific.pdf>.
- Gibbs M & Hill T (2011) *Coastal Climate Change Risk - Legal and Policy Responses in Australia* (Commonwealth of Australia: Canberra, ACT) available from: <http://www.climatechange.gov.au/publications/coastal-climate-change-risk/~media/publications/coastal-climate-change-risk/CoastalLegislationReport-20120228-PDF.pdf>.
- Gibbs M & Hill T (2011) *Coastal Climate Change Risk - Legal and Policy Responses in Australia* (Commonwealth of Australia: Canberra, ACT) available from: <http://www.climatechange.gov.au/publications/coastal-climate-change-risk/~media/publications/coastal-climate-change-risk/CoastalLegislationReport-20120228-PDF.pdf>.
- Gilfedder L, MacGregor N, Bridle K, Carter O & Sprod D (2012) *Implementing Adaptation to Climate Change in Terrestrial and Freshwater Natural Environments in Tasmania*, Report on an expert workshop held in Hobart on 28-29 November 2011 (DPIPWE: Hobart, Tasmania).
- Good M (2011) *Government coastal planning responses to rising sea levels, Australia and overseas. ACE-CRC Technical Report* (ACE CRC: Tasmania), available from: <http://www.acecrc.org.au/access/repository/resource/86d7f302-1512-102f-a3d0-40404adc5e91>.
- Grafton R Q (2010) 'Adaptation to climate change in marine capture fisheries', *Marine Policy* 34: 606-615.
- Graham K, Green G & Heyward O (2012) *Regional Councils Climate Change Adaptation Strategy: Southern Tasmania* [Draft] (Southern Tasmanian Councils Authority: Tasmania).
- Green B S, Gardner C, Linnane A & Hawthorne P J (2010) 'The Good, the Bad and the Recovery in an Assisted Migration' *PLoS ONE* 5(11): e14160, available from: www.plosone.org/article/info:doi/10.1371/journal.pone.0014160.
- Grose M R, Barnes-Keoghan I, Corney S P, White C J, Holz G K, Bennett J B, Gaynor S M, & Bindoff N L (2010) *Climate Futures for Tasmania: General Climate Impacts Technical Report* (ACE CRC:

Hobart, Tasmania), available from:
http://www.climatechange.tas.gov.au/government_action/climate_futures.

- Gross C, Pittock J, Finlayson M & Geddes M C (2011) *Climate Change Adaptation in the Coorong, Murray Mouth and Lakes Alexandrina and Albert*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Gurran N, Norman B, Gilbert C, Hamin E (2011) *Planning for climate change adaptation in Coastal Australia: State of practice*, Report No. 4 for the National Sea Change Taskforce (Faculty of Architecture, Design and Planning, University of Sydney: New South Wales).
- Hadwen W L, Arthington A H, Boon P I, Taylor B & Fellows C S (2011a) 'Do Climatic or Institutional Factors Drive Seasonal Patterns of Tourism Visitation to Protected Areas Across Diverse Climate Zones in Eastern Australia?', *Tourism Geographies: An International Journal of Tourism Space, Place and Environment* 13(2): 187-208.
- Hadwen W L, Capon S J, Poloczanska E, Rochester W, Martin T, Bay L, Pratchett M, Green J, Cook B, Berry A, Lalonde A & Fahey S (2011b) *Climate Change Responses and Adaptation Pathways in Australian Coastal Ecosystems: Synthesis Report*, (NCCARF: Gold Coast, Queensland).
- Hallegraeff G M (2010) 'Ocean climate change, phytoplankton community responses, and harmful algal blooms: a formidable predictive challenge', *Journal of Phycology* 46: 220-235.
- Handmer J, McKellar R, McLennan B, Whittaker J, Towers B, Duggie J & Woolf M (2012) *National Climate Change Adaptation Research Plan: Emergency Management* [Revised Edition] (NCCARF: Gold Coast, Queensland) 60.
- Hansen A, Bi P, Saniotis A, Nitschke M, Benson J, Tan Y, Smyth V, Wilson L & Han G S (2012) *Extreme heat and climate change: adaptation in culturally and linguistically diverse (CALD) communities* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Harle K J, Howden S M, Hunt L P & Dunlop M (2007) 'The potential impact of climate change on the Australian wool industry by 2030', *Agricultural Systems* 93: 61-89
DOI:10.1016/j.agsy.2006.04.003.
- Harrington P, Reeks G & Helle L (2008) *Impact of Climate Change on Tasmania's Food and Beverage Industry*, Report prepared by Pitt & Sherry for the Department of Economic Development and Tourism Department of Primary Industries and Water (Pitt & Sherry: Hobart, Tasmania).
- Hart M (ed.) (2011) *Effects of severe weather on agriculture in Tasmania, January to April 2011*, [Unpublished report] (Tasmanian Institute of Agricultural Research: Hobart, Tasmania).
- Haward M, Davidson J, Hockings M, Lockwood M, Kriwoken L, Allchin R (2012) 'Changing currents in marine biodiversity governance and management responding to climate change', *Report 2: Scenarios for marine environments in Eastern Australia and implications for biodiversity*, (FRDC/UTAS: Tasmania).
- Haward M, Davidson J, Lockwood M, Hockings M & Kriwoken L (2012) 'Climate change, scenarios and marine biodiversity conservation', *Marine Policy* 38, available from:
<http://dx.doi.org/10.1016/j.marpol.2012.07.004>.
- Hayman P, Rickards L, Eckard R & Lemerle D (2012) 'Climate change through the farming systems lens: Challenges and opportunities for farming in Australia', *Crop & Pasture Science* 63: 203-214 DOI.org/10.1071/CP11196.

- Haynes K, Bird D K, Carson D, Larkin S & Mason M (2011) *Institutional response and Indigenous experiences of Cyclone Tracy*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Helman P, Thomalla F & Metusela C (2010) *Storm tides, coastal erosion and inundation*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Henry B, Charmley E, Eckard R, Gaughan J B & Hegarty R (2012) 'Livestock production in a changing climate: Adaptation and mitigation research in Australia', *Crop & Pasture Science* 63: 191-202 DOI.org/10.1071/CP11169.
- Henry G W & Lyle J M (eds.) (2003) 'National Recreational Fishing Survey', in *The National Recreational and Indigenous Fishing Survey*, FRDC Project No. . 99/158 (Australian Government Department of Agriculture, Fisheries and Forestry: Canberra, ACT) 27-97.
- Herriman E J, Kuruppu N, Gero A & Mukheibir P (2012) 'Cross-scale barriers to climate change adaptation in local government, Australia - Workshop Two report', prepared for National Climate Change Adaptation Research Facility (Institute for Sustainable Futures, UTS: Sydney, New South Wales) 1-47.
- Hobday A J & Lough J (2011) 'Projected climate change in Australian marine and freshwater environments' *Marine and Freshwater Research* 62: 1000-1014.
- Hobday A J & Pecl G T (in press) 'Identification of global marine hotspots: sentinels for change and vanguards for adaptation', *Reviews in Fish Biology and Fisheries*.
- Hobday A J, Lyne V, Thresher R, Spillman C & Norman-Lopez A (2011) *Atlantic Salmon Aquaculture Subprogram: Forecasting ocean temperatures for salmon at the farm site*, FRDC report 2010/217, (delivered draft final 13 Sept 2011).
- Hobday A J, Poloczanska E S & Matear R (2008) *Implications of Climate Change for Australian Fisheries and Aquaculture: A preliminary assessment*, Report to the Department of Climate Change (DCC) (DCC: Canberra, ACT), available from: <http://www.cmar.csiro.au/climateimpacts/reports.htm>.
- Hobson K & Niemeyer S (2011) Public responses to climate change: *The role of deliberation in building capacity for adaptive action*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Hochman Z & Carberry P S (2011) 'Emerging consensus on desirable characteristics of tools to support farmers management of climate risk in Australia' *Agricultural Systems* 104: 441-450 DOI:10.1016/j.agsy.2011.03.001.
- Hodgkinson J H, Littleboy A, Howden M, Moffat K & Loechel B (2010) *Climate Adaptation in the Australian Mining and Exploration Industries*, CSIRO Climate Adaptation Flagship Working paper No. 5, available from: <http://www.csiro.au/resources/CAF-working-papers.html>.
- Holbrook N J (2011) *Australian Marine Stakeholder Needs in a Changing Climate*, Report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Holbrook N J, Brown J N, Davidson J, Feng M, Hobday A J, Lough J M, McGregor S, Power S B & Risbey J S (2012) 'El Niño – Southern Oscillation', in Poloczanska E S, Hobday A J & Richardson A J (eds.) *A Marine Climate Change Impacts and Adaptation Report Card for Australia 2012*, available from: <http://www.oceanclimatechange.org.au/>.

- Holbrook N L & Bindoff N L (1997) 'Interannual and decadal temperature variability in the southwest Pacific Ocean between 1955 and 1988' *Journal of Climate* 10: 1035-1049.
- Holz G K, Grose M R, Bennett J C, Corney S P, White C J, Phelan D, Potter K, Kriticos D, Rawnsley R, Parsons D, Lisson S, Gaynor S M & Bindoff N L (2010) *Climate Futures for Tasmania: impacts on agriculture technical report* (ACE CRC: Hobart, Tasmania).
- House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts (2009) *Managing Our Coastal Zone in a Changing Climate: The Time to Act is Now*, report to the House of Representatives Committee (Commonwealth of Australia: Canberra, ACT).
- Hovenden M J, Miglietta F, Zaldei A, Vanderschoor J K, Wills K E & Newton P C D (2006) 'The TasFACE climate-change impacts experiment: design and performance of combined elevated CO₂ and temperature enhancement in a native Tasmanian grassland', *Australian Journal of Botany* 54: 1-10.
- Howden S M, Soussana J F, Tubiello F N, Chhetri N, Dunlop M & Meinke H (2007) 'Adapting agriculture to climate change', *Proceedings of the National Academy of Sciences* 104(5): 19691-19696 DOI:10.1073/pnas.0701890104.
- Hughes L, Hobbs R, Hopkins A, McDonald J, Stafford Smith M, Steffen W & Williams S (2010) *National Climate Change Adaptation Research Plan for Terrestrial Biodiversity* (National Climate Change Adaptation Research Facility: Gold Coast, Queensland) 64.
- Hunter J (2008) *Historical and Projected Sea-Level Extremes for Hobart and Burnie, Tasmania*, Technical Report prepared by the Antarctic and Climate and Ecosystems Cooperative Research Centre (DPIW: Hobart, Tasmania).
- Hunter J (2010) 'Estimating Sea-level Extremes under Conditions of Uncertain Sea-level Rise' *Climatic Change* 99: 331–350 DOI 10.1007/s10584-009-9671-6.
- Hunter J (2012) 'A simple technique for estimating an allowance for uncertain sea-level rise', *Climatic Change* 113: 239-252 DOI 10.1007/s10584-011-0332-1.
- Hunter J, Allison I & Jakszewicz T (2012) *Report card: Sea-level rise 2012* (ACE CRC: Hobart, Tasmania).
- Hydro Tasmania (2012) *Climate Change Framework*, available from: <http://www.hydro.com.au/environment/climate-change>.
- Jenkins K M, Kingsford R T, Closs G P, Wolfenden B J, Matthaei C D & Hay S E (2011) 'Climate change and freshwater ecosystems in Oceania: an assessment of vulnerability and adaptation opportunities', *Pacific Conservation Biology* 17: 201-219.
- Johnson C R, Banks S C, Barrett N S, Cazassus F, Dunstan P K, Edgar G J, Frusher S D, Gardner C, Haddon M, Helidoniotis F, Hill K L, Holbrook N L, Hosie G W, Last P R, Ling S D, Melbourne-Thomas J, Miller K, Pecl G T, Richardson A J, Ridgway K R, Rintoul S R, Ritz D A, Ross D J, Sanderson J C, Shepherd S A, Slotwinski A, Swadling K M & Taw N (2011) 'Climate change cascades: Shifts in oceanography, species' ranges and subtidal marine community dynamics in eastern Tasmania' *Journal of Experimental Marine Biology and Ecology* 400(1-2): 17-32 DOI:10.1016/j.jembe.2011.02.032.
- Johnston F H (2009) 'Bushfires and Human Health in a Changing Environment', *Australian Family Physician* 38: 720-725.

- Johnston F H, Williamson G J & Bowman D M J S (2012) 'A Review of Approaches to Monitoring Smoke from Vegetation Fires for Public Health', *Air Quality and Climate Change* 44(2): 17-21.
- Johnston G S, Burton D L, Baker-Jones M & Best P (2013) *Climate Change Adaptation in the Boardroom*, Final Report (NCCARF: Gold Coast, Queensland).
- Jones R (in progress) *Valuing adaptation under rapid change: anticipatory adjustments, maladaptation and transformation*, available from:
http://www.nccarf.edu.au/sites/default/files/attached_files_research_projects/SEID1112%20Website%20snippet%20Jones.pdf.
- Kahneman D & Tyersky A (1984) 'Choices, Values, and Frames', *American Psychologist* 39(4): 341-350.
- Keating B A, Carberry P S, Bindraban P, Asseng S, Meinke H & Dixon J (2010) 'Eco-efficient agriculture: Concepts, challenges and opportunities' *Crop Science* 50: 109-119
 DOI:10.2135/cropsci2009.10.0594.
- Kellett J, Ness D, Hamilton C, Pullen S & Leditschke A (2011) *Learning from Regional Climate Analogues*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Kiem A S & Austin E K (2012) *Limits and barriers to climate change adaptation for small inland communities affected by drought*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Kiem A S, Askew L E, Sherval M, Verdon-Kidd D C, Clifton C, Austin E, McGuirk P M & Berry H (2010a) *Drought and the Future of Rural Communities: Drought impacts and adaptation in regional Victoria, Australia*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Kiem A S, Verdon-Kidd D C, Boulter S L, & Palutikof J P (2010b) *Learning from Experience: Historical Case Studies and Climate Change Adaptation* (NCCARF: Gold Coast, Queensland).
- King D, Ginger J, Williams S, Cottrell A, Gurtner Y, Leitch C, Henderson D, Jayasinghe N, Kim P, Booth K, Ewin C, Innes K, Jacobs K, Jago-Bassingthwaighe M & Jackson L (2012) *Planning, Building and Insuring: Adaptation of Built Environment to Climate Change Induced Increased Intensity of Natural Hazards* (NCCARF: Gold Coast, Queensland).
- Koehn J D, Hobday A J, Pratchett M S & Gillanders B M (2011) 'Climate change and Australian marine and freshwater environments, fishes and fisheries: synthesis and options for adaptation', *Marine and Freshwater Research* 62: 1148-1164.
- Kuruppu N, Murta J, Mukheibir P, Chong J & Brennan T (2013) *Understanding the Adaptive Capacity of Small to-Medium Enterprises (SMEs) to Climate Change and Variability* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Lacey M, Hunter J & Mount R (2012) *Coastal inundation mapping for Tasmania – Stage 2*, Report to the Department of Premier and Cabinet by the Blue Wren Group, School of Geography and Environmental Studies, University of Tasmania and the Antarctic Climate and Ecosystems Cooperative Research Centre (UTAS & ACE CRC: Hobart, Tasmania), available from:
http://www.dpac.tas.gov.au/__data/assets/pdf_file/0004/176458/Coastal_Inundation_Mapping_Stage2_V1.pdf.
- Langton M, Parsons M, Leonard S, Auty K, Bell D, Burgess P, Edwards S, Howitt R, Jackson S, McGrath V & Morrison J (2012) *National Climate Change Adaptation Research Plan for*

Indigenous Communities (National Climate Change Adaptation Research Facility: Gold Coast, Queensland).

- Last P R, White W T, Gledhill D C, Hobday A J, Brown R, Edgar G J & Pecl G T (2011) 'Long-term shifts in abundance and distribution of a temperate fish fauna: a response to climate change and fishing practices' *Global Ecology and Biogeography* 20: 58-72 DOI: 10.1111/j.1466-8238.2010.00575.x.
- Lawrence G, Richards C & Lyons K (2013) 'Food security in Australia in an era of neoliberalism, productivism and climate change', *Journal of Rural Studies* 29: 30-39 DOI:10.1016/j.jrurstud.2011.12.005.
- Leith P L, Rooney M & Tilden J (2012) *Kingborough responding to coastal hazards – Snug case study*, report prepared by the Blue Wren Group Pty Ltd for Kingborough Council (Kingborough Council: Kingston, Tasmania), available from: <http://www.kingborough.tas.gov.au/webdata/resources/files/Snug%20Case%20Study%20Final%20Report.pdf>.
- Ling S D & Johnson C R (2012) 'Marine reserves reduce risk of climate-driven phase shift by reinstating size- and habitat-specific trophic interactions', *Ecological Applications* 22: 1232-1245.
- Ling S D (2008) 'Range expansion of a habitat-modifying species leads to loss of taxonomic diversity: a new and impoverished reef state', *Oecologia* 156: 883-894 DOI 10.1007/s00442-008-1043-9.
- Ling S D, Johnson C R, Frusher S D & Ridgway K R (2009a) 'Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift', *Proceedings of the National Academy of Sciences* 106: 22341-22345.
- Ling S D, Johnson C R, Ridgway K, Hobday A J & Haddon M (2009b) 'Climate driven range extension of a sea urchin: inferring future trends by analysis of recent population dynamics', *Global Change Biology* 15: 719-731.
- Linnenluecke M, Stathakis A & Griffiths A (2011) 'Firm Relocation as Adaptive Response to Climate Change and Weather Extremes', *Global Environmental Change* 21: 123-133 DOI:10.1016/j.gloenvcha.2010.09.010.
- Lisson S, Acuna T, Parsons D, Bridle K, Phelan D, Prior S, Brown C & Mohammed C (2012) *Impact of climate change on wheat production – opportunities for growers* (Tasmanian Government and the Tasmanian Institute of Agriculture: Hobart, Tasmania), available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8V27FZ?open>.
- Lockwood M, Davidson J, Hockings M, Haward M & Kriwoken L (2012) 'Marine biodiversity conservation governance and management: Regime requirements for global environmental change', *Ocean & Coastal Management* 69: 160-172.
- Lockwood M, Davidson J, Hockings M, Haward M, Kriwoken L, Allchin R (2011) *Changing Currents in Marine Biodiversity Governance and Management: Responding to Climate Change Report 1* (FRDC/UTAS: Hobart, Tasmania).
- Lough J M & Hobday A J (2011) 'Observed climate change in Australian marine and freshwater environments', *Marine and Freshwater Research* 62: 984-999.
- Loughnan M E, Tapper N J, Phan T, Lynch K & McInnes J A (2012) *A spatial vulnerability analysis of urban populations to extreme heat events in Australian capital cities*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

- Lyth A, Allchin R, Bell E & Holbrook N J (2013) *Ross River Virus in Tasmania in a Changing Climate: a vulnerability assessment A Preliminary Assessment of Ross River Virus Risk and Vulnerability in a Changing Climate*, a report prepared for the Tasmanian Government Climate Connect program (UTAS: Hobart, Tasmania), available from http://www.climatechange.tas.gov.au/grants/climateconnect_grants/previous_rounds/project_reports_-_round_four.
- Lyth A, Nichols S & Tilbury D (2007) *Shifting towards sustainability: Education for climate change adaptation in the built environment sector*, a report prepared by the Australian Research Institute in Education for Sustainability (ARIES) (ARIES: New South Wales) 54. .
- Macintosh A, Foerster A & McDonald J (2013) *Limp, Leap or Learn? Developing legal frameworks for climate change adaptation planning in Australia: Spatial Planning Instruments for Climate Change Adaptation*, Final Project Report (NCCARF: Gold Coast, Queensland).
- Madin E M P, Ban N, Doubleday Z A, Holmes T H, Pecl G T & Smith F (2012) 'Socio-economic and management implications of range-shifting species in marine systems', *Global Environmental Change* 22: 137-146.
- Maia A & Meinke H (2010) 'Probabilistic methods for seasonal forecasting in a changing climate: Cox-type regression models', *International Journal of Climatology* 30(15): 2277-2288 DOI: 10.1002/joc.2042.
- Mair J (2011) 'Events and Climate Change: An Australian Perspective', *International Journal of Event and Festival Management* 2 (3): 245-253.
- Mallon K & Hamilton E, Black M, Beem B, Abs J (2013) *Adapting the Community Sector for Climate Extremes* (NCCARF: Gold Coast, Queensland) 286.
- Martin H (2013) 'Hello world, it's Tassie calling', article published in *The Mercury* (3 February 2013), available from: http://www.themercury.com.au/article/2013/02/03/371593_tasmania-news.html.
- Marzloff M, Dambacher J M, Johnson C R, Little L R & Frusher S D (2011) 'Exploring alternative states in ecological systems with a qualitative analysis of community feedback', *Ecological Modelling* 222: 2651-2662.
- Materia C (2008) *Local Government Climate Change Forum Summary Paper, May 2008* (Local Government Association of Tasmania: Hobart, Tasmania).
- Matthews T (2011) *Climate Change Adaptation in Urban Systems: Strategies for Planning Regimes*, Urban Research Program Research Paper 32, available from: http://www.griffith.edu.au/__data/assets/pdf_file/0004/275107/urp-rp32-matthews-2011.pdf.
- McEvoy D, Mullett J, Millin S, Scott H & Trundle A (2013) *Understanding Future Risks to Ports in Australia: Enhancing the Resilience of Seaports to a Changing Climate* (NCCARF: Gold Coast, Queensland).
- McInnes K L, Church J A, Pattiarachi C, Greenslade D, White N & Sexton J (2012a) *Sea Level and Coastal Impacts from Climate Change, Weather and Seismic Disturbances: a Review of Research Activities and Observational Requirements*, paper delivered at the Integrated Marine Observing System Conference 3-4 October 2012, Canberra, available from: www.imos.org.au.

- McInnes K L, Macadam I, Hubbert G D, & O'Grady J G (2009a) 'A Modelling Approach for Estimating the Frequency of Sea Level Extremes and the Impact of Climate Change in Southeast Australia', *Natural Hazards* 51: 115-137 DOI 10.1007/s11069-009-9383-2.
- McInnes K L, O'Grady J G, Hemer M, Macadam I & Abbs D J (2012b) *Climate Futures for Tasmania: Extreme Sea Levels along Tasmania's Coast and the Impact of Climate Change*, Climate Futures for Tasmania Technical Report (ACE CRC: Hobart, Tasmania) 44.
- McLeod D J, Hallegraef G M, Hosie G W & Richardson A J (2012a) 'Climate-driven range expansion of the red-tide dinoflagellate *Noctiluca scintillans* into the Southern Ocean', *Journal of Plankton Research* 34: 332-337.
- McLeod D J, Hobday A J, Lyle J M & Welsford D C (2012b) 'A prey-related shift in abundance of small pelagic fish in eastern Tasmania?' *ICES Journal of Marine Science* DOI: 10.1093/icesjms/fss069.
- McMichael A, Weaver H J, Berry H, Beggs P, Currie B, Higgins J, Kelly B, McDonald J, Tong S (2009) *National Climate Change Adaptation Research Plan for Human Health* (National Climate Change Adaptation Research Facility: Gold Coast, Queensland) 64.
- McMichael A, Woodruff R & Hales S (2006) 'Climate change and human health: Present and future risks', *The Lancet* (UK edition) 367(9513): 859-69 DOI:10.1016/S0140-6736(06)68079-3.
- McNeill I M, Dunlop P D, Heath J B, Skinner T C Morrison D L (forthcoming 2013) 'Expecting the Unexpected: Predicting Physiological and Psychological Wildfire Preparedness from Perceived Risk, Responsibility, and Obstacles', *Risk Analysis: An International Journal* DOI: 10.1111/risa.12037.
- Meinke H & Stone R C (2005) 'Seasonal and inter-annual climate forecasting: the new tool for increasing preparedness to climate variability and change in agricultural planning and operations', *Climatic Change* 70: 221-253.
- Meinke H, Howden S M, Struik P C, Nelson R, Rodriguez D & Chapman S C (2009) 'Adaptation science for agricultural and natural resource management – urgency and theoretical basis', *Current Opinion in Environmental Sustainability* 1: 69-76 DOI:10.1016/j.cosust.2009.07.007.
- Meinke H, Nelson R, Kokic P, Stone R, Selvaraju R & Baethgen W (2006) 'Actionable climate knowledge – from analysis to synthesis', *Climate Research* 33: 101-110, available from: http://www.int-res.com/articles/cr_oa/c033p101.pdf.
- Middelmann M H (ed.) (2007) *Natural Hazards in Australia: Identifying Risk Analysis Requirements* (Geoscience Australia: Canberra, ACT).
- Ministerial Council for Police and Emergency Management (2009) *Climate Change Adaptation Action Plan*, available from: <http://www.em.gov.au/Documents/ClimateChangeActionPlan%20EndorsedbyMCPPEM.pdf>.
- Mokany K, Harwood T D & Ferrier S (2013) 'Comparing habitat configuration strategies for retaining biodiversity under climate change', *Journal of Applied Ecology* 50: 519-527.
- Morrison C & Pickering C M (2011) *Climate change adaptation in the Australian Alps: impacts, strategies, limits and management*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

- Morrongiello J R, Beatty S J, Bennett J C, Crook D A, Ikedife D N E E, Kennard M J, Kerezszy A, Lintermans M, McNeil D G, Pusey B J & Rayner T (2011) 'Climate change and its implications for Australia's freshwater fish', *Marine and Freshwater Research* 62: 1082-1098.
- Moser S & Ekstrom J (2010) 'A framework to diagnose barriers to climate change adaptation', *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* 107(51): 22026-22031 DOI: 10.1073/pnas.1007887107.
- Mount R E, Lacey M J & Hunter J R (2010) *Tasmanian Coastal Inundation Mapping Project Report Version 1.2* [Consultants Report] (Tasmanian Planning Commission: Tasmania).
- Mount R E, Lacey M J & Hunter J R (2011) *Tasmanian Coastal Inundation Mapping Project Report Version 2.0* [Consultants Report] (Tasmanian Planning Commission: Tasmania).
- Mukheibir P, Gero A & Herriman E J (2012a) *Cross-scale barriers to climate change adaptation in local government, Australia - Workshop Three report*, prepared for National Climate Change Adaptation Research Facility (NCCARF) (Institute for Sustainable Futures, University of Technology: Sydney, New South Wales) 1-27.
- Mukheibir P, Kuruppu N, Gero A & Herriman J (2012b) *Cross-Scale Barriers to Adaptation in Local Government, Australia*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Murta J, Gero A, Kuruppu N & Mukheibir P (2012) *Enhancing Adaptive Capacity of Small to Medium Enterprises – Background Report*, report prepared for NCCARF (Institute for Sustainable Futures, University of Technology: Sydney, New South Wales).
- Nelson D R, Adger W N & Brown K (2007) 'Adaptation to environmental change: contributions of a resilience framework', *Annual Review of Environment and Resources* 32: 395-419 DOI: 10.1146/annurev.energy.32.051807.090348.
- Nelson R, Kokic P, Crimp S, Martin P, Meinke H, Howden S M, de Voil P & Nidumolu U (2010b) 'The vulnerability of Australian rural communities to climate variability and change: Part II - Integrating impacts with adaptive capacity', *Environmental Science and Policy* 13(1): 18-27 DOI:10.1016/j.envsci.2009.09.006.
- Nelson R, Kokic P, Crimp S, Meinke H & Howden S M (2010a) 'The vulnerability of Australian rural communities to climate variability and change: Part I—Conceptualising and measuring vulnerability', *Environmental Science & Policy* 13(1): 8-17 DOI:10.1016/j.envsci.2009.09.006.
- .
- Nichols N (2008) *Australian Climate and Weather Extremes: Past, Present and Future*, a report for the Department of Climate Change (Department of Climate Change: Canberra, ACT).
- Norman-Lopez A, Pascoe S & Hobday A J (2011) 'Potential economic impacts of climate change on Australian fisheries and the need for adaptive management', *Climate Change Economics* 2: 209-235 DOI: 10.1142/S2010007811000279.
- Nursey-Bray M, Pecl G, Frusher S, Gardner C, Haward M, Hobday A J, Jennings S, Punt A, Revill H & van Putten I (2012) 'Communicating climate change: climate change risk perceptions and rock lobster fishers, Tasmania', *Marine Policy* 36: 753-759 DOI:10.1016/j.marpol.2011.10.015.
- O'Neill C, Green D & Lui W (2012) 'How to Make Climate Change Research Relevant for Indigenous Communities in Torres Strait, Australia', *Local Environment: The International Journal of Justice and Sustainability* 17(10): 1104-1120.

- Page L & Thorp V (2010) *Tasmanian Coastal Works Manual: A Best Practice Management Guide for Changing Coastlines* (DPIPWE: Hobart, Tasmania).
- Park S E, Marshall N A, Jakku E, Dowdd A M, Howden S M, Mendham E & Fleming A (2012) 'Informing adaptation responses to climate change through theories of transformation', *Global Environmental Change* 22: 115-126 DOI:10.1016/j.gloenvcha.2011.10.003.
- Pecl G T, Frusher S, Gardner C, Haward M, Hobday A J, Jennings S, Nursey-Bray M, Punt A, Revill H & van Putten I (2009) *The east coast Tasmanian rock lobster fishery – vulnerability to climate change impacts and adaptation response options*, report to the Department of Climate Change (DCC) (DCC: Australia).
- Pecl G T, Ward T, Doubleday Z, Clarke S, Day J, Dixon C, Frusher S, Gibbs P, Hobday A J, Hutchinson N, Jennings S, Jones K, Li X, Spooner D & Stoklosa R (2011) *Risk Assessment of Impacts of Climate Change for Key Marine Species in South Eastern Australia. . Part 1: Fisheries and Aquaculture Risk Assessment*, Fisheries Research and Development Corporation, Project 2009/070.
- Pecl G, Frusher S, Sauer W & Hobday A J (2010) 'Networking across Global Marine Hotspots', report from workshop in Sendai, Japan, in *Climate change effects on fish and fisheries* 18: 26-28.
- Petheram L, Zander K K, Campbell B M, High C & Stacey N (2010) "Strange changes": Indigenous perspectives of climate change and adaptation in NE Arnhem Land (Australia)', *Global Environmental Change* 20: 681-692.
- Phelan D, Bridle K, Parsons D, Ball P, Prior S, Brown C A & Mohammed C (2012b) *Impact of climate change on irrigated pastures – opportunities for dairy farmers*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8V27CL?open>.
- Phelan D, Parsons D, Bridle K, Prior S Brown C, Holz G & Mohammed C (2012a) *Impact of climate change on Meander Valley – opportunities for agricultural enterprises*, available from:
- Phelan D, Parsons D, Bridle K, Prior S, Brown C & Mohammed C (2012c) *Impact of climate change overview – opportunities for Tasmanian agriculture*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8V277F?open>.
- Pitt & Sherry (n.d.) *ClimateAsyst@: Climate Susceptibility, Analysis & Communication tool*, available from: <http://www.pittsh.com.au/documents/climateasyst.pdf>.
- Pitt N R, Poloczanska E S & Hobday A J (2010) 'Climate-driven range changes in Tasmanian intertidal fauna', *Marine and Freshwater Research* 61: 963-970.
- Poloczanska E S, Booth T, Carter W, Dekeyser S, Roiko A, Wang X, Wong C & Martin T (2012b) *iClimate: Final Report to the National Climate Change Adaptation Research Facility*, (CSIRO: Australia).
- Poloczanska E S, Hobday A J, & Richardson A J (eds.) (2009) *Report Card of Marine Climate Change for Australia*, NCCARF Publication 05/09 ISBN 978-1-921609-03-9.
- Poloczanska E S, Hobday A J, & Richardson A J (eds.) (2012a) *Marine Climate Change in Australia, Impacts and Adaptation Responses*, 2012 Report Card ISBN 978-0-643-10927-8.
- Prince B (2007) 'How Should We Manage the Impact of Climate Change on Coastal Aboriginal Cultural Heritage in the Tasmanian Wilderness World Heritage Area?' [Conference abstract] *Sixth World Archaeological Congress*, Dublin, Ireland 29 June to 4 July 2008, available from: <http://www.ucd.ie/wac-6/>.

- Prober S M & Dunlop M (2011) 'Climate change: a cause for new biodiversity conservation objectives but let's not throw the baby out with the bathwater', *Ecological Management and Restoration* 12: 2-3.
- Prober S M, Hilbert D W, Ferrier S, Dunlop M & Gobbett D (2012) 'Combining community-level spatial modelling and expert knowledge to inform climate adaptation in temperate grassy eucalypt woodlands and related grasslands', *Biodiversity Conservation* 21:1627-1650.
- Productivity Commission (2012) *Barriers to Effective Climate Change Adaptation: Productivity Commission Inquiry Report No. 59*, Final Report released 14 March 2013 (Australian Government: Canberra, ACT), available from: <http://www.pc.gov.au/projects/inquiry/climate-change-adaptation/report>.
- Rao K, Lopoukhine N & Jones K (2008) *Tasmanian Wilderness (Australia) Report of the Reactive Monitoring Mission*, 15 to 20 March 2008 (UNESCO: Paris, France).
- Reser J P, Bradley G L, Glendon A I, Ellul M C & Callaghan R (2012) *Public Risk Perceptions, Understandings, and Responses to Climate Change and Natural Disasters in Australia, 2010 and 2011*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Ridgway K R (2007) 'Long-term trend and decadal variability of the southward penetration of the East Australian Current', *Geophysical Research Letters* 34: 1-5.
- Risbey J & O'Kane T (2011) 'Sources of knowledge and ignorance in climate research', *Climatic Change* 108(4): 755-773.
- Robson B J, Chester E T, Allen M, Beatty S, Close P, Cook B, Cummings C R, Davies P M, Lester R, Lymbery A, Matthews T G, Morgan D & Stock M (2013) *Novel methods for managing freshwater refuges against climate change in southern Australia*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Roemmich D, Gilson J, Davis R, Sutton P, Wijffels S & Riser S (2007) 'Decadal spin-up of the South Pacific subtropical gyre' *Journal of Physical Oceanography* 37(2): 162-173.
- Rudman T, Horton B M & Balmer J (2008) *Monitoring Dry Coastal Vegetation in the Tasmanian Wilderness World Heritage Area, Part 1 Monitoring Priorities*, Nature Conservation Report 2008/1 (Department of Primary Industries and Water: Hobart, Tasmania).
- SGS Economics & Planning (2012a) *Tasmanian Coastal Adaptation Pathways Project, Kingston Beach – Public Interim Report*, Tasmanian Coastal Climate Adaptation Pathways Project: January 2012 (SGS Economics & Planning, Melbourne, Victoria).
- SGS Economics & Planning (2012b) *Tasmanian Coastal Adaptation Pathways Project Documentation of Methodology* [Final Report] (Local Government Association of Tasmania: Hobart, Tasmania).
- SGS Economics & Planning and UNSW Water Research Laboratory (2009) *Climate Change Impacts on Clarence Coastal Areas*, report prepared for Clarence City Council [Final Report] (Clarence City Council: Hobart, Tasmania).
- Sharples C (2004) *Indicative Mapping of Tasmanian Coastal Vulnerability to Climate Change and Sea Level Rise: Explanatory Report*, Consultant Report to Department of Primary Industries & Water (DPIW: Hobart, Tasmania).

- Sharples C (2006) *Indicative Mapping of Tasmanian Coastal Vulnerability to Climate Change and Sea-Level Rise: Explanatory Report (Second Edition)*, Consultant Report to Department of Primary Industries & Water (DPIW: Hobart, Tasmania).
- Sharples C (2010) *Technical Report: Shoreline Change at Roches Beach, South-Eastern Tasmania 1957-2010* (ACE CRC: Hobart, Tasmania).
- Sharples C (2011) 'Potential climate change impacts on geodiversity in the Tasmanian Wilderness World Heritage Area: A management response position paper', *Nature Conservation Report Series 11/04* (DPIPWE: Hobart, Tasmania).
- Steffen W & Hughes L (2011) *The Critical Decade: Tasmanian Impacts and Opportunities* (The Climate Commission: Canberra, ACT), available from: http://climatecommission.gov.au/wp-content/uploads/Tasmanian-impacts-report_web.pdf.
- Stokes C J & Howden S M (eds.) (2010) *Preparing Australian agriculture, forestry and fisheries for the future* (CSIRO Publishing: Melbourne, Victoria).
- Stokes C J, Howden S M, Gifford R G, Meinke H, Bange M, McRae D, Roth G, Gaydon D, Beecher H G, Reinke R, Crimp S, Park S, Inman-Bamber G, Webb L, Barlow E W R., Hennessy K, Whetton P H, Booth T H, Kirschbaum M U F, Battaglia M, Stone G, Cobon D, Ash A, McKeon G, Miller C J, Jones R N, Hobday A J & Poloczanska E S, edited by Stokes C J & Howden S M (2008) *An Overview of Climate Change Adaptation in Australian Primary Industries – Impacts, Options and Priorities*, a report prepared for the National Climate Change Research Strategy for Primary Industries (CSIRO: Australia).
- Stone R C & Meinke H (2006) 'Weather, climate, and farmers: an overview', *Meteorological Applications* 13(Supplement S1): 7-20 DOI:10.1017/S1350482706002519. .
- Sullivan K (2008) 'Policy Implications of Future Increases in Extreme Weather Events due to Climate Change', *Australian Journal of Emergency Management* 23(4): 37-42.
- Tasmanian Government (2011) 'Tasmanian Government Submission: Barriers to Effective Climate Change Adaptation', a submission to the Productivity Commission's Inquiry into Barriers to Effective Climate Change Adaptation, December 2011, CA405923: 1-17.
- Thom B, Cane J, Cox R, Farrell C, Hayes P, Kay R, Kearns A, Low Choy D, McAneney J, McDonald J, Nolan M, Norman B, Nott J & Smith T (2010) *National Climate Change Adaptation Research Plan for Settlements and Infrastructure*, (National Climate Change Adaptation Research Facility: Gold Coast, Queensland).
- Thompson P A, Baird M E, Ingleton T & Doblin M A (2009) 'Long-term changes in temperate Australian coastal waters: implications for phytoplankton' *Marine Ecology Progress Series* 394: 1-19.
- Tilden J (2011) *How Vulnerable are Circular Head Coastal Habitats to Sea Level Rise?* (Cradle Coast NRM: Burnie, Tasmania).
- Turton S, Dickson T, Hadwen W, Jorgensen B, Pham T, Simmons D, Tremblay P & Wilson R (2010) 'Developing an Approach for Tourism Climate Change Assessment: Evidence from Four Contrasting Australian Case Studies', *Journal of Sustainable Tourism* 18(3): 429-447.
- Verdon-Kidd D (2012) *Bridging the gap between end user needs and science capability: dealing with uncertainty in future scenarios* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

- Watson R A, Nowara G B, Tracey S R, Fulton E A, Bulman C M, Edgar G J, Barrett N S, Lyle J M, Frusher S D & Buxton C D (2012) 'Ecosystem model of Tasmanian waters explores impacts of climate-change induced changes in primary productivity', *Ecological Modelling* (in press) DOI.org/10.1016/j.ecolmodel.2012.05.008.
- Wayte S (2012) 'Management implications of including a climate-induced recruitment shift in the stock assessment for jackass morwong (*Nemadactylus macropterus*) in south-eastern Australia', *Fisheries Research* 142: 47-55 DOI.org/10.1016/j.fishres.2012.07.009.
- Wenger C, Hussey K & Pittock J (2012) *Living with floods: key lessons from Australia and abroad* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Werner A K, Goater S, Carver S, Robertson G, Allen G R & Weinstein P (2012) 'Environmental Drivers of Ross River Virus in South-Eastern Tasmania, Australia: Towards Strengthening Public Health Interventions', *Epidemiology and Infection* 140(2): 359-371.
- West J & Brereton D (2013) *Climate Change Adaptation in Industry & Business – Climate Change Adaptation: A Framework for Best Practice in Financial Risk Assessment, Governance and Disclosure*, Final Report (NCCARF: Gold Coast, Queensland).
- West J (2013) 'Obstacles to progress', *Griffith Review* 38, available from: <https://griffithreview.com/edition-39-tasmania-the-tipping-point/obstacles-to-progress>.
- White C J, Fox-Hughes P, Grose M R, Corney S, Bennett J C, Holz G K, Gaynor S & Bindoff N L (2010b) *Climate Futures for Tasmania, Discussion document: implications for fire danger in bushfire prone areas of Tasmania* (ACE CRC: Hobart, Tasmania).
- White C J, Grose M R, Corney S P, Bennett J C, Holz G K, Sanabria L A, McInnes K L, Cechet R P, Gaynor S M & Bindoff N L (2010a) *Climate Futures for Tasmania: extreme events technical report* (ACE CRC: Hobart, Tasmania).
- Whitehead J (2011) *Climate Change Mitigation - Natural Coastal Assets: Derwent Estuary Program Planning Tool Discussion Paper for Tidal Wetlands & Saltmarshes*, (Derwent Estuary Program: Hobart, Tasmania).
- Williams A L, Wills K E, Janes J K, Vanderschoor J K & Newton P C D (2007) 'Warming and free-air CO₂ enrichment alter demographics in four co-occurring grassland species', *New Phytologist* 176: 365-374.
- Wolf J, O'Neill N R, Rogers C A, Muilenberg M L & Ziska L H (2010) 'Elevated Atmospheric Carbon Dioxide Concentrations Amplify *Alternaria alternata* sporulation and total antigen Production', *Environmental Health Perspectives* 118(9): 1223-8 DOI:10.1289/ehp.0901867.
- Zeppel H (2011) 'Collaborative Governance for Low-Carbon Tourism: Climate Change Initiatives by Australian Tourism Agencies', *Current Issues in Tourism* 15(7): 603-626.

APPENDIX 1: STAKEHOLDER AND RESEARCHER REFERENCE GROUPS MEMBERSHIP

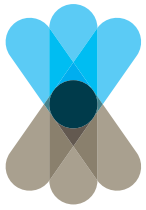
Researcher Reference Group

Associate Professor Leon Barmuta	School of Zoology, UTas
Associate Professor Erica Bell	Department of Rural Health, UTas
Associate Professor Stewart Frusher	Institute for Marine and Antarctic Studies, UTas
Associate Professor Neil Holbrook	Institute for Marine and Antarctic Studies, UTas NCCARF Marine Adaptation Network Convenor
Associate Professor Marcus Haward	School of Government, UTas
Associate Professor Mark Hovenden	School of Plant Science, UTas
Professor John Hunter	ACE-CRC, UTas
Dr Sarah Jennings	Head, School of Economics and Finance, UTas
Professor Ted Lefroy	Centre for Environment, UTas
Dr Michael Lockwood	School of Geography and Environmental Studies, UTas

Stakeholder Reference Group

Andrew Scanlon	Hydro-Tasmania
Melanie Brown	Local Government Association of Tasmania
Kathleen Broderick	NRM South
James McKee / Andrew Baldwin	NRM North
Roger Jaensch	Cradle Coast Authority
Derek LeMarchant	Northern Tasmanian Development
Katrina Graham	Southern Tasmanian Councils Authority
Luke Martin	Tourism Industry Council of Tasmania
Phil Bayley	Tasmanian Chamber of Commerce and Industry
Mary Massina	Property Council of Australia
Terry Long	Tasmanian Minerals Council
Brigid Morrison	Tasmanian Farmers and Graziers Association
David Sanderson	Wine Industry Association
Lucy Gregg	Fruit Growers Tasmania and Biosecurity Action Alliance
Neil Stump / Julian Harrington	Seafood Industry Council
Peter McGlone	Tasmanian Conservation Trust
Dr Sally Bryant	Tasmanian Land Conservancy
Kath McLean	Tasmanian Council of Social Services
Todd Houstain	Sustainable Living Tasmania
Heather Sculthorpe, Andry Sculthorpe & Sharnie Everett	Tasmanian Aboriginal Centre

Louise Gilfedder	Department of Primary Industries, Parks, Water and Environment
Caroline Brown	Department of Primary Industries, Parks, Water and Environment
Claire Jansen	Department of Premier and Cabinet



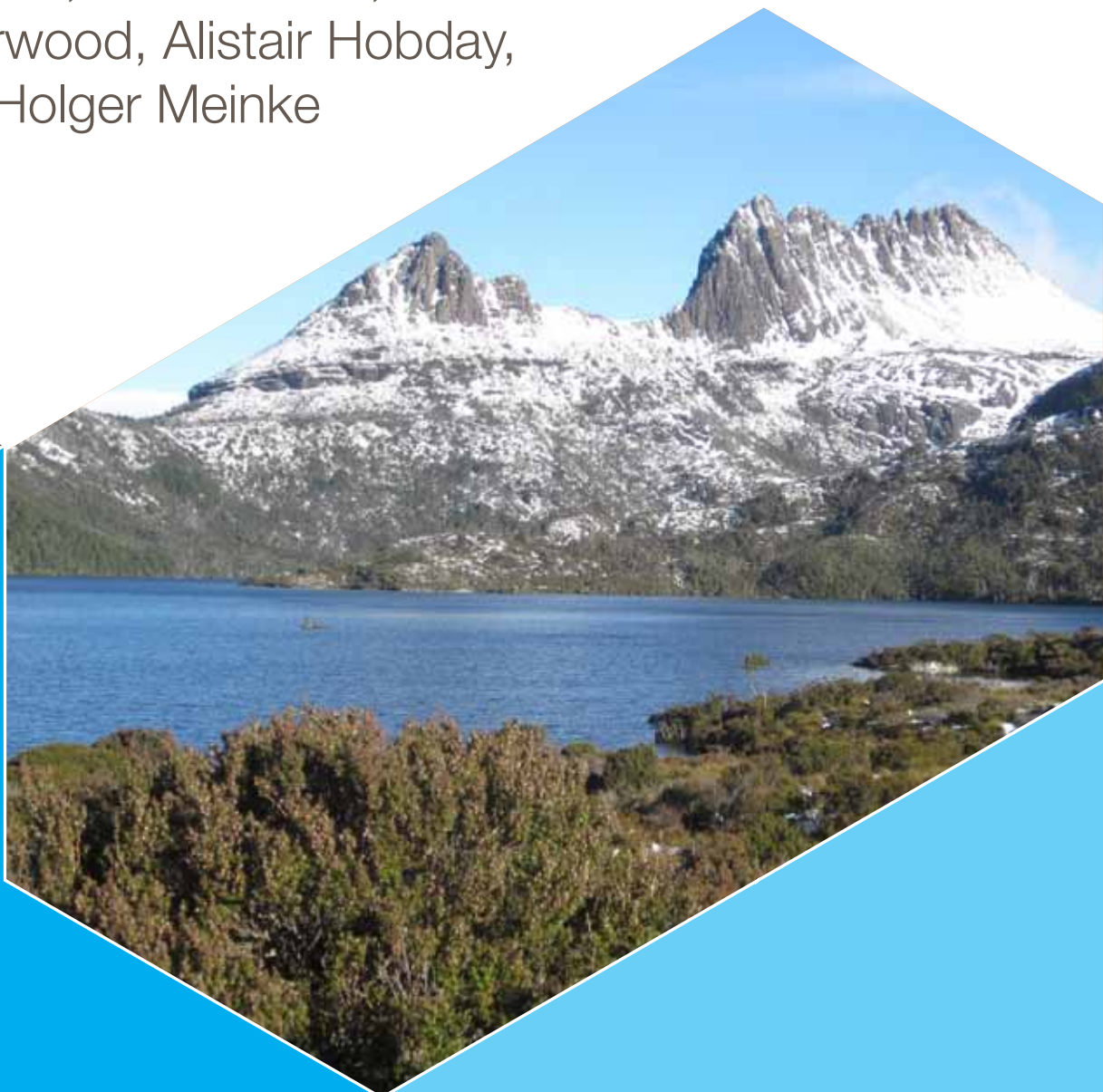
NCCARF

National
Climate Change Adaptation
Research Facility

Synthesis and Integrative Research Final report

Supporting evidence-based adaptation decision-making in Tasmania: a synthesis of climate change adaptation research

Jan McDonald, John Harkin,
Andrew Harwood, Alistair Hobday,
Anna Lyth, Holger Meinke



SUPPORTING EVIDENCE-BASED ADAPTATION DECISION-MAKING IN TASMANIA

A synthesis of of climate change adaptation research

JAN MCDONALD

JOHN HARKIN

ANDREW HARWOOD

ALISTAIR HOBDAY

ANNA LYTH

HOLGER MEINKE



National Research
FLAGSHIPS



Published by the National Climate Change Adaptation Research Facility

ISBN: 978-1-925039-81-8NCCARF Publication 110/13

© **2013 University of Tasmania**

This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without prior written permission from the copyright holder.

Please cite this report as:

McDonald, J, Harkin, J, Harwood, A, Hobday, A, Lyth, A, Meinke, H 2013 *Supporting evidence-based adaptation decision-making in Tasmania a synthesis of climate change adaptation research*, National Climate Change Adaptation Research Facility, Gold Coast, pp. 173.

Acknowledgements

This work was carried out with financial support from the Australian Government (Department of Climate Change and Energy Efficiency) and the National Climate Change Adaptation Research Facility. The views expressed herein are not necessarily the views of the Commonwealth or NCCARF, and neither the Commonwealth nor NCCARF accept responsibility for information or advice contained herein. The role of NCCARF is to lead the research community in a national interdisciplinary effort to generate the information needed by decision-makers in government, business and in vulnerable sectors and communities to manage the risk of climate change impacts.

Graphics for the icons representing the terrestrial biodiversity, policy and governance, business and industry, and emergency management sectors, human health and community well-being were supplied by AECOM. Icons used to represent infrastructure and essential services, primary industries, land use planning, and marine biodiversity and fisheries were modified by Louise Bell, CSIRO, from those supplied by AECOM. Louise Bell designed the icon for Indigenous issues.

Cover picture

Alpine areas are considered vulnerable to climate change in Tasmania © Jan McDonald

Contents

EXECUTIVE SUMMARY	7
PROJECT BACKGROUND.....	7
CURRENT AND FUTURE CLIMATE IN TASMANIA	7
SYNTHESIS OF FINDINGS BY SECTOR	9
CROSS-CUTTING THEMES.....	14
CONCLUSIONS.....	14
1 INTRODUCTION.....	17
1.1 PROJECT BACKGROUND.....	17
1.2 PROJECT PURPOSE AND OBJECTIVES.....	17
2 PROJECT METHODOLOGY.....	20
2.1 PROJECT SCOPING AND PRELIMINARIES	20
2.2 LITERATURE REVIEW AND SYNTHESIS.....	21
2.3 CRITERIA FOR INCLUSION.....	23
2.4 SECTOR EXPERT INTERVIEWS.....	25
2.5 PROJECT WORKSHOP	26
2.6 REVIEW AND DEVELOPMENT OF CROSS-CUTTING THEMES	27
2.7 PROJECT LIMITATIONS	27
3 ADAPTATION CONTEXT	28
3.1 ENVIRONMENTAL CONTEXT	29
3.2 SOCIO-ECONOMIC CONTEXT	29
3.3 CLIMATE PROJECTIONS.....	30
4 RESEARCH FINDINGS BY SECTOR.....	36
4.1 PRIMARY INDUSTRIES	36
4.2 TERRESTRIAL AND FRESHWATER BIODIVERSITY	44
4.3 MARINE BIODIVERSITY AND RESOURCES	57
4.4 LAND USE PLANNING	68
4.5 INFRASTRUCTURE AND ESSENTIAL SERVICES.....	77
4.6 HUMAN HEALTH AND COMMUNITY WELLBEING	84
4.7 BUSINESS AND INDUSTRY.....	90
4.8 EMERGENCY MANAGEMENT	97
4.9 POLICY AND GOVERNANCE	102
4.10 INDIGENOUS ISSUES	108
5 SYNTHESIS AND CROSS-CUTTING THEMES.....	114
5.1 DRIVERS OF ADAPTATION.....	114
5.2 FUTURE VISIONS: COMMON ELEMENTS AND THEMES	120
5.3 BARRIERS TO ADAPTATION.....	125
5.4 SECTORAL DEPENDENCIES.....	133

6	CONCLUSIONS.....	143
6.1	THE STATE OF ADAPTATION ACTIVITY AND RESEARCH	143
6.2	RESEARCH GAPS AND PRIORITIES.....	144
6.3	FUTURE DIRECTIONS	148
	BIBLIOGRAPHY.....	150
	APPENDIX 1 STAKEHOLDER AND RESEARCHER REFERENCE GROUPS MEMBERSHI.....	172

List of tables

Table 1. The objectives and content of report sections	19
Table 2. Websites searched	22
Table 3. Academic databases searched	23
Table 4. Ongoing research relevant to Tasmania	51
Table 5. Marine biodiversity and resources projects relating to Tasmania	63
Table 6. NCCARF projects of likely significance to Tasmanian business and industry	95
Table 7. NCCARF projects of potential significance to Tasmanian Indigenous communities	111
Table 8. Workshop participant opinions on drivers of climate change adaptation interest and action	116
Table 9. Barriers to adaptation identified by interviewees, categorised against the elements of the Moser and Ekstrom (2010) framework	131
Table 10. Summary of sectoral adaptation research priorities	145

List of figures

Figure ES1. The state of adaptation activity and awareness for 10 Tasmanian sectors and the degree to which research, sectoral needs, and government policy influence. The size of the circles indicates the relative influence for each category	15
Figure 1. Project methodology	20
Figure 2. Composition of project workshop participants	27
Figure 3. Sectoral representation at project workshop in each of 10 categories	27
Figure 4. Current and projected air temperature for Tasmania Mean historical daily temperature from the Bureau of Meteorology high-quality climate site data for Tasmania and projections from downscaled CFT modelling simulations under the A2 and B1 emissions scenarios. The time series plot shows the 11-year moving average the high-quality climate site data (black line), the six-model mean (A2 = bold red line, B1 = bold blue line) and the range of the six models (respective faint lines)	31
Figure 5. Ensemble average ocean warming for south-east Australia by 2050 relative to 1990	31
Figure 6 Total annual rainfall projections for Tasmania under the A2 emissions scenario For the six-model-mean proportional change in rainfall between 30-year periods indicated by numerals (1 = 1978-2007, 2 = 2010-2039, 3 = 2040-2069, 4 = 2070-2099). Source: Figure 6.5, Grose et al 2010.	33
Figure 7. Hydrological risks to native fish condition where blue indicates a positive impact and red indicates a negative impact (original Figure 15 in Barmuta et al 2012)	55
Figure 8 Map of planning regions in Tasmania	74
Figure 9. TCAP Pathway process	105
Figure 10. Top 10 drivers of climate change adaptation interest and activity	119
Figure 11. Barriers framework used in the project to evaluate stakeholder perceptions about sectoral barriers	127
Photo 16. Workshop participants assessed barriers to adaptation using TurningPoint® software. Photo: Holger Meinke	128
Figure 12. Example of scoring for the barrier analysis, for the first element in the framework	129
Figure 13. Average scores for each of the nine elements in the barriers framework	130
Figure 14. Average scores for each of the three stages (each composed of three elements) for researchers and non-researchers	130
Table 9. Barriers to adaptation identified by interviewees, categorised against the elements of the Moser and Ekstrom (2010) framework	131
Figure 15. A worksheet used by workshop participants to identify sectoral dependencies	134

Figure 16. Dependency diagram: Influence of Marine biodiversity & resources on other sectors, national scale	135
Figure 17. Average number of linkages identified by workshop participants at three spatial scales..	136
Figure 18. Aggregated sectoral linkages identified by workshop participants	137
Figure 19. Proportion of 'influenced by' and 'influence on' linkages	141
Figure 20. The state of adaptation activity and awareness for 10 Tasmanian sectors and the degree to which research, sectoral needs, and government policy influence.....	144

List of photos

Photo 1. Participants at the project workshop, Photo: Holger Meinke	26
Photo 2. Poppy production could increase under climate change Photo: Mark Dowsett	38
Photo 3. The amount and reliability of water for irrigation will become increasingly important Photo: Veronica Foale	41
Photo 4. The Burrowing Crayfish may have reduced distribution in the future Photo: Thomas-Stromberg	47
Photo 5. Movement of grazing animals into alpine areas will change vegetation patterns Photo: Patrick Medved	53
Photo 6. The value of the seafood industry makes the impacts of climate change a major concern Photo: Alistair Hobday	59
Photo 7. Poleward range expansion of <i>Centrostephanus rodgersii</i> creates species 'barrens' Photo: Scott Ling	60
Photo 8. High summer temperatures pose significant risks to salmon production systems Photo: Alistair Hobday	62
Photo 9. Climate change will exacerbate existing exposure to coastal hazards Photo: Alistair Hobday	71
Figure 8 Map of planning regions in Tasmania	74
Photo 10. The TCAP project involved significant engagement with the community at Lauderdale ..	75
Photo 11. Hydro Tasmania has explored the impacts and risks for its hydro electricity generation capacity Photo: Anna Lyth	82
Photo 12. The 2013 bushfires highlighted the potential impacts of climate-related events on infrastructure. Photo: Sarah Brabazon	83
Photo 13. Storm damage to world heritage listed Port Arthur Historic Site, 2011, Photo: Port Arthur Historic Site Management Authority	92
Photo 14. Circular Head is significant for education in traditional use of land and sea Photo: DCCXLIX, Flickr	109
Photo 15 Workshop participants were asked to identify significant drivers of adaptation. Photo: Holger Meinke	115
Photo 16. Workshop participants assessed barriers to adaptation using TurningPoint® software. Photo: Holger Meinke	128

Shortened forms

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ACCARNSI	Australian Climate Change Adaptation Research Network for Settlements and Infrastructure
ACE CRC	Antarctic Climate & Ecosystems Cooperative Research Centre
ACOSS	The Australian Council of Social Services
AFAC	Australasian Fire and Emergency Service Authorities Council
ALCT	Aboriginal Land Council of Tasmania
ALGA	Australian Local Government Association
ARIES	Australian Research Institute in Education for Sustainability
BAL	Bushfire Attack Level
BRAM	Bushfire Risk Assessment Model
CCAP	Climate Change Adaptation Planning
CCRLUS	Cradle Coast Regional Land Use Strategy
CCRPI	Cradle Coast Regional Planning Initiative
CFEV	Conservation of Freshwater Ecosystem Values
CFT	Climate Futures Tasmania
CIS	Conservation Information System
CMAR	CSIRO Marine and Atmospheric Research
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DCC	Department of Climate Change
DCCEE	(Commonwealth of Australia) Department of Climate Change and Energy Efficiency
DEDTA	Department of Economic Development, Tourism and the Arts
DIER	Department of Infrastructure, Energy and Resources
DPAC/DPC	Department of Premier and Cabinet
DPIW	Department of Primary Industries and Water [former name for DPIPWE]
DPIPWE	Department of Primary Industries, Parks, Water and Environment
DPSIR	Driving forces-Pressures-States-Impacts-Responses
EAC	East Australian Current
FACE	Free Air CO ₂ Enrichment Facility
GHG	Greenhouse Gas
HIA	Housing Industry Association
IPCC	Intergovernmental Panel on Climate Change
LAPP	Local Adaptation Pathways Program
LGAT	Local Government Association of Tasmania
NARP	National Adaptation Research Plan
NCCARF	National Climate Change Adaptation Research Facility
NGO	Non-Governmental Organisation
NRM	Natural Resource Management
NTRCA	Northern Tasmania Regional Councils Authority
NVA	Natural Values Atlas

PPRR	Prevention-Preparedness-Response-Recovery
RCCCAP	Regional Councils Climate Change Adaptation Project
SEAP	South-East Australia Fisheries and Climate Change Program
SCCC	(COAG) Select Committee on Climate Change
SLR	Sea-Level Rise
SME	Small to Medium Enterprise
SRES	Special Report on Emissions Scenarios
SST	Sea-Surface Temperature
STCA	Southern Tasmanian Councils Association
STCRC	Sustainable Tourism Cooperative Research Centre
STRLUS	Southern Tasmania Regional Land Use Strategy
STRPP	Southern Tasmania Regional Planning Project
TAC	Total Allowable Catch
TAC	Tasmanian Aboriginal Centre
TALSC	Tasmanian Aboriginal Land and Sea Council
TasCOSS	Tasmanian Council of Social Services
TCAP	Tasmanian Coastal Adaptation Decision Pathways Project
TCCI	Tasmanian Chamber of Commerce and Industry
TCCO	Tasmanian Climate Change Office
TFGA	Tasmanian Farmers and Graziers Association
TIA	Tasmanian Institute of Agriculture
TICT	Tourism Industry Council Tasmania
TSIC	Tasmanian Seafood Industry Council
WWHA	Wilderness World Heritage Area

EXECUTIVE SUMMARY

Project background

Tasmania faces unique challenges under climate change. It is likely to become a climate refuge for Australia in a number of contexts – it represents the southernmost refuge for a range of terrestrial and marine species and may become a residential destination for mainland émigrés and industries displaced by significant warming or other climate change related consequences. It has a unique socio-economic profile with a limited mix of industry, a low-density dispersed population. There are also some distinct regional socio-economic, geographic and climatic differences.

While the focus of the international community and national government has been on policies aimed at reducing atmospheric greenhouse gas concentrations in an attempt to avoid dangerous climate change, there is now increasing recognition of the need simultaneously to adapt to the impacts of unavoidable climate change. The National Climate Change Adaptation Research Facility (NCCARF) was established in 2008 to harness Australian research capabilities to support adaptation decision-making. Through the NCCARF program, more than 100 research projects have been funded to support decision makers in climate change adaptation.

This report contributes to the emerging body of adaptation research relating to Tasmania. Undertaken with funding from NCCARF's synthesis and integrative research program, the report evaluates the current state of adaptation knowledge in Tasmania, based on published and on-going research and applied research findings. The findings seek to inform public and private sector decision-makers, improve awareness of adaptation issues and challenges, and contribute to the uptake of adaptation strategies by stakeholders and sectors most likely to be affected by climate change in Tasmania.

The project methodology was designed to reflect the specific circumstances of adaptation research and practice in Tasmania. In particular, the small number of agencies, organisations and actors active in adaptation presented an opportunity to engage widely and deeply across the adaptation community. In addition to reviewing the published adaptation literature relating to Tasmania, the project was informed by interviews with, and two workshops of, adaptation practitioners, stakeholders and researchers.

Current and future climate in Tasmania

Tasmania's current climate is cool temperate, with four distinct seasons. Since 1950, mean land surface temperatures have increased by an average of 0.10° C per decade, a slower rate of increase than that experienced by mainland Australia (Grose et al. 2010). Projections for changes over the 21st century indicate that average annual temperatures across

What is adaptation?

This project adopts the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as:

'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'

(IPCC 2007)

Tasmania will increase between 1.6° C to 2.9° C by 2100, lower than projections for global and national increases, due to the moderating effect of the Southern Ocean.

Waters off Tasmania's east and north-east coast are warming at a rate almost four times the global average (Holbrook & Bindoff 1997; Ridgway 2007), resulting in the area being recognised as part of a global warming 'hot spot'. Mean sea surface temperatures are projected to increase around Tasmania in all seasons by the end of the century. Southward extension and strengthening of the east Australian current is likely to result in east coast water temperatures rising by up to 2°–3° C by 2070 relative to 1990 levels (Grose et al. 2010).

Since the 1970s, Tasmania has experienced a general trend of reduced annual average rainfall, and greater year-to-year variability in rainfall (Grose et al. 2010). These trends in rainfall are projected to continue, but with significant regional differences and seasonal variation. The central highlands and parts of the north-west are likely to experience increased drying, while the east and west coasts are projected to experience increased rainfall (Grose et al. 2010).

Changes to key climate variables such as temperature and rainfall are likely to amplify aspects of existing climate variability and result in changes in the intensity and frequency of extreme weather events (White et al. 2010), including intense rainfall events and localised flooding and storm surge, and extreme heat and fire danger days.

In Tasmania, sea-level rises have been slightly slower than global trends (Steffen & Hughes 2011). It is estimated that sea-levels will rise by 0.76 m on 2010 levels by 2100 (TCCO 2012a).

The *Climate Futures for Tasmania* (CFT) project is widely regarded as providing an excellent foundation upon which to undertake more detailed adaptation planning at the enterprise-, sector- or region-specific level. These projections have allowed most Tasmanian sectors to understand future environmental risk and several projects have used them to further inform sectoral adaptation plans.

Synthesis of findings by sector



Primary Industries

- ◆ Extreme variability in micro-climates, soils and production systems across the state makes it hard to translate climate impacts into state-wide sectoral impacts.
 - ◆ The effects of climate change impacts on demand-side issues and the implications of transformational change are poorly understood.
 - ◆ The plans of government agencies, suppliers, corporate agricultural business and individual farms in Tasmania already reflect the need to respond to climate variability and change.
 - ◆ Conditions for particular industries will change over time, so the trade-offs required across agricultural sectors will also need to vary.
 - ◆ Options analysis needs to take a systems approach that considers industries re-locating to Tasmania, and biosecurity threats under changed climatic conditions.
 - ◆ A key research priority is understanding how multi-level and indirect impacts of climate change can best be recognised in sector-specific adaptation research for Tasmanian primary industries.
-



Terrestrial and freshwater biodiversity

- ◆ Climate change represents a significant threat to Tasmania's endemic and refuge fauna (species extinct on the mainland) and associated ecosystems. Changes to fire regimes, increased shrub and tree invasion of alpine regions, and changes in runoff will threaten Tasmania's terrestrial and freshwater ecosystems.
- ◆ Government departments have developed a range of planning and management options for Tasmanian species and ecosystems.
- ◆ Management of non-climate threats to build ecosystem resilience to climate change is a key element in adaptation planning.
- ◆ Protecting individual species may not be viable under climate change, and a focus on continued delivery of ecosystem services is emerging as a complimentary adaptation strategy.
- ◆ Species distribution modelling and limited experiments are informing development of conservation strategies, including reserve design and active interventions, such as translocation.

- ◆ Key research priorities include: determining the effectiveness of reducing non-climate stressors, changing agricultural practices, and fire management for building resilience to climate change; and developing policies with regard to Tasmania's role in preserving biodiversity from mainland Australia.
-



Marine biodiversity and resources

- ◆ The east coast of Tasmania is part of a global warming hotspot where the rate of ocean warming is about four times above the global average. The East Australia Current has strengthened, carrying warmer water southward which, with the background warming, has led to many new species extending their range into Tasmania.
 - ◆ Changes in species composition have led to declines in marine productivity and generally negative effects.
 - ◆ In some regions, aquaculture is experiencing production impacts due to warming waters and the presence of novel species, including blooming algal species.
 - ◆ Reduction of non-climate threats through fisheries management and marine protected areas has been an adaptation focus to date.
 - ◆ Recognition of climate threats has led to changes in management by fisheries and aquaculture and limited experiments with translocation and ecosystem-based management, such as protection of large predators.
 - ◆ Arrival of new species will offer some new opportunities for commercial and recreational fishers, although declines in productivity mean these arrivals are not likely to offset losses.
 - ◆ Identification and protection of 'refuge areas', careful use of management options such as translocation, and reduction of non-climate stressors will all be important strategies.
 - ◆ The focus on ocean warming as the prime driver of change in Tasmania's marine environment should be complemented by additional targeted research on ocean acidification.
 - ◆ Development of strategies to respond to observed change are being developed, but additional simulation testing can further inform stakeholders about their response options.
-



Land use planning

- ◆ Land use planning can minimise or avoid the location of new settlements in vulnerable areas; and reduce the exposure of and promote adaptation efforts in existing settlements.
 - ◆ The state has introduced sea-level rise planning allowances and a Bushfire Planning Code. Regional land use strategies all refer to the need to minimise exposure of new and existing settlements to climate change hazards.
 - ◆ Transferring the lessons learned from numerous local and regional initiatives, such as the Tasmanian Coastal Adaptation Pathways project, will facilitate statewide improvements in planning.
 - ◆ The current ambit of land use planning will need to be extended to promote adaptation for existing settlements and infrastructure.
 - ◆ Key research priorities include how best to apply and transfer adaptation planning insights across places and projects; and assessing the suitability of the current governance arrangements for planning in Tasmania for adaptation needs.
-



Infrastructure and essential services

- ◆ The degree of vulnerability of infrastructure to climate change depends on the severity of climate change impacts, the adaptive capacity of the local community, and the location, age, design and construction method of the physical infrastructure.
 - ◆ Several recent local projects and assessment tools reflect best-practice for climate change risk assessments for infrastructure.
 - ◆ Little is known about the flow-on effects to communities and economies from disruption or damage to infrastructure or essential services.
 - ◆ Climate change is being reflected in the management plans for several departments and organizations, including the Department of Primary Industries, Water, and Environment, and Hydro-Tasmania.
 - ◆ Where location or relocation to hazard-free areas is not feasible, new technologies, design and construction standards, and management, operating and maintenance protocols will be required to minimise risks to infrastructure.
 - ◆ The 2013 bushfires should be used as a case study to understand the full costs of infrastructure disruption and how to avoid these costs through design, modification, re-engineering of processes or other techniques.
-



Human health and community wellbeing

- ◆ The health impacts of climate change include respiratory illnesses caused by changes in pollen allergens and bushfire smoke; infectious diseases; and mental health and overall community wellbeing issues associated with direct climate impacts, including disruption from extreme events and prolonged conditions, such as drought.
 - ◆ There is virtually no adaptation activity occurring in respect of human health, but research is examining impact assessment tools and early warning techniques for dangerous weather conditions. Assessments of risk, vulnerability and adaptive capacity have been conducted for Ross River virus.
 - ◆ A deeper understanding is needed at regional and community levels of indirect impacts from biophysical changes and the risks and social vulnerability associated with these.
 - ◆ Key research gaps and priorities include: regionally-focussed vulnerability and risk assessment and monitoring; and techniques for improving the responsiveness and management of health impacts or events as they arise, as well as preparing communities for longer term adjustment to changing environmental and health conditions.
-



Business and industry

- ◆ The implications of temperature increases, regional changes in rainfall patterns, and increased frequency and intensity of extreme weather events have not yet been assessed for business and industry sectors.
- ◆ There will be direct physical disruptions to business operations from extreme events, and indirect impacts on the production and supply chains of Tasmanian businesses resulting from the effects of climate change elsewhere.
- ◆ There may be opportunities flowing from business relocations and shifts in consumer preference, but there is very little evidence of businesses or industry addressing climate change impacts.
- ◆ Limited adaptation research and practice relating to Tasmanian businesses suggests that businesses are likely to respond reactively rather than proactively to climate change impacts as they occur.
- ◆ A key challenge will be to change the attitudes of businesses to medium-to-longer term climate-related threats.
- ◆ Business- and industry-specific research is needed to understand climate change impacts and adaptation options at temporal and spatial scales suited to specific planning and decision-making processes.



Policy and governance

- ◆ There is growing recognition that climate change impacts are likely to place pressure on existing governance arrangements and on the allocation of roles, responsibilities and resources between levels of government, and between government and private actors.
- ◆ The impacts of climate change on coastal hazards are the major focus of current adaptation policy.
- ◆ The Regional Councils Climate Adaptation Project has enabled climate change impacts and adaptation options to be considered and incorporated into a Southern regional adaptation strategy and council adaptation plans.
- ◆ There is a growing consensus that transformative change is necessary to transition successfully to a climate change-adapted society.
- ◆ The barriers to both incremental and transformative change require close attention.
- ◆ Research emphasises the need for attenuated engagement processes that recognise and respond to characteristics of individual communities rather than attempting to impose uniform, top-down policy responses.



Indigenous issues

- ◆ Tasmanian Aboriginal cultural heritage is particularly at risk from sea level rise and associated impacts, since many sites are located in intertidal and sub-tidal areas.
 - ◆ There has been no specific assessment of the vulnerability of Indigenous communities in Tasmania to the direct or indirect impacts of climate change, based on socio-economic, geographical, or cultural differences.
 - ◆ A clearer understanding of impacts and vulnerabilities is needed before future options can be considered.
 - ◆ A proper assessment of the impacts of climate change on Tasmanian Indigenous communities is needed, taking into account the vulnerability and adaptive capacity of Indigenous individuals, households, communities, businesses and institutions.
-

Cross-cutting themes

Drivers of adaptation

The most important drivers of adaptation in Tasmania are: general risk management, the desire to avoid catastrophic change or loss, mitigating discomfort of change and transformation, avoiding legal liability, and developments in research and understanding, capacity and know-how. Changes in policy and political environment and community or public pressure are important in some sectors. The desire to seize new opportunities or to act for the benefit of future generations is considered less influential as drivers of adaptation.

There is very little evidence of transformative change or even discussion of the need for such change in the near- or medium-term future. To the extent that any industry is currently undertaking adaptation measures, they are driven by understandings of short-term changes that are likely to affect profitability within budgetary planning horizons.

Visions for a climate-adapted future Tasmania

While it is impossible to articulate a single vision, or even a set of visions, for adaptation in Tasmania, the following themes cut across all sectors:

- the need for adaptation to become more integrated and mainstreamed into core business decision-making and policy-making;
- improved governance for adaptation, including better cross-sectoral arrangements and processes;
- better resourcing and training for adaptation;
- moving from planning to implementation; and,
- the need for monitoring and evaluation of adaptation strategies.

Barriers to adaptation

Barriers exist at all three stages of adaptation: understanding, planning and managing. Higher barriers were recognised at the planning stage than at the earlier understanding stage, while the barriers were higher again at the implementation stage. Overcoming these barriers would go far in delivering the common elements of the adaptation visions identified in this report.

Sectoral dependencies

As a small state with a small population, the activities of, and issues facing, one sector have a significant impact on others. While some may view these sectoral dependencies as a barrier to adaptation, they also create opportunities for more embedded and holistic approaches that achieve efficiencies across the entire community, economy and environment. Developing consultation, policy- and decision-making processes that reflect these interdependencies will be challenging, but could have spin-off benefits for good governance more generally.

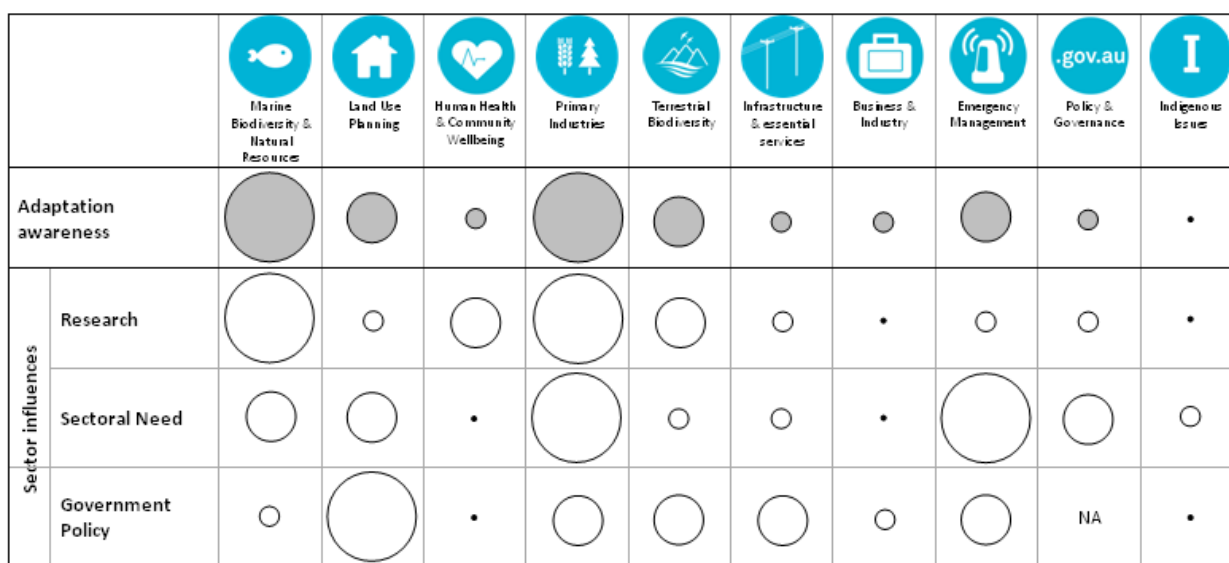
Conclusions

There are significant differences between sectors in terms of their perceptions of climate change impacts and the need for response. A subjective assessment was made of the state of adaptation, based on the synthesis of literature and stakeholder consultation information





(Figure ES1). Awareness and motivation for adaptation is highest in the marine, primary industries, and emergency management sectors. This awareness and motivation appears linked, in part, to one or more of three main influences on adaptation: research, sectoral needs, and/or government policies. In some sectors, such as marine and primary industries, research has played a major role, while in others any adaptation that has occurred has been driven almost entirely by issues relating specifically to the sector (e.g. emergency management), or to policy-related drivers (e.g. land use planning)(Figure ES1).

The report highlights areas of significant research strength in Tasmania, and others where there is little or no research specific to the state. Research is strongest in marine biodiversity and resources, and to a lesser extent primary industries and terrestrial and freshwater biodiversity. There is no Tasmania-specific work relating to the impacts of climate change on Indigenous Tasmanians, and very little coverage of health and community well-being issues or business and industry perspectives (other than the primary industries). Some major recent projects of relevance to coastal adaptation, land use planning and (to a lesser extent) infrastructure and emergency management have started to fill significant policy gaps in these areas.

Figure ES1. The state of adaptation activity and awareness for 10 Tasmanian sectors and the degree to which research, sectoral needs, and government policy influence. The size of the circles indicates the relative influence for each category



Legend

				NA
High	Moderate	Minimal	None or virtually none	Not applicable

Given the qualitative relationship between research strength and sectors with greatest climate adaptation awareness, investment in research is clearly important to develop climate impact and adaptation strategies in Tasmania. Thus, strategies for increasing and maintaining high quality research should be a government priority.

Significant gaps remain in our understanding of adaptation needs and successes across all sectors. There is a range of research priorities that seek to clarify the application of national or international research in Tasmania or further develop earlier findings of Tasmanian projects, including action research such as the Coastal Adaptation Pathways Projects. These priorities fall into one of three general categories: climate and system understanding; evaluating adaptation options; and resolving societal issues around adaptation. Research investment is needed in all three areas and future research endeavours should engage stakeholders and end-users in the earliest stages of research design, including the refinement of research objectives and questions.

Wherever possible, opportunities for multi-sectoral synergies and relevance should be maximised as the dependencies identified in this project showed strong connectivity in Tasmania.

1 INTRODUCTION

1.1 Project background

Tasmania faces unique challenges under climate change. It is likely to become a climate refuge for Australia in a number of contexts - it represents the southernmost refuge for a range of terrestrial and marine species and may become a residential destination for mainland émigrés and industries displaced by significant warming or other climate change related consequences. It has a unique socio-economic profile with a limited mix of industry, a low-density dispersed population. There are also some distinct regional socio-economic, geographic and climatic differences.

While the focus of the international community and national government has been on policies aimed at reducing atmospheric greenhouse gas concentrations in an attempt to avoid dangerous climate change, there is now increasing recognition of the need simultaneously to adapt to the impacts of unavoidable climate change. The National Climate Change Adaptation Research Facility (NCCARF) was established in 2008 to harness Australian research capabilities to support adaptation decision-making. Through the NCCARF program, more than 100 research projects have been funded to support decision makers in climate change adaptation.

This report contributes to the emerging body of adaptation research relating to Tasmania. Undertaken with project funding from NCCARF's synthesis and integrative research program, the report assesses the current state of adaptation knowledge in Tasmania, based on published and on-going research and applied research findings.

The project team consisted of:

- Professor Jan McDonald (PI), Faculty of Law, University of Tasmania
- Mr John Harkin, Tasmanian Climate Change Office, Department of Premier and Cabinet
- Dr Alistair Hobday, CSIRO Climate Adaptation Flagship
- Dr Anna Lyth, School of Geography and Environmental Studies, University of Tasmania
- Professor Holger Meinke, Director TIAR, University of Tasmania
- Dr Andrew Harwood, Project Officer, University of Tasmania.

1.2 Project purpose and objectives

This synthesis seeks to understand the emerging state of adaptation research and practice in Tasmania, in order to inform public and private sector decision-makers, improve awareness of adaptation issues and challenges, and contribute to the uptake of successful adaptation approaches by stakeholders and sectors most likely to be impacted by climate change in Tasmania. It adds value to existing research by aggregating the findings of individual research reports and publications to extract common themes.

The objectives of the project were to:

- identify and review the adaptation research projects specific to Tasmania;
- identify the relevance of existing adaptation research from across Australia for Tasmania, based on information from the mainland Australia project;
- prepare sector summaries, map linkages between direct and indirect climate change impacts, consequences for individual sectors and across sectors, and the adaptation responses and implementation actions;
- identify recurring themes regarding how adaptation research recommendations may be better implemented;
- support adaptation in Tasmania by providing information to inform adaptation policy, investment and decision-making; and
- identify critical information gaps, barriers, and research opportunities as a basis for future planning of research investment and projects to develop and implement adaptation policy.

1.2.1 Structure of this report

The report consists of six parts and one appendix, the objectives and contents of which are set out in Table 1.

Table 1. The objectives and content of report sections

Report section	Objectives	Content
1. Introduction	To explain project background, context and objectives	Project background, purposes and objectives, report structure; project scope
2. Project methodology	To describe the project methodology	Description of project methodology, including identification of participants, modes of participation and literature review processes; project limitations
3. The context of climate adaptation in Tasmania	To summarise current research relating to current climate and future climate projections for Tasmania	Description of Tasmania’s environmental and socio-economic context and current and projected climate conditions
4. Research findings by sector	To synthesise adaptation research reviewed based on ten sectors	Key findings and summaries for the following sectors: primary industries; terrestrial and freshwater biodiversity; marine biodiversity and resources; land use planning, infrastructure and essential services; emergency management; human health and community well-being; industry and business; policy and governance; and indigenous issues
5. Cross-cutting themes	To present common themes of Importance for private sector, state and local government policy and decision-making.	Discussion of the following themes: Drivers of adaptation; future visions; governance; resourcing; implementation, monitoring and evaluation, attitudinal change; opportunities; research and action; barriers to adaptation; sectoral dependencies.
6. Conclusions	To summarise key lessons and articulate key challenges facing public and private decision-makers	Evaluation and assessment of current state of adaptation action and research, summary of adaptation challenges and opportunities for Tasmania, lessons for decision-makers and future research opportunities.
Appendix 1 Memberships of Research and Stakeholder Reference Groups		
Bibliography	To present the complete list of research reports reviewed for the project	The bibliography includes all research cited or reviewed for the project.

2 PROJECT METHODOLOGY

The project has been undertaken in five phases (see Figure 1):

1. project scoping and preliminaries;
2. literature review and sectoral synthesis;
3. sector expert interviews;
4. project workshop; and
5. review and development of cross-cutting themes.

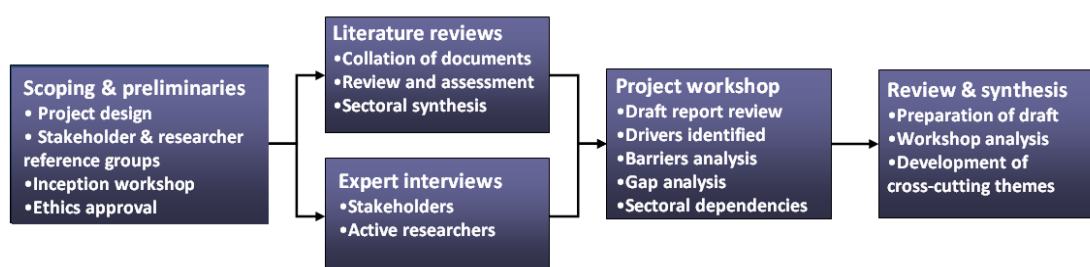


Figure 1. Project methodology

Each of these phases is discussed below.

2.1 Project scoping and preliminaries

2.1.1 Project design and methodology

This project was designed to reflect the specific circumstances of adaptation research and practice in Tasmania. In particular, the small number of agencies, organisations and actors active in adaptation presented an opportunity to engage widely and deeply across the adaptation community.

The call for expressions of interest in this project indicated a strong preference for stakeholder-driven research. Accordingly, this project engaged the Tasmanian adaptation stakeholder and researcher community from the very earliest stages of project design during preparation of the project proposal. A representative from the Tasmanian Climate Change Office – the key State Government agency responsible for mainstreaming adaptation policy into State Government business – was included as part of the project team and advised on appropriate stakeholder groups.

2.1.1.1 Establishment of stakeholder and researcher reference group

Separate researcher and stakeholder reference groups were established to advise on the project. During development of the project proposal, the project CI emailed a wide range of researchers known to be active in adaptation research at the University of Tasmania and CSIRO, to gauge interest in the project and, in particular, involvement in either the project team or an advisory role. Responses from this initial correspondence enabled the resulting project team to adopt a snow-ball technique for identifying additional researchers. Researchers gave their in-principle support for participating in the researcher reference group, and confirmed their involvement when the project formally commenced.

A similar approach was taken to the membership of the stakeholder reference group. The TCCO provided contact details of key industry and sector stakeholder groups. A personal email was sent to each of the contact persons associated with these groups, in order to raise their awareness of the project and gain their support. Virtually all groups contacted gave in-principle support for involvement in the stakeholder reference group prior to submission of the project proposal, and confirmed their involvement when the project formally commenced. Several organisations and individuals were added following project commencement, based on the suggestions of project team members and other stakeholders/researchers.

Membership of these groups is listed in Appendix 1.

2.1.1.2 Inception workshop

The stakeholder reference group met at an inception workshop held on 14 August 2012, to discuss and refine objectives, determine their information priorities, and identify the most appropriate forms of deliverables. The stakeholder reference group also provided the project team with information about adaptation projects completed or underway within their industry or organisation, and the outcomes of those initiatives. To the extent that they are relevant, these initiatives are discussed in each of the sectoral summaries in section 6 of this report.

2.1.2 Ethics approvals

Since the project involved interviews and workshop activities, Human Research Ethics Approval was required. Documentation including draft interview protocols and invitations to workshops was prepared in July 2013, and approval for the project was granted on 14 August 2012 (Ethics Ref No: H001267).

2.2 Literature review and synthesis

The second phase of the project involved the assembly, compilation and synthesis of published results of past and current research projects funded by NCCARF and other bodies, as well as other adaptation policies and initiatives.

The identification and compilation of literature for review and synthesis was conducted using four techniques:

- materials already known by the research team
- materials provided by the research and stakeholder reference groups
- searches of University of Tasmania online databases of scholarly journals
- searches of government and other websites.

Literature was gathered between August and November 2012. Research not publicly available by November 2012 was only included if nominated during stakeholder and researcher discussions.

Table 2 lists the government and other websites searched for adaptation-relevant documents. Table 3 lists the academic databases searched.

Table 2. Websites searched

Website	Address
Housing Industry Association	http://hia.com.au/
Tasmanian Council of Social Services (TasCOSS)	http://www.tascoss.org.au/
Tasmanian Seafood Industry Council	http://www.tfic.com.au/
Tasmanian Farmers & Graziers Association	http://www.tfga.com.au/
Tasmanian Land Conservancy	http://www.tasland.org.au/
Tasmanian Minerals Council	http://tasminerals.com.au/home/
Tasmanian Conservation Trust	http://www.tct.org.au/
Tourism Industry Council of Tasmania	http://www.tict.com.au/
Wine Tasmania	http://winetasmania.com.au/
Tasmanian Chamber of Commerce & Industry	http://www.tcci.com.au/tcci/
Tasmanian Aboriginal Centre	http://www.tacinc.com.au/
Sustainable Living Tasmania	http://www.sustainablelivingtasmania.org.au/
Property Council of Australia	http://www.propertyoz.com.au/
Fruit Growers Tasmania	http://www.fruitgrowerstas.com.au/
Forest Industries Association of Tasmania	http://www.fiatas.com.au/
City of Clarence	http://www.ccc.tas.gov.au/page.aspx
Hobart City Council	http://www.hobartcity.com.au/Home
Kingborough Council	http://www.kingborough.tas.gov.au/page.aspx
Launceston City Council	http://www.launceston.tas.gov.au/lcc/
Southern Midlands Council	http://www.southernmidlands.tas.gov.au/
Southern Tasmanian Councils Authority	http://stca.tas.gov.au/
Cradle Coast Authority	http://www.cradlecoast.com/
Cradle Coast NRM	http://www.cradlecoastnrm.com/
NRM North	http://www.nrmnorth.org.au/
NRM South	http://www.nrmsouth.org.au/home/
Local Government Association of Tasmania (LGAT)	http://www.lgat.tas.gov.au/page.aspx
Forestry Tasmania	http://www.forestrytas.com.au/
Hydro Tasmania	http://www.hydro.com.au/
State Emergency Services Tasmania	http://www.ses.tas.gov.au/
Forest Practices Authority	http://www.fpa.tas.gov.au/
Department of Premier and Cabinet	http://www.dpac.tas.gov.au/
Environmental Protection Authority Tasmania	http://epa.tas.gov.au/epa/
Department of Primary Industries, Parks, Water and Environment (DPIPWE)	http://www.dpiw.tas.gov.au/inter.nsf/Home/1?Open
Department of Infrastructure, Energy & Resources	http://www.dier.tas.gov.au/
Tasmanian Climate Change Office (TCCO)	http://www.climatechange.tas.gov.au/
Department of Economic Development, Tourism & the Arts	http://www.development.tas.gov.au/
Department of Treasury and Finance, Tasmania	http://www.treasury.tas.gov.au/
State Library of Tasmania	http://www.linc.tas.gov.au/
University of Tasmania	http://www.utas.edu.au/
Institute for Marine and Antarctic Studies (IMAS)	http://www.imas.utas.edu.au/
Australian Maritime College (AMC)	https://www.amc.edu.au/marine-environment
Tasmanian Institute of Agriculture	http://www.tia.tas.edu.au/
Integrated Marine Observing System (IMOS)	http://imos.org.au/

Website	Address
National Climate Change Adaptation Research Facility (NCCARF)	http://www.nccarf.edu.au/
CSIRO	http://www.csiro.au/
CSIRO Marine & Atmospheric Research (CMAR)	http://www.cmar.csiro.au/
CSIRO Climate Adaptation Flagship	http://www.csiro.au/en/Organisation-Structure/Flagships/Climate-Adaptation-Flagship.aspx
Antarctic Climate & Ecosystems Cooperative Research Centre (ACE-CRC)	http://www.acecrc.org.au/
Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)	www.abares.gov.au
Australian Centre of Excellence for Local Government	http://www.acelg.org.au/
Australian Emergency Management Institute	http://www.em.gov.au/Pages/default.aspx
Climate Change Research Strategy for Primary Industries (CCRSPI)	http://www.ccrspi.org.au/
Australian Government Climate Commission	http://climatecommission.gov.au/
Australian Government Department of Resources, Energy and Tourism	http://www.ret.gov.au/Pages/default.aspx
Australian Government Department of Climate Change and Energy Efficiency (DCCEE)	http://www.climatechange.gov.au/
The Australian Research Institute for Environment and Sustainability	http://aries.mq.edu.au/
Australian Government Department of Agriculture, Fisheries & Forestry (DAFF)	http://www.daff.gov.au/
AusIndustry	http://www.ausindustry.gov.au/Pages/default.aspx
Australian Antarctic Division (AAD)	http://www.antarctica.gov.au/
Cooperative Research Centre for Forestry	http://www.crcforestry.com.au/

Table 3. Academic databases searched

SUMMON	Current Contents Connect
Scopus	Wiley Online Library
Web of Science	GeoRef
Taylor & Francis	CAB Abstracts
SAGE Journals	Google Scholar
JSTOR	Informit
ProQuest	Geobase

2.3 Criteria for inclusion

Literature was included in the review if it:

- was a primary research report or peripheral/secondary research outputs (such as fact sheets)
- was publicly available
- specifically considered the impacts of climate change, vulnerability and/or responses to future climate change
- related specifically to Tasmania.

The project took a broad view of published research. Government reports, consultant reports that form part of local or regional adaptation projects, and other material was analysed provided it was in the public domain or forthcoming.

The time and resource constraints of the project meant that the following material was excluded:

- international adaptation research, unless it was specific to Australia or offered a specific analytical tool
- climate change science research, unless it specifically related to Tasmania
- research of relevance to adaptation, such as human health or disaster management, unless to expressly mentioned climate change.

2.3.1 Sectoral classification

Literature was assigned to one or more of ten focal area/sectoral categories:

- primary industries
- terrestrial biodiversity
- marine biodiversity and resources
- land use planning
- infrastructure
- human health and community wellbeing
- business and industry
- emergency management
- policy and governance
- indigenous issues.

These sectors were selected following early consultations with NCCARF and the Forum for NCCARF, States and Territories (FORNSAT) and with the project team's expert judgment about the categorisation of existing research and areas of research need. The choice of sectors was discussed and validated at the project inception meeting.

It is recognised that other sectors or differently constituted categories are possible, and we recognise the potential limitations of any attempt to break into 'sectors' the complex array of cross-cutting issues and available literature. As noted above, the multi-sectoral relevance of many documents was partially overcome by allocating documents to more than one sector where there was clear overlap or relevance to multiple areas. Omissions and overlaps are unavoidable in any selection of themes and sectors, and the project sought to minimise those issues and maximise the synergies across sectors as much as possible.

2.3.2 Sectoral analysis and synthesis

The next phase involved the preparation of the draft sectoral findings.

The project team reviewed each document and used expert judgment to extract the findings most relevant to each sector. The Driving forces-Pressures-States-Impacts-Responses (DPSIR) framework was considered a useful platform for each sectoral analysis, because it

provided a logical structure and ensured thorough coverage of issues. The terminology was modified, however, to reflect the limited state of research available and to enhance the accessibility of the content and concepts. The resulting sectoral summaries synthesised research according to:

- the nature of the climate change impacts;
- the implications of sector-specific vulnerabilities;
- current adaptation efforts;
- future options; and
- research gaps and opportunities.

2.4 Sector expert interviews

In addition to the literature review, this mapping and synthesis exercise drew on semi-structured telephone or in-person interviews with members of the researcher and stakeholder reference groups (active researchers (n~13) and stakeholders (n~23)). These interviews explored participants involvement in adaptation research, models of collaboration across researchers and end-users, challenges faced in undertaking adaptation research and in converting research findings into policy or practical outcomes. The results of these interviews helped inform the identification of common themes, gaps and opportunities, and future research directions.

2.5 Project workshop

The Project workshop was held on December 11, 2012. A draft project report was prepared and distributed to Researcher and Stakeholder Reference Groups in advance of the project workshop, to enable the project team to verify the comprehensiveness and accuracy of content, and to provide a foundation of discussion at the workshop.



Photo 1. Participants at the project workshop, Photo: Holger Meinke

The workshop reviewed the focal area/sectoral summaries; mapped linkages within and between sectors and from direct to indirect impacts; explored drivers of adaptation and barriers to effective adaptation; and identified key gaps in adaptation knowledge/capacity/practice and future priorities. All members of the Researcher and Stakeholder Reference Groups were invited to the workshop. Those individuals were also invited to suggest other invitees. Including the project team, the workshop involved ten researchers and ten stakeholders.

While several participants indicated that they sat across both researcher and stakeholder communities, when asked to identify with one group, a total of ten of workshop participants described themselves as researchers, eight described themselves as research end-users and five as research managers (Figure 2). Participants elected to represent one of the ten sectors covered in this project, and the breakdown of sectoral representation is presented in Figure 3.

1. Researcher
2. End-user
3. Research Manager

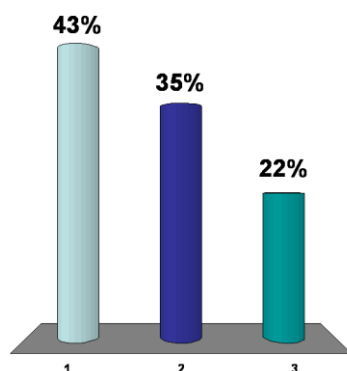


Figure 2. Composition of project workshop participants

1. Primary industries
2. Terrestrial biodiversity
3. Marine biodiversity and resources
4. Land use planning
5. Infrastructure and essential services
6. Human health and community wellbeing
7. Business and industry
8. Emergency management
9. Policy and governance
10. Indigenous issues

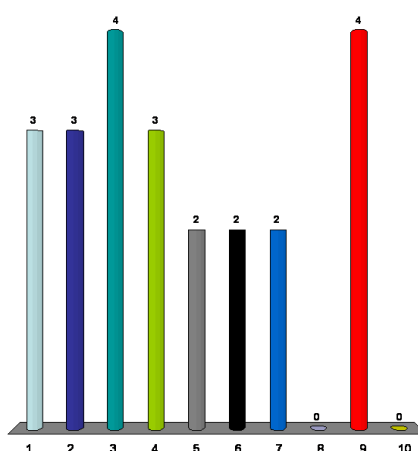


Figure 3. Sectoral representation at project workshop in each of 10 categories

2.6 Review and development of cross-cutting themes

In the final phase, the project team refined the project findings and developed the cross-cutting themes. Cross-cutting themes were identified from the workshop discussions as well as expert review based on interview analysis and workshop discussions. With these new sections included, and existing material refined, the draft project report was then subject to a second round of consultation and feedback from researchers and stakeholders.

2.7 Project limitations

This project assesses the state of adaptation research *in Tasmania*. National work of specific relevance to Tasmania is discussed but the project does not, and cannot, purport to evaluate in detail the growing national and international adaptation literature that may also offer insights for the Tasmanian context. The companion project conducted for the Australian mainland state and territories by AECOM reviews and synthesises national material, and the results of that project also offer insights for Tasmania. This means that some of the sectoral analyses contained in part 4 of this report are more detailed than others, based on the availability and sophistication of research that relates specifically to Tasmania.

3 ADAPTATION CONTEXT

Adaptation has been defined as the process of developing local responses to climate change and involves deliberate change in anticipation of or in reaction to external stimuli and stress (Nelson et al. 2007). In some contexts, adaptation can be either autonomous biological (e.g. changing distribution or growth rates) or directed (biological, infrastructural, socio-economic adaptation) (e.g. coastal planning may set new limits given expected physical change). Here we focus on the body of adaptation research that can inform directed adaptation.

The likely changes in climate that Tasmania will experience as a result of changes in global climate drivers need to be understood within the context of how Tasmania's geographical position, island geography and topography interact with complex global, regional and local climate dynamics. For example, being located in the Southern Ocean exerts a moderating effect on some key global climate variables, such as increases in land surface temperatures. Likewise, the impacts of changes to climate and the associated emerging risks and adaptation challenges also need to be understood in the context of Tasmania's social, cultural, economic and political geographies:

What is adaptation?

This project adopts the Intergovernmental Panel on Climate Change (IPCC) definition of adaptation to determine research for inclusion in this synthesis. The IPCC defines adaptation as

'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC 2007b).

While Tasmania is expected to experience less severe climate change impacts compared to other parts of Australia (due to its temperate maritime climate), it is important to recognise that these impacts will have an effect. Further, the effects will be particularly felt by socially, physically and economically vulnerable communities who may not have the capacity or resources to effectively adapt to climate change (TCCO 2012a, p.3).

Tasmania has the benefit of strong regionally specific climate change modelling, by virtue of the *Climate Futures for Tasmania* (CFT) project. The CFT was jointly funded by the Tasmanian Government, NCCARF and Hydro Tasmania (ACE CRC 2010). It adopted six global climate model simulations and used dynamic downscaling to produce fine-resolution (approximately 10km x 10km) projections of key climate variables for Tasmania over the 21st century. These projections are based on two IPCC emissions scenarios (one high, A2 and the other low, B1). Detailed accounts of how shifts in key climate drivers (such as El Niño Southern Oscillation, Indian Ocean Dipole, Southern Annular Mode, and blocking highs) will affect Tasmanian climate, are contained in the CFT reports (available from <http://www.acecrc.org.au/Research/Climate%20Futures>), particularly the *General Climate Impacts Technical Report* (Grose et al. 2010) and the *Extreme Events Technical Report* (White et al. 2010).

At the time of writing, the CFT was the best regional-level information in the country. As climate modelling and downscaling techniques improve, they are likely to reveal the project's limitations (see, for example, Risbey & O'Kane 2011), but for present purposes CFT continues to provide an invaluable platform for adaptation planning. Below we provide a brief overview of the environmental and socio-economic context for adaptation in Tasmania, then outline some of the anticipated key climate changes that Tasmania will experience over the coming century, based on CFT findings.

3.1 Environmental context

Tasmania is located in the path of the 'Roaring Forties' winds, which circulate around the Southern Ocean. Most recently, it separated from the Australian mainland some 6000–10000 years ago, when sea level rose at the end of the last ice age. Its rugged mountainous topography results in part from glaciation in some parts of the island, which has also had an influence on soil quality and hence vegetation patterns.

Tasmania's geographical and genetic isolation have preserved a unique combination of flora and fauna, with remnant Gondwanan taxa that provide insights into evolutionary processes. Close to half of the state's land mass is located in some form of conservation reserve, although these areas are principally alpine and low-productivity environments. Tasmania's natural values are already affected by a range of threats, including fire, weeds, pests and diseases (TPC 2009).

3.2 Socio-economic context

Tasmania has a population of 512 000, divided into 29 local government areas. About half of the state's population lives in southeast Tasmania, in the greater Hobart area. The state's economy is heavily dependent on environmental goods and services, dominated by mining, tourism, fisheries and aquaculture, forestry, and primary industries. Tasmania's current economic performance is ranked eighth of the eight states and territories (ComSec 2013) in the following sectors: economic growth; retail spending; equipment investment; construction work done; population growth; housing finance and dwelling commencements; and seventh of eight in unemployment (ComSec 2013).

There is considerable public debate about the state's future social and economic well-being. Recent discussions have highlighted Tasmania's low levels of post-year ten educational retention and attainment; high levels of welfare dependence, public sector employment and teenage pregnancy; and an underdeveloped private sector (Cica 2013, West 2013). At the same time, however, others have noted the overall high levels of satisfaction among the state's residents: accordingly to Gale, a 2012 survey of community attitudes showed that nearly 90% of Tasmanians were satisfied or very satisfied with their own life and personal circumstances (Gale 2013).

3.3 Climate projections

3.3.1 Temperature

3.3.1.1 Land temperatures

Tasmania's current climate is cool temperate, with four distinct seasons. Throughout the first half of the 20th century, Tasmania experienced a stable mean land temperature. Since 1950, mean land surface temperatures in Tasmania have increased by an average of 0.10° C per decade, which is a slower rate of increase than that experienced by mainland Australia (0.16° C per decade) (Grose et al. 2010). Steffen and Hughes (2011) note that average annual temperatures in Tasmania have increased by around 0.8° C over the last 100 years. Projections for changes over the 21st century indicate that average annual temperatures across Tasmania will increase between 1.6° C to 2.9° C by 2100 (Figure 4).

Increases in temperature for Tasmania are less than that projected for global average temperatures and for the Australian mainland, mainly due to the moderating effect of the Southern Ocean. Increases in average land surface temperatures are matched by increases in both maximum and minimum temperatures, with daily minimum temperatures projected to increase slightly more than daily maximum temperatures. Notwithstanding existing variations in temperature based on changes in elevation, the average annual increase is anticipated to be relatively uniform across the island. There are, however, seasonal spatial differences in projected temperature rises, with the west coast of Tasmania experiencing greater increases during summer (Grose et al. 2010). Increases in temperature are likely to be associated with changes in a number of other climate variables. According to the ACE CRC (2010d: np), temperature increases are likely to result in 'increases in evaporation, decreased average cloud cover, increases in relative humidity and increased winds in spring'.

Mean historical daily temperature from the Bureau of Meteorology high-quality climate site data for Tasmania and projections from downscaled CFT modelling simulations under the A2 and B1 emissions scenarios. The time series plot shows the 11-year moving average the high-quality climate site data (black line), the six-model mean (A2 = bold red line, B1 = bold blue line) and the range of the six models (respective faint lines).

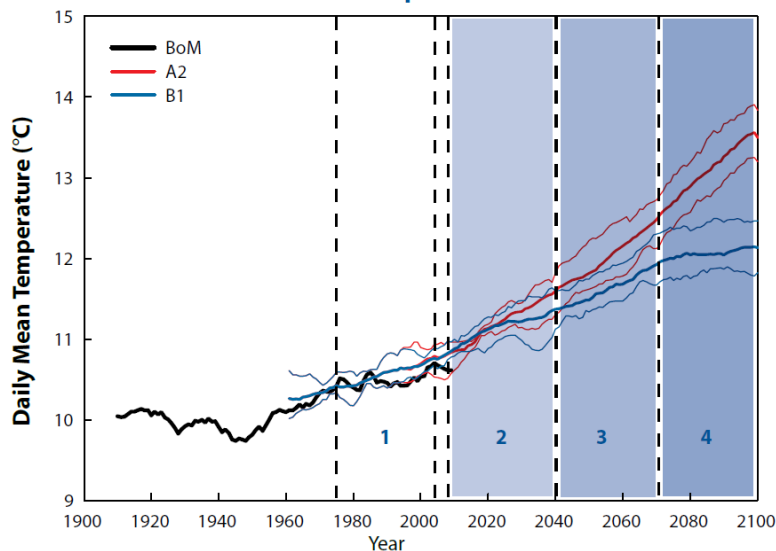


Figure 1. Current and projected air temperature for Tasmania Mean historical daily temperature from the Bureau of Meteorology high-quality climate site data for Tasmania and projections from downscaled CFT modelling simulations under the A2 and B1 emissions scenarios. The time series plot shows the 11-year moving average the high-quality climate site data (black line), the six-model mean (A2 = bold red line, B1 = bold blue line) and the range of the six models (respective faint lines)

Source Figure 6.1 in Grose et al. 2010

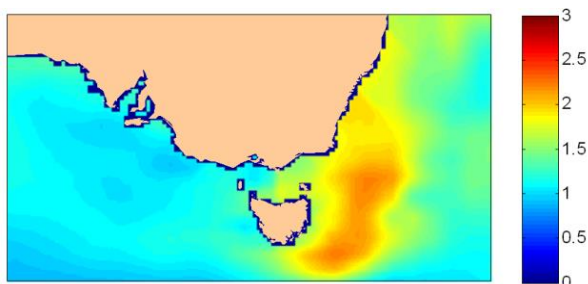


Figure 5. Ensemble average ocean warming for south-east Australia by 2050 relative to 1990

Source: Hobday & Lough, 2011

3.3.1.2 Ocean temperatures

Globally, sea-surface temperatures (SST) have risen by an average of around 0.8° C since 1910 (IPCC 2007b). Increases in ocean temperatures are seasonally, regionally and locally distributed, and consequently the waters around Tasmania are warming at different rates. Significantly, waters off Tasmania’s east and north-east coast are warming at a rate almost four times the global average (Holbrook & Bindoff 1997; Ridgway 2007), resulting in the area being recognised as part of a global warming ‘hot spot’. Mean SSTs are projected to increase around Tasmania in all seasons by the end of the century (Grose et al. 2010, p.56). Southward extension and strengthening of the east Australian current is likely to result in east coast water temperatures rising by up to 2°C to 3°C by 2070 relative to 1990 levels (see Figure 5, above, and Grose et al. 2010). Increases in SST have already resulted in significant changes to Tasmania’s marine biology and biophysical processes, with major implications for both wild fisheries and aquaculture.

3.3.2 Rainfall

Since the 1970s, Tasmania has experienced a general trend of reduced annual average rainfall, and greater year-to-year variability in rainfall (Grose et al. 2010). These trends are projected to continue. The modelling of changes to rainfall carried out by CFT under the A2 (high) emissions scenario suggests a change in the total annual rainfall for Tasmania of less than 100 mm by the end of the 21st century. This minor state-wide change masks significant changes in regional and seasonal rainfall and runoff patterns, which are also affected by temperature and soil dryness (Figure 6).

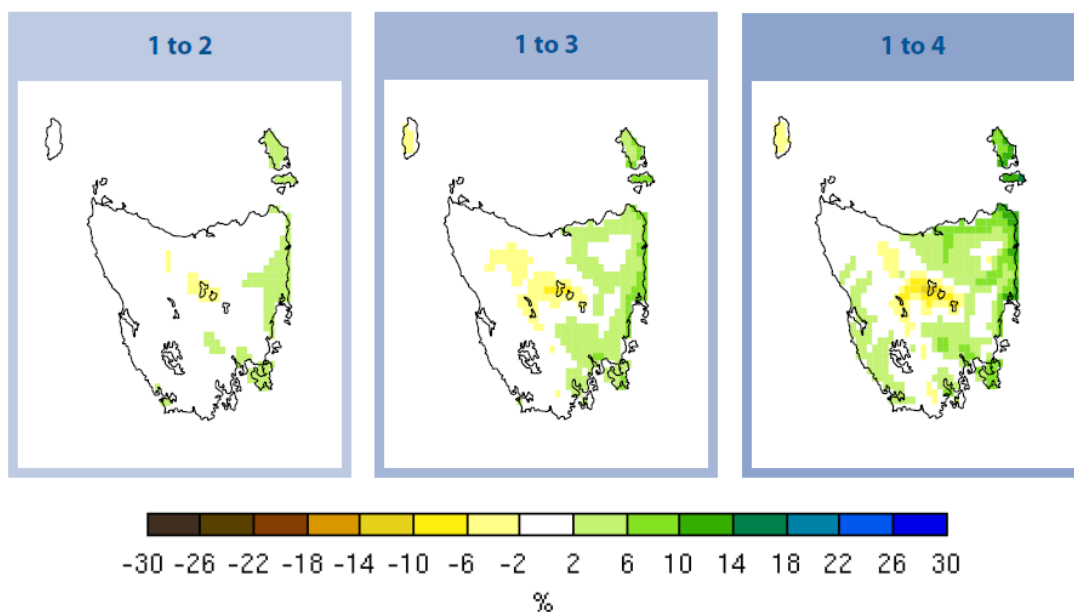


Figure 2 Total annual rainfall projections for Tasmania under the A2 emissions scenario For the six-model-mean proportional change in rainfall between 30-year periods indicated by numerals (1 = 1978-2007, 2 = 2010-2039, 3 = 2040-2069, 4 = 2070-2099). Source: Figure 6.5, Grose et al 2010.

Source Figure 6.5 in Grose et al. 2010

Risbey and O’Kane (2011) highlight that it is currently impossible to provide meaningful sub-regional rainfall projections to 2100 for anywhere in the world, including Tasmania. The CFT’s projections to 2100 should be considered with this proviso in mind, but projections for near- and medium-term can be considered with greater confidence. The CFT project concluded that both emissions scenarios project significant regional differences in rainfall, with ‘a steadily emerging pattern of drying in the central highlands and parts of the north-west, and an increase in rainfall on the east and west coasts’ (Grose et al. 2010, p. 29). This pattern is also seasonal. During summer and autumn, the west coast is anticipated to experience reduced rainfall, while the coastal margin on the east coast will experience increased rainfall. During winter and spring, rainfall in the west is expected to increase, while rainfall in the east is expected to decrease slightly. Lower rainfall across all seasons is likely in the central plateau (Grose et al. 2010, p. 31).

Runoff in Tasmania's Central Highlands will decrease by 2100, with implications for water resources used in hydro-electricity generation (Bennett et al. 2010). Conversely, it is anticipated that runoff will increase in certain regions, such as the Midlands and in the Derwent Valley, with potential benefits for agricultural production. In addition to changing seasonal and regional patterns in rainfall, it is anticipated that there will be an increase in extreme rainfall events, with 'more extreme wet days, more intense rainfall and more dry days – that is, less 'average' conditions' (Steffen & Hughes 2011, p. 3).

3.3.3 Extreme weather events

Changes to key climate variables (such as temperature and rainfall) in Tasmania are likely to amplify aspects of existing climate variability, resulting in changes in the intensity and frequency of extreme weather phenomenon and shifts in a number of climate indices (White et al. 2010). Some of these changes are summarised below.

- Tasmania will likely experience more intense rainfall events and a greater number of extreme wet days in the south-west and north-east (White et al. 2010), resulting in an increased risk of localised flooding in these regions. Overall, the number of rain days will decrease for the island as a whole, with the north-west experiencing the brunt of this change. It is projected that there will be increases in periods of both drier and wetter conditions across Tasmania (White et al. 2010).
- For most regions, there will be an increase in the number of summer days (maximum temperatures over 25° C), 'tropical nights' (minimum temperatures over 20° C) and greater frequency of heat waves (where maximum temperatures exceed 28°C for more than three consecutive days) (White et al. 2010). Steffen and Hughes (2011) note that the number of days above 25° C is projected to double or triple and some areas may experience an additional 40 days above 25° C per year by the end of the century. There will also be a concomitant reduction in the frequency of cold waves (where maximum temperatures do not exceed 5° C for three consecutive days), particularly in the central highlands (White et al. 2010). These changes in climate are likely to result in a corresponding increase in the number of fire danger days and associated bushfire risk.
- There is anticipated to be a halving in the incidence of severe frosts, and a shortening of the period of frost risk from March to December, to May to October in many areas (Holz et al et al. . 2010).. Changes to the incidence and timing of frosts are likely to impact on both the natural environment and agricultural production.


3.3.4 Sea-level rise

During the 20th century, global sea levels have risen by around 20cm through thermal expansion and the melting of glaciers and ice sheets (Hunter et al. 2012). This corresponds to an average sea-level rise of around 1.7mm per year, although the rate of sea-level rise is accelerating. From 1993 to 2009 it was recorded as being between 2.8mm and 3.2mm per year (Hunter et al. 2012). Spatial variations in the extent of sea-level rise are thought to be due largely to regional differences in the rate of thermal expansion and salinity levels and the location of sources of melting ice (Hunter et al. 2012). In Tasmania, sea-level rises have been slightly slower than global trends (Steffen & Hughes 2011). Estimations of future sea-

level rise are complex, because of the multiple uncertainties surrounding future greenhouse gas levels and emissions trajectories, differences between climate models, and the response of glaciers and ice caps (Hunter et al. 2012). Based on IPCC modelling, it is anticipated that sea levels will rise by between 0.2m to 0.8m by 2100, while other estimations based on semi-empirical models project greater increases of up to 1.6m by the end of the century (Hunter et al. 2012). In Tasmania, it is estimated that sea levels will rise by around 0.76m by 2100 (TCCO 2012a).

4 RESEARCH FINDINGS BY SECTOR

4.1 Primary Industries

 Key findings – Primary industries	
Climate change impacts	<ul style="list-style-type: none"> ◆ projected temperature increases of up to 2.9C by 2100, although this average may mask changes in overall variability ◆ projected changes in rainfall are less reliable, and may be buffered by wider use of irrigation
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ extreme variability in micro-climates, soils and production systems across the state makes it hard to translate climate impacts into state-wide sectoral impacts ◆ the effects of climate change impacts to demand-side issues and the implications of transformational change are poorly understood
Current adaptation efforts	<ul style="list-style-type: none"> ◆ the plans of government agencies, suppliers, corporate agricultural business and individual farms already reflect the need to respond to climate variability and change
Future options	<ul style="list-style-type: none"> ◆ conditions for particular industries will change over time, so the trade-offs required across agricultural sectors will also need to vary ◆ options analysis needs to take a systems approach that considers industries re-locating to Tasmania, and biosecurity threats under changed climatic conditions
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ understanding how multi-level and indirect impacts of climate change can best be recognised in sector-specific adaptation research for Tasmanian primary industries

This section considers the impact of climate change on Tasmania's agricultural sector, and the sector's response to those impacts. Many of the outcomes reported here are direct or indirect consequences of the *Climate Futures for Tasmania* (CFT) project that was jointly funded by The Tasmanian Government, NCCARF and Hydro Tasmania (ACE CRC 2010d). Follow-on work led to the development of a series of fact sheets for agriculture, produced by the Tasmanian Institute of Agriculture (TIA), in partnership with the Tasmanian Government (see Section 5.1.2 below).

Although there exists a plethora of peer-reviewed articles and research reports about adaptation to climate change in Australia (e.g. Stokes et al. 2008; Stokes & Howden 2010), publications that explicitly relate to Tasmania are rare. This is in spite of Tasmania's

institutions being proactive and highly engaged in the debate (e.g. the Tasmanian Government's (2011) contribution to the Productivity Commission Inquiry into 'Barriers to Effective Climate Change Adaptation'). Most of the articles cited in this review are therefore of a more general nature, unless specifically stated otherwise.

4.1.1 Understanding climate change impacts

The *Climate Futures for Tasmania* (CFT) project provides an excellent starting point to assess the likely physical changes related to climate change that have already occurred and that are likely to occur in the future. Particularly relevant for agriculture, mean annual temperature has increased by 0.1°C per decade since the 1950s. Daily minimum temperatures have increased more than daily maximum temperatures. Total annual rainfall has decreased, with the greatest reduction in autumn.

Average temperatures across the state are projected to increase by around 2.9° C by the end of the century, which is low compared to the rest of Australia (projections are based on the A1FI high emissions SRES scenario). Coupled with the fact that Tasmania has a relatively cool-to-mild and maritime climate, such changes appear to be within the envelope of the adaptive capacity of the agricultural sector. However, care needs to be taken with such projections that are based on likely changes to the average as climate change might result in increases to the overall variability.

Most agricultural systems are particularly sensitive to extreme conditions. This is of particular concern in regard to issues such as damaging frosts that could locally increase even as the underlying average temperatures are increasing (Crimp et al. 2008). Similarly, changes to rainfall variability are important, as the damaging floods of the recent La Niña season (2010/11) have shown (Hart 2011). While changes to rainfall are a lot less certain, Tasmania is in the fortunate position of having access to substantial fresh water reserves for irrigation that can mitigate against possible downwards shifts in rainfall (Gaydon et al. 2012): a fact often quoted is that Tasmania has just over 1% of Australia's agricultural land use, but over 12% of Australia's fresh water reserves. Large irrigation schemes are currently being developed and rolled out to make better use of this valuable resource (<http://www.tasmanianirrigation.com.au/>).

4.1.2 Understanding sectoral vulnerabilities

Tasmania has a strong and diverse agricultural sector that contributes about \$1.15 billion annually to the Tasmanian economy (2009/10 figures). Important sub-sectors include mixed farming enterprises, dairy, fruit, vegetables, red meat, wool (Harle et al. 2007), poppies, pyrethrum and viticulture (Cozzolino et al. 2010) as well as many niche products (TCCO 2012). Translating the impacts of climate change into an assessment of the likely effects on production remains challenging (Stone & Meinke 2006), especially in Tasmania, which is characterised by extreme variability in micro-climates, soils and production systems.

Occupying the coolest and most maritime climate in Australia means that Tasmanian conditions cannot immediately be compared with similar (analogue) locations on the mainland – in many cases they simply don't exist. Tasmania's unique and diverse production systems further complicate the assessment and prediction of climate change impacts on the

various sectors. Tasmania grows crops such as poppies and pyrethrum that cannot be compared to any other production environments (over 50% of all commercially produced alkaloids globally come from Tasmania as well as over 70% of the world's pyrethrum production). Tasmania's current climate is ideal for cool wine production, and the conditions to produce milk on highly productive pastures are amongst the best in the world. Hence, any climatic changes pose an immediate threat to these industries, unless adaptive measures are developed early and are ready for deployment.



Photo 2. Poppy production could increase under climate change Photo: Mark Dowsett

Farmers have been exposed to climate variability (and hence risk) ever since farming was invented; they have always adapted to highly variable and at times changing climates. Changes in temperature and rainfall will impact differently on the various sectors of Tasmania's diverse agriculture industries. However, the translation of climate information into real-life action requires three essential components: salience (the perceived relevance of the information), credibility (the perceived technical quality of the information) and legitimacy (the perceived objectivity of the process by which the information is shared) (Meinke et al. 2006). A culture of resilience and adaptation has already developed in Tasmania. Farmers need to continue to respond to immediate and short-to-medium term climate variability, as well as start preparing for longer-term changes in climate.

A series of information sheets about climate change impacts and opportunities for Tasmanian primary producers has been developed by TIA and the State Government. These information sheets identify climate impacts and opportunities for Tasmanian

agriculture. The series includes an overview (Phelan et al. 2012c) and specific information sheets for: dryland pastures and red meat production (Bridle et al. 2012a); extensive dryland pastures and wool production (Bridle et al. 2012b); irrigated pastures and dairy production (Phelan et al. 2012b); wheat production (cereals, Lisson et al. 2012); wine grape production (Bridle et al. 2012c); special regions and crops (Meander Valley – barley, poppies, pyrethrum, blueberries and hazelnuts under irrigation, Phelan et al. 2012a); and farmer perceptions of climate change (Bridle et al. 2012c). A full set of these fact sheets can be downloaded from www.dpipwe.tas.gov.au/climatechange. Other adaptation research funded by NCCARF in Tasmania focussed mainly on issues such as biodiversity and marine systems, rather than agriculture (NCCARF 2012).

Research to date suggests a range of direct and indirect impacts of climate variability and change on agriculture in the State (Holz et al. 2010). Chill hours are projected to decrease at lower elevations of Tasmania and increase at higher elevations. This may have localised impacts on crops that require a period of cold before they can bud, flower and set fruit. A growing number of warmer days are projected with time. This will impact on the performance of crop types and varieties. For example, by mid-century wine varieties such as cabernet sauvignon are predicted to ripen reliably in some areas, but by 2085 will do so in all wine growing regions of Tasmania.

These projected impacts pose a range of challenges on-farm, across industry sectors, and across markets. Complex systems interactions need to be thought through. For instance, new crop opportunities will need to be carefully managed to avoid the establishment of new pests and weeds in the state. Integration of climate-change with other risk factors, such as market, environmental or social risks is becoming increasingly important and will require active research and support (Howden et al. 2007).

In addition to production or management-related issues, the post-farm gate consequences of climate changes on the entire value chain have not yet been assessed. These can relate to multiple drivers influencing the demand for agricultural produce, such as demographic changes, changes in costs and prices, storage and transport issues and the marketing of often perishable produce.

In addition, the design of policies for risk management in agriculture raises many challenges. These policies range from generating sound, quantitative information on the types of risks and the tools available to deal with them (Maia & Meinke 2010), to creating incentives that encourage farmers to adopt a proactive risk management strategy (Meinke et al. 2009). It is now widely accepted that this requires participatory approaches, whereby farmers become valued members of research teams (e.g. Crimp et al. 2008; Howden et al. 2007; Meinke et al. 2009; Stone & Meinke, 2006).

Changes to the socio-economic conditions of rural enterprises and communities will be inevitable through the introduction of transformational changes (Gaydon et al. 2012; Park et al. 2012). These impacts need to be carefully considered so that benefits can be maximised and potential downsides managed. At a national scale, research into the climate vulnerability of Australian rural communities is just beginning to emerge. Current research is dominated by hazard/impact modelling, drawing on a heritage of managing the risks posed by seasonal climate variability (Nelson et al. 2010a, 2010b). There is a natural tendency to use the same

risk management approach to understand the emergent nature of vulnerability. Nelson et al. (2010a, 2010b) explore the consequences for policy advice of imperfectly examining vulnerability through the lens of an impact/hazard modelling approach to risk management. They show how hazard/impact modelling can be complemented with more holistic measures of adaptive capacity to provide quantitative insights into the vulnerability of Australian rural communities to climate variability and change. Transformational changes usually result in winners and losers. Hence a clear a priori understanding of the likely impact of transformational change is paramount.

4.1.2.1 Existing adaptation efforts

Issues related to climate change are included in most if not all strategic plans (or other planning documents) of Australia's R&D corporations, and where appropriate extension is included. Climate change is also included in the plans of all Government departments (e.g. TCCO 2012a; Tasmanian Government 2011) and some major input suppliers. These include hybrid seed companies, who must breed plants for the new realities. It also includes fertiliser and agricultural chemical companies who are faced with providing inputs in a changed environment where fertiliser efficiency is critical, and new biotic challenges due to changes in generation, time and location of incidence of pests, weeds and diseases are driving new or modified management strategies.

Many corporate agricultural business (Galbreath 2011) and farm plans already reflect an understanding of and need to respond to climate variability and change. For example: the wine industry's selection of varieties (Galbreath 2011); the roll out of irrigation schemes to buffer against future rainfall variability (Gaydon et al. 2010); protecting high value crops via risk management strategies such as netting (for cherries); and breeding for varieties that are best adapted to local climates and stresses (such as barley).

4.1.2.2 Understanding future options

As noted above, there are several projections in the black and grey literature about the likely future impacts of climate change on particular regions. These projections can be used to consider what the possible responses from a manager's or policy maker's perspective could be. Structured systems analysis and simulation modelling combined with some facilitated 'foresighting' can help in the development of responses to such projected changes (Meinke et al. 2009). In this context, it is important to consider the extent to which research on adaptation to climate change in farming systems is different or additional to research on farming systems in a variable climate (Hayman et al. 2012).

Below are some specific examples of such projections and the opportunities and challenges they present

- By 2085, dry land pasture production from ryegrass is projected to increase in some regions of Tasmania, particularly those that are currently temperature limited. Irrigated ryegrass yields are projected to increase by around 20 to 30% by 2040 but thereafter decline to current levels due to increases in the number of hot days during summer months (ACE CRC 2010d). This might allow for an extension of the dairy industry into those regions, particularly if access to irrigation is secured.

- A reduction in drought in the south-east, north-east and south-west and an increase in drought for the central to north-west regions of Tasmania is projected. Hence, the amount and reliability of irrigation water becomes a critically important factor for long-term, strategic business plans (Gaydon et al. 2012).
- Given that most agricultural regions in mainland Australia will be adversely affected by climate change, a relocation of agricultural enterprises to Tasmania is a distinct possibility (Linnenluecke et al. 2011). This could have profound impacts on our local industries. There is evidence that this might already be occurring in both the vegetable and wine industries.
- Changing climate, in particular increasing temperature, will alter the spread and impact of invasive species and predators. Some pests and diseases already present in a region are likely to become more virulent and widespread. In areas where higher temperatures are also coupled with reduced rainfall, a reduction in fungal infections or the preferential promotion of pest predators may occur. For example, the mild Tasmanian climate is currently unsuitable for the Queensland fruit fly. With a warming climate, populations could more easily establish on the Bass Strait islands and then move into the north and eventually across the state (ACE CRC 2010c).

A systems-approach based on bio-physical modelling of the climate – soil – crop – management interface often assists in gaining additional insights into likely consequences of G x E x M (genotype x environment x management) interactions (Crimp et al. 2008; Meinke & Stone 2005). Outcomes of such modelling exercises can be used with agricultural stakeholders to underpin discussions about future management options. This can provide useful discussion support, rather than decision support (Hochman & Carberry 2011; Meinke & Stone 2005; Stone & Meinke 2006).



Photo 3. The amount and reliability of water for irrigation will become increasingly important Photo: Veronica Foale

A realignment of some industries might be required in order to benefit from the market opportunities that emerge through, for instance, earlier or later availability of quality product. Opportunities are mostly likely to emerge slowly, so the immediate and short-term economic impacts are likely to be small and perhaps not even identified as being a result of climate change. Real business opportunities require a confluence of unrelated factors such as market opportunities, skills and reliable value chains. Climate is only one of the critical components that must converge for opportunities to be turned into reality. However, availability of water in Tasmania, coupled with constraints being imposed on water availability in the Murray Darling Basin and other mainland production regions will provide increasing opportunities for Tasmania. Whole new industries could emerge, and although many options are actively debated (e.g. industrial hemp); there is no immediately-obvious large-scale industry. Many of these require large investments in processing capacity, which appears unlikely in the near future given the current economic environment. What is more likely is the emergence of small niche market industries servicing the changing food tastes or the market demands created by the rapidly expanding middle classes in Asia.

In addition to research that can improve on-farm management of climate change risks, research has been undertaken in Tasmania to understand how best to effect behavioural changes more rapidly. Using Tasmania as a case study Fleming and Vanclay (2010) found that discourse analysis is useful in understanding how to affect beliefs, values and behaviours of farmers. Interviews were conducted in 2008 with 63 respondents, including 22 apple growers, 29 dairy farmers and 12 agricultural consultants across Tasmania. The authors identified four specific discourses as being important in shaping farmers' perspectives of climate change and sustainability: money, earth, human responsibility and questioning. They found that each discourse contributed to resistance to changing behaviour in particular ways. An understanding of these discourses might offer an alternative approach to facilitating behaviour change.

4.1.3 Research gaps and future opportunities

Climate change presents threats and opportunities for Tasmania's primary industries sector. The choice of adaptation options needs to recognise the potential for multi-level impacts – across geographical and temporal scales. Allenby and Sarewitz (2011) point out that good local decisions generally don't add up to good global outcomes. Adaptation to climate change involves issues of 'wicked' complexity; what is regarded as either 'smart' or 'dumb' depends on the actors' world views, priorities and ultimately who benefits from a certain type of action and when. Allenby and Sarewitz (2010, p.110) write:


Something that may be unimportant in one area, such as how much atmospheric N is being deposited on agricultural land, may be quite important elsewhere (for example, in an estuary), and one society may be seriously engaged with questions of global climate-change policy while another is simply trying to find enough food and relatively clean water to keep people alive and the economy growing.

Research into how multi-level and indirect impacts can best be recognised in Tasmania would enhance the efficiency, equity and effectiveness of adaptation efforts and should be a cross-cutting priority for primary industries research, as well as for other sectors.

Other specific research gaps have already been identified in NCCARF's National Adaptation Plan for Primary Industries (<http://www.piarn.org.au/about-piarn/national-adaptation-research-plan>). Priorities specifically for Tasmania include:

- understanding trends in variability and the impact and frequency of extreme events (Maia & Meinke 2010);
- evaluating alternative cropping options for a wide range of locations throughout Tasmania; and
- understanding the likely socio-economic and environmental consequences of adaptation options (Lawrence et al. 2012; Meinke et al. 2009; Nelson et al. 2010a, 2010b).

4.2 Terrestrial and freshwater biodiversity

 Key findings – Terrestrial and freshwater biodiversity	
Climate change impacts	<ul style="list-style-type: none"> ◆ historical warming over the past 50 years and a general drying trend and reduction in stream flow since the 1970's ◆ future projections suggest further warming, at rates slightly slower than for mainland Australia, and drying for the east coast
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ climate change represents a significant threat to Tasmania's endemic and refuge fauna (species extinct on the mainland) and associated ecosystems ◆ changes to fire regimes, increased shrub and tree invasion of alpine regions, and changes in runoff will threaten Tasmania's terrestrial and freshwater ecosystems
Current adaptation efforts	<ul style="list-style-type: none"> ◆ government departments have developed a range of planning and management options for Tasmanian species and ecosystems ◆ management of non-climate threats to build ecosystem resilience to climate change is a key element in adaptation planning
Future options	<ul style="list-style-type: none"> ◆ protecting individual species may not be viable under climate change, and a focus on continued delivery of ecosystem services is emerging as a complimentary adaptation strategy ◆ species distribution modelling and limited experiments are informing development of conservation strategies, including reserve design and active interventions, such as translocation
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ determining the effectiveness of reducing non-climate stressors, changing agricultural practices, and fire management for building resilience to climate change ◆ developing policies with regard to Tasmania's role in preserving biodiversity from mainland Australia

This section includes a summary of both freshwater and terrestrial biodiversity impacts and adaptation options for Tasmania and the close islands, but not sub-Antarctic territories (Macquarie Island, Heard Island). The summary reports produced by DPIPWE (DPIPWE

2010a; Gilfedder et al. 2012) provide outstanding recent reviews, and this section draws heavily on these summaries which have synthesised information from many primary publications and from the *Climate Futures for Tasmania* (CFT) project.

4.2.1 Understanding climate change impacts

Tasmania has a temperate climate, with much of the state having a mild summer, and the Central Highland and alpine areas having a cool summer. Annual rainfall ranges from <700 mm to 2,300 mm (DPIPWE 2010a). Most of Tasmania has a wetter winter than summer, with the exception of the east and south-east of Tasmania which have no dominant rainfall season.

Much of Tasmania has experienced a warming in average maximum temperatures since the 1950s, with an average temperature rise of 0.10° C per decade, compared to 0.16° C per decade average rise for Australia as a whole (Grose et al. 2010). Since 1970, there have been strong decreases in rainfall across Tasmania, typically around 20 to 40 mm per decade (DPIPWE 2010a). Most of Tasmania experienced the three driest years on record in 2006-2008. Decreased rainfall leads to decreased stream flow, and stream gauge sites in Tasmania show a 15 to 30% reduction in stream flow over the last 15 years compared to historic records. The decrease in stream flow in turn leads to an increase in water temperature in small pools. There is anecdotal evidence for a reduction in the amount and duration of snow in the Tasmanian alpine regions in the past few decades but historical data is not available for Tasmanian snowfields. Sea level has risen 10 to 20 cm in the last century, including a 14 cm rise on the south-east Tasmanian coast.

The *Climate Futures for Tasmania* (CFT) project produced fine-scale dynamically downscaled projections (resolution ~10 km) based on six IPCC AR4 climate simulation models (Corney et al. 2010). The CFT projections are the highest resolution for Australia, and have provided a unique resource for climate scale planning in Tasmania. Over the coming decades Tasmania is expected to experience increased land and sea temperatures, changes to rainfall patterns and higher evaporation in most areas, wind speed changes; and sea level rises. The range of projected mean temperature rises for Tasmania to 2100 (1.6° C to 2.9° C) are lower than the projected globally-averaged mean temperature rises (1.8° C to 3.4° C) (Grose et al. 2010).

Climate change is likely to lead to ecosystem changes, including transformed and novel ecosystems, and local species extinctions. Changes such as decreased rainfall and increased temperature, and increased frequency of extreme events such as drought, storm surges, and fire, will variably impact on biodiversity in different regions in Tasmania. Tasmania's natural values are already affected by a range of threats and disturbance regimes such as fire, weeds and diseases – climate change may exacerbate these or lead to complex and cumulative interactions.

Tasmania has been isolated from the Australian mainland for the last 10,000 years, and supports a wide variety of plants and animals. Tasmania contains a wide range of rock types, landforms and soils. Climate change will impact on geomorphic process, landforms and soil systems both directly and indirectly, with fluvial (rivers, lakes and wetlands) and

coastal/estuarine (particularly soft, sandy coasts) systems likely to be impacted most significantly. Climate-induced changes to rainfall intensity, vegetation cover, fire frequency and intensity, and windstorm intensity all have the potential to impact on soils leading to changes in soil hydrology, soil organic carbon, salinity, erosion and sedimentation. Since soils form a critical link between landforms and vegetation type, provide valuable ecosystem services, influence vegetation health, and moderate infiltration and runoff, impacts on soils represent a key process in understanding broader climate change impacts.

4.2.2 Understanding sectoral vulnerabilities

Tasmania has been described as one of Australia's large regional hotspots of botanical diversity and endemism, with elements of biodiversity and geological diversity that reflect southern biogeographic and Gondwanan affinities (DPIPWE 2010a). There are approximately 1,900 native plant species, 34 native terrestrial mammals, 159 resident terrestrial species of birds, 21 land reptiles, 11 amphibians and 44 freshwater fish. Many of the Gondwanan elements are endemic to Tasmania – 20% of the flowering plant species are found nowhere else, and these endemics tend to be concentrated in alpine and rainforest environments in western Tasmania. High levels of endemism can also be found in invertebrate taxa (up to 100% for some groups) and for freshwater fish, with these endemics concentrated in western and central Tasmania (DPIPWE 2010a).

Tasmania has provided a refuge for species that have either died out or are threatened with extinction on the Australian mainland, and it has been protected from most of the introduced animal species that have so greatly affected the flora and fauna of mainland Australia. The dingo is absent, and feral goats and pigs have restricted distributions in Tasmania, however, the recent introduction of the fox is considered a major threat to native wildlife and an eradication program is underway (Dennis 2002). Reintroduction of the Tasmanian Bettong from Tasmania to mainland Australia (www.mfgowoodlandexperiment.org.au/bettong.html) has also demonstrated the value of Tasmania as a refuge for threatened species. Several other species may also be the focus of such reintroduction programs in the future. The other stressors to biodiversity in Tasmania include fire, invasive species, wildlife disease and pathogens, and landscape change as a result of anthropogenic activities (DPIPWE 2010a).

Over 40% of the state is protected in reserves, including the Tasmanian Wilderness and Macquarie Island World Heritage areas (DPIPWE 2010a), and so non-climate threats to biodiversity might be considered lower than elsewhere in Australia. However, more than 600 species of plant and animal are listed under Tasmania's Threatened Species Protection Act 1995, and climate change is likely to exacerbate some existing threats.

Terrestrial ecosystems considered potentially highly vulnerable include alpine ecosystems, moorlands and peatlands, particularly to altered fire regimes (Sharples 2011). Increased shrub and tree invasion in these ecosystems could lead to significantly transformed ecosystems, including increased fuel loads (DPIPWE 2010a). In addition, Tasmanian moorlands and peatlands may shift from accumulating carbon to releasing carbon into the atmosphere. Species distribution modelling has shown that moorland fauna such as the broad-toothed rat and burrowing crayfish are sensitive to climate change and may have reduced distribution in the future (DPIPWE 2010a).



Photo 4. The Burrowing Crayfish may have reduced distribution in the future Photo: Thomas-Stromberg

Species with restricted ranges such as mountain tops or low-lying islands and coasts, or those with life strategies or specialised habitats and ecological requirements are also at risk to the impacts of climate change (DPIPWE 2010a). Loss of some species is also projected under climate change, with the decline of the Central Plateau endemic miena cider gum (*Eucalyptus gunnii* subsp. *divaricata*) the best known Tasmanian case study (DPIPWE 2010a) It is sensitive to the effects of drought, which has led to the death of mature trees in relatively large patches since the mid 1990s. The species is listed as endangered under state and federal legislation.

Tasmania's freshwater ecosystems are also considered to be vulnerable to climate change as a result of changes in rainfall and to human demands for declining water resources

(DPIPWE 2010a). Reductions in rainfall and runoff have the potential to reduce the amount of suitable habitat available for aquatic species, as flows decline and parts of river systems are either reduced to pools or dry up. Freshwaters on Tasmania's Central Plateau will experience the most significant declines in runoff, with average projected decreases of between 15 and 35% by 2100. Lakes in the Central Plateau region support six endemic fish species, all likely to be affected by climate change in addition to significant existing stressors (Morrongiello et al. 2011). Declining water flows are also exacerbated by rising water temperatures, which may be significant for some species (e.g. giant crayfish). Tasmania's 'swamp forests' are another freshwater ecosystem that will be potentially affected by climate change and associated sea level rise (DPIPWE 2010a).

Potential impacts for a range of species, habitats and ecosystems are summarised by Gilfedder et al. (2012). These are based on limited Tasmanian-specific research and thus largely on parallels with national and internationally similar systems.

Impacts on plant species include:

- changes to timing and success of germination, recruitment, and establishment processes;
- changes in native species composition (e.g. species re-sorting);
- changes to species' habitat (e.g. changed fire regimes, changed soil hydrology, flooding);
- changes in species' geographic distributions; and
- increased pests that will prey on, or compete with, native plant species.

Impacts on animal species include:

- thermal tolerance of some species being exceeded;
- changes to species' habitat (e.g. changed fire regimes) affecting breeding success and survival;
- changes to species interactions and communities;
- changes in extent of some communities (due to direct impacts of climate change as well as indirect impacts relating to changed land use);
- reduced health/resilience of some communities;
- changes to disturbance regimes affecting component species and processes;
- release thresholds for some species being crossed, leading to changes to community type (e.g. buttongrass succession to dry forest);
- changed timing of seasonal events (e.g. flooding, burning, fish spawning) and potential mismatches in timing between species; and
- increased spread of pests and pathogens.

Changes to ecosystem structure and function include:

- changes in nutrient status of soils or changes to nutrient cycling;
- decreased opportunities for recruitment events reducing long-term ecosystem persistence;
- changes to structural dominants;

- changes to hydrological processes;
- changes to perenniality/ephemerality; and
- potential loss of key species, which may affect ecosystem processes.

Coastal wetlands will be particularly vulnerable to changes in hydrology and the impacts of sea level rise. Climate change influences on bushfires in Tasmania may have a significant negative impact on the natural environment by liberating stores of carbon in the soils and vegetation. One of the most significant contributions that Tasmania can make to the level of global atmospheric greenhouse gases is to ensure that natural carbon stores are also protected from catastrophic natural events and uncontrolled releases of the carbon they contain (TCCO 2008).

4.2.3 Existing adaptation efforts

The terrestrial biodiversity sector has benefitted from a number of government-led strategic planning documents (DPIPWE 2010a; Gilfedder et al. 2012) identifying areas for attention with regard to adaptation, including the World Heritage Areas (Sharples 2011) and prioritising ongoing monitoring (RMC 2012). The DPIPWE (2010a) review identified four adaptation priorities for marine, terrestrial and freshwater systems:

1. Ensuring scientific research provides a firm foundation for taking action in different regions and different sectors by measuring and predicting climate change and identifying new approaches.
2. Giving individuals, communities and businesses appropriate information, resources, skills and incentives to plan and adapt to climate change and manage their own risks.
3. Providing an adequate and appropriate emergency response to more frequent and intense events, such as bushfires, floods and storms, and assisting communities to recover from such events.
4. Managing risks to public infrastructure, assets and values (including roads, biodiversity, national parks and reserves), and protecting industry and the community against health and bio-security risks.

It is not clear whether these have guided research outside the state agency, as funding for external scientists has been limited. Partnerships between state and university researchers have been established which should see the perspectives of the government agencies guiding research efforts.

Existing adaptation for terrestrial biodiversity, particularly landscapes, has focussed on reduction of existing threats (Dunlop & Brown 2008). Gilfedder et al. (2012) emphasise the importance of minimising current threats and disturbances (e.g. from fire, pests, weeds, disease and inappropriate land management) as a foundation for future adaptation in all ecosystems. Other conservation adaptation goals identified for ecosystems in general included:

- protect and maintain connectivity (especially for species whose current location may become unsuitable);
- facilitate species movement;
- identify and protect contemporary and future refuges;

- minimise the impacts of current threats and land-use change, including through creation and protection of 'no go' areas in which access would be controlled to protect particularly fragile and vulnerable species and ecosystems;
- protect, maintain and increase extent of habitat, including restoration of degraded habitat; and,
- protect keystone species.

Gilfedder et al. (2012) provide more detail on adaptation options for terrestrial and freshwater systems. A measure of last resort for Tasmanian plants, *ex situ* conservation, has also been initiated in Tasmania, with collaboration between DPIPWE, Tasmanian Botanical Gardens and the Kew Gardens Millennium seed bank (DPIPWE 2010a).

The National Environmental Research Program Landscapes and Policy hub is developing tools, techniques and policy options to integrate biodiversity into regional scale planning using the Tasmanian midlands as a case study (see: <http://dev.nerplandscapes.edu.au/home>). On-going projects with outcomes relevant to Tasmania are listed in Table . The results are expected in 2013.

Table 4. Ongoing research relevant to Tasmania

Title	Objectives
<p>The TasFACE Project</p> <p>Mark Hovenden (University of Tasmania)</p>	<p>TasFACE (Free Air CO₂ Enrichment Facility) is a state of the art facility for investigating the impact of global climate change on an intact native grassland at Pontville, just north of Hobart, Tasmania, Australia.</p> <p>The experiment investigates the way that increasing temperature and atmospheric carbon dioxide concentrations affect the growth and nature of an ecosystem important from both an agricultural and conservation point of view. Investigations going on in the experiment cover the whole range of possible impacts from the growth, physiology and reproduction of individual species to community interactions and ecosystem level processes such as nutrient cycling and pasture feed quality.</p> <p>(http://www.utas.edu.au/plant-science/about/facilities/tasface)</p>
<p>Contributing to a sustainable future for Australia's biodiversity under climate change: conservation goals for dynamic management of ecosystems.</p> <p>Michael Dunlop (CSIRO Climate Adaptation Flagship)</p>	<p>The objectives of this project are to:</p> <ol style="list-style-type: none"> 1. Review existing conservation and NRM goals and objectives in Australia as set out in legislation, policies, strategies, plans and other documents relevant to national, state and territory, and regional scales and how these inform investment in conservation. 2. Explore the implications of climate change for the effectiveness of existing goals based on the underpinning conservation and ecological theory and observed and projected climate and ecological changes (using available existing environmental and ecological projections). 3. Identify existing, revised and new goals and objectives that might be achievable under climate change to conserve Australia's terrestrial and freshwater biological heritage and ecosystem services, through prioritised, focussed case studies with relevant conservation agencies (policy and management), NRM bodies and private organisations (i.e., that may reflect contrasting values for biodiversity). 4. Communicate the outcomes of the research to these stakeholders and provide tools (e.g., conceptual models, adaptation guidelines) for decision- and policy-makers who are preparing to act on the implications of climate change by transforming goals and objectives. <p>(http://www.nccarf.edu.au/content/contributing-sustainable-future-australias-biodiversity-under-climate-change-conservation)</p>

Title	Objectives
<p>Identification and characterisation of freshwater refugia in the face of climate change</p> <p>Jeremy VanDerWal (James Cook University)</p>	<p>Objectives</p> <p>A) identify, characterise and map the biophysical environments that will enhance the persistence of freshwater biodiversity across Australia providing an invaluable resource to better inform climate change adaptation actions; and</p> <p>B) inform the selection and implementation of appropriate adaptation actions for the protection of freshwater refugia.</p> <p>Freshwater ecosystems have very high biodiversity relative to their areal extent. They are particularly vulnerable to climate change because of their limited extent, their limited connectivity and, in much of Australia, their susceptibility to drying resulting from the vagaries of temperature and rainfall. The possible impacts of climate change on fresh waters must be assessed in relation to changes in both temperature and riverine networks (e.g., flow and linear connectivity) and their interactions with existing stressors (e.g., impoundments, agriculture, urbanization) and the surrounding landscape (e.g., topographic features and riparian vegetation). Here we propose to:</p> <ol style="list-style-type: none"> 1. Define a typology of refugia for freshwater ecosystems. <p>This will include a literature review in addition to a PI and stakeholder workshop to identify, review and synthesise existing knowledge on the biophysical attributes of freshwater ecosystems that are likely to act as refugia that will enhance the persistence of freshwater biodiversity into the future.</p> <ol style="list-style-type: none"> 2. Identify the spatiotemporal extent and quality of freshwater refugia under a range of future climate scenarios. <p>This will bring together knowledge, data, novel analysis and state-of-the-art modelling techniques to identify the location, extent and quality of freshwater refugia now and into the future. This will be done, where possible, across Australia at spatial and temporal scales necessary to inform adaptation actions at the local, catchment and regional scales. Calibration and validation of refugia identification will utilise biodiversity datasets in several fine-scale case studies across the country.</p> <ol style="list-style-type: none"> 3. Inform the selection and implementation of appropriate adaptation actions for the protection of freshwater refugia <p>Using a consistent approach across Australia, a decision tree and broad spatial optimisation framework will be created to inform the selection and implementation of appropriate adaptation actions to protect and enhance freshwater refugia at catchment and regional scales under a range of scenarios.</p> <p>(http://www.nccarf.edu.au/content/identification-and-characterization-freshwater-refugia-face-climate-change)</p>

4.2.4 Understanding future options

Future responses to climate change, and hence some of the response options have been explored with experimental systems and species distribution modelling. Using experimental systems such as the free CO₂ (FACE) system has shown that some species will be advantaged by climate change, while others will not (Hovenden et al. 2006; Williams et al. 2007). Species distribution modelling has been important in identifying future distribution and refugia (e.g. Prober et al. 2012).

Results from these and other studies suggest that future conservation goals may need to be revised. Prober and Dunlop (2011) suggest it will be important to shift our focus from preserving species and current species composition towards maintaining ecological and evolutionary processes.

Establishing new conservation reserves is a key management response to promote the persistence of biodiversity under climate change. Mokany et al. (2013) simulated a number of reserve design strategies for Tasmania using a dynamic macroecological modelling approach to compare the outcomes under climate change for plant biodiversity in Tasmania (a set of 2051 species). The most effective reserve design strategy under climate change depended on the specific conservation goal and demonstrated that adherence to a single habitat configuration strategy, such as connectivity, is unlikely to result in the best outcomes for biodiversity under climate change. The best reserve design strategy under climate change will vary between regions due to unique combinations of attributes and between taxa due to contrasting dispersal abilities. More quantitative assessments are required to identify Tasmania's reserve configurations that will best retain the biodiversity of each region under climate change.



Photo 5. Movement of grazing animals into alpine areas will change vegetation patterns
Photo: Patrick Medved

The future options will include selection of a combination of passive (e.g. reduce stressors) and active management (e.g. translocation). The balance of these will differ by region and ecosystem – tools to select these options are needed. In freshwater systems for example, translocation of species and control of invasive species are considered the main active adaptations. Reducing impacts of water consumption and protecting or restoring connectivity and refugia are examples of passive adaptations for conservation of freshwater ecosystems (Jenkins et al. 2011; Morrongiello et al. 2011). Development of holistic catchment impact and management plans (e.g. NRM South Tasman Catchment Report) will form a baseline for planning climate adaptation.

Monitoring change in terrestrial systems is underway in Tasmania, particularly in World Heritage areas (RMC 2012), and for iconic alpine species (e.g. pines, Fitzgerald 2011).

The availability of the Climate Futures Tasmania model projections has supported development of an adaptation planning framework for freshwater biodiversity. Barmuta et al. (2012) investigated how these projections could be coupled with more detailed hydrological models and freshwater biodiversity data to evaluate adaptation actions at local, regional and state scales for Tasmania, and to explore how adaptation priorities might be set. This research showed that downscaled climate modelling, linked with modelling of catchment and hydrological processes, led to improved projections for climate-driven risks to aquatic environments, allowing for comparisons between biodiversity assets. These projections at a river scale allowed visualization of regions that differed in climate-related risk (Figure 7).

The framework developed in this project for using and downscaling outputs from improved global climate models allow for improved and timely modelling, but projections are still dependent on the underlying biological data. In the freshwater systems investigated by Barmuta et al. (2012), improved data on thermal tolerances of freshwater biota are also needed. Climate model output may not represent the suite of variables needed for biological modelling, and so improved methods for predicting key variables from say, air temperature are also needed. In the case of freshwater systems, projections also need improved and high quality biodiversity data sets, and better spatially explicit information on the contributions of groundwater to surface waters and rates of recharge.

A range of adaptation options in four classes were derived to enhance the resilience of freshwater systems to climate change, including:

- direct interventions with in-stream, riparian or wetland habitats, such as fencing to exclude farm stock;
- water management options including dam management strategies or trading in water licenses;
- catchment management options including incentives for changes to farm management or incentives for riparian management; and,
- policy options that impact water or biodiversity management in freshwater environments, including management of freshwater fisheries or Ramsar listing of wetlands.

Organising these options by assessment of costs, benefits, feasibility and social acceptability should help with setting priorities (Barmuta et al. 2012). The next stage for Tasmanian water managers and users is to evaluate the range of options, and meet the challenge of water management for both biodiversity and human usage.

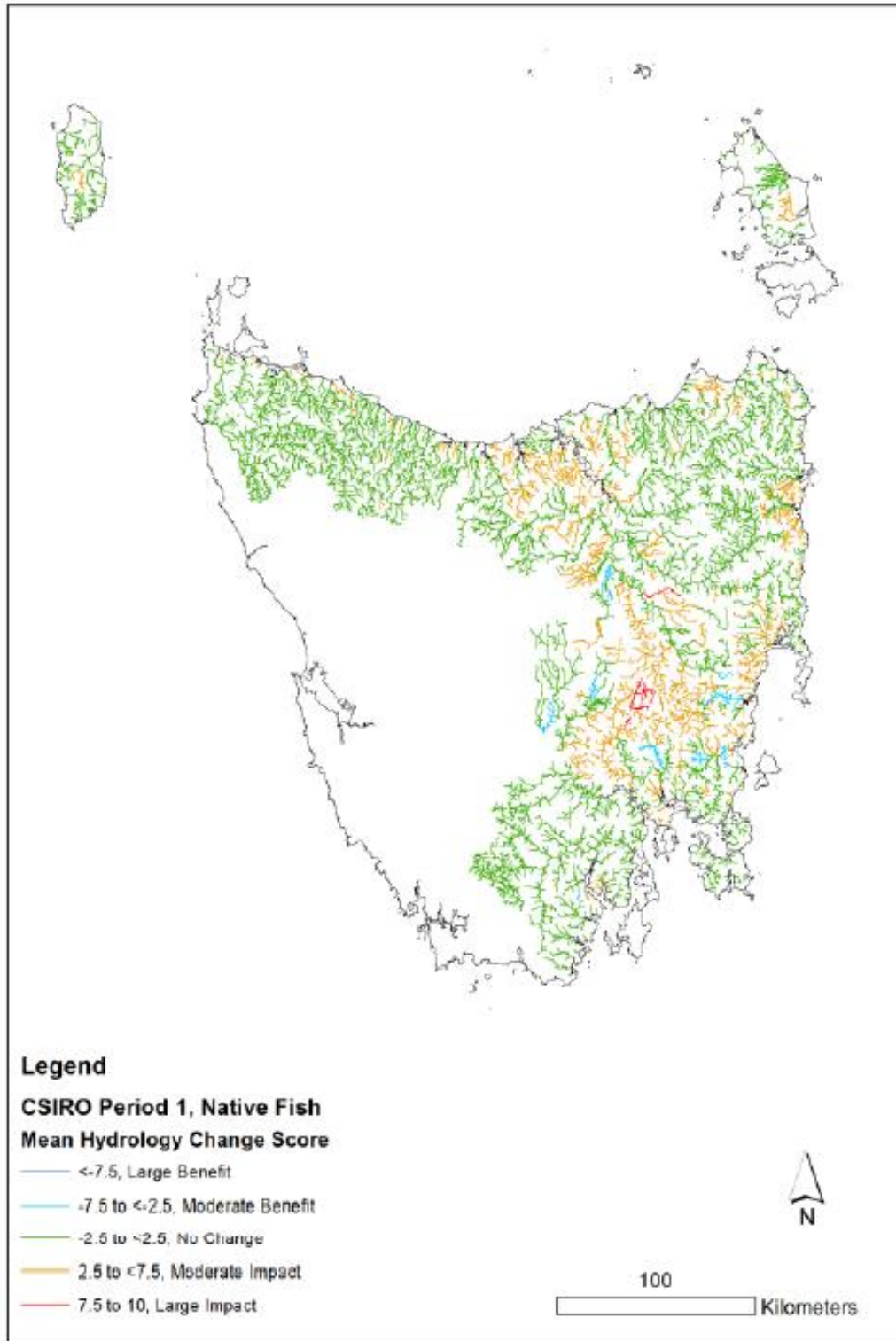


Figure 3. Hydrological risks to native fish condition where blue indicates a positive impact and red indicates a negative impact (original Figure 15 in Barmuta et al 2012)

4.2.5 Research gaps and future opportunities

Research on the impacts of climate change on Tasmanian terrestrial and freshwater species will continue to guide adaptation planning. However, given the number of species (e.g. 1,900 plants, 44 fresh water fish, 34 mammals), it is impossible to follow an ‘impact to adaptation’ pathway for most species. Priority species should continue to be those that are known to be threatened or vulnerable to existing threats. Vulnerability assessments based on coarse taxonomic groupings, or the limited available data can also direct particular attention to some species, but again dedicated impacts research might take many years to complete. Even without proof of climate impact, some testing of adaptation options can occur now. For example, studies evaluating the success of translocations to higher mountains to provide altitudinal refuge could be undertaken, building both the skill base of researchers and managers, and providing insurance populations for restricted species. This will require some more effort into distribution mapping, both of species, ecosystems and landscape stressors. Together, these approaches will help identify regions of Tasmania where opportunities for improved outcomes exist.

However, just as a complete set of species-level studies cannot underpin timely adaptation planning and action for Tasmanian biodiversity, so too is species-by-species implementation of adaptation options unrealistic and undesirable. This reality is reflected in recent calls for a shift in focus from individual species management to an ecosystem-level approach (Prober & Dunlop 2011). Thus, research on impacts and adaptation options for whole systems, while limited, are a priority. Research gaps at this scale include:

- determining the advantage of reducing the non-climate stressors on species and landscapes. For example, does improved water flow lead to more resilient watersheds, that can better cope with climate related trends and extremes?
- how should agricultural practices (such as wind breaks) and rotation of livestock be managed to increase biodiversity outcomes.
- how should fire management practices consider biodiversity impacts. Current debates around burning off to protect infrastructure and conservation management will intensify as dangerous fire weather days become more frequent.


Finally, adaptation to climate change in Tasmania cannot be considered in isolation, as Tasmania will both gain and lose species. Tasmania will be a natural refuge for some species, including those that can cross Bass Strait autonomously, but directed translocations are also an option, both from and to Tasmania. Policy may need to be updated to accommodate or prevent proposed translocation adaptation options, and will need to address questions such as:

- Should Tasmania be a refuge for mainland Australia?
- What species should be accepted as climate refugees to Tasmania?

In preparing adaptation options, it is important to consider the community support for a range of options, and social research is needed to determine where extension and education will be needed to overcome barriers to some adaptation options.

Lessons learned from Tasmania’s terrestrial and freshwater environments could be extended to other regions in Australia, where stressors are less easily manipulated (e.g. water flow management).

4.3 Marine biodiversity and resources

 Key findings – Marine biodiversity and resources	
Climate change impacts	<ul style="list-style-type: none"> ◆ The east coast of Tasmania is part of a global warming hotspot where the rate of ocean warming is about four times above the global average. ◆ The East Australia Current has strengthened, carrying warmer water southward which, with the background warming, has led to many new species extending their range into Tasmania.
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ Changes in species composition have led to declines in marine productivity and generally negative effects. ◆ Increased availability of northern fish species has been welcomed by recreational fishers. ◆ In some regions, aquaculture is experiencing production impacts due to warming waters and the presence of novel species, including blooming algal species.
Current adaptation efforts	<ul style="list-style-type: none"> ◆ Reduction of non-climate threats through fisheries management and marine protected areas has been a focus. ◆ Recognition of climate threats has led to changes in management by fisheries and aquaculture and limited experiments with translocation and ecosystem-based management, such as protection of large predators.
Future options	<ul style="list-style-type: none"> ◆ Arrival of new species will offer some new opportunities for commercial and recreational fishers, although declines in productivity mean these arrivals are not likely to offset losses. ◆ Identification and protection of ‘refuge areas’, careful use of management options such as translocation, and reduction of non-climate stressors will all be important strategies.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ The focus on ocean warming as the prime driver of change in Tasmania’s marine environment should be complemented by additional targeted research on ocean acidification. ◆ Development of strategies to respond to observed change are being developed, but additional simulation testing can further inform stakeholders about their response options.

4.3.1 Understanding climate change impacts

Tasmania lies at the intersection of three ocean currents – the warm southward flowing east Australia Current along the east coast, the southward flowing Zeehan (or Leeuwin current) on the west coast, and the circumpolar flow of southern ocean waters (Cresswell 2000). These currents are responsible for the movement of heat, nutrients, and a range of species to Tasmanian waters. The east coast of Tasmania has warmed at almost four times the global average rate (Holbrook & Bindoff 1997; Ridgway 2007). Reports of this rapid warming led to recognition of the south-east Australia marine region as one of about two dozen global marine ‘hotspots’ – where warming is in the fastest 10% of regions worldwide (Hobday & Pecl in press).

Marine research in this area has a long history. Time series are available of various physical and biological parameters essential for a detailed understanding of physical properties of the ocean and to identify trends and changes in these properties (Lough & Hobday 2011). Between the 1940s and 1970s, some 45 coastal monitoring stations were established around Australia. By 2000, only three monitoring sites remained, including one located off the east coast of Tasmania close to Maria Island. Oceanographic analyses based on this time series and nearby data showed that over recent decades, Australia’s south-east marine waters have warmed rapidly (Holbrook & Bindoff 1997; Ridgway 2007) as a result of increased southward penetration of the East Australia Current (EAC) (Ridgway 2007). Satellite altimetry (post-1990) together with *in situ* subsurface temperature and salinity measurements suggested that the EAC extension is likely to be due to the decadal-scale ‘spin-up’ of the South Pacific Gyre (Roemmich et al. 2007). Furthermore, ocean modelling studies suggested that the spin-up of the gyre is caused, in part, by the combination of greenhouse warming and ozone depletion (Cai 2006; Cai et al. 2005).

Average sea surface temperatures in this region are projected to be 2 to 3° C higher than the 1990–2000 average by 2050 (Hobday & Lough 2011), due in part to increased southward flow of the EAC (Cai et al. 2005). Inter-annual variability (e.g., El Niño – Southern Oscillation (Holbrook et al. 2012)) also results in warmer than average marine conditions in some years and can affect fishery production and profits (e.g. salmon, Battaglione et al. 2008). Thus, operating in a warmer ocean climate is both a current and a long-term challenge for many marine users and industries (Hobday et al. 2008).

Changes in other ocean variables also have an impact on Tasmanian marine waters, but temperature and ocean circulation are the dominant factors reported to date (Lough & Hobday 2011). Ocean acidification may be important in future, but no impacts have been detected in our region (Poloczanska et al. 2012a). To the south, changes in phytoplankton species composition have been attributed to ocean acidification (Cubillos et al. 2007).

There have been documented changes at most levels of the marine food chain in south-east Australia (Frusher et al. in press). In Tasmania, changes include poleward range shifts for 50% of intertidal invertebrates (Pitt et al. 2010); the sub-tidal urchin *Centrostephanus rodgersii* (Ling et al. 2009a; Ling et al. 2009b); over 45 coastal fish species (Last et al. 2011); phytoplankton (Hallegraeff 2010; McLeod et al. 2012a; Thompson et al. 2009); and several zooplankton species (Johnson et al. 2011). There have also been changes in recruitment in lobster populations (Pecl et al. 2009) and regional changes in prey availability for small pelagic

fishes (McLeod et al. 2012b), which may have changed the relative abundance and distribution of small pelagic fishes such as jack mackerel and redbait.

Observational evidence from commercial and recreational fishers reporting sightings of species that were new to southern waters has become common, even if climate change is not seen as the driver of change (Nurse-Bray et al. 2012). However, many commercial fishers now realise that their target species may be potentially vulnerable to climate related changes.



Photo 6. The value of the seafood industry makes the impacts of climate change a major concern Photo: Alistair Hobday

4.3.2 Understanding sectoral vulnerabilities

These changes in distribution and abundance have an impact on fisheries, conservation and aquaculture (e.g. Madin et al. 2012). Fisheries impacts garner much of the attention (e.g. Hobday et al. 2008). Australia's fishery production (wild and aquaculture) was worth \$2.18 billion in 2009–10 (ABARES 2011). Tasmania accounted for the largest share of gross value of production (26%), followed by South Australia (18%) and Western Australia (17%). In Tasmania, seafood contributes over a third of the state's overall agricultural production, and so impacts of climate change are of particular concern. Additional statistics for seafood value by species are available from ABARES (2011).

4.3.2.1 Recreational fishing

Recreational fishing is a major activity with nearly 28% of Tasmanians actively involved (Henry & Lyle 2003). The sector is anticipating the increased occurrence or arrival of sought-after recreational species such as yellowfin tuna, marlin, pink snapper, king george whiting, and

yellowtail kingfish. Declines in availability of popular species such as rock lobster, abalone, and striped trumpeter have been attributed to commercial overfishing, rather than recreational impact, or climate change.

4.3.2.2 *Marine biodiversity*

Global climate change is predicted to have major negative impacts on biodiversity, particularly if important habitat modifying species undergo range shifts. Changes to marine habitats and biodiversity are best understood for the east coast of Tasmania, where sea urchin-induced changes to sub-tidal habitat have received wide attention (Ling 2008; Ling et al. 2009a, 2009b). The sea urchin *Centrostephanus rodgersii* has recently undergone poleward range expansion to relatively cool, macroalgal-dominated rocky reefs of eastern Tasmania. In high densities, this species creates 'barrens' – habitat grazed free of macroalgae, which can impact on local fisheries productivity (Johnson et al. 2011). The faunal community of the barrens habitat is overwhelmingly impoverished.

Ling (2008) reported that only 72 surveyed species were present within incipient barrens, compared with 221 within intact macroalgal beds. Options for managing or reversing these impacts have been proposed, and include translocation of large predators (Casper et al. 2011; Green et al. 2010) and creation of marine reserves (Ling & Johnson 2012). Limited economic analysis shows that Tasmanian fisheries, particularly abalone, may be vulnerable without adaptation efforts (Norman-Lopez et al. 2011).

Marine tourism in Tasmania includes recreational fishing and diving opportunities, as well as limited iconic animal viewing (whales, seals, seabirds). Evidence elsewhere suggests that some of these iconic species will be winners and others losers as a result of climate change (see Marine Report Card by Poloczanska 2009, seabirds, mammals; Chambers et al. 2011).

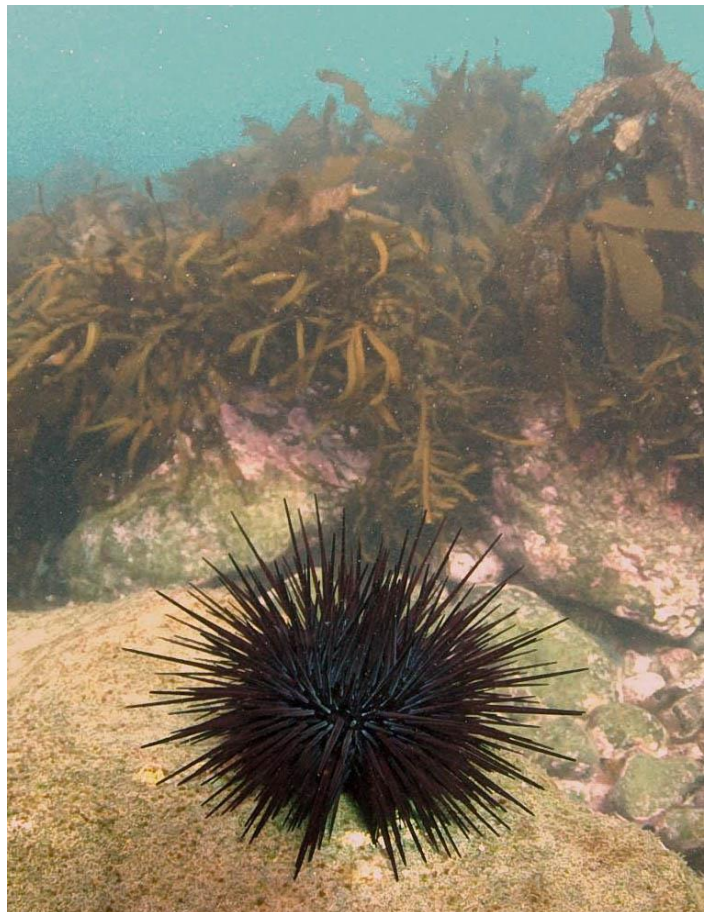


Photo 7. Poleward range expansion of *Centrostephanus rodgersii* creates species 'barrens' Photo: Scott Ling

4.3.2.3 *Wild fisheries*

The target species in Tasmania's most valuable wild fishery, southern rock lobster, are potentially vulnerable to climate change due to their very long larval duration (up to 24 months) and thus to changes in currents, and to their dependence on a habitat type impacted

by the range-extending urchin *Centrostephanus* (Johnson et al. 2011; Pecl et al. 2009). There is a negative correlation between observed larval settlement and rising temperatures, suggesting that stock size may be lower in future. There is also increased lobster mortality in traps due to octopus predation (Pecl et al. 2009) which is projected to increase in future as octopuses are advantaged by a warming ocean (Andre et al. 2010).

Risk assessment of a number of other Tasmanian fishery species (Pecl et al. 2011) is also guiding more detailed assessment of impacts and adaptation options (e.g. the SEAP NARP project noted in Table below).

4.3.2.4 Aquaculture

The Tasmanian aquaculture industry is dominated in volume and value by the cage-based Atlantic salmon industry, which has grown from establishment in 1984 to now represent Australia's most valuable seafood industry (ABARES 2011). Australian salmonid production increased from 14, 673 tonnes in 2000–01 to 31, 915 tonnes in 2009–10 (117% growth), almost entirely due to production in Tasmania. In 2009–10, Tasmania produced 30, 950 tonnes of salmonids, accounting for 97% of Australian total salmonid production. The remaining 965 tonnes were produced in New South Wales and Victoria. The value of salmonid production rose by 13% (\$43 million) in 2009–10 to \$369.1 million. This increase was driven mainly by a 14% (\$43.2 million) increase in the value of Tasmanian salmonids production, with Tasmania's total production accounting for 98% of the total value. Additional expansion in volume and farm sites is underway and planned over the next decade. In Tasmania, the salmonid industry is an important regional employer.

Salmon are produced in land-based hatcheries, grown in ponds for 6–12 months, and then moved to coastal sea cages for the final two years of production. These sea cages are located in sheltered embayments, and are influenced by open ocean conditions, terrestrial freshwater runoff and air temperatures. Fish health and growth are both strongly influenced by ocean temperatures, with salmon in some Tasmanian regions grown in waters approaching their upper critical temperature range (>20°C) in summer (Battaglene et al. 2008). High summer temperatures pose a significant risk to the production systems of these farms, and even more so in the future given projected temperature increases under climate change in this climate hotspot. Under climate change this upper thermal limit is predicted to be exceeded more frequently, particularly in south-east Australia (Hobday & Lough 2011), which could lead to degraded fish health, increased disease outbreaks and mortality (Battaglene et al. 2008).

Other aquaculture industries in Tasmania include land-based abalone farming and rack-based mussel and oyster production. The land-based abalone farms are considered less vulnerable to climate change (Doubleday et al. 2013), while the mussel and oyster farms are at risk from extreme rainfall events, which lead to sudden declines in salinity, and the warming and stratification of the surface waters which can lead to increased risk of harmful algal blooms (Hallegraeff 2010).



Photo 8. High summer temperatures pose significant risks to salmon production systems Photo: Alistair Hobday

4.3.3 Existing adaptation efforts

One of the eight National Climate Change Adaptation Research Facility (NCCARF) research networks is focussed on marine biodiversity and resources (<http://www.nccarf.edu.au/marine/>) and hosted at the University of Tasmania (convenor Neil Holbrook). While this is a national network, it has also been responsible for raising awareness of the rapid change in Tasmanian waters, and become an important vehicle for advancing some of the research responses and for delivering the research findings, in particular with a range of fact sheets and guidance documents (see www.nccarf.edu.au/marine/).

Table 5 sets out the on-going Tasmanian-relevant projects funded by the Fisheries Research and Development Corporation and the Department of Climate Change and Energy Efficiency on behalf of the Australian Government in respect of marine biodiversity and resources.

Table 5. Marine biodiversity and resources projects relating to Tasmania

Title	Objectives
<p>2010/532 FRDC-DCCEE Changing currents in marine biodiversity governance and management: responding to climate change Michael Lockwood September 2013</p>	<p>This project will identify adaptive governance and management arrangements for conserving marine biodiversity in the context of climate change. Case study areas have been selected as the Whitsunday region (Cth/Qld waters), Tweed-Moreton region (Cth/Qld/NSW waters) and Freycinet bioregion (Cth/Tas waters). Requirements for adaptive governance and management of marine biodiversity have been developed through analysis of the literature, consultations with our agency and technical advisory groups, and judgements of an expert panel.</p>
<p>2010/506 FRDC-DCCEE Adaptive management of temperate reefs to minimise effects of climate change: developing new effective approaches for ecological monitoring and predictive modelling Neville Barrett End date April 2014</p>	<p>This work builds on data collected from past surveys to determine shifts in distribution and abundance of species. It will suggest adaptation strategies for fishery and marine park managers. Based on a long-term database spanning over 20 years of the abundance of temperate reef biota in southern NSW and Tasmania, and another database of the abundance of reef taxa collected all around Australia (Reef Life Survey project), this project is developing adaptive management strategies from models of the changes of abundance distributions of organisms. These temporal changes relate to environmental parameters such as temperature, which will inform potential management decisions.</p>
<p>2010/533 FRDC-DCCEE Human adaptation options to increase resilience of conservation-dependent seabirds and marine mammals impacted by climate change Alistair Hobday End date January 2013</p>	<p>This work will provide an insight into the effects of climate change on a number of iconic species, develop adaptation options, and recommend best-practice monitoring.</p>
<p>2010/564 FRDC-DCCEE Preadapting a Tasmanian coastal ecosystem to ongoing climate change through reintroduction of a locally extinct species Nic Bax End date March 2013</p>	<p>Using highly valued species, including blue groper, the potential for translocating fish as an adaptation policy is being investigated.</p>

Title	Objectives
2010/542 FRDC-DCCEE A climate change adaptation blueprint for coastal regional communities Stewart Frusher and Nadine Marshal End date June 2013	The project aims to develop a blueprint for coastal regional communities that enables these communities to understand the biophysical, social and economic implications of climate change on marine resources (commercial and recreational fishing, tourism, aquaculture) and thus facilitate appropriate adaptation options.
2011/039 FRDC-DCCEE SEAP Case Studies Gretta Pecl and Tim Ward End date March 2014	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 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.

There has been rapid development of an adaptation-focussed research agenda in marine systems, which has occurred despite limited understanding of biological climate impacts (Frusher et al. in press). This shift in focus to research required to deliver adaptation outcomes has led to more multi-disciplinary teams involving stakeholders from the beginning of the research process. For example, the potential impacts of climate change on marine biodiversity conservation on the east coast of Australia, including Tasmania are variable, so engaging with stakeholders has been used to provide ongoing reference points for contemporary decision making and planning (Haward et al. 2012). Refinement of management and governance in the marine sector may also lead to improved outcomes under climate change (Lockwood et al. 2012).

There have been few examples of direct response by the marine sector to climate change, despite the overwhelming evidence to date. This is in part due to the range of other issues that require attention in the marine sphere, including fisheries management and aquaculture zoning, and the perceived time horizon for climate change impacts to become critical. Many marine resource users do recognise that an understanding of future environmental conditions can assist in planning activities, minimising risks due to adverse conditions, and maximising opportunities.

For several fisheries and aquaculture industries, knowledge of climate impacts has altered decision-making. For example, the rock lobster fisheries managers in south-east Australia have altered their assessment models to account for the decline in recruitment associated with warming waters. There is also overall industry acceptance of the implications of increasing water temperatures on the future harvest potential of the Tasmanian rock lobster fishery (DPIPWE 2010c). In the year following the release of the Pecl et al. (2009) case study, the rock lobster industry accepted reduction in the Total Allowable Catch (TAC) and linked decreases in catch rate on the East Coast of Tasmania to reduced larval settlement (DPIPWE

2010c). Other fisheries sectors are also considering the implication of climate change on their assessment processes (e.g. Wayte 2012).

In aquaculture, the salmon industry recognised warming waters as a potential threat and identified research initiatives to reduce risk, such as disease management, selective breeding, infrastructure development and improved climate forecasting (Battaglione et al. 2008). Short-term farm management is assisted by weather forecasts, whereas longer-term planning may be hampered by an absence of useful climate information at relevant spatial and temporal scales. Seasonal forecasts of water temperatures for south-east Tasmanian Atlantic salmon farm sites several months into the future are provided by CSIRO (Hobday et al. 2011). Information on future ocean conditions up to several months into the future for the salmon aquaculture industry will enhance environment-related decision making of marine managers and increase industry resilience to climate variability.

A range of adaptation options exist for marine species and fisheries (Koehn et al. 2011). For example, translocation of some marine species to more suitable habitats around Tasmania is an option under climate change, and pilot translocations have occurred for rock lobster (Green et al. 2010). Other options remain to be tested.

4.3.4 Understanding future options

Future fisheries productivity will be impacted by climate change, particularly if the nutrient-poor EAC continues to influence the East coast of Tasmania. Projections using an ecosystem model based on assumed increases and decreases in primary productivity show a range of outcomes for target and non-target species in Tasmania (Watson et al. 2012) that may constrain future adaptation options for some fisheries. Such models provide a useful starting point for discussing these options.

Ecosystem impacts as a result of range extension of habitat-modifying organisms will be heterogeneous in space, and based on evidence that marine systems with a more natural complement of functional predators, can reinstate size and habitat-specific predator–prey dynamics eroded by fishing, marine reserves have been proposed as important in reducing the impacts of some range changing species such as *Centrostephanus* (Ling & Johnson 2012).

As climate change is just one of several stressors on marine environments, adaptation strategies must complement current efforts to improve marine management. Thus, developing decision-support tools that integrate non-climate stressors and inform decisions about when, where and what adaptation action is appropriate are critical in future adaptation research. These tools and approaches (e.g. Koehn et al. 2011) should also seek to resolve how governance at all scales, from the individual through to jurisdictions, can be coordinated for better outcomes (Frusher et al. in press). Researchers must also work across these scales to support wise and timely decision making.

Research currently underway is seeking to test these approaches and support end-users. Simulation testing is critical to inform options and design appropriate monitoring, as proposed for the Tasmanian rock lobster fishery (e.g. Marzloff et al. 2011).

4.3.5 Research gaps and future opportunities

Knowledge regarding the primary impacts of climate change on species is limited to species of conservation or commercial importance, and is limited in the range of impacts that are understood. For example, while impacts of warming oceans are reasonably clear, resulting in changes in distribution, the impacts of ocean acidification on marine resources, particularly valuable fishery (e.g. abalone) and aquaculture (e.g. oyster) species is extremely limited. Experimental studies need to be completed for a range of species, across their life cycle, as vulnerability varies with life stage. These candidate species should be selected on the basis of economic value to Tasmania, and obvious candidates are abalone, rock lobster and oyster.

Where research on impacts is included as part of an adaptation research program, such research should also be guided by the prospect of intervention – for example, investigation of the impacts of ocean acidification on phytoplankton, while important, are not likely to improve adaptation options. Thus, research projects that can include consideration of adaptation options – e.g. what options will be available for aquaculture businesses that rely on species impacted by declining pH – should guide research providers.

There is recognition that some adaptation options will require considerable lead times, and hence research into the timeliness of adaptation interventions – such as cost-benefit studies – are needed. Should a business relocate before impacts are apparent, or will post-impact adaptation suffice?

In the case of changing species distributions, there may need to be development of policy positions that clarify the allocation of new resources to users – how to manage access to range-changing species that could form valuable new fisheries.

Integrated multi-disciplinary studies are also needed, particularly to evaluate the socio-economic impacts of climate change on marine species and resources. These studies can then support additional research, or focus efforts where socio-economic impacts will be greatest.

Traditionally, marine conservation management and marine resource management have been separate – in future, these research and management areas should overlap to a greater extent. Considerable focus should be on developing win-win options (Grafton 2010), where short-term benefit is also compatible with long-term sustainability, for both marine sectors.


'... focus should be on developing win-win options, where short-term benefit is also compatible with long-term sustainability, for both marine conservation and marine resource management.'

Communication is a key priority identified by stakeholders (Holbrook 2011), and researchers should continue to develop tools, skills and products for communicating both climate impacts and adaptation options. For the marine conservation sector, communication and education was identified as being either uniquely most important, or at least equally most important, by government, NRM and NGO representatives. This represents a clear message by the sector of the need for improved communication and education to better facilitate marine conservation in a changing climate.

Leading examples from the marine sector include both Tasmanian and National products and include the two marine report cards (Poloczanska et al. 2009, 2012) which discussed observed and projected impacts, adaptation options and knowledge gaps (<http://www.oceanclimatechange.org.au>), and targeted Tasmanian seafood industry information (e.g. TSIC Seaing change – http://www.tsic.org.au/files/Projects/Seaing_Change_Optimised2.pdf). Tasmania has also been the home to the innovative citizen science program REDMAP (www.redmap.org). This web-based initiative sees marine users report their unusual species for verification and mapping by a team of scientists and has now been extended to provide national coverage.

Hotspot regions, such as on Tasmania's East coast, provide natural laboratories for considering the impacts of global warming and thus an opportunity to test approaches and methodologies (Frusher et al. in review; Hobday & Pecl in press). The identification of marine waters off south-east Australia as a hotspot location has seen this region become a central focus for marine climate change research in Australia – a review in 2011 identified some 40 active projects focussed on fisheries, aquaculture and biodiversity (Pecl & Hobday pers comm.). Lessons from this region can see early adaptation and lessons transferred to other regions warming less rapidly (Pecl et al. 2010). A range of adaptation options exist (Koehn et al. 2011), but effectiveness needs to be explored, tested and observed in practice, under an adaptive management philosophy; indeed, an adaptive management approach is likely to be required as there are still many unknowns in this hotspot region. As part of such an approach, monitoring will be critical to assess the effectiveness of adaptation actions. However, existing monitoring programs in this region of rapid change are sparse with regard to ecological components while social or economic indicators are almost entirely absent. Progress will only be enhanced with improved and targeted monitoring, and research to design cost-effective approaches, including use of new technologies, is needed.

4.4 Land use planning

 Key findings – Land use planning	
Climate change impacts	<ul style="list-style-type: none"> ◆ storm surge, coastal erosion and inundation are all projected to increase with sea level rise. Inundation and storm surge mapping is available for sea level rise at 0.2 m increments up to 1.2 m. Erosion maps are in preparation ◆ fire risk is also expected to increase
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ numerous values and assets are located within current or potential storm surge and SLR coastal hazard zones. ◆ land use planning can minimise or avoid the location of new settlements in vulnerable areas; reduce the exposure of and promote adaptation efforts in existing settlements
Current adaptation efforts	<ul style="list-style-type: none"> ◆ the state has introduced sea-level rise planning allowances and a Bushfire Planning Code ◆ regional land use strategies all refer to the need to minimise exposure of new and existing settlements to climate change hazards
Future options	<ul style="list-style-type: none"> ◆ transferring the lessons learned from numerous local and regional initiatives, such as the Tasmanian Coastal Adaptation Pathways project will facilitate state-wide improvements in planning ◆ the current ambit of land use planning will need to be extended to achieve adaptation for existing settlements and infrastructure
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ how best to apply and transfer adaptation planning insights across places and projects ◆ assessing the suitability of the current governance arrangements for planning in Tasmania for adaptation needs

Land use planning plays an important role in determining the scope, location and operating conditions for a range of sectors. . It affects development for human settlements in areas prone to bushfire, flood or coastal hazards, as well as the allocation of land for industry, agriculture, forestry, conservation, water catchment management, and hazard mitigation. . The way in which land use planning responds to the impacts of climate change therefore has a critical influence on the way other activities, sectors and business adapt. . To date, the primary

focus has been on planning responses to risks posed to urban development and the built environment.

The impacts of climate change will affect human settlements and the infrastructure that supports them in a range of ways. Coastal communities will face increased risks from hazards such as inundation, storm surge and coastal erosion. More intense precipitation events will cause flooding and increased bushfire conditions will expose communities to greater risk from bushfire. The expansion or establishment of new settlements in areas vulnerable to flooding, inundation, erosion or bushfire will exacerbate the risks posed by climate change. There is a significant body of literature nationally and internationally (see Macintosh et al et al 2013) to suggest that land use planning that considers these future risks and that ensures new development is located away from vulnerable areas will be a critical part of the adaptation challenge.

4.4.1 Understanding climate change impacts

The *Climate Futures for Tasmania* project has provided a significant research base for planning in respect of several climate change risks, notably flooding and extreme events (White et al. 2010a). State-based and national research has examined the likely impacts of projected sea level rise on coastal inundation in the form of increased frequency of high sea-level events (Hunter 2012). New estimates of historic coastal sea levels over the last few hundred years have been made based on examination of sedimentary records along the east coast of Tasmania (Gehrels et al. 2012). They confirm a significant acceleration in the rate of sea-level rise since the early 20th century.

Other research has considered the impacts of storm surge and erosion combined with sea-level rise (SLR). Sharples (2006) conducted a first pass assessment of the vulnerability of 84% of the Tasmanian coastline to storm surge inundation and shoreline erosion as a consequence of sea level rise. T

The study mapped the potential storm surge inundation zones based on historically recorded storm surge events, factoring in an increase in the hazard zone with projected sea-level rise. These zones corresponded to coastal areas potentially susceptible to flooding in a 0.01% exceedance (approximately 2 year return period) storm surge event. Further work to identify extreme sea-level exceedance levels for the state was undertaken by Hunter (2008).

Two additional phases of coastal inundation mapping have now been completed for Tasmania. Stage 1 (Mount et al. 2011) mapped:

- 1 locations potentially affected by sea level rise at 0.2 m increments up to 1.2 m, plus 1.6 and 2.0 m above a base tidal height; and
- 2 locations potentially affected by flooding associated with storm-tide exceedance events at exceedance probabilities of 25%, 50% and 75%, averaged for the periods 2010–2050 and 2010–2100, with and without sea level rise.

It also provided coastal reference heights in a 1 km grid for the Tasmanian coastline. These can be used to look up hazard threshold heights for a specific 1 km square area. Stage 2 mapped a set of sea level rise scenarios around the coast using allowances, based on the

A1FI SRES scenarios and regional SLR projections. The result of this phase was a set of coastal area inundation maps to inform future coastal planning (DPAC 2012b; Lacy et al. 2012).

A similar spatial mapping exercise is currently underway for coastal erosion. About half of Tasmania's coastline is rocky, which means that there is likely to be limited recession as a result of SLR (DCC 2009). Sandy coasts comprise the other half, with risks of shoreline recession dependent upon whether the sandy coast is backed by soft sediment or bedrock. Several sections of sandy coast are already subject to severe erosion.

Storm surge, coastal erosion and inundation are all projected to increase, as will their likely impacts on coastal infrastructure, ecosystems and lifestyles.'

4.4.2 Understanding sectoral vulnerabilities

An assessment of Tasmania's coastal vulnerability formed part of the 2009 National First Pass Coastal Vulnerability Assessment (DCC 2009). Like everywhere else in Australia, the impacts of coastal erosion and other coastal hazards have been exacerbated by coastal development occurring too close to the shoreline and with little regard for sea-level rise and the active shoreline (Church et al. 2012).

Tasmania's population is concentrated along the coast, with about 75% of the population and most industry located in coastal local government areas. There is already a moderate exposure to storm surge, erosion and other natural hazards (DCC 2009; TCCO 2012a).

An estimated 6,100 properties are located within 110m of sandy shorelines, and hence potentially exposed to future coastal erosion, and 240 square km of coastal land is currently vulnerable to storm surge flooding (DCC 2009).

Storm surge, coastal erosion and inundation are all projected to increase, as will their likely impacts on coastal infrastructure, ecosystems and lifestyles. Inundation analysis based on a 1.1 m SLR estimates that 8,700–11,600 residential buildings with a replacement value of \$2.4–3.3 billion are vulnerable to inundation, more than half of which are located in the local government areas of Clarence, Central Coast, Break O'Day and Waratah/Wynyard (DCC 2009).



Photo 9. Climate change will exacerbate existing exposure to coastal hazards Photo: Alistair Hobday

A DPIW (2008a) desktop audit showed that numerous values and assets are located within current or potential storm surge and SLR coastal hazard zones, based on a SLR of 0.84 m above 2004 levels by 2100, plus a 50 m buffer. Vulnerable assets and values include natural reserves and other public land, public buildings, public recreation areas, highways and roads, schools, service stations, emergency services buildings, sewage and wastewater treatment plants.

Detailed analysis of exposure to inundation, coastal erosion and flooding has been undertaken for Clarence Council (SGS Economics & UNSW WRL 2008), with more modest investigations having been prepared for three other councils under the Tasmanian Coastal Adaptation Decision Pathways project (SGS Economics 2012a & b).

Work is currently underway on the impacts of climate change on bushfire conditions in Tasmania. Fire risk is expected to increase under climate change (White et al. 2010b) with associated risks for existing and new settlements. The recovery effort following the 2013 bushfires will provide important insights into the operation of the new Bushfire Planning Code in hindering or aiding adaptation.

The exposure of current settlements, and the limited application of land-use planning to new development, highlights the need for a three-pronged approach to planning for future impacts:

1. the use of planning instruments to minimise or avoid the location of new settlements in vulnerable areas;
2. the use of planning instruments to reduce the exposure of existing settlements (or mitigate existing and emerging hazards or risks), through mechanisms controlling redevelopment and in some places, implementation of managed retreat policies; and
3. the use of broader spatial planning instruments such as information instruments, financial mechanisms, and regulation to direct adaptation efforts in existing settlements (Macintosh et al. 2013).

4.4.3 Existing adaptation efforts

A range of adaptation activities in relation to land use planning are in place or underway, many of which have either been informed by, or have themselves produced, research outputs.

4.4.3.1 Planning for hazards framework

The State Government has embarked on an important initiative that will influence law and policy in respect of planning for coastal and other hazards. The development of Principles for the Consideration of Natural Hazards in the Planning System (DPAC OSM 2012) is addressing a wide range of natural hazards with climate change dimensions, including coastal erosion and inundation, bushfire, flooding, storms, and landslide. These principles, together with implementation guides, will form the basis for a new planning code in respect of each hazard.

4.4.3.2 Planning for bushfire hazards

The first such planning code – relating to development in bushfire prone areas in Tasmania – was released in September 2012. *Planning Directive No. 5: Bushfire-Prone Areas Code* requires all new planning schemes and Interim Planning Schemes to contain the requirements specified in the *Bushfire Code*. The purpose of the Code is:

to ensure that use and development is appropriately designed, located, serviced, and constructed, to reduce the risk to human life and property, and the cost to the community, caused by bushfires (TPC 2012).

The Code makes no reference to climate change as an exacerbating influence on bushfire in the state, but is nonetheless a valuable element of adaptation planning for bushfire. The Code is the product of a 2010 *Review of Construction and Development Control in Bushfire Prone Areas* (DPAC OSM 2010) by the Office of Security and Emergency Management within the Department of Premier and Cabinet. That Review recommended statewide mapping of bushfire-prone areas, but the Code uses a definition to identify bushfire-prone areas, rather than a spatial mapping approach.

4.4.3.3 Planning for coastal hazards

As noted above, considerable research has focussed on the identification and mapping of areas vulnerable to coastal hazards under future SLR. Hunter (2012) developed the technique used by the Tasmanian Climate Change Office for setting the sea level rise allowances required for Tasmania in order to preserve current return periods for extreme sea-level events. TCCO (2012b) has outlined the derivation of the state's planning allowance of:

- 0.2 m above 2010 levels by 2050; and
- 0.8 m above 2010 levels by 2100.

This allowance will form the basis of the Coastal Hazards Planning Code currently under development, and the subsequent modification of local government planning schemes across the state. The State Government has also released coastal inundation maps for the state, based on the sea level rise planning allowances, and is in the process of completing coastal erosion maps (TCCO 2012b). The Coastal Hazards Planning Code will form part of a broader statewide coastal protection and planning framework, which is expected to include provisions regarding protection of existing assets and infrastructure, allocation of roles and responsibilities, and liability principles (TCCO 2012b).

The former Department of Primary Industries and Water produced a General Information Paper articulating its policy on coastal hazards in Tasmania, and a set of internal principles guiding its management of Crown Land (DPIW 2008b). It is understood that the following principles are articulated in that guidance document:

- risks associated with coastal hazards rest with the property owner, whether public or private;
- DPIW (now DPIPWE) has no future obligation to repair or reduce the impacts of coastal hazards on private property or assets sited on public land;
- an open, evidence-based, risk-based approach will be taken to land use planning and decision making in coastal risk areas that will consider both the short- and longer-term consequences of planning and land use decisions;
- on land managed by DPIPWE, intensification of uses will be avoided, considering both short- and longer-term consequences; and
- human-made protections will generally be avoided.

4.4.3.4 Regional planning initiatives

Tasmania is divided into three regions for the purposes of regional land use planning (see Figure 8). Recent regional planning initiatives have explicitly mentioned climate change adaptation. The *Southern Tasmania Regional Land Use Strategy 2010–2035* (STRLUS) specifically identifies the impacts of climate change as an overarching consideration (STRLUS 2011). Strategic Direction 6 relates to ‘Increasing Responsiveness to the natural environment’ (STRLUS 2011) and advises that settlement planning needs to recognise natural values and hazards, and factor the presence of hazards into the identification of suitable areas for future development. It commits to minimising inappropriate residential development in areas at risk from hazards, including sea level rise and bushfire.

The strategy sees land use planning that takes hazards and risks into account as the single most important mitigation measure in areas of new development. In addition, the *Southern Tasmania Regional Land Use Strategy 2010–2035* specifically addresses bushfire risk. The first priority of the ‘Regional Policy for Management Risks and Hazards’ is to: ‘Minimise the risk of loss of life and property from bushfires’. This goal is to be achieved by addressing the management and mitigation of bushfire issues at the rezoning or subdivision stages, including in relation to vegetation clearance and the provision of safe road exit points; by identifying and protecting buffer zones; and through site design and layout – measures that are now covered by the Bushfire Code (STRPP 2011).



Figure 4 Map of planning regions in Tasmania

Source: Australian Dept of Education, Employment and Workplace Relations, jobsearch.gov.au

The policies on land use contained in the *Cradle Coast Regional Land Use Strategy* (CCRPI 2011) recognise that land use planning needs to ‘monitor the effects of climate change on the Region and apply an integrated mitigation, adaptation and risk management approach taking into account all relevant knowledge and available information.’ (CCRPI 2011) New development or intensification of existing development should be avoided on land that is already exposed to or affected by natural hazards, including coastal inundation and erosion and bushfire. The CCRLUS also provides that current and future landowners should be put on notice of existing and future risks. The *Regional Land Use Strategy of Northern Tasmania* (NTRCA 2011) also supports a risk-avoidance approach for new development and requires all local planning schemes to include provisions for areas subject to high coastal hazard, through overlays or zones and to restrict development so as to minimise the long term risk to life and property and minimise its impact on the coastal process. The *Northern Regional Land Use Strategy* (NTRCA 2011) also contains a regional policy of ensuring that future land use and development minimises the risk to people and property resulting from bushfire hazard. The associated actions for achieving this policy are to ‘include controls in planning schemes based on current best practice to minimise risk to persons and property resulting from bushfire hazard’ and ‘ensure subdivision design responds to bushfire hazard risks by providing for alternative access, building setbacks and buffer distances based on current best practice.’ (NTRCA 2011) These actions are likely to be achieved via the introduction of the new Bushfire Code.

4.4.3.5 Local planning

At present, in the absence of clear guidance from the state, responsibility for introducing planning controls relating to coastal climate hazards rests with local authorities. The sophistication with which local planning schemes address coastal hazards is highly variable across the state (Gibbs & Hill 2011; Macintosh et al. 2013). Clarence City Council, for example, has conducted extensive research into the present risks facing its coastline and the likely future scenarios under climate change, and has amended its planning scheme to provide controls that reflect these risks.

4.4.3.6 Adaptation training for planning professionals

The training of future planning professionals in climate change adaptation should enhance the incorporation of climate change impacts into future planning initiatives (Lyth et al. 2007). A project funded by the Australian Government Climate Change Adaptation Skills for Professionals Program entitled 'Climate Change Adaptation Planning for Planners of Built and Natural Environments', trialled the mainstreaming of climate change adaptation into existing postgraduate environmental planning and management coursework (Davidson & Lyth 2012). The *Climate Change Adaptation Planning (CCAP) for Planners of Built and Natural Environments* project produced curriculum materials for a core introductory module and four content modules for on-campus and distance learning modes. The result of this project has been the establishment of the postgraduate course unit, *Planning and Managing for Climate Change*, within the UTAS Master of Environmental Planning and Masters of Environmental Management courses in which Tasmanian students are enrolled and Tasmanian specific case studies and problems are included.

4.4.4 Understanding future options

The research undertaken to date has allowed significant progress on reforms to the planning regime. Completion of this reform is likely to minimise the exposure of new settlements to future risks. The NCCARF project *Limp, leap or Learn: A socio-legal analysis of planning laws for adaptation to climate change in Australian coastal settlements and bushfire-prone areas* developed a framework of design criteria and considerations for use in selecting the best legal instruments by which to implement spatial planning policy objectives for adaptation.

Photo 10. The TCAP project involved significant engagement with the community at Lauderdale

Source: www.ccc.tas.gov.au



This project has reviewed the current planning framework for coastal and bushfire climate hazards across all Australian jurisdictions including Tasmania, and has conducted in-depth interviews with planners in State Government and two Tasmanian local councils (Kingborough and Clarence) (Macintosh et al. 2013). The project did not attempt to guide local government in making policy choices around retreat, protection or accommodate for *existing settlements*, but instead, outlined the pros and cons of each instrument for implementing policy objectives agreed through other processes.

The State Coastal Framework is seeking to establish the policy settings at a state level, but further research will be needed to help guide those policy decisions. SGS Economics (2012b) suggests that this type of research will have to be highly place-based and there will be limited scope for transferability or extrapolation from other locations or experiences (SGS Economics 2012b). Experimentation with applying the outputs from the TCAP project to new locations could test this claim.

‘The assumption that planning can provide certainty for future development may need to be re-evaluated ... and the current ambit of land use planning will need to be extended to achieve adaptation for existing settlements and infrastructure.’


4.4.5 Research gaps and future opportunities

The importance of land use planning as a tool for adaptation means that we are likely to see new policies, laws and approaches over the coming decades, and on-going modifications to existing frameworks. The assumption that planning can provide certainty for future development may need to be re-evaluated in a future of uncertain bio-physical change and the current ambit of land use planning will need to be extended to achieve adaptation for existing settlements and infrastructure. Much of this research can occur at a national level and will apply with equal relevance to Tasmania.

The following gaps and opportunities of particular relevance to Tasmania are distilled from TCCO (2012a), Booth et al. (2011) and Cox et al. (2012):

- How the planning framework, including regional planning, should accommodate the long-term impacts of climate change, the likely impacts of extreme events, and the cumulative impact of multiple extreme events?
- Improving the communication of climate change impacts and engaging communities in adaptive responses
- The evaluation of costs of various adaptation options for existing communities in a way that is itself efficient and cost-effective
- Enhancing the processes of adaptation of existing communities to ensure they are consultative, locally-driven and participatory, and cost-effective
- Design and mix of instruments and incentives to promoting private adaptation
- Exploiting the synergies between climate change adaptation and mitigation
- Transferring adaptation planning insights across places and projects
- Assessing the suitability of the current governance arrangements for planning in Tasmania for adaptation needs.

4.5 Infrastructure and essential services

 Key findings – Infrastructure and essential services	
Climate change impacts	<ul style="list-style-type: none"> ◆ Research into climate change impacts on Tasmanian infrastructure and essential services has focussed on the implications of sea level rise. ◆ Increases in inundation, storm surge, flooding and bushfire as a result of climate change are likely to have impacts on infrastructure and essential services.
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ The degree of vulnerability of infrastructure to climate change depends on <i>the severity of climate change impacts, the adaptive capacity of the local community, and the location, age, design and construction method of the physical infrastructure.</i> ◆ Little is known about the flow-on effects to communities and economies from disruption or damage to infrastructure or essential services.
Current adaptation efforts	<ul style="list-style-type: none"> ◆ Several recent local projects and assessment tools reflect best-practice for climate change risk assessments for infrastructure. ◆ Climate change is being reflected in the management documents for several departments and organizations, including the Department of Primary Industries, Water, and Environment, and Hydro-Tasmania.
Future options	<ul style="list-style-type: none"> ◆ Where location or relocation to hazard-free areas is not feasible, new technologies, design and construction standards, and management, operating and maintenance protocols will be required to minimise risks to infrastructure.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ Use the 2013 bushfires as a case study to understand the full costs of infrastructure disruption and how to avoid these costs through design, modification, re-engineering of processes or other techniques.

Infrastructure and essential services encompasses public and private roads, rail routes and stock, power, water and sewerage utilities, waste disposal sites and an array of other less obvious but nonetheless significant infrastructure important to the functioning of communities and local economies. The physical impacts of climate change are likely to cause disruption and damage to, or loss of such infrastructure. The impacts generically and commonly mentioned include sea level rise, storm surge, wind and heavy rain damage, flooding, bushfire and heat stress. Examples of specific direct impacts include inundation or intermittent flooding

of transport routes and bridges (including major roads and local access routes serving industry, towns or communities), wind and heavy rain damage to power utility infrastructure, storm damage or flooding of water and sewerage plants. For Tasmania, most of these are relevant, although there has been a distinct focus on the impacts for infrastructure in coastal regions and the physical climate factors relevant to coasts. There has been some work undertaken on the indirect implications of climate change on river catchments and river flows important for Tasmania's hydro-electric power generation and future hydro-electricity infrastructure investment.

4.5.1 Understanding climate change impacts

Research into climate change impacts on Tasmanian infrastructure and essential services has focussed on the implications of sea level rise, although there has also been more limited attention to impacts from extreme weather events such as storms, flooding, and bushfire.

Sea level rise and coastal weather events have the potential for significant impacts in Tasmania. The majority of Tasmania's population lives in coastal areas (Steffen & Hughes 2011), with some 75% living in coastal councils (ABS 2012; TCCO 2012b), and key major industries and infrastructure assets located on or near the coast. Coastal regions have high social and economic significance (DCC, 2010). Tasmania is included in recent national assessments of climate change impacts relevant to infrastructure and essential services (e.g. DCC 2010; DCCEE 2011), and multi-sectoral adaptation responses (Gurren et al. 2011; Booth & Cox 2012). There are also a number of comprehensive state-based studies focussed only on Tasmania and the impact of sea level extremes (DPIW 2008a; DPIW 2008b).

In recent years, local government-driven projects have produced studies that explore vulnerability, risk and adaptation options associated with sea level rise and extreme coastal weather events such as storm surges (Clarence City Council see SGS Economics & Planning 2009); and vulnerability and adaptation issues for flood prone towns and communities in the Break O'Day Council (LGAT 2010). The first study was supported by the State Emergency Service and the Australian Department of Climate Change, the second by the Australian Government's Natural Disaster Mitigation Program.

Indirect effects on infrastructure and essential services through biophysical changes to the environment are mentioned in the literature. Climate Futures for Tasmania and the CSIRO Tasmanian Sustainable Yields project consider the future capacity for hydro-electric power generation given a likely reduction by 2100 of inflows to water catchments used for hydroelectric power generation (Bennett et al. 2010; CSIRO 2009). Other indirect effects on infrastructure and essential services do not appear to be a significant concern. For instance, a climate change impacts study for Clarence City Council (on Hobart's eastern shore) discusses salt-water intrusion into fresh groundwater and its potential impact on water supplies, but concludes that

Infrastructure and essential services

- Public and private roads
- Rail routes and stock
- Power, water and sewerage utilities
- Waste disposal sites
- Schools
- Parks and recreational assets

the short to medium term danger to health or property is likely to be minimal (SGS Economics & Planning 2009). There is also brief mention of contamination or pollution issues emerging as a result of sea level rise and flooding of coastal infrastructure such as service stations (DCC 2010).

4.5.2 Understanding sectoral vulnerabilities

Vulnerabilities are predominantly discussed in the context of how infrastructure and essential services:

1. might be damaged or altered by changing climatic conditions affecting both the service delivery capacity of the infrastructure and essential service; or
2. where infrastructure components may need to be more regularly serviced or replaced.

There is little research into the flow-on effects to communities and economies and the adaptive capacity of these in the face of disruption or damage to infrastructure or essential service. The State Government's *Adapting to Climate Change in Tasmania Issues Paper 2012* acknowledges that the vulnerability of human settlements and infrastructure to climate change varies across the state and the degree of vulnerability depends on a range of factors:

including the severity of climate change impacts, the adaptive capacity of the local community, and the location, age, design and construction method of the physical infrastructure (TCCO 2012a: 10).

The same paper also acknowledges that essential infrastructure and services across the state are vulnerable to long-term impacts of climate change but that low-lying coastal settlements will be particularly vulnerable in the future (TCCO 2012a).

4.5.2.1 Assessing the extent and cost of 'at risk' infrastructure and essential services

Assessments of infrastructure and essential services that may be affected by climate change, in particular impacts associated with sea level rise, storms, or floods have been undertaken in projects led at the national, state and local levels. For example the Australian Department of Climate Change *Climate Change Risks to Australia's Coast: A first pass national assessment* (DCC 2010) assessed the potential extent of 'at risk' infrastructure for each state and territory, although most of its Tasmania-specific conclusions were based on work by the former Tasmanian Department of Primary Industries and Water, *Climate Change and Coastal Asset Vulnerability: An audit of Tasmania's coastal assets potentially vulnerable to flooding and sea-level rise* (DPIW 2008a).

This audit identified the following infrastructure as being at risk: schools, emergency services (primarily their capability to function and respond), service stations, sewerage and wastewater facilities, major roads and bridges, important local roads, parks and wildlife infrastructure, waste disposal sites and storage tanks or facilities (DPIW 2008a). Some 12 school sites were identified as being at risk, with these difficult to move in the short and medium term. Some 22 sewerage and wastewater treatment plants are exposed; and some 140 km of highway

sections and 706 km of local access roads are at risk (DPIW 2008a, DCC, 2010). The Clarence City Council and Break O'Day Council projects (SGS Economics and Planning 2009; LGAT 2012) mentioned above also make some assessments of infrastructure most at risk for their areas.

An NCCARF-funded study of climate change adaptation issues for country towns (including relevance to Tasmania) raised issues about the vulnerability of small country towns and communities, including the implications of the cost of damaged infrastructure and their capacity to pay for maintenance, mitigation of risk, or replacement. It also highlights the potentially significant social (e.g. community health impacts) and economic loss (e.g. loss of business and personal income) associated with disruption to infrastructure and essential services (Beer et al. 2012).

4.5.2.2 Understanding effects on resilience and adaptive capacity

There has been little Tasmanian-specific work on the flow-on effects of infrastructure damage or disruption to communities or economies. A national study of the vulnerability of community sector organisations under climate change is currently underway, led by the Australian Council of Social Services (ACOSS) and funded by NCCARF (NCCARF 2012c). The project, *Climate Change and the Community Welfare Sector* has surveyed almost 300 organisations nationally, including Tasmanian community sector organisations. The survey investigates the implications of a range of climate change factors on the delivery of services by these organisations, and the implications of this for adaptive and resilient communities. The survey included specific questions about the organisation's vulnerability associated with disruption of essential services such as power, water, telecommunications and transport. Project results should help guide Tasmanian organisations in prioritising the complexity of inputs required for to building resilient communities and adaptive capacity (Mallon et al. 2013).

4.5.3 Existing adaptation efforts

A limited number of Tasmanian projects have been cited as positive initiatives and best practice approaches to planning for and managing the implications of climate change on infrastructure and essential services in the national literature. For example, the NCCARF Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNIS) project, *Case Studies of Climate Change Adaptation Tools and Application Processes Used by Local Government Practitioners* (Booth & Cox 2012) notes the following Tasmanian initiatives and approaches:

- Launceston City Council: Local Adaptation Pathways Program (LAPP) funded risk assessment
- Devonport City Council and Cradle Coast Authority: coastal and regional risk assessments and adaptation action plans
- Clarence City Council: comprehensive coastal vulnerability study of climate change impacts and adaptive responses (includes the use of integrated spatial mapping, assessments of social and economic impacts, cost benefit analyses and risk communication strategies)
- Developments in spatial mapping tools that have since been used elsewhere in Australia.

The Booth and Cox study (2012) notes the lack of in-house expertise of local councils in adaptation planning. Tasmanian councils reported that council employees provided vital local context but this element also constitutes a potential weakness, and that local knowledge may not constitute the necessary expertise required to identify and assess risks.

The report refers to the difficulties of risk assessment experienced by Tasmanian councils, for example:

at Devonport and Launceston, the lack of in-house technical knowledge 'up-front' made it an onerous task for staff to source expert advice, conduct research, and apply high-level knowledge to [...] generate risk ratings (Booth & Cox 2012: 26).

Booth and Cox also evaluate the benefits and lessons from the Clarence City Council integrated coastal impacts study (SGS Economics 2009), including different ways of thinking and doing things in council, especially in conducting an iterative learning process (Booth & Cox 2012). Tasmanian projects funded by the Local Adaptation Pathways Program (LAPP) are also noted in a report to the National Sea Change Taskforce (see Gurren et al. 2011).

Other adaptation efforts in this sector relate to the development of tools for risk assessment for certain sectors (such as transport infrastructure) or use by local government. An example of the former is the acknowledged need for climate risk assessment in infrastructure, planning and assessment especially for roads. For example sea level rise is identified as a particular risk to the Bridgewater Bridge due to its location in the Derwent Estuary and past experience of flooding during extreme sea level events. The replacement bridge currently being planned will take into account climate change risks recognising that the majority of the risks associated with service quality and public safety may be avoided by building the replacement bridge in a location which is not prone to erosion from sea level rise or extreme events (DIER 2012; DIER n.d).

An example of the latter is the 'Climate-Asyst' tool developed by the Tasmanian-based engineering firm Pitt & Sherry. Climate-Asyst is a climate change decision-support tool providing resources to assist infrastructure owners, managers and planners to help determine the effect that projected changes in climate will have on services and infrastructure assets. (Pitt & Sherry n.d.). It was developed using CFT data and descriptions of the physical impacts of a warming climate in local government areas.

The former Department of Primary Industries and Water also produced a range of reports and tools to support adaptation. The 2008 desktop audit of infrastructure vulnerable to coastal hazards included suggestions on possible adaptation options (DPIW 2008a). These include a template coastal risk management plan (DPIW 2009a), for use by state agencies and local governments to manage risks to specific assets from coastal flooding and erosion, or discrete local areas where a number of particular assets at risk occur together. It has also populated the template using two 'amalgam' case study locations (DPIW 2009b). DPIW has also produced a Coastal Works Manual for local government and other land managers and contractors (Page & Thorp 2010). The Manual sets out best practice guidelines for small-scale works in coastal areas, taking into account likely changes to coastal processes under climate

change. Hydro Tasmania has also explored the impacts and risks for its hydro electricity generation capacity (see Bennett et al. 2010). Climate change opportunities, risks and adaptation are embedded into its organisational strategic planning processes and frameworks (Hydro Tasmania 2012).



Photo 11. Hydro Tasmania has explored the impacts and risks for its hydro electricity generation capacity Photo: Anna Lyth

4.5.4 Understanding future options

Future options for new infrastructure must be understood in the context of adaptation in land use planning. A logical response is simply to locate new infrastructure in locations that are not vulnerable to the impacts of future climate change (see Section 6.4 above). This is not always possible, however, so new technologies, design and construction standards, and management, operating and maintenance protocols will be required to minimise risks to infrastructure.

For existing infrastructure, replacement may provide opportunities for changes in technologies and materials, or relocation, if necessary, for critical infrastructure located in vulnerable areas. For existing infrastructure that is still fully functional, further understanding is required about how to re-engineer processes so as to minimise service disruption, and to understand the flow-on effects of infrastructure disruption and damage on community and economic resilience and adaptive capacity.

Both new and existing infrastructure will benefit from further development and trialling of new assessment and decision support tools, including integrated spatial mapping, and

technological innovations in data collection. It will also require new financing models. At the national level, it has been noted that regulatory barriers such as fixed pricing deters power utilities and transport infrastructure companies from investing in adaptation (Kiem et al. 2010b).

4.5.5 Research gaps and future opportunities


Recent summer (January 2013) bushfires in the southeast of Tasmania have confirmed thinking about research gaps and future research opportunities for a range of climate-related events. During these fires, the Tasman and Forestier Peninsulas lost road transport access and energy supply, isolating and affecting both resident and visiting populations (such as restricting access to local food, electricity, fuel, water supply and health services). Future research might include a case study of these events, their impacts on Tasmanian communities and their infrastructure and essential services, in order to understand:

- the full costs of infrastructure disruption, whether associated with bushfire or other climate associated events (including downstream or cascading impacts) on: communities; utility providers (such as energy, telecommunications and water utilities); property damage; and maintenance or replacement costs (especially those local government authorities that are resource poor);
- how to avoid these costs through design, modification, re-engineering of processes or other techniques;
- what the design options and principles should be for adapting new and existing infrastructure and buildings to climate change in Tasmania, and how these might be implemented;
- how to distribute the future costs of infrastructure upgrade and increased risk;
- approaches to, and development of, Tasmanian professional capabilities (knowledge and practical skills) to more confidently and effectively assess, plan and manage climate risks in the future. This includes education of engineers, trade workers, planners, designers, and local government practitioners; and strategies for community coping and response to loss in infrastructure and essential services.



Photo 12. The 2013 bushfires highlighted the potential impacts of climate-related events on infrastructure. Photo: Sarah Brabazon

4.6 Human health and community wellbeing

 Key findings – Human health and community wellbeing	
Climate change impacts	<ul style="list-style-type: none"> ◆ The direct adverse impacts on human health from extreme climate related events or conditions that face other parts of Australia may be less relevant in Tasmania and the state may even derive positive health benefits, for example through warmer winters. ◆ Climate change impacts are likely to be felt more through indirect impacts than direct impacts.
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ The health impacts of climate change include the implications for respiratory illness of changes in pollen allergens and bushfire smoke; infectious diseases; and mental health and overall community wellbeing issues associated with direct climate impacts, including disruption from extreme events and prolonged conditions, such as drought.
Current adaptation efforts	<ul style="list-style-type: none"> ◆ There is virtually no adaptation activity occurring in respect of human health, but research is examining impact assessment tools and early warning techniques for dangerous weather conditions. ◆ Assessments of risk, vulnerability and adaptive capacity have been conducted for Ross River virus.
Future options	<ul style="list-style-type: none"> ◆ A deeper understanding is needed at regional and community levels of indirect impacts from biophysical changes and the risks and social vulnerability associated with these.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ Regionally-focussed vulnerability and risk assessment and monitoring. ◆ Techniques for improving the responsiveness and management of health impacts or events as they arise, as well as preparing communities for longer term adjustment to changing environmental and health conditions.

The impacts of climate change on the health and wellbeing of the Tasmanian population remains largely unstudied, despite reference to potential impacts in some work (Steffen & Hughes 2011). As a consequence, there is equally little research about adaptive options and approaches.

Climate change adaptation and human health research undertaken at the national level has been guided by the *National Climate Change Adaptation Research Plan for Human Health* (McMichael et al. 2009). The Research Plan identifies key research questions within sub-themes – heat, extreme weather events, vector-borne diseases, food safety and quality, air quality, water quality, mental health, community and Indigenous health, and health care services and infrastructure. Tasmania’s temperate climate and more subtle climate change projections relative to other parts of Australia mean that Tasmania has tended to be on the periphery of national research activity in this field. This does not mean that Tasmania should not be concerned or complacent about the health effects of climate change on its population. Instead the national focus to date may, in fact, reflect the incremental and iterative nature of impacts and adaptation research over time, especially where indirect health issues are concerned.

4.6.1 Understanding climate change impacts

There is no published research into the impacts of climate change on human health and community wellbeing in Tasmania. The *Climate Futures for Tasmania* (CFT)’s downscaled modelling provides a useful foundation for future regional and local analysis of impact and adaptation research in relation to human health. Much of the relevant Australian literature discusses the implications for human health in a very generic way: that is, not specifically relating to an assessment of a Tasmanian region or community. For example, the health effects of bushfire smoke with the likelihood of increasing risk of bushfire (see Johnston 2009); rural community health, including mental health impacts, and community social and economic costs associated with drought periods and climate associated extreme weather events (see Hanna et al. 2011; Steffen & Hughes 2011);

There is growing understanding of the climate factors contributing to the ecological drivers of the vector borne disease, Ross River virus, specific to Tasmanian regions (see Werner et al. 2011). While this work is not specifically focussed on climate change impact assessment, it does look at the significance of climate variables and the findings from the research are important inputs to current and future risk assessment and adaptation efforts in this area. This kind of research also suggests that there are probably other studies investigating the impacts of climate and climate change on a range of biophysical systems that may be important in contributing to health issues.

The direct impacts on human health from extreme climate related events or conditions that face other parts of Australia (such as heat waves) are considered in the literature as being of less relevance to Tasmania (see Bi et al. 2011), and there is even suggestion that Tasmania may receive some positive health benefits, for example warmer winters may lead to a reduction in cold-related illnesses (see Steffen & Hughes 2012). The relative vulnerability to changes in temperature and extreme heat events of other parts of Australia is largely assumed, however; there is nothing in the public or peer-reviewed literature that more deeply understands the impacts of social vulnerability. The occurrence of more extreme events, including storms, floods and bushfire are, nonetheless,

The occurrence of more extreme events, including storms, floods and bushfire are likely to pose direct threats, including death and injury, to Tasmanian communities, visitors and tourists.

likely to pose direct threats, including death and injury, to Tasmanian communities, visitors and tourists (TCCO 2012a).

Reviewing the potential impacts of climate change on human health Australia-wide, McMichael et al. (2006) suggest that the risks for Tasmania may be more subtle consequences of indirect climatic influences on the ecological and social systems that have implications for human health. These include:

- The impacts of climate change on bushfire hazard risk where this may affect rural and urban communities. Issues for human health in Tasmania are specifically focussed on respiratory illnesses associated with bushfire smoke and the sensitivity of some sectors of the community to this (see Johnston 2009).
- The impacts of climate change on the incidence and severity of drought in Tasmanian rural areas. Issues in the literature focus on the multi-faceted effects on rural communities including mental health, and community and regional social and economic wellbeing and resilience issues (see Hanna et al. 2011).
- The impact of climate change on ecological systems and components that are significant for the transmission to humans of vector borne diseases such as Ross River virus (Werner et al. 2012; Lyth et al. 2013) and the occurrence and severity of respiratory illnesses associated with the distribution and seasonality of plant allergens (Steffen & Hughes 2011).

Despite the absence of Tasmanian specific work on human health impacts, there is evidence of emerging interest and activity in understanding the indirect or more complex human health implications of climate change associated with biophysical changes, and the specific risks and adaptation challenges for Tasmanian regions, communities or groups. The Tasmanian Government's *Adapting to Climate Change in Tasmania Issues Paper* (TCCO 2012a: 29) acknowledge the importance of better understanding the health risks faced by vulnerable groups in the community (including the elderly, people with disability or chronic illnesses, remote communities, children and the poor), and the consequences of both direct and indirect impacts on health and health services, other services and critical infrastructure.

4.6.2 Understanding sectoral vulnerabilities

While health issues are largely recognised to be a consequence of the biophysical impacts of climate change, the human health and community wellbeing effects will be mediated by social factors, such as the characteristics of populations and indicators of their adaptive capacity. These include population vulnerability linked to socio-economic resources, the capacity of on-the-ground health services, monitoring and management systems (Bell 2011; Black et al. 2013). Understanding the socio-economic context of a region, community, or potentially vulnerable group is imperative, as is the need to engage with the agents in the system that contribute to the baseline and potential future adaptive capacity, for example, on the ground health services, monitoring and management systems. This is particularly significant for Tasmania for a range of health implications (see Johnston 2009; Bell & Towle 2011), because of the state's demographic, and socio-economic profiles (Bell 2011; Bell & Towle 2011; Lyth et al. 2013) and the poor health outcomes of its population, which are largely a function of socio-economic disadvantage and the ageing population (ABS 2011).

Steffen and Hughes (2011: 9) mention the potentially vulnerable members of the Tasmanian community as being 'the elderly, the very young, those with existing medical problems, those in rural communities and those in lower socio-economic groups'. They also refer to tourists as being at risk due to their lack of familiarity with the local climate, resources, local hazard or emergency resources and processes, such as emergency evacuation routes in the case of bushfire.

There is broad agreement (Steffen & Hughes 2012; TCCO 2012a) on the health issues that may affect Tasmania, including:

- the implications for respiratory illness of changes in pollen allergens and bushfire smoke;
- infectious diseases; and
- mental health and overall community wellbeing issues associated with a range of impacts, including disruption from extreme events and prolonged conditions, such as drought.

It is likely that there will be other issues and cumulative health and wellbeing implications that have not yet been considered because of the overall lack of attention and investment in climate change and human health research or practical studies in Tasmania. For example, Mallon et al. conclude that many community service organisations are vulnerable to extreme events. Temporary closure of such organisations will have serious flow-on effects for individuals who rely on such organisations to overcome difficulties faced by existing vulnerabilities (Mallon et al. 2013).

Beyond these broad statements about possible health futures in a changing climate and those potentially most at risk there is little evidence of any deeper assessment of social vulnerability as it relates to climate change in Tasmania, although there is work emerging in this area funded by the Tasmanian Government, for example Lyth et al. (2013) explore socio-economic and geographical vulnerability indicators most relevant to Ross River virus risk in Tasmania, as well as preliminary assessment of the adaptive capacity of the professional communities of practice likely to be involved in local risk assessment, hazard management and health service response.

4.6.3 Existing adaptation efforts

There is virtually no research into existing adaptation efforts in relation to human health in Tasmania, nor is there any current government policy addressing climate change-health issues. Work that has been done has been initiated by researchers, but undertaken with support from the State Government and either the local government association or regional natural resource management organisations. These projects fall into four categories:

1. Improved techniques for monitoring weather variables to allow for improved early warning of dangerous conditions. For example, Johnston et al. (2010) reviewed approaches to monitoring smoke from vegetation fires for public health monitoring

- systems, explaining that the availability of more precise temporal and spatial air quality data will improve the ability to issue health alerts for those most vulnerable.
2. Health impact assessment tools. For example, Bell and Towle (2011) discuss the need for, and approaches to, regional and community health risk assessments in Tasmania, using community and primary health carer involvement to better understand local social vulnerability and adaptive capacity contexts. Bell et al. (2012) piloted an online climate change health impact and risk assessment tool for use by local government.
 3. Risk and vulnerability assessments. For example, Lyth et al. (2013) explore the risk and vulnerability (including adaptive capacity) of Tasmanian regions to the vector borne disease Ross River virus.
 4. Developing adaptation options. Lyth et al. (2013) investigate adaptation options for managing the risk of Ross River virus, including preliminary assessment of the adaptive capacity of the professional communities of practice likely to be involved in local risk assessment, hazard management and health service response. At a systemic level, Bell et al. (2012) reflect on the type of adaptation responses required to tackle the health implications of climate change through addressing health services in particular and the professional education of health practitioners and workforce across the sector.

Research supported by the Bushfire CRC is examining psychological factors associated with community preparedness for bushfires in order to inform adaptation and emergency management responses in Tasmania and around Australia (see McNeill et al. 2013). The Tasmanian Fire Service has also commissioned research relating to the January 2013 Tasmanian bushfires.

4.6.4 Understanding future options

Hanna and Spickett (2011:12) state that:

Australia [including Tasmania] still requires much work to guide the development of a comprehensive strategy to underpin the adaptation of its health system. Adaptation will be an evolving process as impacts emerge.

Some emerging evidence (Lyth et al. forthcoming 2013) suggests that small or subtle changes in climate could have significant health effects on already vulnerable populations or the capacity of health services in Tasmania. The case of pollen allergens, bushfire smoke and Ross River virus are initial examples. A deeper understanding is required of indirect impacts from biophysical changes and the elements of risk and social vulnerability associated with these. This research must occur at the regional and community levels (Bell & Towle 2011).

McMichael et al. (2006: 866) talk about the potential for many communities to buffer themselves, at least temporarily, against some of the effects of climate change and so refer to the need for understanding the 'buffering capacity' of regions and communities where there are differences in geography, technological resources, governance, and wealth.

4.6.5 Research gaps and future opportunities

Bell (2011: 811) explains that climate change literature needs to extend to provide an evidence base for managing the specific challenges of regional policy and health service development that is responsive to climate change. Currently the climate change literature informs policymakers of the likely bigger picture health implications but does not offer the more nuanced region-specific information required as referred to by McMichael et al. (2006) in the global and national context. In Tasmania it particularly includes the need for:


- Understanding the social, environmental and institutional determinants of vulnerability in a given region (groups and areas most vulnerable to what under what circumstances), including rural communities and cumulative health and well-being vulnerabilities (Bell 2013).
- Community-based vulnerability and health risk assessments (Bell & Towle, 2011).
- Improvements in regional and local monitoring of: bushfire smoke (Johnston et al. 2012), aero allergen (pollen allergen) concentrations and seasonality (Beggs 2010), vector (mosquito) densities in highest risk areas with respect to Ross River virus (Carver et al. 2011) or other vector borne diseases that may emerge as a threat.

In addition to regionally-focussed vulnerability and risk assessment and monitoring and research identifying gaps in understanding, adaptation options to manage health vulnerability and community well-being need to be formulated, evaluated, costed, and tested (McMichael et al. 2006). This includes how we can improve responsiveness and management of health impacts or events as they arise, as well as preparing communities for longer-term adjustment to changing environmental and health conditions.

This will require:

- raising community awareness of health risks and approaches to assessing and mitigating local and individual risks (Bell & Towle 2011). Communication and public education about impacts and adaptation should be targeted to specific populations, including older people, low income groups, people with disabilities, people from culturally and linguistically diverse backgrounds and newly-arrived migrants and Indigenous communities (Fritze et al. 2009; Reser et al. 2012; Boon et al. 2012; Hansen et al. 2012);
- building community-wide resilience, particularly in rural communities (Hannah et al. 2011);
- adjusting and improving how professional education, practitioner and health service capacity is developed (e.g. Bell et al. 2012; Bell 2011); and
- raising awareness and response-capacity within the community support and services sector about the needs of regions, communities or groups most at risks that are relevant to them (Mallon et al. 2013).

4.7 Business and industry

 Key findings – Business and industry	
Climate change impacts	<ul style="list-style-type: none"> ◆ the implications of temperature increases, regional changes in rainfall patterns, and increased frequency and intensity of extreme weather events have not yet been assessed for business and industry sectors ◆ sea-level rise and associated impacts will affect business and industry in vulnerable coastal locations
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ there will be direct physical disruptions to business operations from extreme events, and indirect impacts on the production and supply chains of Tasmanian businesses resulting from the effects of climate change elsewhere. ◆ there may be opportunities flowing from business relocations and shifts in consumer preference
Current adaptation efforts	<ul style="list-style-type: none"> ◆ there is very little evidence of businesses or industry addressing climate change impacts
Future options	<ul style="list-style-type: none"> ◆ limited adaptation research and practice relating to Tasmanian businesses suggests that businesses are likely to respond reactively rather than proactively to climate change impacts as they occur. ◆ a key challenge will be to change the attitudes of businesses to medium-to-longer term climate-related threats.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ business- and industry-specific research into climate change impacts and adaptation options at temporal and spatial scales suited to their planning and decision-making processes.

The *Tasmanian Framework for Action on Climate Change* (TCCO 2008: 11) noted that ‘many sectors of Tasmania’s economy will need to adapt to the environmental impacts of climate change as well as adjusting to the requirements of a carbon-constrained economy’. While there has been considerable research relating to primary industries and natural resource management, there has been very little climate change adaptation research explicitly focussed on the impacts of a changing climate for other Tasmanian businesses such as tourism, mining, retailing, construction and manufacturing.

The vast majority of businesses operating within Tasmania are either non-employing micro-businesses (58.8%), small enterprises of less than 20 staff (36%) or medium enterprises of between 20 and 199 staff (4.9%) (DEDTA 2011). Hence, notwithstanding the economic importance of major enterprises such as mineral processing, a diverse mix of small and medium enterprises (SMEs) comprise around 99.7% of all businesses in the state and are especially important in terms of supporting Tasmania's decentralised population. There is likely to be great diversity in the vulnerability and risk profiles of different SMEs to the impacts of climate change. Likewise, national research (Chong et al. 2012; Murta et al. 2012) suggests that SMEs are also likely to differ markedly in their adaptive capacities.

4.7.1 Understanding climate change impacts

The *Climate Futures for Tasmania* (CFT) project (Grose et al. 2010) provides Tasmanian businesses with a high quality information basis from which to understand the likely physical impacts of climate change. It has provided fine-scale information on a number of key climate variables anticipated to change as a result of global climate change. The implications of temperature increases, regional changes in seasonal rainfall patterns, and increased frequency and intensity of extreme weather events for the sectors of agriculture and water resources have been elaborated in related CFT reports (ACE CRC 2010a; Bennett et al. 2010) but this information is yet to be applied to other industry sectors.

The concentration of most business and industry along the coast means that research at national, state and local levels into the impact of sea-level rise and coastal inundation is also directly relevant to Tasmanian businesses and industries (DCC 2009; TCCO 2012a). A 1.1 m sea level rise would threaten significant transport infrastructure and up to 300 commercial buildings (Steffen & Hughes 2011; DCCEE 2011). Disruption, loss or damage to transport and telecommunication infrastructure and limited access to fuel supplies through damage or inaccessibility to service stations can have far reaching impacts on the operation of businesses and services of all sizes, and as a consequence on the vulnerability and resilience of communities, local and state economies. While national and Tasmanian research has identified the broad extent of risk to infrastructure and essential services and noted the social and economic implications (DCCEE 2011; DPIW 2008a), the extent and cost of sea-level rise to Tasmanian businesses and industries remains largely unknown.

4.7.2 Understanding sectoral vulnerabilities

There is limited peer-reviewed research on the implications of the biophysical impacts of climate change on key industry sectors and businesses in Tasmania.

There appears to have been very little peer-reviewed research into the vulnerabilities of Tasmanian businesses and industries as a result of climate change. Beer et al. (2012) examined the vulnerability of some Tasmanian non-coastal settlements to the impacts of climate change, but this report was primarily focussed on primary production industries, and did not extend to assessing the vulnerability of communities dependent on other industries and businesses. Based on national research (e.g. Linnenluecke et al. 2011), it can be expected that there will be direct physical disruptions to business operations from extreme events, and indirect impacts on the production and supply chains of Tasmanian businesses

resulting from the effects of climate change elsewhere. Steffen and Hughes (2011) have suggested that there may be benefits for Tasmanian businesses and industries as a result of climate change impacting mainland Australia more severely relative to Tasmania, resulting in firm relocations (Galbreath 2011; see also Linnenluecke et al. 2011; Tasmanian Department of Treasury and Finance 2012) or shifts in consumer preferences southward.



Photo 13. Storm damage to world heritage listed Port Arthur Historic Site, 2011, Photo: Port Arthur Historic Site Management Authority

A sector of particular interest is tourism. It is anticipated that the tourism industry in Tasmania will be affected by climate change, especially in terms of risks to the status of iconic natural and cultural drawcards, such as the biodiversity of Tasmania's world heritage areas (DPIPWE 2010a; Rudman et al. 2008) and significant Indigenous and colonial cultural heritage sites (see Section 5.1). Detailed research into the impacts of climate change on the Tasmanian tourism industry is yet to be undertaken, but national-level research (e.g. STCRC 2009; Turton et al. 2010; see also summary by Carter in Poloczanska et al. 2012b) points to impacts arising from:

- direct physical changes associated with sea-level rise and coastal hazards. For example, the Port Arthur Historic site has already experienced significant damage from storm surge events (ABC News 2011)
- regional impacts, such as localised water shortages and increased frequency of extreme weather events, are also likely to impact on businesses. For example, in early January 2013 communities located south-east of Hobart experienced a severe bushfire. The bushfire cut off access to the Tasman Peninsula and the iconic Port Arthur Historic site. A representative from the Tourism Industry Council of Tasmania noted in an article in *The Mercury* early February 2013 that 'it was too early to tell just how much the bushfires would cost the state's tourism industry' (Martin 2013)

- indirect impacts resulting from changes to ecosystem services, and threats to the biodiversity and geodiversity that underpin much of the island's nature-based tourism
- opportunities for increased visitation to Tasmania, as tourists seek out experiences in cooler climatic zones and avoid destinations that are more prone to extreme weather events (Hadwen et al. 2011a; Mair 2011; Steffen & Hughes 2011; TCCO 2012a). Hadwen et al. (2011a) identified climatic variables as significant determinants of destination choice among tourists, one implication being that climate changes will positively affect destination choice for Tasmanian tourism. With this may arise opportunities for business and industry, but also pressures on the places and infrastructure most attractive to tourists and seasonal visitors. Moreover, Steffen and Hughes (2011) query whether tourists constitute a potentially vulnerable group, as they are unfamiliar with the location, local services and emergency response messages

Climate change risk assessments have tended to focus on the impacts of shifting to a low-carbon economy, including issues of energy efficiency and mitigation of carbon emissions. A report conducted for the Tasmanian Government by Pitt & Sherry (Harrington et al. 2008) into the *Impact of Climate Change on Tasmania's Food and Beverage Industry* investigated how climate change will affect aspects of the supply chain (production, manufacture and processing, transportation and retailing) of Tasmanian food and beverage products. While acknowledging the importance of adaptation research, and recommending that state and federal governments maintain adaptation research funding (Harrington et al. 2008: 4), the report concentrated on the opportunities for businesses to reduce their exposure to the risks presented by national carbon policies. Likewise, within the tourism industry the focus has been shared between energy efficiency and carbon reduction, often cohering around industry desire to meet consumer demands for environmentally friendly businesses or to protect the 'clean and green' brand values of the island-state.

4.7.3 Existing adaptation efforts

There is institutional recognition that Tasmanian businesses and industries will face added risks as a result of climate change, and a number of risk management assessment projects have been undertaken directed towards the identification of vulnerabilities. As noted above, however, these risk assessments have primarily focussed on actions designed to reduce GHG emissions and implement more energy efficient processes and practices (Gardner 2010; DPAC 2012e). Reflecting broader national trends (West & Brereton 2013) the primary focus of business and industry to date has been adapting to changes in policy (especially energy policy).

There is very little documented research into the adaptive efforts of Tasmanian businesses and industries. A national study by Zeppel (2011) noted Tourism Tasmania's intent to "market Tasmania as a climate friendly destination" (TICT 2007 cited by Zeppel 2011: 612). Booth and Williams (2012) contributed to an NCCARF-funded study (King et al. 2012) by examining what role insurance might play as an adaptive response to the impacts of climate change by focussing on bushfire management in Tasmania.

At a national level, research shows that the effectiveness of assistance for small and medium enterprises (SMEs) was limited by the short duration of business recovery programs, the lack

of specific support in responding to climate hazards, and a lack of consideration for the psychological impacts of such events (Kuruppu 2013).

There is some evidence that businesses have used the framework provided by the Australian Greenhouse Office's (2006) *Climate Change Impacts & Risk Management Guide for Business and Government* to undertake risk assessments (Materia 2008). Additionally, one significant outcome of the CFT project was a tool to assess the susceptibility of Tasmanian infrastructure to climate change impacts. Developed by Pitt & Sherry, a private engineering consulting firm, in partnership with the Antarctic Climate & Ecosystems Cooperative Research Centre (ACE CRC), ClimateAsyst® is likely to be of relevance to some major Tasmanian businesses and industries as a means of assisting them to assess their exposure to the impacts of climate change.

Table 6. sets out the national NCCARF projects of potential broad significance to Tasmanian business and industry (NCCARF 2012).

Table 6. NCCARF projects of likely significance to Tasmanian business and industry

Title	Objectives
<p>Climate change adaptation for Australian minerals industry professionals – Best practice guidelines</p> <p>Damien Giurco (University of Technology, Sydney)</p>	<p>The minerals industry generates 50% of Australia’s export earnings, yet research into its ability to adapt to climate change is limited. In a recent study, stakeholders identified the major challenges as use of scarce resources such as water and energy; impacts on the environment and community; hazards and workforce issues; impacts on infrastructure; and mine planning and design. This project will evaluate industry awareness, and existing strategies, and develop best practice guidelines for climate change adaptation and planning by minerals industry professionals.</p>
<p>Assessing the potential for, and limits to, insurance and market-based mechanisms for encouraging climate change adaptation</p> <p>John McAnaney (Macquarie University)</p>	<p>Insurance provides a means of helping communities recover from natural disasters. It is clear, however, that many people afflicted by flooding in southern Queensland in 2011 lacked suitable insurance cover, making recovery difficult and prolonged. This project seeks to understand why cover for riverine flood was so limited when damage from other natural hazards like bushfire, earthquake, tropical cyclone and hail storm are explicitly covered and routinely dealt with in home and contents policies. This project will propose solutions to align the incentives necessary at various levels of government to reduce the risk to Australian communities.</p>
<p>Climate change adaptation – Building community and industry knowledge</p> <p>Jenny Shaw (WA Marine Science Institute)</p>	<p>This project will increase knowledge and understanding of likely climate change and adaptation measures open to local communities. It will support a Case Study for Australia in adaptive management that cross-correlates regional needs with Australia-wide management policies. Key climate change information will be synthesised, analysed and adapted for marine biodiversity and fisheries businesses, and extension and knowledge sharing activities tailored for regional needs.</p>

4.7.4 Understanding future options

Climate change may well afford positive opportunities for Tasmanian businesses and industries. For example, Hodgkinson et al. (2010) suggested that there may be opportunities to export Tasmanian mining expertise and practice to areas of mainland Australia as an adaptive response for mines affected by higher rainfall. Without further research, however, it is impossible to assess the magnitude of these opportunities relative to potential risks.

Current limited research and practice suggests that businesses are likely to respond reactively rather than proactively to climate change impacts as they occur. Summarising a national report, Johnston et al. (2013: v) noted that ‘most Australian companies appear to be struggling to move forward in responding to climate change impacts, apparently paralysed by short-term profit-first thinking, uncertain political risks and a corporate culture unused to volatility and

disruption'. A key challenge will be to change the attitudes of businesses to medium-to-longer term climate-related threats.

4.7.5 Research gaps and future opportunities

In its submission to the Productivity Commission's inquiry into the barriers to adaptation, the Tasmanian Government (2011: 6) argued that:

Adaptation policy responses are limited by the depth of understanding of how information pertaining to climate change impacts relates to different end users, sectors and purposes. Across a number of industry sectors in Tasmania, imperfect information on how climate change may impact economic performance has been identified as a barrier to adaptation.

Interview and workshop participants reinforced the view that quality information on climate change impacts and adaptation needs to be relevant to business and industry end users, at temporal and spatial scales suited to their planning and decision-making processes. Such research needs to be cognisant of the myriad factors that will influence any business' ability to identify, develop and act upon adaptation decisions. Such information will be critical in order to identify and assess the adaptive capacity of individual businesses and industry sectors, as it is likely to be highly variable and dependent on a range of factors that will often take precedence over adaptation per se. Accordingly, business and industry sectors need to be engaged in the process of adaptation research for adaptation options to be incorporated into business and industry strategic planning.

'While the new climate simulations are invaluable, their full potential is not realised unless researchers and policy makers use them in their research, business planning and decision making processes.'


(ACE CRC 2012b)

At present, a significant information gap exists in terms of business and industry preparedness, expertise and knowledge about climate change impacts and adaptation options. This information gap is not unique to Tasmania (e.g. Johnston et al. 2013; West & Brereton 2013).

The CFT project has set a high standard in terms of researcher-industry collaboration, and could form the basis for further Tasmanian industry-specific studies. As noted by the ACE CRC (2010b: 13):

While the new climate simulations are invaluable, their full potential is not realised unless researchers and policy makers use them in their research, business planning and decision making processes. Therefore, to make sense of the mathematically complex simulations, an intermediate step is required to extract and interpret the simulations for particular geographic areas, industry sectors or applications.

4.8 Emergency management

 Key findings – Emergency management	
Climate change impacts	<ul style="list-style-type: none"> ◆ Tasmania is likely to experience more extreme weather, with increases in rainfall intensity and temperature extremes ◆ there will also be more dry days, with an associated increase in bushfire conditions
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ there are likely to be longer fire seasons with more frequent and more intense fires. ◆ there will be more storms, with increased flooding, coastal inundation and estuarine flooding
Current adaptation efforts	<ul style="list-style-type: none"> ◆ emergency management issues are being reflected in new planning reforms, such as the bushfire code ◆ the State Natural Hazards Policy Framework provides a foundation for refining and implementing reforms in the emergency management sector
Future options	<ul style="list-style-type: none"> ◆ the cost of future extremes and options for resourcing emergency responses is being examined at the national level, but requires state-specific analysis ◆ future efforts will involve a combination of householder and community education, land use planning measures, and enhanced resourcing and capacity building the emergency management organisations
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ the uncertainty associated with extreme events is unlikely to be reduced by further modelling work, so future research should focus on aspects of community resilience, community and organisational preparedness and adaptive capacity

4.8.1 Understanding climate change impacts

The *Climate Futures for Tasmania: Extreme Events* study shows that the state is moving towards a pattern of more extreme conditions (White et al. 2010a). This is consistent with research at the national and international levels (AFAC 2009b; IPCC 2012). The CFT project examined a range of extreme temperature, rainfall, and bushfire conditions to assess the likely impacts of climate change on the characteristics of these events this century.

The study projects an increase of up to 60% in peak intensity rainfall events across the state. Extreme rainfall events are likely to become more frequent, with associated flooding issues, but with an overall decrease in the number of rain days that will affect bushfire conditions (White et al. 2010a). The report concludes that:

the emerging pattern of change represents a consistent and progressive adjustment of the current climate and its weather patterns to a new climate where there will be more hot days and warm nights, more extreme wet days, an increase in the size of heavy downpours, and more dry days. The intensifying of rainfall events also leads to a tendency for increased drier and wetter conditions on seasonal and annual bases and the reduced occurrence of normal conditions (White et al. 2010a: executive summary).

Work on climate change and emergency management conducted at the national level suggests the following impacts of these projected changes to extreme events relevant to Tasmania:

- longer fire seasons;
- greater frequency and higher average intensity of bushfires;
- more storms and higher winds, with resulting vegetation and infrastructure damage; and
- increased flooding, coastal inundation and estuarine flooding (AFAC 2009b).

In addition to the statewide modelling of coastal inundation and storm surge that has been undertaken (see section 5, bushfire modelling for the southern region of Tasmania has been conducted as part of the Regional Councils Climate Adaptation Project. The modelling used the Tasmanian Bushfire Risk Assessment Model (BRAM) (Graham et al. 2012) and the A2 scenario to model bushfire scenarios over near-future, mid-century and end-of-century time scales. It showed increased bushfire risk across Tasmania, but especially in the central plateau (Graham et al. 2012).

The *Climate Futures for Tasmania* project and other work has provided Tasmanian decision-makers with detailed and comprehensive fine-scale climate change modelling. It is especially valuable in adaptation planning for gradual, iterative change. Despite the rigour of this work, however, uncertainty remains over factors such as the timing, frequency and severity of extreme events. The uncertainty associated with extreme events is unlikely to be reduced by further modelling work, so future research is likely to focus on aspects of community resilience, community and organisational preparedness and adaptive capacity.

4.8.2 Understanding sectoral vulnerabilities

The shift towards more extreme weather conditions and more bushfire conditions has major implications for the emergency management sector. Handmer et al. (2012) see the broader societal consequences of weather-related disasters as a function of the effectiveness of disaster reduction efforts, emergency services activities, and the social and economic resilience of the affected community. These impacts will be exacerbated or responses made more complicated by virtue of demographic and socioeconomic trends such as ageing

populations, work patterns, land-use change, migration to and from rural areas and changed volunteering levels.

A national assessment of the impact of climate change specifically on the bushfire and the emergency services sector (AFAC 2009a, 2009b) concluded that the impacts on the sector will be influenced by changes in the frequency and intensity of emergencies and the exposure of the community (e.g. increased fire or flooding risk); and indirect impacts on the capacity of the service providers to deliver services (cost and security of supply of energy and water). Not only will the emergency services sector have to deal with extreme events and the uncertainty around projected changes over the long term, it will also have to modify the way it does business in response to changes in event profiles, and community resilience and exposure and in response to increased demand for services across sectors/events, regions, and even internationally (AFAC 2009b).

The Australasian Fire and Emergency Service Authorities Council (AFAC 2009b) identifies important roles for emergency services managers in providing input on infrastructure design, land use planning and building standards, negotiating new allocations of responsibility and expectations between the sector and the community. The AFAC (2009b) also warns that the sector needs to monitor demographic and socio-economic trends, and engage in on-going community education and awareness.

There are several research initiatives underway at the national level considering the impacts of climate change on extreme events. Loughnan et al. (2012) have identified threshold weather conditions for mortality in Australian capital cities; described spatial distributions of human vulnerability to extreme heat; and provided information to target emergency responses during heat waves. It developed an index for each capital city that describes baseline (current) risk and predicted changes in risk in relation to climate change impacts for 2030, taking into account altered risk profiles from age, population density (as a surrogate for urban heat island), and wealth. Others have focussed on various aspects of the Prevention-Preparedness-Response-Recovery (PPRR) emergency management framework (Handmer et al. 2012). These are directly relevant to adaptation insofar as both focus on risk and vulnerability reduction (Gero et al. 2010).

4.8.3 Existing adaptation efforts

A significant body of research exists to inform the emergency management sector's response to the current climate, and a growing body of literature about the likely changes to extreme events in the future. There are some major policy documents relating to climate change adaptation and emergency management (Ministerial Council for Police and Emergency Management 2009, COAG 2011), but there is relatively little research that explores the implications of future climatic conditions for emergency management (Handmer et al. 2012).

Considering the first element of the PPRR emergency management spectrum, preventing the effects of extreme events falls largely outside the domain of emergency management agencies and relates principally to planning and building standards. The National Strategy for Disaster Resilience (AEMI 2011) highlights land use planning as a critical way of strengthening climate-related disasters, although Handmer et al. (2012) note the trend across Australia to deal with increased risks by using greater reliance on emergency

management responses rather than tighter land use planning. The tension between planning imperatives and emergency management considerations has also been observed in Macintosh et al. (2013), in the context of approaches to land use planning for bushfire hazard in Tasmania and nationally.

The Tasmanian State Government has developed a policy framework for natural hazards and policy responses (DPAC 2012d). On the basis of this framework, it has reviewed arrangements for land use and development in bushfire prone areas and produced a new Planning Code for Development in Bushfire Prone Areas (discussed in more detail in Section 6.4.3.). Neither the Bushfire Code nor the hazards framework specifically addresses the exacerbating influences of climate change on hazards. Macintosh et al. (2013) suggest that climate change is being actively considered in planning for coastal hazards, but not for bushfire. The exacerbating effect of climate change on bushfire threat is likely to be considered by altering the bushfire attack level (BAL) that influences the building standards to which new buildings must conform, rather than in any explicit adjustment to the planning framework (Macintosh et al. 2013). Additional policy statements outlining the State Government's approach to managing the risks of coastal erosion and inundation and severe weather in land use planning are under development (DPAC 2012c).

Several local government climate change adaptation projects have also considered emergency management dimensions. Each local council in the Southern Tasmanian Region has recently prepared a climate change risk assessment as part of the Southern Tasmanian Councils Climate Change Adaptation Project (RCCCAP) and is completing a Climate Change Adaptation Action Plan. A toolkit for local government to promote community adaptation to bushfire in a climate change context has been developed for the Southern Tasmanian Councils Authority, based on research in Kingborough and Huon Councils (Chaplin & Fairbrother 2012). In 2010, LGAT produced a series of climate change studies addressing particular climate risks in specific local government areas around the state (LGAT 2010).

4.8.4 Understanding future options

Research for the Southern Tasmanian Councils Authority identified important barriers or impediments to bushfire preparedness, including:

- urban expansion leading to new residents with little understanding of risks;
- lifestyle choices leading to gaps between awareness of risk and actual householder preparedness; and
- an ageing population, leading to greater reliance on emergency services (Chaplin & Fairbrother 2012).

The resource constraints of the emergency services agencies will also be major factors in future. It is clear that the future financial and social costs of extreme events are likely to increase with the severity of these events. Governments across the country are recognising the limits to their ability to fund emergency management resources. Greater emphasis is being placed on the importance of prevention over response and recovery, and sharing of responsibility and cost across government, the community and private actors (Climate Commission 2011; NCDR 2011).

Support for those who experience climate-related emergencies also requires closer investigation. Current approaches to disaster relief funding may be either inefficient or maladaptive (Bird et al. 2011; Vernon-Kidd et al. 2010; Wenger 2012; Kuruppu 2013). Research by the insurance industry has modelled that removing premium-based taxes would reduce the number of households without contents insurance in Tasmania from 47,000 to 2,600, and without building insurance from 7,000 to 800 (Productivity Commission 2012). Other national research shows that the potential for insurers to drive adaptation by incentivising actions that reduce or avoid future risks associated with climate change is currently under-utilised (Bird et al. 2011).

4.8.5 Research gaps and future opportunities


The January 2013 bushfires have triggered further research into bushfire prevention, preparedness and response. At the same time, they have launched a broader community conversation about roles and responsibilities in respect of mitigating, preparing for, responding to, and recovering from extreme events. At the same time, extreme events on the mainland such as the Queensland floods offer important lessons for emergency management agencies in Tasmania.

The uncertainty associated with extreme events is unlikely to be reduced by further modelling work, so future research is likely to focus on aspects of community resilience, community and organisational preparedness and adaptive capacity. At the national level, Handmer et al. (2012) have identified a range of national information needs for the emergency management sector. The following list represents those research priorities for which Tasmania-specific research would be particularly beneficial:

- changes to community vulnerability resulting from demographic and other processes;
- how the capacity of communities to respond to projected climate impacts can be enhanced;
- institutional responses to changed climate conditions and consequential demands on emergency services;
- how communication tools can manage emerging climate change induced emergency service demands;
- compounding effects of climate-change derived climate conditions and weather events, such as drought and heat waves; and
- trade-offs between prevention and other values, such as native vegetation conservation.

Given the paucity of research on these issues that is specific to Tasmania's social, demographic and economic and institutional context, further exploration of these issues from a specifically Tasmanian perspective should yield valuable insights.

4.9 Policy and governance

 Key findings – Policy and governance	
Climate change impacts	<ul style="list-style-type: none"> ◆ local climate profiles have been developed for Tasmania’s 29 local government areas ◆ the impacts of climate change on coastal hazards are the major focus on current adaptation policy
Sector-specific vulnerabilities	<ul style="list-style-type: none"> ◆ there is growing recognition that climate change impacts are likely to place pressure on existing governance arrangements, and on the allocation of roles, responsibilities and resources between level of government, and between government and private actors.
Current adaptation efforts	<ul style="list-style-type: none"> ◆ advances have been made in coastal adaptation policy in Tasmania recently and further initiatives are underway ◆ the Regional Councils Climate Adaptation Project has enabled climate change impacts and adaptation options to be considered for Tasmania’s Southern region and incorporated into a regional adaption strategy and council adaptation plans
Future options	<ul style="list-style-type: none"> ◆ there is a growing consensus that transformative change is necessary to successfully transition to a climate change adapted society ◆ the barriers to both incremental and transformative change require close attention ◆ research emphasises the need for attenuated engagement processes that recognise and respond to characteristics of individual communities rather than attempting to impose uniform, top-down policy responses.
Research gaps and opportunities	<ul style="list-style-type: none"> ◆ research opportunities should focus on maximising the transformative potential of medium-term adaptation responses, and practical approaches to improving policy, planning and governance frameworks. ◆ approaches that align bottom-up initiatives with top-down framework and policy development are required as a priority

The implications of climate change impacts and adaptation for policy and governance in Australia have been explored across a range of sectors, with particular attention given to coastal zone management. More generally, the roles and responsibilities of different levels of

government in managing risks, raising awareness and creating the circumstances in which adaptation may occur efficiently and effectively have been the focus of recent research.

4.9.1 Understanding climate change impacts

As detailed in previous sections of this report, the CFT project and subsequent work based on CFT data have provided the basis for much of the Tasmania-specific work focussed on understanding climate change impacts at a scale relevant to decision-making and policy formulation. This includes a series of research reports tailored to particular sectors (e.g. Holz et al. 2010; White et al. 2010a) and *Local Climate Profiles for Tasmania's 29 Local Government Areas* (DPAC 2012a). These reports have been useful in policy development, providing a basis for further investigations such as the Tasmanian Coastal Adaptation Decision Pathways project (LGAT 2012), and the development of the *Adapting to Climate Change in Tasmania: Issues Paper* (DPAC 2012a), which will inform the development of the Tasmanian 2020 Climate Change Strategy, due for completion in 2013.

Emerging hazards associated with sea level rise in the coastal zone have been the focus of Tasmania-specific research effort since at least 2004 (DPIW 2004), owing to the importance of the coast to our society and the fact that these hazards are presenting current day management challenges to community and all levels of government (e.g. Carley et al. 2008). For 'the Island State', coastal hazards are an immediate priority for policy development, and an ongoing challenge for the state government and 25 of the 29 local governments with responsibilities for coastal areas.

4.9.2 Understanding sectoral vulnerabilities

Recent work in the Tasmanian context has focussed on understanding sea level rise and coastal hazards (Hunter 2012, DPAC 2012b) and translating this understanding into effective policy responses. As noted in section 6.4.3 the Tasmanian Government has established a sea level rise planning allowance and released a second stage of coastal inundation mapping (Lacey et al. 2012), which incorporates the sea level rise planning allowance (see DPAC 2012c) and coastal erosion mapping is due to be completed by early 2013.

General (as distinct from coastal) climate change impacts and options for adaptation have been examined at a national level (DCCEE 2010) and more recently via an in-depth examination in Southern Tasmania through the Regional Councils Climate Adaptation Project (STCA 2012).

Traditional policy development approaches in rural and primary industries settings have been assessed as inadequate to deal with the complex and multi-faceted impacts of climate change (Nelson et al. 2010a). Demographics of rural and regional communities have attracted a particular research focus, as the barriers to adaptation in these communities may require specific strategies and policy approaches in order to progress effective responses (Nelson et al. 2010b). These findings are of particular relevance to Tasmania, given the

'...many climate change impacts are likely to place pressure on existing governance arrangements, and on the allocation of roles, responsibilities and resources between level of government, and between government and private sectors.'

preponderance of rural and regional communities and older mean age relative to the overall population.

There is growing recognition that many climate change impacts are likely to place pressure on existing governance arrangements, and on the allocation of roles, responsibilities and resources between level of government, and between government and private actors. National studies have identified the need of reform in relation to coastal governance arrangements for adaptation (ALGA 2011; Forbes 2009; Gibbs & Hill 2011; Good 2011; Gurran et al. 2011; House of Representatives 2010). Coastal climate change policies have been found to be particularly lacking in Tasmania, in comparison to other states (Gibbs & Hill 2011).

The Royal Commissions following both the Victorian bushfires and Queensland floods have also highlighted legal, policy and institutional failures. Several studies have concluded that collaborative approaches to address weaknesses in areas crucial to policy and governance are required (e.g. knowledge management, legislative frameworks) (ALGA 2011; DCCEE 2010).

4.9.3 Existing adaptation efforts

State, territory and national governments have started to articulate the appropriate allocation of roles and responsibilities for adaptation – across levels of government and between government and private interests (COAG 2012; DPAC 2012c; TCCO 2012a). The Tasmanian Government (TCCO 2012a) identifies four roles for government in adaptation:

1. providing sound public information at the regional and local level;
2. taking climate change risks and opportunities into account in public policy, planning and regulation;
3. managing climate change risks and impacts to state-owned and managed infrastructure, assets and services; and
4. assisting vulnerable communities to build climate resilience and adaptive capacity.

These draft statements of policy have yet to be thoroughly tested or validated in either practice or adaptation theory.

Considerable advances have been made in coastal adaptation policy in Tasmania in very recent times, and a number of initiatives are underway at the time of writing. As noted above, the announcement of a sea level rise planning allowance and the development of a state coastal framework will significantly enhance the state's response to coastal climate hazards.

Some recent coastal adaptation projects have contained significant research components of significance to policy and governance arrangements. This research can be classified as either technical modelling and mapping of vulnerable areas, or 'action research' that focuses on the decision-making and community engagement processes. Work in Clarence Council and under the Tasmanian Coastal Adaptation Pathways Project has identified a 15-step decision pathway for assisting in coastal adaptation that involved two parallel processes – a community process and a policy and planning process (SGS 2012), set out in Figure 9.

Community process

Policy and planning process

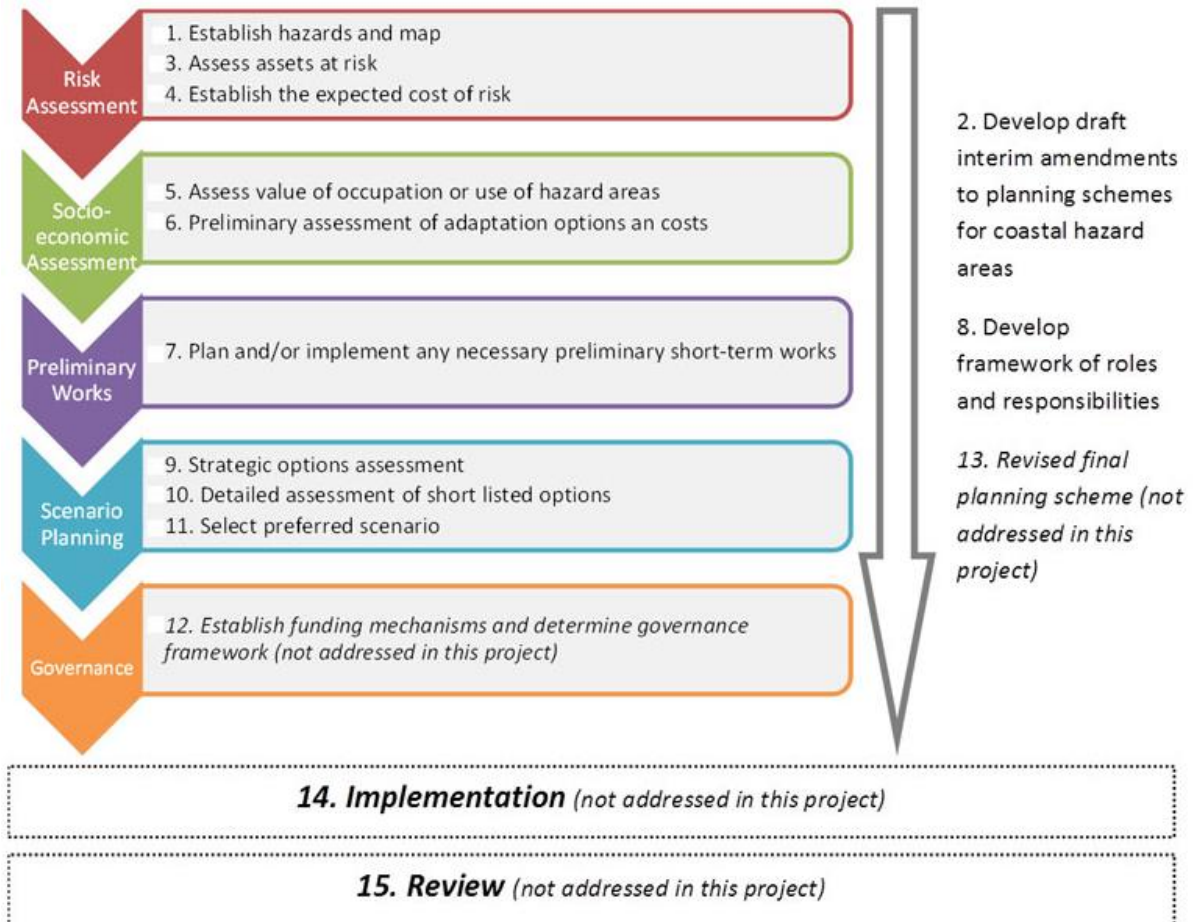


Figure 9. TCAP Pathway process

Source: SGS Economics 2012, www.dpac.tas.gov.au

Studies covering steps 1-9 have been undertaken in Kingston (Kingborough Council), St Helens/Georges Bay (Break O'Day Council), and Port Sorell (Latrobe Council). For Lauderdale in Clarence City Council, step 12 was reached (SGS 2012a). In addition to these projects, a pilot study of the township of Snug in Kingborough explored community interest in, and capacity to adapt to, coastal hazards and sea level rise (Leith et al. 2012). Leith et al. recommended the development of community-based approaches to managing current and future coastal hazards that integrate the efforts of Council, community and science; improvement in Council's level and quality of consultation and communication with the community in coastal hazards management; and development of a citizen science program to collect information about coastal hazards and risks.

Twelve other projects funded through the Australian Government's *Coastal Adaptation Decision Pathways Program* will release findings and reports early in 2013. These projects from across the country have been funded 'to develop leading practice approaches to better manage future climate risk to coastal assets and communities' (DCCEE 2012). They will provide valuable insights into a range of process issues relating to the way adaptation can and should occur in the coastal zone, as well as economic valuation approaches.

Hadwen et al. (2011b) have undertaken research into adaptation pathways for coastal ecosystems and recommend the following principles for coastal zone adaptation (Hadwen et al. 2011b):

1. Adaptation needs clearly defined goals
2. Decision-making must include stakeholders from environmental, social and economic realms
3. Decision-making requires data to be easily available and shared
4. Adaptation demands a drastic re-think of existing policy and planning constraints
5. Adaptation requires a thorough understanding of connectivity within and between ecosystems
6. While adaptation must occur at the local or regional scale, broader perspectives are also important
7. Climate change adaptation should not be considered in isolation of non-climate threats coastal environments already face.

The Regional Councils Climate Adaptation Project has enabled climate change impacts and adaptation options to be considered for Tasmania's Southern region and incorporated into a regional adaption strategy and council adaptation plans which are expected to be published in 2013 (STCA 2012).

4.9.4 Understanding future options

Recognition of barriers to effective adaptation at a range of spatial and temporal scales is of key importance in policy development (Gero et al. 2012; Barnett and Waters 2013). Development and implementation of effective strategies to overcome these barriers must be responsive to the scale at which the barrier is occurring. They must also recognise the limited impact of relatively straightforward short-term 'no-regrets' actions aimed at helping communities and organisations to deal with current climate variability and extreme events (Productivity Commission 2012).

In the longer term, it is important to ensure that policy responses are grounded in paradigms that recognise the game-changing nature of climate change and avoid maladaptation (Herriman et al. 2012; Mukheibir et al. 2012a). There is a growing consensus that transformative change is necessary to successfully transition to a climate change adapted society (including economy, polity) (Moser & Ekstrom 2010). Research focussing on the preconditions for transformative change is highlighting limitations in our legislative and regulatory frameworks (Macintosh et al. 2013) and urban planning (Matthews 2012). Key themes emerging in this research focus on social, economic and institutional circumstances that either hinder or facilitate adaptation initiatives in terrestrial management (Gilfedder et al. 2012; Hughes et al. 2010; Jones in progress), as well as marine systems (Haward et al. 2012; Lockwood et al. 2011). Research also emphasises the need for attenuated engagement processes that recognise and respond to characteristics of individual communities (Leith et al. 2012; SGS Economics 2012b) rather than attempting to impose uniform, top-down policy responses.


Valuation of environmental assets may enable objective prioritisation of adaptive actions designed to manage impacts of climate change on particular natural systems. The current state of knowledge in this field is improving and in time may become consistent enough for policy makers to confidently apply a benefit-cost methodology to underpin decision making for natural systems (Bennett 2011).

4.9.5 *Research gaps and future opportunities*

Governance arrangements, especially those that clarify the roles and responsibilities of public and private sector actors, and different tiers of government, are increasingly being recognised as enablers of adaptation. Conversely, the absence of supportive governance arrangements is a key barrier to adaptation (Barnet et al. 2013). While some additional research may be required to inform governance choices, much of this information is already available and decisions over which option to select will depend upon political preference.

Key research opportunities will focus on maximising the transformative potential of medium-term adaptation responses, and practical approaches to improving policy, planning and governance frameworks to better recognise the dynamic circumstances that climate change creates. Although much of this work will necessarily be conducted on a sector-by-sector basis, and work will continue at a local and community basis, approaches that align bottom-up initiatives with top-down framework and policy development are required as a priority.

4.10 Indigenous issues

 Key findings – Indigenous issues	
Climate change impacts	<ul style="list-style-type: none"> information about projected climate change impacts has yet to be translated into specific understandings of how physical and biophysical impacts will affect Indigenous Tasmanian communities
Sector-specific vulnerabilities	<ul style="list-style-type: none"> Tasmanian Aboriginal cultural heritage is particularly at risk from sea level rise and associated impacts, since many sites are located in intertidal and subtidal areas there has been no specific assessment of the vulnerability of Indigenous communities in Tasmania to the direct or indirect impacts of climate change, based on socio-economic, geographical, or cultural differences
Current adaptation efforts	<ul style="list-style-type: none"> no evidence of any research detailing current climate change adaptation efforts relating to Tasmanian Aboriginal communities or heritage values was identified
Future options	<ul style="list-style-type: none"> a clearer understanding of impacts and vulnerabilities is needed before future options can be considered
Research gaps and opportunities	<ul style="list-style-type: none"> a proper assessment of the impacts of climate change on Tasmanian Indigenous communities, taking into account the vulnerability and adaptive capacity of Indigenous individuals, households, communities, businesses and institutions

4.10.1 Understanding climate change impacts

The *Climate Futures for Tasmania* (CFT) project provides a substantial baseline of research identifying the physical changes that Tasmania will experience as a result of climate change. While much of the detailed climate change information presented in the CFT project is relevant to Tasmania's Indigenous communities and heritage values, this information has yet to be translated into specific understandings of how physical and biophysical impacts will affect Indigenous Tasmanian communities. One physical change already identified as critical for Indigenous communities is sea-level rise. Sea-levels have already risen around Tasmania over the last century (Church et al. 2012; Gehrels 2012), and will continue to rise throughout the 21st century. The TCCO suggest an allowance of 0.8m above 1990 levels by 2100 (TCCO 2012). Sea-level rise, increased flooding and storm surge events are already affecting Tasmania's coasts (Sharples 2004, 2006). These processes threaten Tasmanian Aboriginal heritage, including coastal rock art, middens, burials, sacred and ceremonial sites, hut depressions, stone and ochre resources. It is anticipated that significant Aboriginal cultural

heritage will be destroyed and removed from context by these forces. Tasmanian Aboriginal cultural heritage is particularly at risk since many sites are already located in intertidal and subtidal areas (Page & Thorp 2010).

4.10.2 Understanding sectoral vulnerabilities

There has been no peer-reviewed research into climate change impacts or adaptation specific to Indigenous Tasmanian communities and associated heritage values, practices, landscapes and seascapes. At the national level, Indigenous communities have been identified as particularly vulnerable to the impacts of climate change (Langton et al. 2012), especially in the areas of physical and mental health, because of their remoteness, socio-economic conditions, and exposure to extreme events and natural disasters (House of Representatives 2009). There is also recognition at state government level that Indigenous heritage and culture is under threat from the impacts of climate change (TCCO 2012a; Tasmanian Planning Commission 2009).

This recognition is often focussed on the detrimental impacts of sea-level rise, coastal erosion and inundation on Tasmania's Aboriginal cultural heritage. Sea-level rise is likely to profoundly transform Tasmania's coastal landscapes (DCC 2009); environments economically, culturally and spiritually significant for Aboriginal Tasmanians, providing numerous natural resources upon which many traditional cultural practices are based, but also aesthetic and geographic landscapes important to delineate country. A report into the impact of sea-level rise on the Circular Head region of the North-West coast noted that 'Aboriginal people have identified the Circular Head region as being especially significant for education in traditional use of the land and sea' (Tilden 2011: 2), highlighting the interlinked connections between natural, economic and social values impacted by climate change.



Photo 14. Circular Head is significant for education in traditional use of land and sea
Photo: DCCXLIX, Flickr

While there is awareness that sea-level rise will have ‘catastrophic consequences for the survival of important elements of Tasmania’s Aboriginal heritage’ (Aboriginal Heritage Tasmania 2012: np), no research was identified as specifically focussed on ascertaining site vulnerability or detailing the extent of anticipated impacts. A study into the vulnerability of Tasmanian coastal assets could not assess the extent of Aboriginal heritage likely to be affected since relevant datasets were not available or accessible for Aboriginal cultural heritage sites (DPIW 2008).

It may be speculated that climate change induced impacts on Tasmanian landscapes will have profound consequences for Indigenous physical and spiritual associations to country (Langton et al. 2012), including changes to hunting, fishing and cultural practices. The Tasmanian Planning Commission (2009: np) has noted that:

There is concern about the implications of changes in traditional recreational activities such as mutton-birding due to species population changes. A decline in the productivity of Tasmania’s coastal and marine environment due to increases in sea-surface temperatures and other climate related changes may have implications for traditional recreational activities.... Changes in the timing of plant and animal life cycle events may have implications for traditional Aboriginal activities.

While there is published research relating to some of these biophysical impacts, how they will affect Indigenous communities remains undocumented. A number of areas within Tasmania are administered by Indigenous land management agencies, such as the Tasmanian Aboriginal Centre (TAC), the Aboriginal Land Council of Tasmania (ALCT) and the Tasmanian Aboriginal Land and Sea Council (TALSC), and these organisations are likely to require access to information about the biophysical impacts resulting from climate change to inform their decision-making, planning and management activities.

There has not been any specific assessment of the vulnerability of Indigenous communities in Tasmania, based on socio-economic, geographical, or cultural differences, to the impacts of climate change. Nor has there been any research into indirect effects from changes to Tasmania’s natural environments (for example, changes to fishing, hunting and cultural practices). Research of potential relevance to Indigenous Tasmanian communities has been conducted either generically at a national level, is embedded in studies of Indigenous communities from other parts of Australia, or derives from Tasmanian-specific research related to other sectors.

Given the dearth of research relating specifically to Indigenous Tasmanians, research projects undertaken in furtherance of the *National Adaptation Research Plan for Indigenous Communities* (Langton et al. 2012) could form the basis for future inquiries into the impacts, vulnerabilities, adaptation options and future opportunities relating to Indigenous communities in Tasmania. Potentially relevant projects are listed in Table .

Table 7. NCCARF projects of potential significance to Tasmanian Indigenous communities

Title	Objectives
<p>Health impacts of climate change on Indigenous Australians: identifying climate thresholds to enable the development of informed adaptation strategies</p> <p>Donna Green (University of New South Wales)</p>	<p>This project aims to provide decision-makers with clear and robust policy-relevant evidence that identifies the connections between climate, and the health and well-being of Indigenous people in the tropical north of Australia. It is the first major comparative study to test the hypothesis of disproportionate climate impacts on health, through two separate but related projects in urban and remote Indigenous communities. The study disaggregates data by indigeneity for past climate-morbidity and mortality relationships in order to identify thresholds in the urban setting. These identified thresholds would then be used to project mortality and morbidity of Indigenous people to future climate change, assuming no acclimatisation or adaptive strategies occur.</p> <p>In the remote community sites, in addition to the quantitative analysis, the project will also perform a qualitative study to assess the psychosocial impacts of climate change through the use of semi-structured interviews. Overall, we anticipate this research will better enable policy-makers to develop effective adaptation strategies to increase the resilience of Indigenous Australians to the health impacts of climate change.</p> <p>(http://www.nccarf.edu.au/content/health-impacts-climate-change-indigenous-australians-identifying-climate-thresholds-enable)</p>
<p>Changes to Country and Culture, Changes to Climate: strengthening institutions for Indigenous resilience and adaptation</p> <p>Jessica Weir (Australian Institute of Aboriginal and Torres Strait Islander Studies)</p>	<p>To understand the barriers to and enablers of Registered Native Title Bodies Corporate (RNTBCs) in facilitating community driven adaptation on native title lands and develop best practice for participatory climate change decision-making, specifically through:</p> <ol style="list-style-type: none"> 1. analysing and documenting the role and capacity of RNTBCs in climate change adaptation, through collaborative research partnerships; and 2. providing relevant stakeholders with knowledge to develop effective working relationships with RNTBCs, based upon an appreciation of their unique systems of communal land ownership and governance circumstances <p>(http://www.nccarf.edu.au/content/changes-country-and-culture-changes-climate-strengthening-institutions-indigenous-resilience)</p>

Title	Objectives
<p>Learning from the past, adapting in the future: identifying pathways to successful adaptation in Indigenous communities</p> <p>Meg Parsons (University of Melbourne)</p>	<p>This project will examine how Indigenous individuals, households, communities, business, and institutions perceive and respond to climate variability and extreme weather events. It will explore the importance of climate events and climate change relative to other risks facing Indigenous communities. It will identify entry points for the development and implementation of equitable, efficient and appropriate climate change adaptation plans and policies for Australian Indigenous communities. Using case studies, and a systematic review of experiences and cases from across Australia and internationally, it will produce information to assist Indigenous communities and decision makers to engage in and develop community level adaptation strategies, and suggest strategies to enhance adaptive capacity within the communities.</p> <p>(http://www.nccarf.edu.au/content/learning-past-adapting-future-identifying-pathways-successful-adaptation-indigenous)</p>
<p>Understanding Urban and Peri-urban Indigenous People's vulnerability and adaptive capacity to Climate Change</p> <p>Daryl Low Choy (Griffith University)</p>	<p>The challenges facing coastal communities in Australia are potentially immense, and while community and stakeholders generally accept that change is occurring, the degree of change remains disputed, and the visual picture of what settlements might have to adapt to and address is very unclear. Using case study areas in Queensland, South Australia and Victoria, this project will investigate the long-accumulated knowledge of Australia's Indigenous community regarding the challenges of climate change for coastal communities.</p> <p>(http://www.nccarf.edu.au/content/understanding-urban-and-peri-urban-indigenous-peoples-vulnerability-and-adaptive-capacity)</p>

4.10.3 Existing adaptation efforts

No evidence of any research detailing current climate change adaptation efforts relating to Tasmanian Aboriginal communities or heritage values was identified in this review. A conference abstract by Prince (2007) and report by Rao et al. (2008) mention efforts by the Parks and Wildlife Service and the TALSC to stabilise and revegetate eroding middens located within the Tasmanian Wilderness World Heritage Area (see also unpublished reports mentioned by the Tasmanian Planning Commission 2009). The *Tasmanian Coastal Works Manual* (Page & Thorp 2010: 11) notes rising sea-levels as an added impetus for protection of 'Aboriginal sites and values from human impacts such as works activities' and suggests that 'land managers should monitor sites carefully for any changes or potential impact and undertake risk assessments to determine the best strategies for mitigation and protection of heritage values where appropriate'.

4.10.4 Understanding future options

In light of the limited research, it is hard to assess the extent to which climate change poses significant threats to Tasmania's Indigenous communities. Without an assessment of potential risks, it is difficult to identify and evaluate future options.

4.10.5 Research gaps and future opportunities

The absence of research into the impacts of climate change on Indigenous communities and cultural heritage values in Tasmania is potentially a significant gap. Hence, it is difficult to identify specific research gaps and opportunities other than to speculate that they echo those existing nationally. According to Langton et al. (2012: 4), research should prioritise the vulnerability and adaptive capacity of Indigenous individuals, households, communities, businesses and institutions.

Whatever research is done must be cognisant of cultural issues and perspectives. For example, Thom et al. (2009: 15) have noted that the 'cultural links of Indigenous communities to sea country create some highly sensitive issues when examining potential adaptation strategies to climate change'. A paper by O'Neill et al. (2012: 1107) on local Indigenous resistance to research on the impacts of climate change in Torres Strait highlighted that 'adaptation responses are likely to be prioritised differently' for Indigenous communities.

5 SYNTHESIS AND CROSS-CUTTING THEMES

This section examines challenges and future directions for Tasmanian policy-makers, researchers and practitioners considering adaptation futures. We first examine the common drivers of adaptation in order to understand better where the entry points for enhancing adaptation actions might be. We then explore common themes and issues that emerged in our exploration of what short- and medium-term vision researchers and stakeholders held for adaptation in their sectors or fields. The barriers to progressing these visions are identified, followed by a discussion of the sectoral dependencies and relationships that may influence future adaptation pathways.

Given the lack of Tasmania-specific research on these cross-cutting issues, the discussion synthesises findings from interviews with researchers and stakeholders, and discussions during the project workshop held in December 2012. Where relevant, literature is cited in support of these findings.

5.1 Drivers of adaptation

Summary – Drivers of adaptation in Tasmania

- ◆ funding and resources (may be a mechanism driving adaptation or lack of funding may be barrier)
- ◆ past events (e.g. extremes, climatic impacts), knowledge of likely physical impact that will result in cost
- ◆ changes in market supply & demand
- ◆ changes in policy and political environment
- ◆ community or public pressure, general awareness and community attitudes
- ◆ developments in research and understanding, capacity and know-how
- ◆ desire to seize new opportunities
- ◆ risk management, avoiding catastrophic change, mitigating discomfort of change and transformation, avoiding legal liability
- ◆ moral impetus, intergenerational equity
- ◆ loss of goods/services etc including personal loss

There are very few published case studies of adaptation in Tasmania. Conclusions about what might be driving adaptation have therefore been drawn through inference from available literature as well as feedback from interviews and the project workshop. Workshop participants were each asked to identify what they thought were the most significant drivers (or motivators) of adaptation for their sector. Examples such as changes in production or market conditions, changes in the policy environment, or changes to supply chains were given as examples, to serve as thought-starters. Participants were asked to write their responses clearly and concisely on sticky notes. These notes were then posted on the wall for all to view, and grouped into themes.

Grouping occurred immediately after all participants had completed their notes, and was done in consultation with workshop participants to verify that the choice of category captured their original intent. Ten emerging themes are outlined in Table 8, below. Against each theme heading is the group of responses provided. While the theme categorisations and rankings are indicative only, based on a snapshot of professional opinions, the findings do largely correspond to those from the larger body of Australian and international literature on the motivations for adaptation (see, for example, Kiem et al. 2012, King et al. 2012).



Photo 15 Workshop participants were asked to identify significant drivers of adaptation. Photo: Holger Meinke

Table 8. Workshop participant opinions on drivers of climate change adaptation interest and action

Driver	Examples of comments	
Funding and resources (may be a mechanism driving adaptation or lack of funding hindering adaptation innovation)	<p>'Money!'</p> <p>'Changing financing mechanisms [for infrastructure](e.g public-private partnerships)'</p>	<p>'Lack of funding /resources....'</p> <p>'Future access to funds and insurance [infrastructure]'</p>
Past events (e.g. extremes, climatic impacts), knowledge of likely physical impact that will result in cost	<p>'Shifting species distribution'</p> <p>'Changes in environmental health condition'</p> <p>'Response (or lack of) to extreme event'</p> <p>'Past events and current variability'</p>	<p>'Warming & drying of wetter uplands (Tasmanian Central Plateau)'</p> <p>'Response to extreme event'</p> <p>'A need to respond to an extreme event – particularly one that is likely to occur again and again (flooding, bushfire, sea level rise, drought etc)'</p>
Changes in market supply & demand	<p>'Changes in markets – demand & supply – across state, national, international scales'</p> <p>'Marine resources – markets & demand'</p> <p>'Changes in other sectors (affecting food supply, production, employment, markets, fiscal environments .'</p> <p>'Changes in water demand and patterns of use'</p> <p>'Shifts in availability of skilled & unskilled labour'</p>	<p>'Economic downturn –profitability of businesses related to climate change impacts'</p> <p>'Changes in markets – as population awareness changes the demand for greener products will drive adaptation. Climate change will limit or create opportunities'</p> <p>'...industry concern/pressures e.g. tourism'</p>
Changes in policy and political environment (not necessarily related to adaptation)	<p>'Water law and policy changes (biodiversity)'</p> <p>'Governance'</p> <p>'Changes in land-use'</p> <p>'National policy (e.g. carbon/energy)'</p> <p>'Climate change as critical external factor in policy setting'</p> <p>'lack of political will'</p> <p>'Broader planning reforms'</p>	<p>'Political will – governments prepared to act'</p> <p>'Changes in policy environment enabling adaptation'</p> <p>'Changes in policy affecting communities (industries, employment, education, housing etc) Biodiversity adaptation responses (e.g. Marine Park Areas)</p>

Driver	Examples of comments	
Community or public pressure, general awareness and community attitudes	'Increased levels of demand from community & industry for certainty in planning' 'Land use planning - changes in community values' 'Knowledge & awareness of impacts, adaptation approaches and opportunities' 'Changes in community awareness around disaster response and recovery'	'Public awareness' 'Changes in community expectations around disaster response & recovery (emergency management)' 'Societal values and attitudes' 'Community knowledge and awareness' 'Increased community acceptance' 'Community concern/support'
Developments in research and understanding, capacity and know-how	'New developments in research – climate impacts – adaptation opportunities & options'	'Know-how' 'Understanding the most effective scales to operate at' 'Projections – for emergency planning'
Desire to seize new opportunities	'Creating/acting on opportunities – ensuring policy settings are appropriate'	'Tourism opportunities'
Risk management, avoiding catastrophic change, mitigating discomfort of change and transformation, avoiding legal liability	'Changes in settlement patterns (density, demographics etc)[risk management] '...implications for liability ...access to insurance' 'Concern about future liability' 'Minimising exposure to risk'	'Risk management approach across many emergencies' 'Risk management – social, economic, environmental' 'Awareness of risk and vulnerability (industry specific)'

Driver	Examples of comments	
Moral impetus, intergenerational equity	'Moral impetus' 'Avoidance of major change – adaptation is a minimalist approach'	'Human desire for preservation'
Loss of goods/services etc including personal loss	'Potential threats to people and assets and desire to avoid these threats' 'Reduce risk to natural assets to reduce risks to life and property from increased frequency and severity of fire'	'Balance between risk & opportunity in coastal areas (enjoy it while it is 'safe' to do so)'

From these ten major themes, participants were asked to rank the drivers in order of importance to them using Turning Point® real-time polling software.

Participants could rank up to ten drivers, in descending order of perceived importance. Figure 10 shows the aggregated scores of the ten themes. Of these, the risk management theme (*risk management, avoidance of catastrophe or transformation and legal liability*) received the highest score, followed by the *threat of loss of goods and services* (such as personal loss), and then *developments in research and understanding*. *Changes in policy and political environments* not necessarily related directly to climate change adaptation, and changes in public environments (*community pressure, awareness and community attitudes* around climate change) scored similarly.

The mid-ranking themes were *changes to markets* (factors contributing to supply and demand of goods and services), availability of *funding and resources* for adaptation work, and the impetus of responding to *past events*, particularly extreme weather events. The final two themes (the *moral impetus and intergenerational equity*, and the *desire to seize new opportunities*) ranked the lowest but were still considered important drivers for a number of participants in some form or another. While this ranking process is obviously only indicative, 83% of participants indicated that they were happy with the overall scoring.

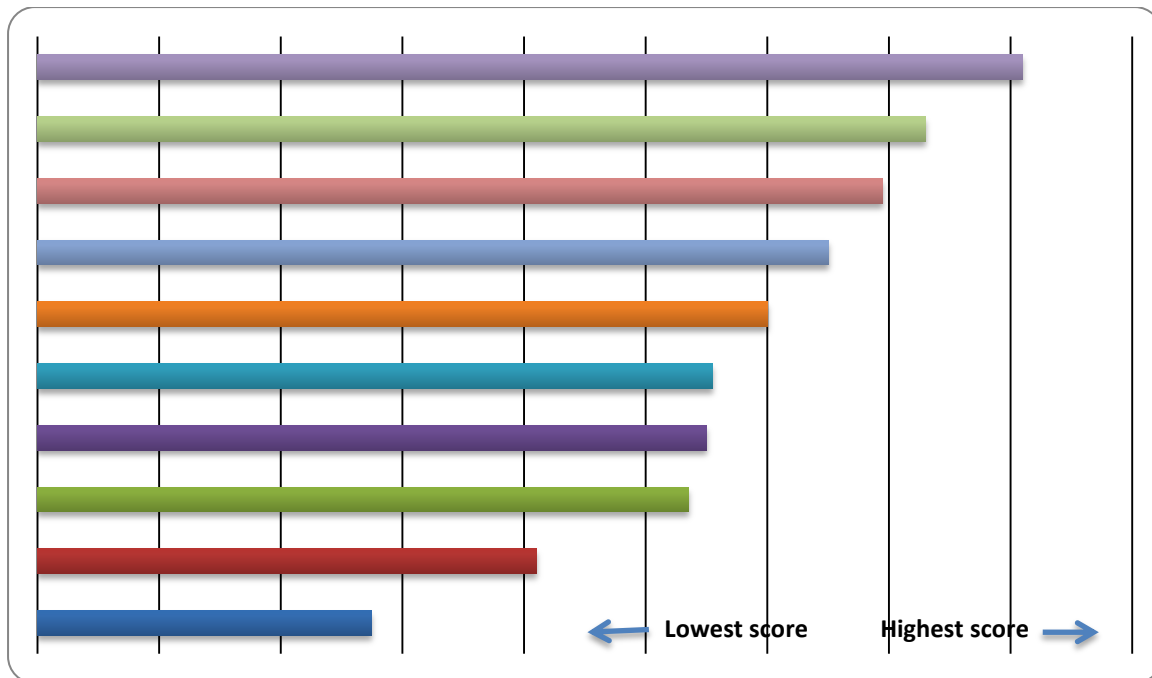


Figure 10. Top 10 drivers of climate change adaptation interest and activity

These results suggest that a high level of direct or private interest is necessary in order to drive adaptation. In many situations, people are having to experience an event first-hand before being able to imagine its potential impact on them. At a policy level, this is evident in significant reforms coming on the back of major extreme events and natural disasters that involve significant losses for governments as well as for private individuals, such as the 2011 and 2013 Queensland floods or 2009 Victorian bushfires. Research elsewhere suggests that the window for action following events may be relatively brief (Helman et al. 2010). Adaptation is more likely to occur where it can be articulated as part of a broader risk management strategy and this assumes that the risk of some adverse outcome has already been identified. The high ranking of *fear of loss* (in the form of business opportunities, property damage or legal liability) also reflects the economics and decision theory literature relating to loss aversion – that is, people are motivated more by a desire to avoid loss than by an expectation of gain (Kahneman & Tversky 1984).

The results also point to the importance of research and research funding programs as a driver of adaptation in its own right. Indeed, the fact that risk assessment was ranked highest may well reflect the importance given to risk-assessments over the first ‘phase’ of adaptation research in Australia between about 2004-2012. While we did not explore the issue in more depth, we suggest that better understandings of both the need for adaptation (for example, through the CFT, sea-level rise, and other sector-specific work) *and* the feasibility of potential adaptation options are driving adaptation planning and action in many sectors in Tasmania.

The lower importance of market influences probably indicates that climate change impacts have not yet penetrated the supply chain or customer demand. One can only assume that this will assume higher importance over time, as prudent risk management interventions give way to more pressing economic or business imperatives that are reactions to external pressures.

The fact that concern for future generations and moral impetus ranked relatively low may also reflect the current stage of adaptation action in Australia more broadly. There are, however, significant risks that decisions taken now will create path dependencies that limit future scope to protect non-human values or future generations. This reinforces the need, emerging from the limited literature on this issue, for mechanisms by which to ensure that these interests are adequately represented and valued in present-day adaptation decision-making. This will be increasingly important in the future, as decisions are made involving difficult trade-offs between current and future interests/generations, and between protection of human versus environmental values. The precise mechanism by which to capture or represent these views will depend upon the interests to be traded-off and the benefits that might flow.

The low ranking of the driver relating to new opportunities is noteworthy, if not entirely surprising. We suggest that it reflects the level of understanding of climate change impacts, the extent of those impacts on current operations and the relative primacy of non-climate drivers in current business decision-making and policy-making.

5.2 Future visions: common elements and themes

Summary – Future visions

- ◆ Climate change adaptation needs to be mainstreamed into government and industry's core business.
- ◆ A more holistic approach to funding recognising the multi-faceted, trans-disciplinary nature of adaptation and adaptation science is required to truly mainstream adaptation.
- ◆ Improvements in governance arrangements will improve adaptation efforts. This includes: the need for clear adaptation plans and policies; roles, responsibilities and leadership); the need for holistic approaches; legal and policy reform; and more adaptive institutional arrangements.
- ◆ Enhancing adaptive capacity and resilience and reducing non-climate stressors is a no-regrets strategy for dealing with climate change.
- ◆ Resourcing is needed for effective adaptation, including adequate training or re-training of personnel, education programs, investment in new processes, and the funding of specific policies and programs.
- ◆ Local government currently lacks the resources required to deliver adaptation policies and actions.
- ◆ The effectiveness of adaptation actions requires ongoing monitoring and evaluation.
- ◆ Achieving required attitudinal shifts requires sector-specific and targeted public education programs.

Adaptation means different things across sectors and between actors. As with other parts of Australia, it is impossible to articulate a single vision for adaptation in a given sector in Tasmania, let alone for the entire state. Not surprisingly, the literature makes very little explicit reference to what adaptation needs to 'look like', but both stakeholder interviews and workshop discussions revealed a remarkably consistent, sector-neutral set of recurring themes that also find reflection in published research.

Workshop participants were asked to identify a vision for adaptation in their sector by 2040, and what steps would be needed over the next 5–10 years in order to achieve this. The

exercise was undertaken for the following sectors: governance, land use planning, marine biodiversity and resources, terrestrial biodiversity, agriculture, and business and industry. While the results of this visioning exercise cannot be taken to be authoritative for any sector, the common issues that emerged are important guides to future adaptation policy, planning, research and implementation. They should be read in conjunction with the discussion in 5.3 of barriers to adaptation, since the elements of 'good adaptation' identified often involve the removal or reduction of barriers.

5.2.1 Mainstreaming adaptation

The need for climate change adaptation to be mainstreamed into government and industry's core business was a powerful, persistent theme. There was a view that the time for 'pilot' projects addressing adaptation was past and there was now a need for adaptation to assume a more central role and become part of 'business as usual'. For government policy, this meant integrating adaptation considerations into all government departments, not just those relating to climate change: 'ideally, every government department would have a climate change adaptation strategy' (Interview 005). It also means ensuring that adaptation goes beyond merely developing a strategy and required training and resourcing within agencies and decision-making processes. From a business perspective, the priority was seen to have adaptation reflected in business plans. The call for mainstreaming also extended to budgetary arrangements: 'everyone has to do it! All budgets should have an allocation for adaptation planning' (Interview 006).

While the call for mainstreaming holds undeniable appeal, it is notoriously hard to deliver in practice. Similar calls have been made in respect of climate change mitigation, environmental protection more generally, as well as a range of other social policy objectives (such as gender and health). Fundamentally, mainstreaming requires a significant change to the way we govern. It requires the dismantling of sectoral 'silos' and a more integrated approach to the range of sectoral dependencies we discuss. Attention to the way governance arrangements support or impede adaptation is a related recurring issue addressed below. In addition, the tendency of governments to allocate funds for specific programs constrains the capacity of agencies and individuals seeking to resource broad-based initiatives that do not fit a linear model of program delivery. A more holistic approach to funding that recognises the multi-faceted, trans-disciplinary nature of adaptation and adaptation science would be required to truly 'mainstream' adaptation.

Moreover, there may be some circumstances in which mainstreaming of adaptation may itself act as a barrier. By definition, mainstreaming presupposes that existing policies and institutional arrangements can accommodate adaptation imperatives. The call for mainstreaming by stakeholders may reflect the fact that virtually all stakeholder insights are constrained by prevailing economic, business, and policy contexts. This may be appropriate in sectors where incremental change will work, but may actually serve to limit the potential for transformative change where this is needed. Our investigations revealed a profound absence of discussion of the potential for transformation, which may reflect either the entrenchment of existing path dependencies or the perceived lack of urgency or need for more fundamental changes.

5.2.2 Governance

The need for enhanced governance arrangements to support adaptation underpinned all 'visions', and was also reflected in most stakeholder interviews. Concerns over governance encompassed a wide range of issues, including: the need for clear adaptation plans and policies; roles and responsibilities (including the need for leadership); the need for holistic approaches; legal and policy reform; and more adaptive institutional arrangements.

While there is a significant body of literature characterising autonomous or reactive adaptation, there was wide agreement among participants that effective adaptation needed to be explicitly planned for. Some described this as a 'clarity of purpose', or 'policy certainty', while others simply expressed the view that we needed to 'have a plan!' or leadership (Hobson and Neimeyer 2011). While the content of these plans was discussed less than the need for the plan itself, implicit in all discussions was the importance of plans taking a pro-active, preventive approach to avoiding climate change risks.

There is broad recognition of the need for governance arrangements to clearly articulate the distribution of roles and responsibilities (Barnett & Waters 2013), and to reflect the multiple spatial and temporal scales at which adaptation needs to occur ((Kellett et al. 2011). A related issue was the importance of ensuring that governance arrangements give effect to the principle of subsidiarity – allowing decisions and actions to be taken at the level at which both scale efficiencies and accommodation of local differences can best be realised (Hadwen et al. 2011b; Robson et al. 2013).

Recognising adaptation's broad reach also means developing mechanisms by which to coordinate and share planning and implementation vertically across tiers of government and horizontally across agencies and organisations (King et al. 2012).

Some sectors foreshadowed the need for legal reform, although there was little detail about what kinds of change might be needed. An exception to this was for the marine sector, which indicated the need for a policy, backed by law, for zoning to achieve a vision of 'increased sustainable production of seafood (both fisheries and aquaculture) under a system that maintains and improves biodiversity services'. Some sectors may also require a fundamental re-think of the current institutional arrangements. For example, land use planning may require reforms to the system of merits review of local government planning decisions, reflecting concern that precautionary planning decisions aimed at minimising future exposure may be overturned by a planning tribunal. Some even suggest the need for a review of the decision-making arrangements themselves, including the role of the Tasmanian Planning Commission and local governments.

Another common theme was the importance of addressing adaptive capacity and resilience (Kiem 2010a and 2010b; Boon et al. 2012). Redoubling our efforts to manage non-climate stressors and enhancing natural resource management governance arrangements is a no-regrets strategy would go far in delivering adaptation benefits. Addressing deficiencies in the way we currently handle non-climate stressors requires attention to deficiencies in current governance regimes.

There was widespread agreement that the improvements in governance needed for adaptation are no different from broader good governance principles in relation to biodiversity, resource management, health and a range of other policy spheres. For example, in the context of biodiversity conservation, this would involve harmonising conservation objectives across agencies with conservation, land use management and resource exploitation responsibilities; and resourcing policies and programs over long timeframes – elements that have hitherto proven very difficult to achieve.

Connecting the related themes of mainstreaming and governance of adaptation is the need for more holistic approaches, requiring integration of policy content and institutional arrangements. In a biodiversity context, it involves an expanded focus to ecosystem services, away from purely species-based approaches (Hadwen et al. 2011b). From a business perspective, a more holistic approach may require diversification of business activities and profiles in order to minimise risks and pursue opportunities from adaptation. In relation to land use planning, it requires that decisions about whether to protect, defend, accommodate or retreat from vulnerable settlements need to consider the needs of other land uses, particularly ecosystem needs in coastal and bushfire-prone areas. In health, a focus on sustainable and resilient communities will demand contributions from sectors beyond health services. As part of this focus on holistic decision-making, some stakeholders also saw significant benefits in more integrated and multi-disciplinary research (Interview 012).

Achieving the changes in governance outlined above will demand new models of collaboration and public participation. In biodiversity conservation, this will include the need for more citizen science (natural and social) to inform adaptation priorities. In land use planning, adaptation requires community agreement on acceptable levels of risk, particularly in a bushfire, flooding, or coastal context. Principles of collaborative governance can enhance the processes by which adaptation is achieved.

5.2.3 Resourcing

Planning and implementation of adaptation will need to be adequately resourced. This involves adequate training or re-training of existing personnel, broader community education programs, investment in new agricultural or business processes, and the funding of specific policies and programs. A recurring theme is the limited capacity of local government to deliver the adaptation policies and actions expected of them by the community and devolved to them by State government (Mukheiber et al. 2012b). Another issue emerging from the national literature is the inefficiency and ineffectiveness of emergency funding as a means of financing adaptation (Crompton et al. 2012; Wenger et al. 2012; Boon et al. 2012).

In both business and agriculture it was recognised that incentives may be needed in order to drive private adaptation and stimulate market demand. Transitional support in the form of subsidies and tax breaks and increased training for new and transitional industries could be considered, although the long-term sustainability of such measures needs to ensure that they do not create new dependencies or entitlement mentalities.

5.2.4 Implementation, monitoring and evaluation

A key correction to current governance arrangements that was identified across sectors was the need for better and ongoing monitoring and evaluation of adaptation policies and actions. As part of the critique that the time for pilot projects had passed, it was recognised that we need to start ‘doing’ adaptation, even if it means doing so imperfectly. While some participants suggested that more baseline information is required, this was not understood to imply that such data collection should occur *before* action begins, rather that existing baselines should be used as a starting point and that such information was crucial for effective monitoring and ongoing adaptive responses. There was widespread support for more adaptive governance models – that implement measures, rigorously monitor their effectiveness, evaluate unforeseen impacts, and then make adjustments to enhance their operation. Across sectors, the importance of program longevity was emphasised, even though the precise elements of the program may change over time.

A few stakeholders – particularly those in the primary industries sector – explored implementation through the lens of the ‘research-to-action’ interface, arguing for more extension work (Interview 003) and boundary organisations to bring new research to the hands of end-users.

5.2.5 Attitudinal change

While information, resources, and policy interventions are essential for successful adaptation, they are unlikely to be sufficient. Some profound shifts in attitude will be required too. Achieving these shifts will require sector-specific and public education programs (QUT 2010). In business, the focus needs to broaden, from impacts and vulnerability towards adaptation planning and implementation. To some extent, this requires increased acceptance of the inevitability and likely future shape of climate change impacts, but it also involves looking beyond climate risks to exploring business opportunities. In a biodiversity context, both the community and policy-makers will have to accept the inevitability of new losses and trade-offs such as species loss, and shift to a policy of conservation triage. At the same time, however, broader community understanding and appreciation of the value of biodiversity and its role in adaptation will need to be engendered. In relation to land use planning, Tasmanians will need to change their views about acceptable levels of risk and the balance of risks and benefits associated with living in vulnerable coastal or bushfire-prone areas.

5.2.6 Opportunities

Very few of the workshop ‘visions’ considered the opportunities that may flow from adaptation imperatives, but opportunities emerged in a few stakeholder interviews. The decision-support tools that are being developed to inform adaptation had potential to result in better risk management more generally. Primary industries and tourism saw potential to exploit the state’s ‘clean, green’ image, while the state’s small size, tight networks, and skilled climate change research base fostered trusted research partnerships (Interview 009; Interview 010).

5.2.7 Research-to-practice translation

Stakeholder participants generally indicated a high level of satisfaction with the impacts and adaptation research completed or currently underway in Tasmania: 'I think the state of adaptation research in Tasmania is really good. We are certainly leading the way in that regard. I am very confident in the adaptation research being done' (Interview 014). For some, however, there was scope to improve the dissemination of research outcomes. There is a desire for information about best-practice experiences from elsewhere in Tasmania, Australia and internationally. In some sectors, particularly primary industries, traditional extension and engagement activities are needed to bring these insights to the level of the local operator:

The best way to improve dissemination of climate change adaptation research would be to rely less on a package of information in the mail and instead return to the old-fashioned approach of someone actually coming and seeing you. (Interview 013)

In the same way that significant gains could be made by applying good-governance principles to current stressors and problems, participants saw considerable untapped potential in current data and tools. In the biodiversity context, consolidation and tweaking of tools that already exist, such as Conservation of Freshwater Ecosystem Values (CFEV), Conservation Information Systems (CIS), and the Natural Values Atlas (NVA) could considerably enhance the information base upon which adaptation decisions are made.

5.3 Barriers to adaptation

Summary – Barriers to adaptation

- ◆ barriers exist across the three phases of understanding, planning and managing adaptation
- ◆ understanding the nature of the climate impact is not enough for effective adaptation: both the planning phase and the managing phase also represent potential barriers.
- ◆ more detailed sector-specific analysis could identify specific barriers for each sector and develop strategies to overcome the potential barriers.

An understanding of the limits and potential barriers to adaptation can enhance the objectives, design and implementation of adaptation efforts (Morrison and Pickering 2011). The concepts of barriers and limits are often used interchangeably in adaptation planning. Limits to adaptation consist of thresholds beyond which activities, land uses, ecosystems, species, or other system states can no longer be maintained, even in a modified form (Moser & Ekstrom 2010). Beyond such limits, irreversible loss occurs unless radical system shifts, known as transformations, can occur. Limits are common in physical and ecological systems in their natural state, but, in some instances, physical and ecological limits have been stretched or overcome with technological innovations (IPCC 2007b). Limits are more likely to be encountered in natural systems than in social, industry or political contexts. Whether Tasmania faces limits to adaptation depends on how adaptation is defined. It will be specific to each sector and place, and to the values of those seeking to adapt. That said, the exceedence of natural limits is likely to result in irreversible loss of places, identities, species and ecosystems comprising Tasmania's unique terrestrial biodiversity and marine ecosystems.

Apparent limits that can be avoided or pushed back through technological or other means are better understood to be barriers to adaptation. Barriers are obstacles that can be overcome through changes in attitude, priorities, values, resources, land use or institutions (Moser & Ekstrom 2010), although these changes may well be extremely hard to achieve. What may first seem to be 'limits', especially social ones, are in fact barriers that can be overcome with sufficient political will, social support, resources, and effort (Adger et al. 2009). However, many barriers will make adaptation less efficient or effective, or may require costly changes that lead to missed opportunities or higher costs.

The barriers to adaptation will be more nuanced and diverse than limits. Even within a specific sector or location, individuals and groups are likely to face difficulties at different stages of the adaptation cycle – some in identifying the need for adaptation, some in developing responses. These differences mean that the processes of adaptation decision-making must be inclusive and pluralist.

Barriers are sometimes perceived to be more problematic than they are in reality, so understanding potential barriers is an important part of adaptation planning (Moser & Ekstrom 2010). Despite this, the complex interrelationships between barriers may make it difficult to distil or prioritise individual barriers (Evans et al. 2011).

This section reports stakeholder perceptions regarding barriers to adaptation drawn from both interviews and workshops techniques, with reference to supporting literature where relevant. The workshop used a high-level structure to consider 'where' barriers can arise in adaptation development, while the interviews showed in more detail 'what' barriers were encountered. Although the interviews were the more comprehensive, we first present the barriers framework, as this high-level overview provides a structure for organising the interviewee perspectives, and also identifies where no apparent barriers exist.

The project workshop used the framework developed by Moser and Ekstrom (2010) to explore where potential 'institutional' barriers in the process of undertaking adaptation for each sector might lie. This framework differs from the interview-based description of barriers, as it focuses on why barriers arise, rather than what barriers exist. The potential barriers are divided into three stages (understanding, planning and managing), each with three elements (Figure 11).

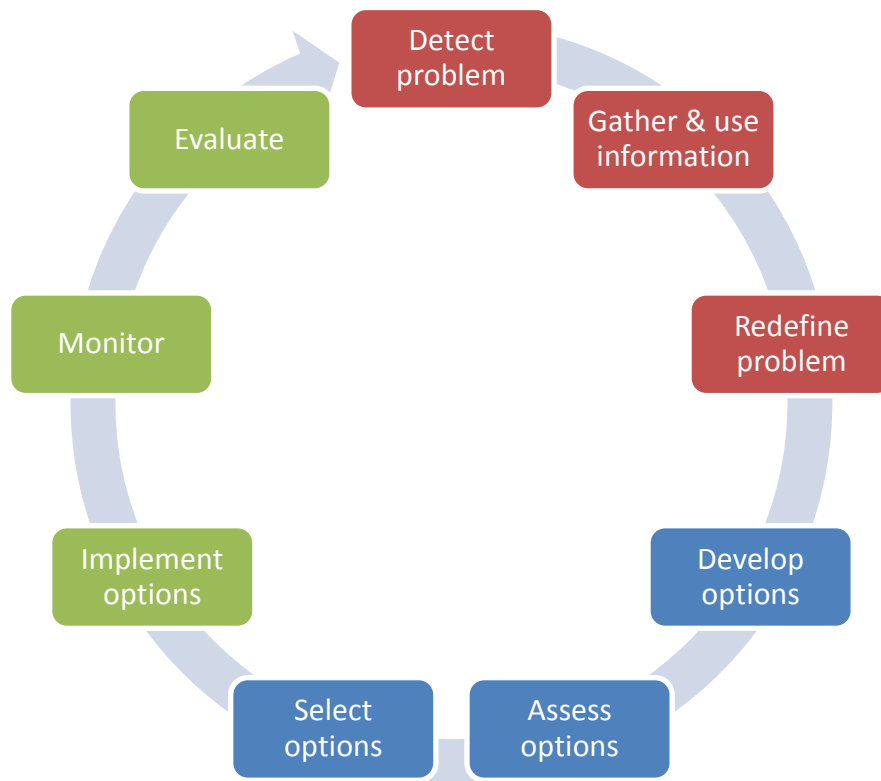


Figure 11. Barriers framework used in the project to evaluate stakeholder perceptions about sectoral barriers

Source: Barmuta et al 2012, adapted from Moser and Ekstrom (2010)

Each of the nine elements in the framework was scored using TurningPoint® software on a Likert Scale from 1-5, where 5 represented a strong barrier for the option, and 1 represented no barrier. Workshop participants ranked general adaptation barriers from the perspective of their sector, according to the following guidance:

Please rate how well your sector (and institutions responsible for that sector) will cope with each of the potential barriers to successful adaptation.

The specific questions for each element were:

- Detecting a signal will be a barrier for adaptation in this sector
- Gathering/using information will be a barrier for adaptation in this sector
- Defining the problem will be a barrier for adaptation in this sector
- Developing options will be a barrier for adaptation in this sector
- Managing the process will be a barrier for adaptation in this sector
- Selecting options will be a barrier for adaptation in this sector
- Implementation will be a barrier for adaptation in this sector
- Monitoring the outcomes will be a barrier for adaptation in this sector
- Evaluating effectiveness will be a barrier for adaptation in this sector



Photo 16. Workshop participants assessed barriers to adaptation using TurningPoint® software. Photo: Holger Meinke

Additional descriptions of each element were provided to participants and discussed on each TurningPoint® PowerPoint slide prior to scoring. The scores for each element were averaged for analysis. As the number of representatives varied from zero to four per sector (see Figure 3, above) rather than analysing the results by sector, and risking unrepresentative views, we instead illustrate the perceived barriers across all participants and sectors. To be representative of each sector, we feel that ten or more representatives should be consulted, and more detail on the types of adaptation being proposed would need to be provided. The coarse result is informative as an example of barrier analysis.

After scoring, results for each question were reviewed and discussed by the workshop participants to clarify and elucidate issues. An example of the scoring is shown in Figure 12. In this case, in response to the element regarding detection of signals, 55% of the group 'agreed' (score of 2) that this would be a barrier to adaptation, with the remainder scoring the other options. Scores of 1 or 2 signify a barrier; while scores above 3 show the participants do not consider this element to be a barrier. The average of all the scores for this question was 2.68, showing that on average, detecting clear signals that would trigger adaptation was considered a barrier for these Tasmanian sectors (score <3, which would be neutral).

Detecting signals will be a barrier

Detecting a response in an indicator for your sector (e.g. fish catch), and knowing likely cause (i.e. climate change)

- Threshold of concern (initial framing as problem)
- Threshold of response need and feasibility (Initial framing of response)

1. Strongly Agree (barrier)
2. Agree
3. Neutral
4. Disagree
5. Strongly Disagree (no barrier)

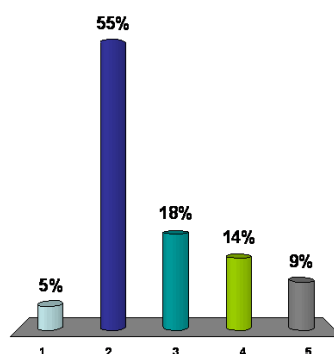


Figure 12. Example of scoring for the barrier analysis, for the first element in the framework

While individual scores spanned the full range of scores (1-5), all of the 9 elements of the Moser and Ekstrom (2010) framework were seen as potential barriers (average score <3; Figure 13).

The elements in the understanding stage were seen as slightly less problematic than the planning and managing stages (scores closer to 1). Interestingly, while researchers were a little more optimistic than the non-researchers (end users and managers), both groups were very similar, and the averages for the three stages showed that the managing phase was likely to be the most significant barrier to successful adaptation (Figure 14). This is borne out in national adaptation literature which identifies a lack of community support and a lack of consensus on adaptation options as barriers to implementing adaptation (Haynes et al. 2011; Poloczanska et al. 2012b; Petheram et al. 2010; Gross et al. 2011; Evans et al. 2011).

While research can contribute to reducing barriers in the understanding phase, it is institutional arrangements that need attention to reduce barriers in the planning phase, and resourcing (financial and people) is needed to see the managing phase occur successfully. From these results, it is clear that more attention needs to be paid to these last two stages, a conclusion reinforced by participants' identifying resourcing and governance as priority areas for reform as part of the visioning exercise.

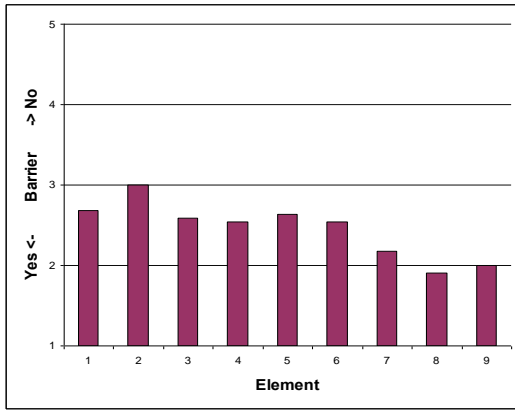


Figure 13. Average scores for each of the nine elements in the barriers framework

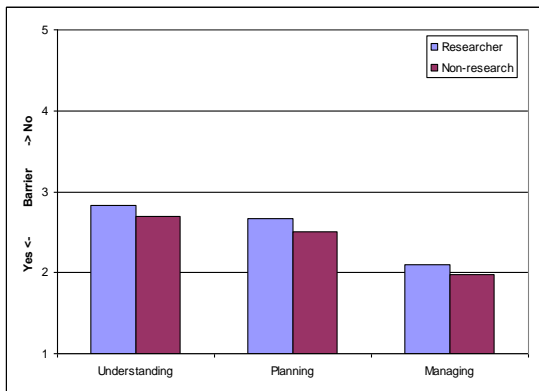


Figure 14. Average scores for each of the three stages (each composed of three elements) for researchers and non-researchers

Interviews with Tasmanian sectoral representatives and research scientists identified common barriers and these barriers all fell within the three main stages of Moser and Ekstrom (2010): understanding of climate change and adaptation options, planning, and managing. Across the set of interviewees as a whole, most barriers were discussed (Table 9).

Interestingly, only one of the nine potential elements in the Moser and Ekstrom framework (#1: Detecting a signal will be a barrier for adaptation) was not identified as a barrier in interviews. Consistent with this, when this element was scored in the workshop, it was the second least ‘problematic element’, after gathering and using information (#2). A possible explanation for this is researchers’ and stakeholders’ widespread satisfaction with the Climate Future for Tasmania work in providing this scientific foundation.

Overall, this analysis confirms that barriers to adaptation planning and action exist, and should be a focus when developing strategies. It also provides further empirical support for the importance of barriers identified in the national literature (Barnett & Waters 2013). Importantly, it suggests that it is not sufficient just to understand the nature of the climate impact; both the planning phase and the managing phase also represent potential barriers. Sectors could undertake more detailed analysis using these methods to develop strategies to overcome the potential barriers.

Table 9. Barriers to adaptation identified by interviewees, categorised against the elements of the Moser and Ekstrom (2010) framework

Element in Moser and Ekstrom framework	Examples of barriers discussed in interviews with stakeholders
Stage in Moser & Ekstrom Framework: <i>Understanding</i>	
1) Detecting a signal will be a barrier for adaptation	none identified.
2) Gathering/using information will be a barrier for adaptation	<p>Information</p> <ul style="list-style-type: none"> • the confusion/uncertainty that surrounds CC science results in confusion in how to respond (Interview 007) • key barriers exist in terms of the ability to know what information to gather and the competency to assess it, and the ability to critically evaluate information and then apply it (Interview 015) • problem in accessing most relevant information (Interview 013A) • plethora of CC research, but much not relevant to Tas and it needs to be presented at temporal and spatial scales that people can relate to. There is lots of info relating to high level principles, but there is a need to bring it down to site scale – what need to do and when and with what priority? I.e., there exists a need to convert principles into tools, systems, frameworks that help decision makers and land managers (Interview 013; Interview 013A) • expectation of the power of projection capability: ‘The state is compact and small, events discrete, we should be able to do exquisite scenario modelling’ (Interview 015)
3) Defining the problem will be a barrier for adaptation	<p>Climate change is only one issue among many:</p> <ul style="list-style-type: none"> • sectors are dealing with a whole range of threats and issues, not just adaptation (Interview 009; Interview 017) • CCA not considered high priority for tourism (ranked 20th out of 20 issues) and for those that want to do something, don’t know what to do (Interview 010). • key barrier to CCA is making it relevant to businesses and that will inevitably be a struggle as it is not the highest priority issue. I am sure it matters to them, but it is a long way down the list when it comes to day-to-day issues (Interview 010) <p>Disincentives for adaptation</p> <ul style="list-style-type: none"> • early adaptors may well experience perverse effects resulting from their response to CC risks (Interview 004) • CCA research needs to adopt time horizons that fit with industry planning horizons (5 to 10 years at most): ‘2050 not on radar’ (Interview 003; Interview 017)
Stage in Moser & Ekstrom Framework: <i>Planning</i>	
4) Developing options will be a barrier for adaptation	<p>Adaptation planning is really hard</p> <p>‘key barrier exists in terms of actually developing viable adaptation options that are not based on reductionist science, but instead engage with the cultural, social and economic aspects’ (Interview 016)</p>
5) Managing the process will be a barrier for adaptation	<p>Policy and governance issues</p> <ul style="list-style-type: none"> • short-sighted political imperatives and anti-policy frame of mind of all political parties key barriers to CCA (Interview 013)

Element in Moser and Ekstrom framework	Examples of barriers discussed in interviews with stakeholders
	<ul style="list-style-type: none"> • legal liability a big issue (Interview 005; Interview 006; Interview 008) • policy settings critical – lack of clear policy direction from State Government and slow pace of policy reform (Interview 005; Interview 019; Interview 009) • need for consistency and clarity in government policy (Interview 011) • lack of clarity in roles/responsibilities critical barrier in CCA planning (Interview 002; Interview 008) • key barrier is for elected reps to develop agreed understanding of the issues – feeds through to everything else (Interview 006) • hesitation by govt to make info available to community in timely manner (Interview 005) • competing policy objectives (Interview 012) <p>hard to constantly update positions and policies in light of new information (Interview 015)</p>
6) Selecting options will be a barrier for adaptation	<p>Selecting options</p> <ul style="list-style-type: none"> • worried about the capacity of govt agencies in Tas to respond to science and review their own goals and objectives – need to look at relevant legislation to ensure that it facilitates change (Interview 013) • major barrier is the cost of exploring adaptation options in practice (not just theoretically) (Interview 007) <p>assessing adaptation options (Interview 016)</p>
Stage in Moser & Ekstrom Framework: <i>Managing</i>	
7) Implementation will be a barrier for adaptation	<p>Resources</p> <ul style="list-style-type: none"> • lack of resources (financial and legislative commitment) at state (Interview 005); local government (Interview 006; Interview 017); or in sector (Interview 014) • differential capacity of local governments (Interview 005) <p>very hard to develop proactive rather than reactive approach (mainly to do with lack of resources) (Interview 012)</p>
8) Monitoring the outcomes will be a barrier for adaptation	<p>Monitoring and evaluation</p> <ul style="list-style-type: none"> • lack of monitoring and evaluation (Interview 005). <p>monitoring and evaluation never get done well (Interview 005; Interview 006; Interview 021)</p>
9) Evaluating effectiveness will be a barrier for adaptation	<p>Monitoring and evaluation (same as previous element)</p> <ul style="list-style-type: none"> • lack of monitoring and evaluation (Interview 005). <p>monitoring and evaluation never get done well (Interview 005; Interview 006; Interview 021)</p>

5.4 Sectoral dependencies

Summary – Sectoral dependencies

- ◆ understanding sectoral dependencies is vital to ensure that adaptation efforts consider the full range of potential influences
- ◆ sectoral dependencies were identified at all scales, including the national and international scales.
- ◆ the high level of connectedness identified by workshop participants (especially at the state scale) might reflect the close relationships in a relatively small polity such as Tasmania, but may also reflect existing efforts to identify sectoral linkages, starting with participants' own networks and communities of interest.
- ◆ a high level of sectoral interconnectedness means that the effects of climate change and adaptation efforts will be complex and multi-layered. It will be important for sectors to remain aware of developments in other sectors, as what one sector is doing will have ramifications for other sectors. Approaches to climate change adaptation based exclusively around individual sectors will not be optimal

The literature review and interviews undertaken for this project show that adaptation planning in Tasmania has been largely sectoral in focus. Despite this sectoral approach, however, there are likely to be a range of interrelationships that affect the effectiveness of adaptation efforts in one sector. These relationships may be supportive or facilitative across sectors, or they may undermine adaptation efforts in other sectors. Understanding sectoral dependencies is therefore vital in order to ensure that adaptation efforts consider the full range of potential influences. Accordingly, we explored the dependencies between and across sectors, which we defined to refer to 'strong linkages'.

5.4.1 Methods and data limitations

Information regarding sectoral dependencies was obtained by canvassing the perceptions of workshop participants. Participants were asked to form sector-specific groups based upon self-identification of the sector they felt captured their primary research or stakeholder interests. A small number of participants with expertise in more than one sector were allocated to sectors in order to balance group size and to ensure representation across sectors. Nine groups were formed based on the sectors examined in Section 5 of this report. In the absence of workshop participants from the Tasmanian Aboriginal community, a decision was made not to anticipate dependencies specific to this sector. Indigenous perspectives on dependencies were identified as an issue for possible future follow-up with interview participants.

Participants were asked to map the influences on their sector's adaptation efforts, and their sector's adaptation influences on other sectors. Each sectoral-group was provided with six A3-sized sheets of paper upon which was printed the diagram in Figure 15. The ten circles represented the ten sectors used throughout the report, and three additional blank circles were included so that participants could identify additional relevant sectors. Each group was asked to draw lines from their sector to others for each of six situations – covering three spatial scales and two 'pathways' of dependence:

1. Within Tasmania, we have influence on these sectors
2. Within Tasmania, we are influenced by these sectors
3. Nationally, we have influence on these sectors
4. Nationally, we are influenced by these sectors
5. Internationally, we have influence on these sectors
6. Internationally, we are influenced by these sectors.

The three spatial scales of analysis (state, national and international) were chosen on the basis that they were likely to reflect relevant geographical, governmental, legislative and social differences. A few workshop participants (e.g., those representing the Primary Industries and Human Health & Community Wellbeing sectors) noted the importance of dependencies operating at finer scales, especially regional, local, family and even enterprise scales. Some groups also identified intra-sectoral dependencies as important, and mapped these by drawing lines that looped from their sector back to that same sector. This was particularly the case when the sector was aggregated (e.g. Marine Biodiversity & Resources contains both conservation and exploitation, Primary Industries contains both grazing and cropping), as there are interactions between these sub-sectors.

Participants were also encouraged to provide additional information about the type and form of dependencies by writing accompanying notes to the links.

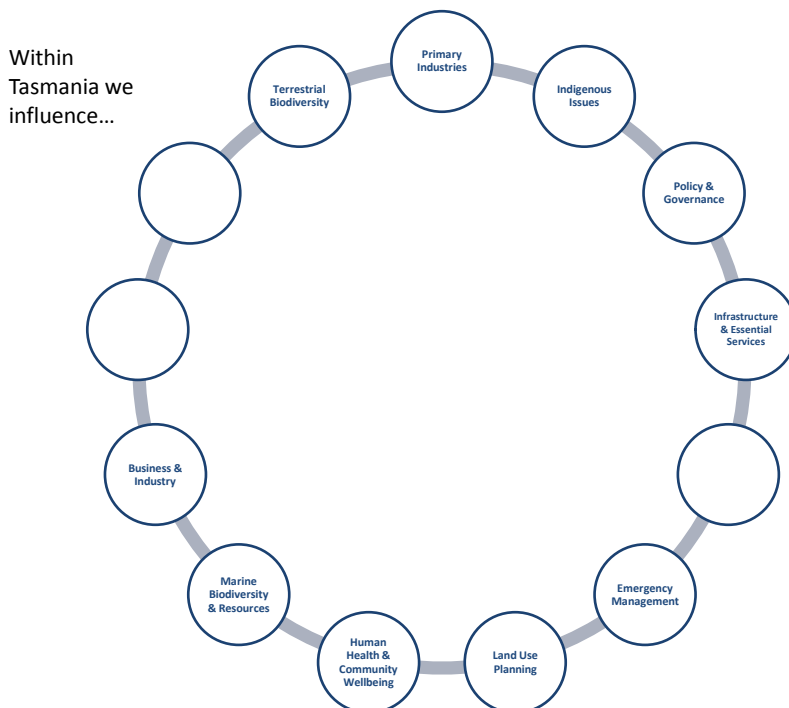


Figure 15. A worksheet used by workshop participants to identify sectoral dependencies

The nine workshop groups were asked to identify the relationships most critical to their sector, and the time allocated to complete the exercise was restricted in order to minimise the masking of significant dependencies by identification of minor linkages. Each sectoral group

completed six worksheets (three spatial scales by two directions for dependencies) indicative of their sector's relationship to other sectors. In total, 54 'dependency maps' were produced.

After the groups completed the exercise, display and discussion of results provided an opportunity for feedback from workshop participants from other groups. Figure 16 reproduces one such dependency diagram, in this case showing the influence of the Marine Biodiversity and Resources sector on other sectors at the national scale.

While information on sector dependencies was collected from sector-specific groups, data has been aggregated for discussion. This decision reflects the small number of participants constituting some sectoral-groups (in some cases, only two 'representatives'), qualitative differences in interpretation of the exercise from sectoral groups, as well as feedback provided by some workshop participants that 'not too much be made of differences between individual sectors'. Hence, data from the dependency diagrams have been aggregated and the results treated as indicative of broad trends, rather than being quantitatively representative of individual sectors. As such, the results provide a broad-brush view of Tasmanian sectoral dependencies at three spatial scales.

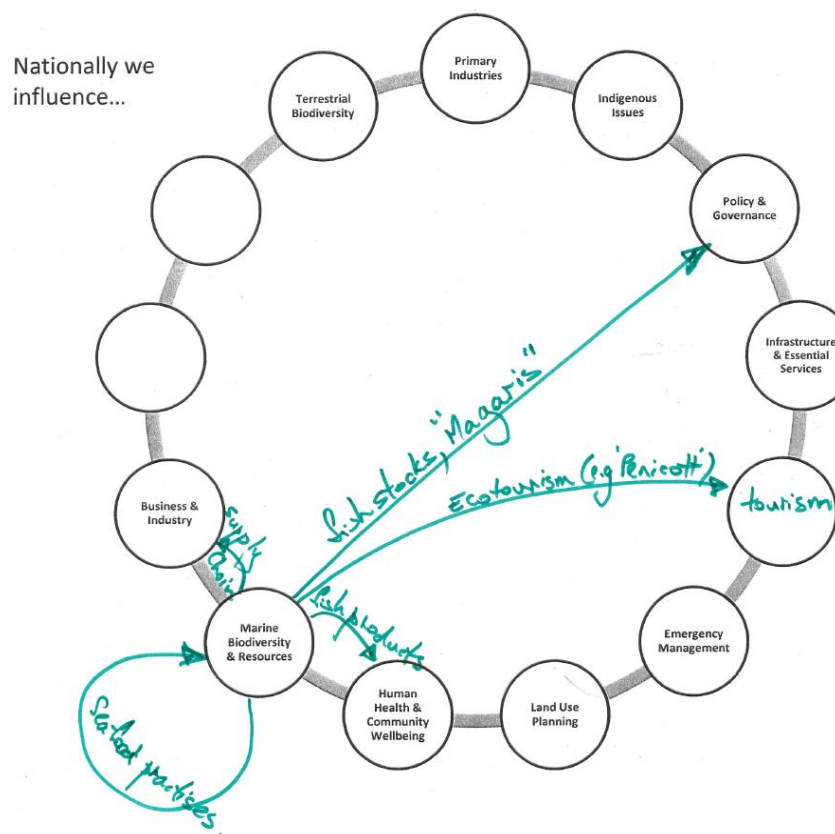


Figure 16. Dependency diagram: Influence of Marine biodiversity & resources on other sectors, national scale

5.4.2 Results

During the identification of dependencies, another eight 'sectors' (e.g. 'water resources') were volunteered by participants. These additional sectors attracted 20 links across all identified sectors, representing 7% of all links described. This suggests either that the groups were constrained by the choices presented on their worksheets and therefore didn't identify other sectors, or that the pre-identified sectors captured the majority of the potential linkages. In discussion with participants during a feedback session, there seemed to be general satisfaction with the sectors identified.

Overall, 279 linkages were identified. The number of links (dependencies) decreased as the spatial scale of analysis increased. At the Tasmanian or state scale, between four and 12 dependencies were identified by each sector for an overall average of 7.6 links, indicating a high degree of interconnectedness. Sectors were influenced by an average of 8.2 other sectors, and considered themselves as influencing 7.0 other sectors. At the national scale between two and ten dependencies were identified, an overall average of 4.8, with influence by other sectors greater than the influence on other sectors (influenced by = 5.6; influence on = 4.0). Finally, at the largest scale – international – between zero to eight dependencies were identified (after removing three combinations that were not completed), for an overall average of 3.7 links, with influenced by (average 4.7 links) greater than influence on (average 2.9 links). Figure 17 summarises these results.

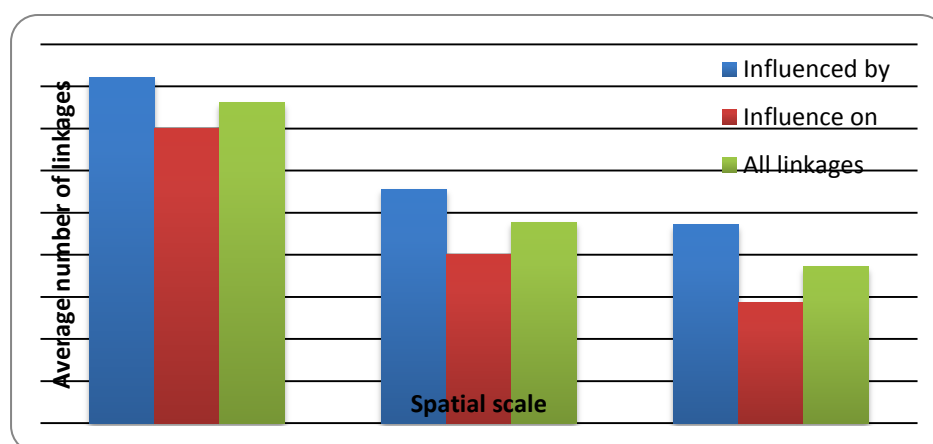


Figure 17. Average number of linkages identified by workshop participants at three spatial scales

Figure 18 summarises the aggregated number of sectoral linkages across all scales identified by workshop participants. Not surprisingly, the most 'connected' sector was Policy & Governance (42 links). The least connected was Indigenous (15 links), although it must again be emphasised that this sector was only represented in other sector's mapping, since the sector was not represented in the exercise of drawing links. The Terrestrial Biodiversity (20 links) and Marine Biodiversity & Resources (21 links) also had low levels of inter-dependency. Of the ten core sectors, the overall average was 25.9 links. The influenced by average was 14.2 links per sector (Policy & Governance highest number of links), while the influence on average was 11.7 links per sector (Policy & Governance highest number of links).

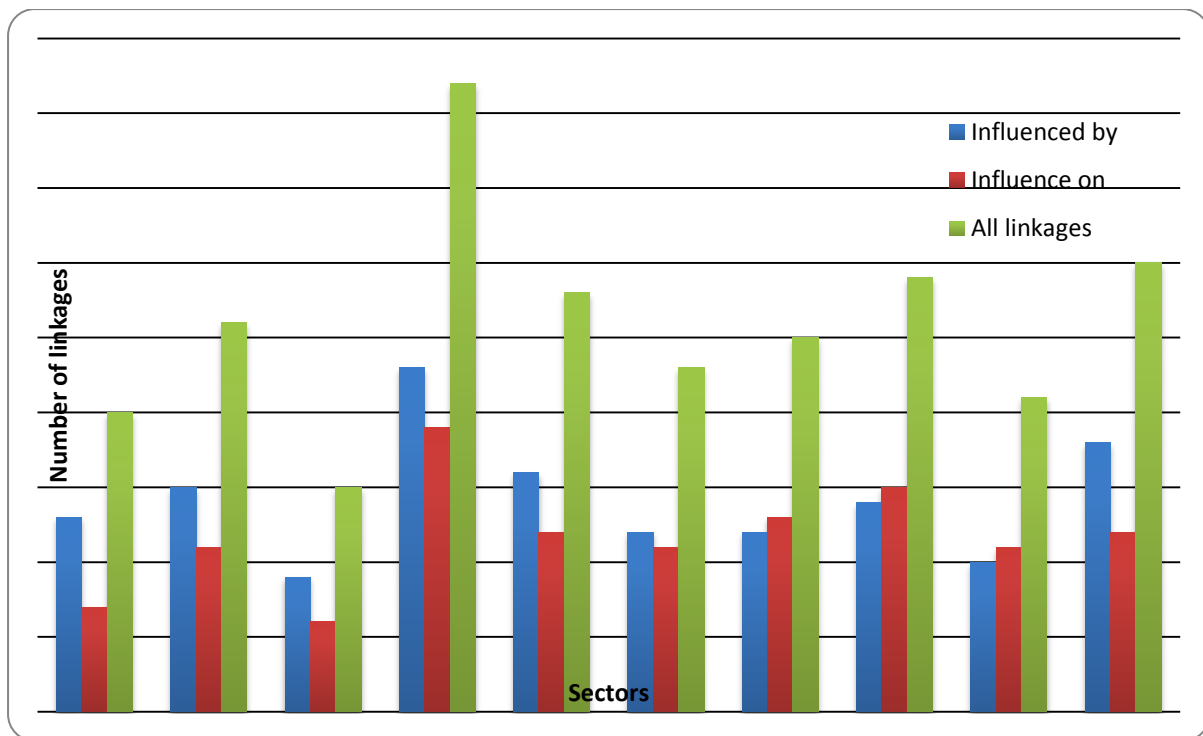


Figure 18. Aggregated sectoral linkages identified by workshop participants

There was a consistent disparity between the number of links influenced by and influence on across all scales. Of the 24 possible sector-scale combinations for which data was completed (3 were not completed), only two sectors identified themselves as stronger at influencing other sectors than they were influenced by other sectors. Ten combinations rated themselves as equally influencing and influencing by; and the remaining 12 combinations saw themselves as more influenced by than influencing other sectors (see Figure 19). This may be a true pattern, although it may also suggest that sectoral representatives were more able to identify what they are influenced by than what they have influence on – more detailed investigation is needed to resolve this issue.

5.4.3 Discussion

The form, type and nature of relationships between sectors are likely to have crucial implications for future climate change adaptation efforts. While the mapping exercise could not provide detailed information that is representative of individual sectors, the aggregated results of perceived linkages raise a number of important issues:

The high level of connectedness identified by workshop participants (especially at the state scale) might reflect the close relationships often taken as typical of small communities like Tasmania. It is also likely, however, to reflect existing efforts made by stakeholders and researchers in identifying sectoral linkages, starting with their own networks and communities of interest.

The high number of linkages identified by workshop participants also suggests that it will be important for sectors to remain aware of developments in other sectors, as what one sector is doing will have ramifications for other sectors. A high level of sectoral interconnectedness means that the effects of climate change and adaptation efforts will be complex and multi-

layered. Approaches to climate change adaptation based exclusively around individual sectors will not be optimal, an issue which harks back to the widespread support for more 'mainstreaming' and integration of adaptation activities. The processes by which these relationships are recognised and explored in adaptation planning are still emerging.

Sectoral dependencies were identified at all scales, including the national and international scales. We anticipated that the disparity between being influenced by and having influence on would increase as the scale of analysis increased, and this general trend was borne out, though the main shift appears to occur when moving from the national to the international, rather than from the state to the national scale. While Tasmania may appear vulnerable to international influences, comparisons with other Australian states and/or regions would be required to contextualise these findings.

The exercise of stakeholders and researchers mapping linkages between sectors was a first-step at developing a tool that can be used to better understand sectoral dependencies in adaptation. In completing the task, participants recognised both climate adaptation issues as well as more general issues in their identification of linkages. A distinction could be made between these types of relationships depending on the requirements of those completing the task. Climate change adaptation planning often requires a high level of detail and the task could also be undertaken with a greater focus on describing the qualities of linkages, rather than just mapping their existence. An example of how these dependency diagrams might highlight key issues for adaptation planning is drawn from the Marine Biodiversity & Natural Resources sector and displayed in

6 CONCLUSIONS

6.1 The state of adaptation activity and research

This project assessed the current state of climate change adaptation knowledge in Tasmania, based on published and on-going research, extensive interviews with researchers and stakeholders, and a project workshop. It aimed to determine the awareness and uptake of successful adaptation approaches by stakeholders and sectors, namely:

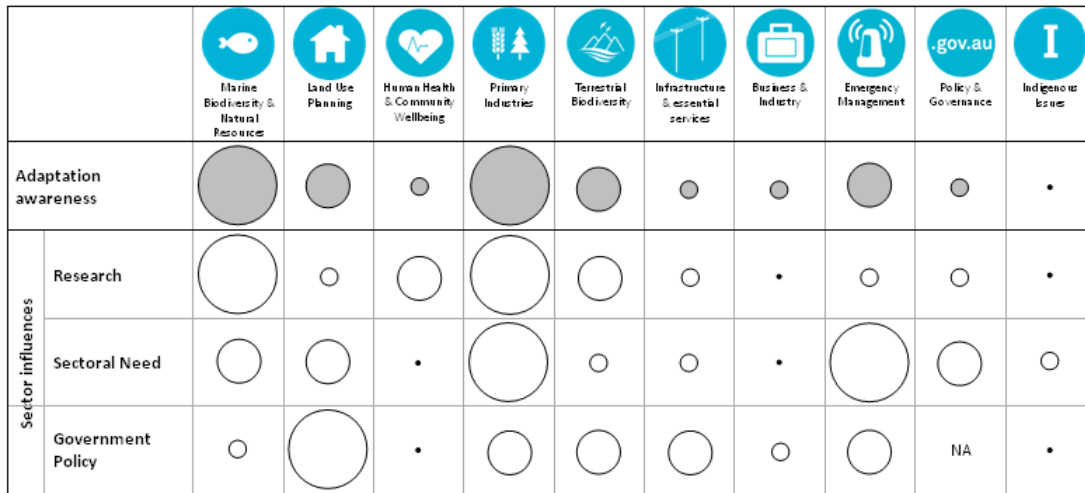
- primary industries
- terrestrial biodiversity
- marine biodiversity and resources

- land use planning
- infrastructure and emergency services
- human health and community well-being
- business and industry
- emergency management
- policy and governance
- Indigenous issues.

We found differences between the sectors in terms of their perceptions of climate change impacts and the need for response. For each sector, we have made a subjective assessment of the state of adaptation, based on the synthesis of literature and stakeholder consultation information (Figure 20). Awareness and motivation for adaptation is highest in the marine, primary industries, and emergency management sectors. This awareness and motivation for all sectors was reported to the project team as linked, in part, to one or more of three main influences on adaptation: research, sectoral needs, and/or government policies (Figure 20). In some sectors, such as marine and primary industries, research has played a major role, while in others any adaptation that has occurred has been driven almost entirely by issues relating specifically to the sector (e.g. emergency management), or to policy-related drivers (e.g. land use planning).

The project has highlighted areas of significant research strength in Tasmania, and others where there is little or no research specific to the state (Figure 20). Research is strongest in marine biodiversity and resources, and to a lesser extent primary industries and terrestrial and freshwater biodiversity. There is no Tasmania-specific work relating to the impacts of climate change on Indigenous Tasmanians, and very little coverage of health and community well-being issues or business and industry perspectives (other than the primary industries). Some major recent projects of relevance to coastal adaptation, land use planning and (to a lesser extent) infrastructure and emergency management have started to fill significant policy gaps in these areas.

Given the qualitative relationship between research strength and sectors with greatest climate adaptation awareness, investment in research is clearly important to develop climate impact and adaptation strategies in Tasmania. Thus, strategies for increasing and maintaining high quality research should be a government priority.



Legend

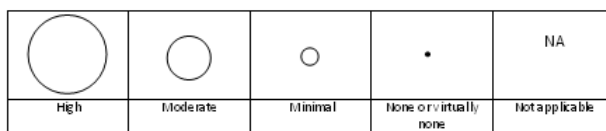


Figure 20. The state of adaptation activity and awareness for 10 Tasmanian sectors and the degree to which research, sectoral needs, and government policy influence. Future development of this work could examine dependencies identified in light of adaptation research, and adaptation research might begin to factor in such sectoral connections and dependencies in order to maximise opportunities and minimising the risk of maladaptation.

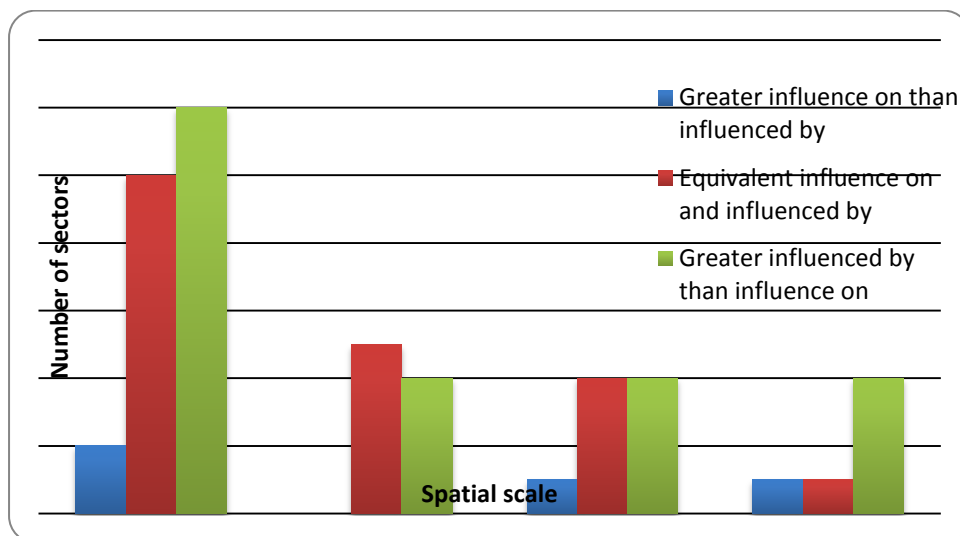


Figure 19. Proportion of 'influenced by' and 'influence on' linkages

Box 1. Example of dependencies identified for the marine biodiversity and resources sector

Tasmania

- influenced by
 - within Tasmania, there are influences within sub-sections of this sector, e.g., commercial fishing and conservation management – intra-sectoral influences/dependencies
- influence on
 - one of the eight linkages identified was with community health and wellbeing. The type of linkage envisaged here was through access to recreational and aesthetic opportunities that arise from a well-managed marine estate

National

- influenced by
 - nationally we are influenced by availability of efficient transport networks (business and industry sector) to deliver seafood and aquacultural products to mainland markets
- influence on
 - approaches to marine tourism in Tasmania have been seen as leading examples nationally and led to similar tourism enterprises in other regions of Australia

International

- influenced by
 - at an international level, international conventions (policy and governance sector), e.g., RAMSAR, WHA influence the management of marine biodiversity and resources in Tasmania
 - one of three linkages identified
- influence on
 - internationally, Tasmanian marine research has influenced international policy and governance through best-practice guidelines resulting from long-term studies on MPAs

An example of an adaption perspective on these dependencies/the significance of these sorts of sectoral dependencies for future adaptation efforts:

7 CONCLUSIONS

7.1 The state of adaptation activity and research

This project assessed the current state of climate change adaptation knowledge in Tasmania, based on published and on-going research, extensive interviews with researchers and stakeholders, and a project workshop. It aimed to determine the awareness and uptake of successful adaptation approaches by stakeholders and sectors, namely:

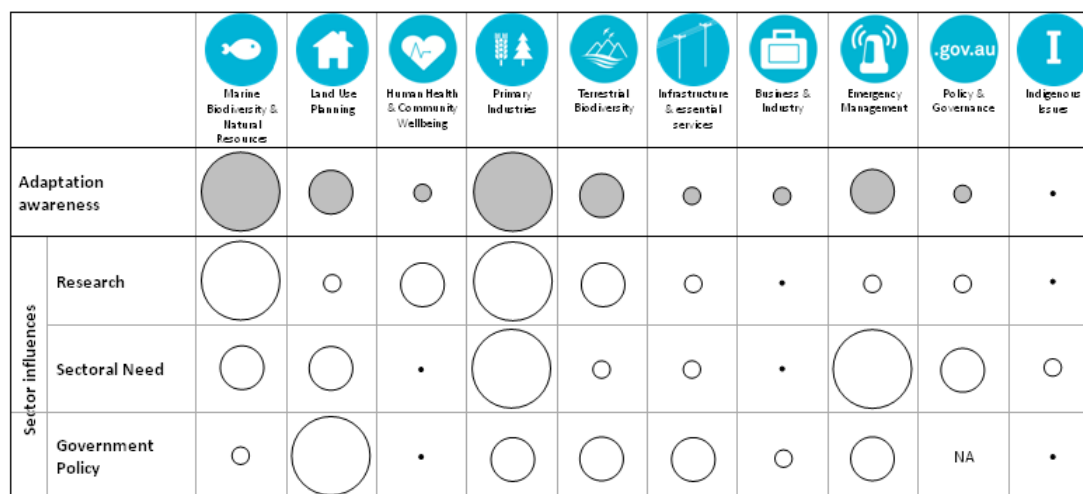
- primary industries
- terrestrial biodiversity
- marine biodiversity and resources
- land use planning
- infrastructure and emergency services
- human health and community well-being
- business and industry
- emergency management
- policy and governance
- Indigenous issues.

We found differences between the sectors in terms of their perceptions of climate change impacts and the need for response. For each sector, we have made a subjective assessment of the state of adaptation, based on the synthesis of literature and stakeholder consultation information (Figure 20). Awareness and motivation for adaptation is highest in the marine, primary industries, and emergency management sectors. This awareness and motivation for all sectors was reported to the project team as linked, in part, to one or more of three main influences on adaptation: research, sectoral needs, and/or government policies (Figure 20). In some sectors, such as marine and primary industries, research has played a major role, while in others any adaptation that has occurred has been driven almost entirely by issues relating specifically to the sector (e.g. emergency management), or to policy-related drivers (e.g. land use planning).

The project has highlighted areas of significant research strength in Tasmania, and others where there is little or no research specific to the state (Figure 20). Research is strongest in marine biodiversity and resources, and to a lesser extent primary industries and terrestrial and freshwater biodiversity. There is no Tasmania-specific work relating to the impacts of climate change on Indigenous Tasmanians, and very little coverage of health and community well-being issues or business and industry perspectives (other than the primary industries). Some major recent projects of relevance to coastal adaptation, land use planning and (to a lesser

extent) infrastructure and emergency management have started to fill significant policy gaps in these areas.

Given the qualitative relationship between research strength and sectors with greatest climate adaptation awareness, investment in research is clearly important to develop climate impact and adaptation strategies in Tasmania. Thus, strategies for increasing and maintaining high quality research should be a government priority.



Legend

				NA
High	Moderate	Minimal	None or virtually none	Not applicable

Figure 20. The state of adaptation activity and awareness for 10 Tasmanian sectors and the degree to which research, sectoral needs, and government policy influence

The size of the circles indicates the relative influence for each category.

The *Climate Futures for Tasmania* (CFT) projections and the subsequent publications are widely regarded as providing an excellent foundation upon which to undertake more detailed adaptation planning at the enterprise-, sector- or region-specific level. These projections have allowed most Tasmanian sectors considerable advantage in terms of understanding future environmental risk, and there are several projects that have since used these projections to further inform sectoral adaptation plans (e.g. freshwater biodiversity, Barmuta et al. 2012). While the marine sector did not benefit in particular from CFT, as the coverage did not extend to marine environment, a strong history and expertise base in Tasmania at CSIRO and the ACE CRC also allows access to state of the art climate projections.

7.2 Research gaps and priorities

Significant gaps remain in our understanding across all sectors, and the report has identified a range of research priorities that seek to clarify the application of national or international research in Tasmania or further develop earlier findings of Tasmanian projects, including action research such as the Coastal Adaptation Pathways Projects. Table 10 presents the research priorities identified for each sector. We note that these priorities fall into one of three general categories, including climate and system understanding (n=13), evaluating adaptation

options (n=15) and resolving societal issues around adaptation (n=20). While some priorities might also be placed in more than one category, this summary shows that research investment is needed in all three areas. Future research endeavours should engage stakeholders and end-users in the earliest stages of research design, including the refinement of research objectives and questions. Wherever possible, opportunities for multi-sectoral synergies and relevance should be maximised as the dependencies mapped for this project showed strong connectivity in Tasmania.

Table 10. Summary of sectoral adaptation research priorities

Each priority is classified into one of three broad categories.

	Improving climate and system understanding	Evaluating adaptation options	Resolving societal issues
Primary industries			
Better understanding of cross-cutting, multi-level and indirect impacts	X		
Enhanced understanding of trends in variability and the impact and frequency of extreme events	X		
Evaluating alternative cropping options for a wide range of locations throughout Tasmania		X	
Understanding the likely socio-economic and environmental consequences of adaptation options		X	
Terrestrial and freshwater biodiversity			
Ecosystem-level analyses of impacts and adaptation options		X	
Determining the advantage of reducing the non-climate stressors on species and landscapes.		X	
The management of agricultural practices (such as wind breaks) and rotation of livestock to increase biodiversity outcomes.		X	
The impacts of fire management practices on biodiversity.	X		
Whether Tasmania should become a refuge for mainland species, and if so, which ones?			X
Social research into where extension and education will be needed to overcome barriers to some adaptation options.			X
Marine biodiversity			
Impacts of ocean acidification on, and adaptation options for, marine resources, especially commercially valuable and aquaculture species (especially abalone, rock lobster, and oyster)	X		
Cost-benefit and other analyses of the timing of adaptation interventions for key industries, especially those requiring long lead-times		X	
How to manage access to range-changing species that could form valuable new fisheries.			X
Integrated multi-disciplinary studies into the socio-economic impacts of climate change on marine species and resources			X

	Improving climate and system understanding	Evaluating adaptation options	Resolving societal issues
Win-win adaptation options for marine conservation management and marine resource management, where short-term benefit is also compatible with long-term sustainability		X	
Assessing the effectiveness of adaptation actions in Tasmania's hotspots based on ecological, social and economic indicators		X	X
Land use planning			
How the planning framework, including regional planning, should accommodate the long-term impacts of climate change, the likely impacts of extreme events, and the cumulative impact of multiple extreme events?			X
Improving the communication of climate change impacts and engaging communities in adaptive responses			X
The evaluation of costs of various adaptation options for existing communities in a way that is itself efficient and cost-effective		X	
Enhancing the processes of adaptation of existing communities to ensure they are consultative, locally-driven and participatory, and cost-effective			X
Design and mix of instruments and incentives to promoting private adaptation		X	
Exploiting the synergies between climate change adaptation and mitigation		X	
Transferring adaptation planning insights across places and projects			X
Assessing the suitability of the current governance arrangements for planning in Tasmania for adaptation needs?			X
Infrastructure and essential services			
Understanding the full costs of infrastructure disruption, from extreme events (including downstream or cascading impacts) on: communities; utility providers (such as energy, telecommunications and water utilities); property damage; and maintenance or replacement costs	X		
How to avoid these costs through design, modification, re-engineering of processes or other techniques		X	
The design options and principles for adapting new and existing infrastructure and buildings		X	
How to distribute the future costs of infrastructure upgrade and increased risk			X
Approaches to, and development of, Tasmanian professional capabilities (knowledge and practical skills) to more confidently and effectively assess, plan and manage climate risks in the future			X
Strategies for community coping and response to loss in infrastructure and essential services			X
Human health and community well-being			
Understanding the social, environmental and institutional determinants of vulnerability in a given region, including rural communities and cumulative health and well-being vulnerabilities	X		

	Improving climate and system understanding	Evaluating adaptation options	Resolving societal issues
Community-based vulnerability and health risk assessments.	X		
Improvements in regional and local monitoring of: bushfire smoke, aero allergen concentrations and seasonality, vector (mosquito) densities in highest risk areas with respect to Ross River virus or other vector borne diseases that may emerge as a threat.	X		
How to improve responsiveness and management of health impacts or events as they arise, as well as preparing communities for longer term adjustment to changing environmental and health conditions.			X
Business and industry			
Enhanced understanding of business and industry preparedness, expertise and knowledge about climate change impacts and adaptation options	X		
Ensuring that cross-cutting adaptation research is presented at temporal and spatial scales suited to the planning and decision-making processes of businesses and industry	X		
Longer-term engagement with specific business and industry sectors to identify specific sectoral needs			X
Emergency management			
Changes to community vulnerability resulting from demographic and other processes	X		
How to enhance the capacity of communities to respond to projected climate impacts	X		
Institutional responses to changed climate conditions and consequential demands on emergency services			X
How communication tools can manage emerging climate change induced emergency service demands			X
Understanding the compounding effects of climate-change derived conditions and extreme weather events, such as drought and heat waves	X		
Trade-offs between prevention/hazard mitigation and other values, such as native vegetation conservation.		X	
Policy and governance			
How to maximise the transformative potential of medium-term adaptation responses		X	
Practical approaches to improving policy, planning and governance frameworks to better recognise the dynamic circumstances that climate change creates			X
Approaches that align bottom-up initiatives with top-down framework and policy development			X
Indigenous issues			
State specific adaptation research priorities need to be identified and developed either by, or in conjunction with, indigenous people, communities and representatives			X

7.3 Future directions

Our findings suggest that there is surprising commonality across sectors in relation to the key drivers and barriers to adaptation and the elements of a climate-adapted future. Risk management principles and fear of losses, including legal liability, are the primary drivers of adaptation at a broad level. Ethical considerations and the pursuit of new opportunities are least important. There is very little evidence of transformative change or even discussion of the need for such change in the near- or medium-term future. To the extent that any industry is currently undertaking adaptation measures, they are driven by understandings of short-term changes that are likely to affect profitability within budgetary planning horizons.

While it was impossible to articulate a single vision, or even a set of visions, for adaptation in Tasmania, several themes emerged strongly. They were:

- the need for adaptation to become more integrated and mainstreamed into core business decision-making and policy-making;
- improved governance for adaptation, including better cross-sectoral arrangements and processes;
- better resourcing and training for adaptation;
- moving from planning to implementation; and the need for monitoring and evaluation of adaptation strategies.

The analysis of barriers to adaptation showed that barriers exist at all three stages of adaptation: understanding, planning and managing. Higher barriers were recognised at the planning stage than at the earlier understanding stage, while the barriers were higher again at the implementation stage. Overcoming these barriers would go far in delivering the common elements of the adaptation visions identified in this report.

As a geographically small state with a small population, the activities of, and issues facing, one sector have a significant impact on others. While some may view these sectoral dependencies as a barrier to adaptation, they also create opportunities for more embedded and holistic approaches that achieve efficiencies across the entire community, economy and environment. Developing consultation, policy- and decision-making processes that reflect these interdependencies will be challenging, but could have spin-off benefits for good governance more generally.

There is an emerging preference in the Australian policy literature for mechanisms that promote private and autonomous adaptation (Productivity Commission 2012; SCCC 2012; TCCO 2012a). Local and small-scale adaptation decision-making is more likely to promote autonomy and resolve trade-offs between competing values, but care will be required to ensure that processes and institutions still ensure the recognition and protection of public goods (SGS Economics 2012b). There will also need to be mechanisms by which to resolve conflicts between competing adaptation priorities within and between sectors. Systemic changes in attitude are likely to require more profound cultural shifts.

The experience of adaptation in Tasmania presents us with a unique opportunity to understand 'system-wide' relationships, influences and constraints. There is neither the time nor the resources to undertake state-specific research for every priority area across every sector. This means that many adaptation challenges must be met through the transfer of lessons learned elsewhere. With careful monitoring and evaluation of the effectiveness, equity and efficiency of adaptation interventions, understanding this unique Tasmanian context will aid in the transfer and adoption of insights drawn from adaptation research across sectors and across jurisdictions.

BIBLIOGRAPHY

- (ABARES) Australian Bureau of Agricultural and Resource Economics and Sciences (2011) *Australian fisheries statistics 2010* (ABARES: Canberra, ACT).
- (ABC News) Australian Broadcasting Corporation News (2011) *Port Arthur climate risk*, available from: <http://www.abc.net.au/news/2011-07-20/20110720-port-arthur-storm-damage/2803354>.
- (ABS) Australian Bureau of Statistics (2011) *1304.6 – Tasmanian Key Indicators, March 2011* (ABS: Canberra, ACT).
- (ABS) Australian Bureau of Statistics (2012) *3218.0 – Regional Population Growth, Australia, 2011* (ABS: Canberra, ACT).
- (ACE CRC) Antarctic Climate & Ecosystems Cooperative Research Centre (2010d) *Climate Futures for Tasmania: General Climate Impacts: The Summary* (ACE CRC: Hobart, Tasmania).
- (ACE CRC) Antarctic Climate & Ecosystems Cooperative Research Centre (2010c) *Climate Futures for Tasmania: Impacts on Agriculture: The Summary* (ACE CRC: Hobart, Tasmania).
- (ACE CRC) Antarctic Climate & Ecosystems Cooperative Research Centre (2008) *Position Analysis: Climate Change, Sea-level Rise and Extreme Events: Impacts and Adaptation Issues* (ACE CRC: Hobart, Tasmania), available from: http://www.cmar.csiro.au/sealevel/downloads/SLR_PA.pdf.
- (ACE CRC) Antarctic Climate and Ecosystems Cooperative Research Centre (2010a) *Climate Futures for Tasmania: Impacts on Agriculture Technical Report* (ACE CRC: Hobart, Tasmania).
- (ACE CRC) Antarctic Climate and Ecosystems Cooperative Research Centre (2010b) *Climate Futures for Tasmania Climate Modelling: The Summary* (ACE CRC: Hobart, Tasmania).
- (AEMI) Australian Emergency Management Institute (2011) *National Strategy for Disaster Resilience*, available at: <http://www.em.gov.au/Publications/Program%20publications/Pages/NationalStrategyforDisasterResilience.aspx>
- (AFAC) Australasian Fire and Emergency Service Authorities Council (2012) *Climate Change and the Fire and Emergency Services Sector* (AFAC: East Melbourne, Victoria).
- (AFAC) Australasian Fire and Emergency Service Authorities Council (2009b) *Climate Change and the Fire and Emergency Services Sector Position* (AFAC: East Melbourne, Victoria).
- (AFAC) Australasian Fire and Emergency Service Authorities Council (2012) *Climate Change and the Fire and Emergency Services Sector* (AFAC: East Melbourne, Victoria).
- (AFAC) Australasian Fire and Emergency Service Authorities Council (2009a) *Climate Change and the Fire and Emergency Services Sector: Discussion Paper* (AFAC: East Melbourne, Victoria).
- (ALGA) Australian Local Government Association (2011) *Local Council Risk of Liability in the Face of Climate Change – Resolving Uncertainties - A Report for the Australian Local Government Association*, available from: <http://www.climatechange.gov.au/~media/publications/local-govt/alga-report-final-pdf.pdf>.

- (CCRPI) Cradle Coast Regional Planning Initiative (2011) *Living on the Coast: the Cradle Coast Regional Land Use Planning Framework*.
- (COAG) Council of Australian Governments (2011) *National Strategy for Disaster Resilience: Building the Resilience of Our Nation to Disasters* (Commonwealth of Australia: Canberra, ACT).
- (COAG) Council of Australian Governments, Standing Committee on Climate Change (2012) *Roles and Responsibilities for Climate Change Adaptation (Draft)*, available from: www.climatechange.gov.au/.../sccc/.../sccc/20150504-sccc-communicue-pdf.pdf.
- (CSIRO) Commonwealth Scientific and Industrial Research Organisation (2009) *Water availability for Tasmania*, Report one of seven to the Australian Government from the CSIRO Tasmania Sustainable Yields Project (CSIRO Water for a Healthy Country Flagship: Australia), available from: <http://www.csiro.au/Organisation-Structure/Flagships/Water-for-a-Healthy-Country-Flagship/Sustainable-Yields-Projects/TASSY.aspx>.
- (DCC) Commonwealth Department of Climate Change (2009) *Climate Change Risks to Australia's Coasts: A First Pass National Assessment* (DCC: Canberra, ACT).
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2011) *Climate Change Risks to Coastal Buildings and Infrastructure: A Supplement to the First Pass National Assessment* (DCCEE: Canberra, ACT).
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2011) *The Critical Decade – Climate Science, Risks and Responses* (Climate Commission Secretariat: Canberra, ACT).
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2010) *Adapting to Climate Change in Australia: an Australian Government Position Paper*, available from: <http://www.climatechange.gov.au/~media/publications/adaptation/gov-adapt-climate-change-position-paper.pdf>.
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2010) *Climate Change Adaptation Actions for Local Government*, available from: http://www.climatechange.gov.au/what-you-can-do/~media/publications/local-govt/localadaption_localgovernment.pdf.
- (DCCEE) Commonwealth of Australia, Department of Climate Change and Energy Efficiency (2012) *Coastal Adaptation Pathways Projects*, available from: <http://www.climatechange.gov.au/en/government/initiatives/coastal-adaptation-decision-pathways.aspx>.
- (DEDTA) Department of Economic Development, Tourism and the Arts (2011) *Businesses in Tasmania*, available from: http://www.development.tas.gov.au/economic/economic_development_plan/achieving_our_vision/supporting_business/businesses_in_tasmania.
- (DIER) Department of Infrastructure, Energy and Resources (2012) *Tasmanian Government 2012 Transport Submission to Infrastructure Australia New Bridgewater Bridge*, Submission to Infrastructure Australia, available from: http://www.dier.tas.gov.au/__data/assets/pdf_file/0010/81946/Burnie_to_Hobart_Freight_Corridor_New_Bridgewater_Bridge.pdf.
- (DIER) Department of Infrastructure, Energy and Resources (n.d) *Australian Government National Building Program Information flyer: The Bridgewater Bridge Replacement*.

- (DPAC OSM) Department of Premier and Cabinet, Office of Security and Emergency Management (2010) *Review of Construction and Development Control in Bushfire Prone Areas* (DPAC: Tasmania).
- (DPAC OSM) Department of Premier and Cabinet, Office of Security and Emergency Management (2012) *Principles for the Consideration of Natural Hazards in the Planning System* (DPAC: Tasmania).
- (DPAC) Department of Premier and Cabinet (2012a) *Local Climate Profiles for Tasmania's 29 LGAs* (DPAC: Tasmania), available from:
http://www.dpac.tas.gov.au/divisions/climatechange/adapting/climate_futures/local_government_area_climate_profiles.
- (DPAC) Department of Premier and Cabinet (2012b) *Derivation of the Tasmanian Sea Level Rise Planning Allowances* (DPAC: Tasmania), available from:
http://www.dpac.tas.gov.au/_data/assets/pdf_file/0003/176331/Tasmanian_SeaLevelRisePlanningAllowance_TechPaper_August2012.pdf.
- (DPAC) Department of Premier and Cabinet (2012c) *Tools* (DPAC: Tasmania), available from:
http://www.dpac.tas.gov.au/divisions/climatechange/what_the_government_is_doing/new_tools_to_improve_planning_for_sea_level_rise_and_coastal_hazards.
- (DPAC) Department of Premier and Cabinet (2012d) *Principles for the Consideration of Natural Hazards in the Planning System (Draft)* (DPAC: Hobart, Tasmania).
- (DPAC) Department of Premier and Cabinet (2012e) *ClimateConnect Grant Program*, available from:
http://www.climatechange.tas.gov.au/grants/climateconnect_grants.
- (DPIPWE) Department of Primary Industries, Parks, Water & Environment Resource Management & Conservation Division (2010a) *Vulnerability of Tasmania's Natural Environment to Climate Change: An Overview* (Unpublished Report) (DPIPWE: Hobart, Tasmania).
- (DPIPWE) Department of Primary industries, Parks, Water and Environment (2010c) *Rock Lobster Management Plan Review Report on Discussion Paper* (DPIPWE: Tasmania), available from:
[http://www.dpiw.tas.gov.au/inter-nsf/Attachments/JPAN-89X76Q/\\$FILE/Report%20on%20the%20Second%20Consultation%20Phase.pdf](http://www.dpiw.tas.gov.au/inter-nsf/Attachments/JPAN-89X76Q/$FILE/Report%20on%20the%20Second%20Consultation%20Phase.pdf).
- (DPIW) Department of Primary Industries and Water (2004) *Information Paper: Sea-Level Change Around Tasmania*, available from: <http://www.dpiw.tas.gov.au/inter,nsf/Publications/PMAS-63K6W5?open>.
- (DPIW) Department of Primary Industries and Water (2008a) *Climate Change and Coastal Asset Vulnerability: an Audit of Tasmania's Coastal Assets Potentially Vulnerable to Flooding and Sea Level Rise* (DPIW: Tasmania).
- (DPIW) Department of Primary Industries and Water (2008b) *Coastal Hazards in Tasmania General Information Paper* (DPIW: Tasmania).
- (DPIW) Department of Primary Industries and Water (2008c) *Sea-level Extremes in Tasmania: Summary and Practical Guide for Planners and Managers* (DPIW: Tasmania).
- (DPIW) Department of Primary Industries and Water (2009a) *Coastal Risk Management Plan: Template and Guidelines, Department of Primary Industries and Water* (DPIW: Tasmania).
- (DPIW) Department of Primary Industries and Water (2009b) *Coastal Risk Management Plan: Case Study* (DPIW: Tasmania).

- (DTF) Department of Treasury and Finance (2012) *Submission to the review of the Tasmanian Climate Change (State Action) Act (2008)*.
- (IPCC) Intergovernmental Panel on Climate Change, 'Summary for Policymakers' in Field C B, Barros V, Stocker T F, Qin D, Dokken D J, Ebi K L, Mastrandrea M D, Mach K J, Plattner G K, Allen S K, Tignor M & Midgley P M (eds.) (2012) *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*, A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (Cambridge University Press: Cambridge, UK & New York, USA) 1-19.
- (IPCC) Intergovernmental Panel on Climate Change, 'Summary for Policymakers' in Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K B, Tignor M & Miller H L (eds.) (2007b) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press: Cambridge, United Kingdom & New York, USA).
- (IPCC) Intergovernmental Panel on Climate Change, Parry M L, Canziani O F, Palutikof J P, Van Der Linden P J & Hanson C E (eds.) (2007a) *Climate Change 2007: Impacts, Adaptation and Vulnerability*, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge University Press: Cambridge, UK).
- (LGAT) Local Government Association of Tasmania (2010) *Tasmanian Local Council Climate Change Case Studies: Lower George River Flood Risk Project*, available from: http://www.lgat.tas.gov.au/webdata/resources/files/Climate_change_case_studies_-_break_o_day.pdf.
- (LGAT) Local Government Association of Tasmania (2010) *Tasmanian Local Council Climate Change Case Studies: Climate Change Impacts on the Clarence Coastal Area*, available from: http://www.lgat.tas.gov.au/webdata/resources/files/Climate_change_case_studies_-_Clarence.pdf.
- (LGAT) Local Government Association of Tasmania (2012), available from: <http://www.climatechange.tas.gov.au/>.
- (NCCARF) National Climate Change Adaptation Research Facility (2012c) *Project Descriptor: Climate Change and the Community Welfare Sector – Risks and Adaptation*, ACOSS project funded by NCCARF Settlements & Infrastructure Climate Change Adaptation Research Grants Program (NCCARF: Gold Coast, Queensland), available from: <http://www.nccarf.edu.au/content/climate-change-and-community-welfare-sector---risks-and-adaptation>.
- (NCCARF) National Climate Change Adaptation Research Facility (2012b) NCCARF Research Portfolio Factsheet 8: Business and Industry (NCCARF: Gold Coast, Queensland).
- (NCCARF) National Climate Change Adaptation Research Facility (2012a) *Climate Change Adaptation Research in Australia: An Overview of Research Funded by the National Climate Change Adaptation Research Facility* (NCCARF: Gold Coast, Queensland).
- (NCCARF) National Climate Change Adaptation Research Facility (2012b) *NCCARF Research Portfolio Factsheet 8: Business and Industry* (NCCARF: Gold Coast, Queensland).
- (NCCARF) National Climate Change Adaptation Research Facility, *Adaptation Research Network: Marine Biodiversity and Resources*, available from: www.nccarf.edu.au/marine/.
- (NTRCA) Northern Tasmania Regional Councils Authority (2011) *Regional Land Use Strategy of Northern Tasmania*.

- (QUT) Queensland University of Technology (2010) *Impacts and adaptation response of infrastructure and communities to heatwaves: the southern Australian experience of 2009*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- (RMC) Department of Primary Industries, Parks, Water and Environment, Resource Management & Conservation Division (2012) *Research and Monitoring in the Tasmanian Wilderness World Heritage Area* [Brochure] (DPIPWE: Hobart, Tasmania), available from: [http://www.dpiw.tas.gov.au/inter.nsf/Attachments/LJEM-8UWVPM/\\$FILE/WWHA%20reportweb.pdf](http://www.dpiw.tas.gov.au/inter.nsf/Attachments/LJEM-8UWVPM/$FILE/WWHA%20reportweb.pdf).
- (SCCC) Select Committee on Climate Change (2012) *Roles and responsibilities for climate change adaptation in Australia*, available from: <http://www.climatechange.gov.au/government/initiatives/sccc/discussion.aspx>.
- (STCA) Southern Tasmanian Councils Association (2012) available from: <http://stca.tas.gov.au/cc/>.
- (STCRC) Sustainable Tourism Cooperative Research Centre (2009) *The Impacts of Climate Change on Australian Tourism Destination: Developing Adaptation and Response Strategies*, (CRC for Sustainable Tourism: Gold Coast, Queensland).
- (STRPP) Southern Tasmania Regional Planning Project (2011) *Southern Tasmania Regional Land Use Strategy 2010-2035*. .
- (TCCO) Department of Premier and Cabinet, Tasmanian Climate Change Office (2008) *The Tasmanian Framework for Action on Climate Change* (TCCO: Hobart, Tasmania).
- (TCCO) Department of Premier and Cabinet, Tasmanian Climate Change Office (2012a) *Adapting to Climate Change in Tasmania – Issues Paper* (TCCO: Hobart, Tasmania), available from: http://www.dpac.tas.gov.au/__data/assets/pdf_file/0009/174834/Adapting_to_climate_change_in_Tasmania.pdf.
- (TCCO) Department of Premier and Cabinet, Tasmanian Climate Change Office (2012b) *Derivation of the Tasmanian Sea Level Rise Planning Allowance Technical Paper* (TCCO: Hobart, Tasmania).
- (TPC) Tasmanian Planning Commission (2009) *State of the Environment Report: Tasmania 2009* (TPC: Hobart, Tasmania), available from: <http://soer.justice.tas.gov.au/2009/>.
- (TPC) Tasmanian Planning Commission (2012) *Planning Directive No. 5: Bushfire-Prone Areas Code*.
- Aboriginal Heritage Tasmania (2012) *The Impacts of Climate Change* (DPIPWE: Tasmania), available from: <http://www.aboriginalheritage.tas.gov.au/editorials/Pages/The-impacts-of-climate-change.aspx>.
- Adger N, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson D R, Naess L O, Wolf J, Wreford A (2009) 'Are there social limits to adaptation to climate change?' *Climatic Change* 93: 335-354.
- Allenby B R & Sarewitz D (2011) *The Techno-Human Condition* (MIT Press: Cambridge, Massachusetts).
- Andre J, Haddon M & Pecl G T (2010) 'Modelling climate-change-induced nonlinear thresholds in cephalopod population dynamics' *Global Change Biology* 16: 2866-2875.
- Australian Greenhouse Office (2006) *Climate Change Impacts and Risk Management – a Guide for Business and Government* (Department of Environment and Heritage: Canberra, ACT).

- Barmuta L A, Davies P E, Watson A, Lacey M, Graham B, Reid M G, Carter S & Warfe D M (2012) *Joining the dots: integrating climate and hydrological projections with freshwater ecosystem values to develop adaptation options for conserving freshwater biodiversity*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Barnett J & Waters E (2013) *Barriers to Adaptation to Sea Level Rise*, Draft Final Research Report to the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Barnett J, Dovers S, Hatfield-Dodds S, McDonald J, Nelson R & Waller S (2011) *National Climate Change Adaptation Research Plan: Social, Economic and Institutional Dimensions* (NCCARF: Gold Coast, Queensland).
- Battaglione S C, Carter C, Hobday A J, Lyne V & Nowak B (2008) 'Scoping Study into Adaptation of the Tasmanian Salmonid Aquaculture Industry to Potential Impacts of Climate Change', *National Agriculture & Climate Change Action Plan: Implementation Programme report* (TAFI, UTAS & CSIRO: Hobart, Tasmania).
- Beer A, Tually S, Kroehn M & Law J (2012) *Australia's Country Towns 2050: What Will A Climate Adapted Settlement Pattern Look Like?* [Preliminary Report] (Centre for Housing, Urban and Regional Planning University of Adelaide: Adelaide, South Australia).
- Beggs P J (2010) 'Adaptation to Impacts of Climate Change on Aeroallergens and Allergic Respiratory Diseases' *International Journal of Environmental Research and Public Health* 7: 3006-3021.
- Bell E & Towle N (2011) 'Climate Change and Primary Health Care: Towards Better Regional Health Impact and Risk Assessments', Proceedings of the 11th National Rural Health Conference: *Rural and Remote Australia – The Heart of a Health Nation* (Perth, 13-16 March 2011), available from: <http://11nrhc.ruralhealth.org.au/plenary-and-concurrent-papers>.
- Bell E (2011) 'Making Health Services 'Climate-ready': A Policy Framework for Regional Development' *American Journal of Public Health* 101: 804-813, DOI 10.2105/AJPH.2010.202820.
- Bell E J (2013) 'Climate change and health research: has it served rural communities?' *Rural and Remote Health* 13: 2343, available online from: <http://www.rrh.org.au>.
- Bell E, Horton G, Blashki G & Seidel B M (2012) 'Climate Change: Could it Help Develop 'Adaptive Expertise'?' *Advances in Health Sciences Education* 17: 211–224.
- Bell E, Turner P & Sainsbury F (2012) *Climate Change Health Impact and Risk Assessment Tool: a Pilot Implementation Project*, Summary Report to the Tasmanian Government Climate Connect Community Grants Program.
- Bennett J (2011) *Estimating the Value of Australian Environmental Assets*, available from: <http://www.tandfonline.com/doi/pdf/10.1080/14486563.2011.566157>.
- Bennett J C, Ling F L N, Graham B, Corney S P, Holz G K, Grose M R, White C J, Gaynor S M & Bindoff N L (2010) *Climate Futures for Tasmania: Water and Catchments Technical Report* (ACE CRC: Hobart, Tasmania), available from: http://www.dpac.tas.gov.au/divisions/climatechange/adapting/climate_futures/climate_futures_f_or_tasmania_reports.
- Bird D, King D, Haynes K, Box P, Okada T & Nairn K (2011) *Impact of the 2010/11 Floods and the Factors That Inhibit and Enable Household Adaptation Strategies* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

- Black D A, Veitch C, Wilson L A & Hansen A (2013), *Heat-Ready: Heatwave awareness, preparedness and adaptive capacity in aged care facilities in three Australian states: New South Wales, Queensland and South Australia*, [Draft] Report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Boon H J, Millar J, Lake D, Cottrell A, King D (2012) *Recovery from Disaster: Resilience, Adaptability and Perceptions of Climate Change* (NCCARF: Gold Coast, Queensland).
- Booth K & Williams S (2012) 'Is Insurance an Under-Utilised Mechanism in Climate Change Adaptation? The Case of Bushfire Management in Tasmania', *Australian Journal of Emergency Management* 27 (4): 38-45.
- Booth P & Cox R (2012) *Case Studies of Climate Change Adaptation Tools and Application Processes Used by Local Government Practitioners*, final Stage 1 Report to the Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNSI) (NCCARF: Gold Coast, Queensland). .
- Booth P (2012) *Stage 1 Report: Case Studies of Climate Change Adaptation Tools and Application Processes Used by Local Government Practitioners*, Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNSI) (School of Civil and Environmental Engineering, University of New South Wales: Sydney, New South Wales). .
- Booth P, Graham P & Chen N (2011) *Framing a National Climate Change Adaptation Policy for the Built Environment*, Australian Climate Change Adaptation Research Network for Settlements and Infrastructure (ACCARNSI) Position Paper, available from: www.nccarf.edu.au/settlements-infrastructure/discussion_papers.
- Bridle K, Jones J, Kerlake F, Sanderson D, Phelan D, Parsons D, Prior S, Brown C & Mohammed C (2012b) *Projected Impact of Climate Change on Wine Grape Production – Opportunities for Growers*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8UT3EQ?open>.
- Bridle K, Lisson S, Parsons D, Phelan D, Prior S, Brown C & Mohammed C (2012c) *Projected Impact of Climate Change – Farmers Talk About Their Options*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8UT37X?open>.
- Bridle K, Phelan D, Parsons D, Prior S, Brown C & Mohammed C (2012a) *Projected Impact of Climate Change on Extensive Dryland Pastures – Opportunities for Graziers*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8UT2PF?open>.
- Cai W (2006) 'Antarctic ozone depletion causes an intensification of the Southern Ocean supergyre circulation', *Geophysical Research Letters* 33 DOI:10.1029/2005GL024911.
- Cai W, Shi G, Cowan T, Bi D & Ribbe J (2005) 'The response of the Southern Annular Mode, the East Australian Current, and the southern mid-latitude ocean circulation to global warming', *Geophysical Research Letters* 32 DOI:10.1029/2005GL024701.
- Carley J T, Blacka M J, Timms W A, Andersen M S, Mariania A, Rayney DS, McArthur J & Cox R J (2008) *Coastal Processes and Hazards for Preparation of a Coastal Management Strategy for Clarence City, Tasmania* (Water Research Laboratory, University of New South Wales: Manly Vale, New South Wales).
- Carver S, Goate S, Allen G R, Rowbottom R M, Fearnley E M & Weinstein P, (2011) 'Relationships of the Ross River virus (Togoviridae: Alphavirus) vector, *Aedes camptorhynchus* (Thomson)

- (Diptera: Culicidae), to biotic and abiotic factors in saltmarshes of south-eastern Tasmania, Australia: a preliminary study', *Australian Journal of Entomology* 50: 344–355.
- Casper R M, Barrett N S, Bax N & Hobday A J (2011) *Review of the Eastern Blue Groper*, Pre-adapting a Tasmanian coastal ecosystem to ongoing climate change through re-introduction of a locally extinct species, FRDC-DCCEE Project No: 2010/564.
- Chambers L E, Devney C A, Congdon B C, Dunlop N, Woehler E J & Dann P (2011) 'Observed and predicted effects of climate on Australian seabirds', *Emu* 111: 235-253.
- Chaplin S & Fairbrother P (2012) *Community Adaptation to Bushfire in a Changing Climate: A Toolkit for Local Government* (Centre for Sustainable Organisations and Work, RMIT: Melbourne, Victoria).
- Chong J, Asker S, O'Rourke A & White S (2012) *Green Chrysalis – Small and Medium-Sized Enterprises: Innovation and Transformation Towards Australia's Low-Carbon Economy*, Report prepared for the Australian Business Foundation (Institute for Sustainable Futures, University of Technology: Sydney, New South Wales).
- Church J A, White N J, Hunter J R & McInnes K L (2012) 'Sea Level', in Poloczanska E S, Hobday AJ & Richardson A J (eds.) *A Marine Climate Change Impacts and Adaptation Report Card for Australia 2012*, available from: <http://www.oceanclimatechange.org.au>.
- Cica N (2013) 'The cracks are how the light gets in', *Griffith Review* 38, available from: <https://griffithreview.com/edition-39-tasmania-the-tipping-point/the-cracks-are-how-the-light-gets-in>.
- ComSec (2013) *State of the States Report: April 2013*, available from: <http://www.investing.commsec.com.au/stateofstates>.
- Corney S P, Katzfey J K, McGregor J, Grose M, White C, Holz G, Bennett J, Gaynor S & Bindoff N L (2010) *Climate Futures for Tasmania: methods and results on climate modelling* (ACE CRC: Hobart, Tasmania).
- Cozzolino D, Cynkar W, Damberg R G, Gishen R G & Smith P (2010) 'Grape (*Vitis Vinifera*) compositional data spanning ten successive vintages in the context of abiotic growing parameters', *Agriculture, Ecosystems and Environment* 139(4): 565-570
DOI:10.1016/j.agee.2010.09.017.
- Cresswell G (2000) 'Currents of the continental shelf and upper slope of Tasmania' *Papers and Proceedings of the Royal Society of Tasmania* 133: 21-30.
- Crimp S, Gartmann A, DeVoi P, Gaydon D, Howden M & Odgers J (2008) *Adapting Australian Farming Systems to Climate Change: a Participatory Approach* [Final Report] (Australian Greenhouse Office: Canberra, ACT), available from: http://www.bcg.org.au/resources/Adapting_Australian_farming_systems_to_climate_change_final_report_web.pdf.
- Crompton R, McAneney D, McAneney J, Musulin R, Walker G & Jr R P (2012) *Market-Based Mechanisms for Climate Change Adaptation: Assessing the potential for and limits to insurance and market-based mechanisms for encouraging climate change adaptation*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Cubillos J C, Wright S W, Nash G, de Salas M F, Griffiths B, Tilbrook B, Poisson A & Hallegraeff G M (2007) 'Calcification morphotypes of the coccolithophorid *Emiliana huxleyi* in the Southern

Ocean: changes in 2001 to 2006 compared to historical data', *Marine Ecology Progress Series* 348: 47-54.

Davidson J & Lyth A (2012) 'Education for Climate Change Adaptation – Enhancing the Contemporary Relevance of Planning Education for a Range of Wicked Problems', *Journal for Education in the Built Environment* (7)2: 63-83, available online from: [http://cebe.cf.ac.uk/jebe/pdf/JulieDavidson7\(2\).pdf](http://cebe.cf.ac.uk/jebe/pdf/JulieDavidson7(2).pdf).

Dennis C (2002) 'Baiting plan to remove fox threat to Tasmanian wildlife', *Nature* 416: 357.

Doubleday Z A, Clarke S M, Li X, Pecl G T, Ward T, Battaglione S, Frusher S, Gibbs P J, Hobday A J, Hutchinson N, Jennings S M & Stoklosa R (2013) 'Assessing the risk of climate change to aquaculture: a case study from south-east Australia', *Aquaculture Environment Interactions* 3(2): 163-175 DOI: 10.3354/aei00058.

Dunlop M & Brown P R (2008) *Implications of climate change for Australia's National Reserve System: A preliminary assessment*, Report to the Department of Climate Change (DCC) (DCC: Canberra, ACT).

Evans L S, Fidelman P, Hicks C, Morgan C, Perry A L & Tobin R (2011) *Limits to climate change adaptation in the Great Barrier Reef: Scoping ecological, institutional and economic limits*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

Fitzgerald N (2011) *Establishment Report for Tasmanian Wilderness World Heritage Area Climate Change Monitoring Program: Montane Conifers*, Nature Conservation Report Series 11/06 (Resource Management and Conservation Division, DPIW: Hobart, Tasmania).

Fleming A & Vanclay F (2010) 'Farmer responses to climate change and sustainable agriculture: a Review', *Agronomy for Sustainable Development* 30: 11-19 DOI:10.1051/agro/2009028.

Folder S (2012) *Climate Ready Farms for the Future: Case Study, Regional NRM Strategy*, a report for Cradle Coast NRM by Pear Consulting (Cradle Coast Authority: Tasmania).

Forbes C (2009) 'The effects of climate change induced coastal inundation' National Environmental Law Review, available from: <http://www.austlii.edu.au/au/journals/NatEnvLawRw/2009/48.html>.

Fritze J, Williamson L & Wiseman J (2009) *Community Engagement and Climate Change: Benefits, Challenges and Strategies*, report for the Victorian Department of Planning and Community Development.

Frusher S & Marshall N (2012) *A Climate Change Adaptation Blueprint for Coastal Regional Communities* [Project synopsis], available from: http://www.nccarf.edu.au/sites/default/files/attached_files_research_projects/2010-542%20Website%20snippet%20Frisher-Marshall.pdf.

Frusher S D, Hobday A J, Jennings S M, Pecl G T, Haward M, Nursey-Bray M, Holbrook N J, van Putten E I, Crighton C & D'Silva D (in press) 'History of a hotspot – from anecdote to adaptation in south-east Australia', *Reviews in Fish Biology and Fisheries*.

Galbreath J (2011) 'To what extent is business responding to climate change? Evidence from a global wine producer', *Journal of Business Ethics* 104: 421-432 DOI 10.1007/s10551-011-0919-5.

Gale F (2013) 'No basket-case – Tasmania on the bumpy road to economic sustainability', *The Conversation*, 8 Feb 2013, available from: <http://theconversation.com/no-basket-case-tasmania-on-the-bumpy-road-to-economic-sustainability-11293>.

- Gardner J, Parsons R & Paxton G (2010) *Adaptation Benchmarking Survey: Initial Report*, CSIRO Climate Adaptation Flagship Working paper No. 4, available from: <http://www.csiro.au/Organisation-Structure/Flagships/Climate-Adaptation-Flagship/CAF-working-papers/CAF-working-paper-4.aspx>.
- Gaydon D S, Meinke H & Rodriguez D (2012) 'The best farm-level irrigation strategy changes seasonally with fluctuating water availability', *Agricultural Water Management: An International Journal* 103: 33-42 DOI:10.1016/j.agwat.2011.10.015.
- Gehrels W R, Callard S L, Moss P T, Marshall W A, Blaauw M, Hunter J, Milton A & Garnett M H (2012) 'Nineteenth and Twentieth Century Sea-level Changes in Tasmania and New Zealand' *Earth and Planetary Science Letters* 315–316: 94-102.
- Gehrels W R, Callard S L, Moss P T, Marshall W A, Blaauw M, Hunter J, Milton A & Garnett M H
- Gero A, Kuruppu N & Mukheibir P (2012) *Cross-scale barriers to climate change adaptation in local government, Australia - Draft background report*, prepared for NCCARF (Institute for Sustainable Futures, University of Technology: Sydney, New South Wales) 1-35.
- Gero A, Meheux K & Dominey-Howes D (2010) *Disaster risk reduction and climate change adaptation in the Pacific: The challenge of integration*, ATRC-NHRL Miscellaneous Report 4, available from:<http://www.nhrl.unsw.edu.au/downloads/UNSW%20DRR%20and%20CCA%20in%20the%20Pacific.pdf>.
- Gibbs M & Hill T (2011) *Coastal Climate Change Risk - Legal and Policy Responses in Australia* (Commonwealth of Australia: Canberra, ACT) available from: <http://www.climatechange.gov.au/publications/coastal-climate-change-risk/~media/publications/coastal-climate-change-risk/CoastalLegislationReport-20120228-PDF.pdf>.
- Gibbs M & Hill T (2011) *Coastal Climate Change Risk - Legal and Policy Responses in Australia* (Commonwealth of Australia: Canberra, ACT) available from: <http://www.climatechange.gov.au/publications/coastal-climate-change-risk/~media/publications/coastal-climate-change-risk/CoastalLegislationReport-20120228-PDF.pdf>.
- Gilfedder L, MacGregor N, Bridle K, Carter O & Sprod D (2012) *Implementing Adaptation to Climate Change in Terrestrial and Freshwater Natural Environments in Tasmania*, Report on an expert workshop held in Hobart on 28-29 November 2011 (DPIPWE: Hobart, Tasmania).
- Good M (2011) *Government coastal planning responses to rising sea levels, Australia and overseas. ACE-CRC Technical Report* (ACE CRC: Tasmania), available from: <http://www.acecrc.org.au/access/repository/resource/86d7f302-1512-102f-a3d0-40404adc5e91>.
- Grafton R Q (2010) 'Adaptation to climate change in marine capture fisheries', *Marine Policy* 34: 606-615.
- Graham K, Green G & Heyward O (2012) *Regional Councils Climate Change Adaptation Strategy: Southern Tasmania* [Draft] (Southern Tasmanian Councils Authority: Tasmania).
- Green B S, Gardner C, Linnane A & Hawthorne P J (2010) 'The Good, the Bad and the Recovery in an Assisted Migration' *PLoS ONE* 5(11): e14160, available from: www.plosone.org/article/info:doi/10.1371/journal.pone.0014160.
- Grose M R, Barnes-Keoghan I, Corney S P, White C J, Holz G K, Bennett J B, Gaynor S M, & Bindoff N L (2010) *Climate Futures for Tasmania: General Climate Impacts Technical Report* (ACE CRC:

Hobart, Tasmania), available from:
http://www.climatechange.tas.gov.au/government_action/climate_futures.

- Gross C, Pittock J, Finlayson M & Geddes M C (2011) *Climate Change Adaptation in the Coorong, Murray Mouth and Lakes Alexandrina and Albert*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Gurran N, Norman B, Gilbert C, Hamin E (2011) *Planning for climate change adaptation in Coastal Australia: State of practice*, Report No. 4 for the National Sea Change Taskforce (Faculty of Architecture, Design and Planning, University of Sydney: New South Wales).
- Hadwen W L, Arthington A H, Boon P I, Taylor B & Fellows C S (2011a) 'Do Climatic or Institutional Factors Drive Seasonal Patterns of Tourism Visitation to Protected Areas Across Diverse Climate Zones in Eastern Australia?', *Tourism Geographies: An International Journal of Tourism Space, Place and Environment* 13(2): 187-208.
- Hadwen W L, Capon S J, Poloczanska E, Rochester W, Martin T, Bay L, Pratchett M, Green J, Cook B, Berry A, Lalonde A & Fahey S (2011b) *Climate Change Responses and Adaptation Pathways in Australian Coastal Ecosystems: Synthesis Report*, (NCCARF: Gold Coast, Queensland).
- Hallegraeff G M (2010) 'Ocean climate change, phytoplankton community responses, and harmful algal blooms: a formidable predictive challenge', *Journal of Phycology* 46: 220-235.
- Handmer J, McKellar R, McLennan B, Whittaker J, Towers B, Duggie J & Woolf M (2012) *National Climate Change Adaptation Research Plan: Emergency Management* [Revised Edition] (NCCARF: Gold Coast, Queensland) 60.
- Hansen A, Bi P, Saniotis A, Nitschke M, Benson J, Tan Y, Smyth V, Wilson L & Han G S (2012) *Extreme heat and climate change: adaptation in culturally and linguistically diverse (CALD) communities* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Harle K J, Howden S M, Hunt L P & Dunlop M (2007) 'The potential impact of climate change on the Australian wool industry by 2030', *Agricultural Systems* 93: 61-89
DOI:10.1016/j.agsy.2006.04.003.
- Harrington P, Reeks G & Helle L (2008) *Impact of Climate Change on Tasmania's Food and Beverage Industry*, Report prepared by Pitt & Sherry for the Department of Economic Development and Tourism Department of Primary Industries and Water (Pitt & Sherry: Hobart, Tasmania).
- Hart M (ed.) (2011) *Effects of severe weather on agriculture in Tasmania, January to April 2011*, [Unpublished report] (Tasmanian Institute of Agricultural Research: Hobart, Tasmania).
- Haward M, Davidson J, Hockings M, Lockwood M, Kriwoken L, Allchin R (2012) 'Changing currents in marine biodiversity governance and management responding to climate change', *Report 2: Scenarios for marine environments in Eastern Australia and implications for biodiversity*, (FRDC/UTAS: Tasmania).
- Haward M, Davidson J, Lockwood M, Hockings M & Kriwoken L (2012) 'Climate change, scenarios and marine biodiversity conservation', *Marine Policy* 38, available from:
<http://dx.doi.org/10.1016/j.marpol.2012.07.004>.
- Hayman P, Rickards L, Eckard R & Lemerle D (2012) 'Climate change through the farming systems lens: Challenges and opportunities for farming in Australia', *Crop & Pasture Science* 63: 203-214 DOI.org/10.1071/CP11196.

- Haynes K, Bird D K, Carson D, Larkin S & Mason M (2011) *Institutional response and Indigenous experiences of Cyclone Tracy*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Helman P, Thomalla F & Metusela C (2010) *Storm tides, coastal erosion and inundation*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Henry B, Charmley E, Eckard R, Gaughan J B & Hegarty R (2012) 'Livestock production in a changing climate: Adaptation and mitigation research in Australia', *Crop & Pasture Science* 63: 191-202 DOI.org/10.1071/CP11169.
- Henry G W & Lyle J M (eds.) (2003) 'National Recreational Fishing Survey', in *The National Recreational and Indigenous Fishing Survey*, FRDC Project No. . 99/158 (Australian Government Department of Agriculture, Fisheries and Forestry: Canberra, ACT) 27-97.
- Herriman E J, Kuruppu N, Gero A & Mukheibir P (2012) 'Cross-scale barriers to climate change adaptation in local government, Australia - Workshop Two report', prepared for National Climate Change Adaptation Research Facility (Institute for Sustainable Futures, UTS: Sydney, New South Wales) 1-47.
- Hobday A J & Lough J (2011) 'Projected climate change in Australian marine and freshwater environments' *Marine and Freshwater Research* 62: 1000-1014.
- Hobday A J & Pecl G T (in press) 'Identification of global marine hotspots: sentinels for change and vanguards for adaptation', *Reviews in Fish Biology and Fisheries*.
- Hobday A J, Lyne V, Thresher R, Spillman C & Norman-Lopez A (2011) *Atlantic Salmon Aquaculture Subprogram: Forecasting ocean temperatures for salmon at the farm site*, FRDC report 2010/217, (delivered draft final 13 Sept 2011).
- Hobday A J, Poloczanska E S & Matear R (2008) *Implications of Climate Change for Australian Fisheries and Aquaculture: A preliminary assessment*, Report to the Department of Climate Change (DCC) (DCC: Canberra, ACT), available from: <http://www.cmar.csiro.au/climateimpacts/reports.htm>.
- Hobson K & Niemeyer S (2011) Public responses to climate change: *The role of deliberation in building capacity for adaptive action*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Hochman Z & Carberry P S (2011) 'Emerging consensus on desirable characteristics of tools to support farmers management of climate risk in Australia' *Agricultural Systems* 104: 441-450 DOI:10.1016/j.agsy.2011.03.001.
- Hodgkinson J H, Littleboy A, Howden M, Moffat K & Loechel B (2010) *Climate Adaptation in the Australian Mining and Exploration Industries*, CSIRO Climate Adaptation Flagship Working paper No. 5, available from: <http://www.csiro.au/resources/CAF-working-papers.html>.
- Holbrook N J (2011) *Australian Marine Stakeholder Needs in a Changing Climate*, Report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Holbrook N J, Brown J N, Davidson J, Feng M, Hobday A J, Lough J M, McGregor S, Power S B & Risbey J S (2012) 'El Niño – Southern Oscillation', in Poloczanska E S, Hobday A J & Richardson A J (eds.) *A Marine Climate Change Impacts and Adaptation Report Card for Australia 2012*, available from: <http://www.oceanclimatechange.org.au/>.

- Holbrook N L & Bindoff N L (1997) 'Interannual and decadal temperature variability in the southwest Pacific Ocean between 1955 and 1988' *Journal of Climate* 10: 1035-1049.
- Holz G K, Grose M R, Bennett J C, Corney S P, White C J, Phelan D, Potter K, Kriticos D, Rawnsley R, Parsons D, Lisson S, Gaynor S M & Bindoff N L (2010) *Climate Futures for Tasmania: impacts on agriculture technical report* (ACE CRC: Hobart, Tasmania).
- House of Representatives Standing Committee on Climate Change, Water, Environment and the Arts (2009) *Managing Our Coastal Zone in a Changing Climate: The Time to Act is Now*, report to the House of Representatives Committee (Commonwealth of Australia: Canberra, ACT).
- Hovenden M J, Miglietta F, Zaldei A, Vanderschoor J K, Wills K E & Newton P C D (2006) 'The TasFACE climate-change impacts experiment: design and performance of combined elevated CO₂ and temperature enhancement in a native Tasmanian grassland', *Australian Journal of Botany* 54: 1-10.
- Howden S M, Soussana J F, Tubiello F N, Chhetri N, Dunlop M & Meinke H (2007) 'Adapting agriculture to climate change', *Proceedings of the National Academy of Sciences* 104(5): 19691-19696 DOI:10.1073/pnas.0701890104.
- Hughes L, Hobbs R, Hopkins A, McDonald J, Stafford Smith M, Steffen W & Williams S (2010) *National Climate Change Adaptation Research Plan for Terrestrial Biodiversity* (National Climate Change Adaptation Research Facility: Gold Coast, Queensland) 64.
- Hunter J (2008) *Historical and Projected Sea-Level Extremes for Hobart and Burnie, Tasmania*, Technical Report prepared by the Antarctic and Climate and Ecosystems Cooperative Research Centre (DPIW: Hobart, Tasmania).
- Hunter J (2010) 'Estimating Sea-level Extremes under Conditions of Uncertain Sea-level Rise' *Climatic Change* 99: 331–350 DOI 10.1007/s10584-009-9671-6.
- Hunter J (2012) 'A simple technique for estimating an allowance for uncertain sea-level rise', *Climatic Change* 113: 239-252 DOI 10.1007/s10584-011-0332-1.
- Hunter J, Allison I & Jakszewicz T (2012) *Report card: Sea-level rise 2012* (ACE CRC: Hobart, Tasmania).
- Hydro Tasmania (2012) *Climate Change Framework*, available from: <http://www.hydro.com.au/environment/climate-change>.
- Jenkins K M, Kingsford R T, Closs G P, Wolfenden B J, Matthaei C D & Hay S E (2011) 'Climate change and freshwater ecosystems in Oceania: an assessment of vulnerability and adaptation opportunities', *Pacific Conservation Biology* 17: 201-219.
- Johnson C R, Banks S C, Barrett N S, Cazassus F, Dunstan P K, Edgar G J, Frusher S D, Gardner C, Haddon M, Helidoniotis F, Hill K L, Holbrook N L, Hosie G W, Last P R, Ling S D, Melbourne-Thomas J, Miller K, Pecl G T, Richardson A J, Ridgway K R, Rintoul S R, Ritz D A, Ross D J, Sanderson J C, Shepherd S A, Slotwinski A, Swadling K M & Taw N (2011) 'Climate change cascades: Shifts in oceanography, species' ranges and subtidal marine community dynamics in eastern Tasmania' *Journal of Experimental Marine Biology and Ecology* 400(1-2): 17-32 DOI:10.1016/j.jembe.2011.02.032.
- Johnston F H (2009) 'Bushfires and Human Health in a Changing Environment', *Australian Family Physician* 38: 720-725.

- Johnston F H, Williamson G J & Bowman D M J S (2012) 'A Review of Approaches to Monitoring Smoke from Vegetation Fires for Public Health', *Air Quality and Climate Change* 44(2): 17-21.
- Johnston G S, Burton D L, Baker-Jones M & Best P (2013) *Climate Change Adaptation in the Boardroom*, Final Report (NCCARF: Gold Coast, Queensland).
- Jones R (in progress) *Valuing adaptation under rapid change: anticipatory adjustments, maladaptation and transformation*, available from:
http://www.nccarf.edu.au/sites/default/files/attached_files_research_projects/SEID1112%20Website%20snippet%20Jones.pdf.
- Kahneman D & Tyersky A (1984) 'Choices, Values, and Frames', *American Psychologist* 39(4): 341-350.
- Keating B A, Carberry P S, Bindraban P, Asseng S, Meinke H & Dixon J (2010) 'Eco-efficient agriculture: Concepts, challenges and opportunities' *Crop Science* 50: 109-119
 DOI:10.2135/cropsci2009.10.0594.
- Kellett J, Ness D, Hamilton C, Pullen S & Leditschke A (2011) *Learning from Regional Climate Analogues*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Kiem A S & Austin E K (2012) *Limits and barriers to climate change adaptation for small inland communities affected by drought*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Kiem A S, Askew L E, Sherval M, Verdon-Kidd D C, Clifton C, Austin E, McGuirk P M & Berry H (2010a) *Drought and the Future of Rural Communities: Drought impacts and adaptation in regional Victoria, Australia*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Kiem A S, Verdon-Kidd D C, Boulter S L, & Palutikof J P (2010b) *Learning from Experience: Historical Case Studies and Climate Change Adaptation* (NCCARF: Gold Coast, Queensland).
- King D, Ginger J, Williams S, Cottrell A, Gurtner Y, Leitch C, Henderson D, Jayasinghe N, Kim P, Booth K, Ewin C, Innes K, Jacobs K, Jago-Bassingthwaighe M & Jackson L (2012) *Planning, Building and Insuring: Adaptation of Built Environment to Climate Change Induced Increased Intensity of Natural Hazards* (NCCARF: Gold Coast, Queensland).
- Koehn J D, Hobday A J, Pratchett M S & Gillanders B M (2011) 'Climate change and Australian marine and freshwater environments, fishes and fisheries: synthesis and options for adaptation', *Marine and Freshwater Research* 62: 1148-1164.
- Kuruppu N, Murta J, Mukheibir P, Chong J & Brennan T (2013) *Understanding the Adaptive Capacity of Small to-Medium Enterprises (SMEs) to Climate Change and Variability* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Lacey M, Hunter J & Mount R (2012) *Coastal inundation mapping for Tasmania – Stage 2*, Report to the Department of Premier and Cabinet by the Blue Wren Group, School of Geography and Environmental Studies, University of Tasmania and the Antarctic Climate and Ecosystems Cooperative Research Centre (UTAS & ACE CRC: Hobart, Tasmania), available from:
http://www.dpac.tas.gov.au/__data/assets/pdf_file/0004/176458/Coastal_Inundation_Mapping_Stage2_V1.pdf.
- Langton M, Parsons M, Leonard S, Auty K, Bell D, Burgess P, Edwards S, Howitt R, Jackson S, McGrath V & Morrison J (2012) *National Climate Change Adaptation Research Plan for*

Indigenous Communities (National Climate Change Adaptation Research Facility: Gold Coast, Queensland).

- Last P R, White W T, Gledhill D C, Hobday A J, Brown R, Edgar G J & Pecl G T (2011) 'Long-term shifts in abundance and distribution of a temperate fish fauna: a response to climate change and fishing practices' *Global Ecology and Biogeography* 20: 58-72 DOI: 10.1111/j.1466-8238.2010.00575.x.
- Lawrence G, Richards C & Lyons K (2013) 'Food security in Australia in an era of neoliberalism, productivism and climate change', *Journal of Rural Studies* 29: 30-39 DOI:10.1016/j.jrurstud.2011.12.005.
- Leith P L, Rooney M & Tilden J (2012) *Kingborough responding to coastal hazards – Snug case study*, report prepared by the Blue Wren Group Pty Ltd for Kingborough Council (Kingborough Council: Kingston, Tasmania), available from: <http://www.kingborough.tas.gov.au/webdata/resources/files/Snug%20Case%20Study%20Final%20Report.pdf>.
- Ling S D & Johnson C R (2012) 'Marine reserves reduce risk of climate-driven phase shift by reinstating size- and habitat-specific trophic interactions', *Ecological Applications* 22: 1232-1245.
- Ling S D (2008) 'Range expansion of a habitat-modifying species leads to loss of taxonomic diversity: a new and impoverished reef state', *Oecologia* 156: 883-894 DOI 10.1007/s00442-008-1043-9.
- Ling S D, Johnson C R, Frusher S D & Ridgway K R (2009a) 'Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift', *Proceedings of the National Academy of Sciences* 106: 22341-22345.
- Ling S D, Johnson C R, Ridgway K, Hobday A J & Haddon M (2009b) 'Climate driven range extension of a sea urchin: inferring future trends by analysis of recent population dynamics', *Global Change Biology* 15: 719-731.
- Linnenluecke M, Stathakis A & Griffiths A (2011) 'Firm Relocation as Adaptive Response to Climate Change and Weather Extremes', *Global Environmental Change* 21: 123-133 DOI:10.1016/j.gloenvcha.2010.09.010.
- Lisson S, Acuna T, Parsons D, Bridle K, Phelan D, Prior S, Brown C & Mohammed C (2012) *Impact of climate change on wheat production – opportunities for growers* (Tasmanian Government and the Tasmanian Institute of Agriculture: Hobart, Tasmania), available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8V27FZ?open>.
- Lockwood M, Davidson J, Hockings M, Haward M & Kriwoken L (2012) 'Marine biodiversity conservation governance and management: Regime requirements for global environmental change', *Ocean & Coastal Management* 69: 160-172.
- Lockwood M, Davidson J, Hockings M, Haward M, Kriwoken L, Allchin R (2011) *Changing Currents in Marine Biodiversity Governance and Management: Responding to Climate Change Report 1* (FRDC/UTAS: Hobart, Tasmania).
- Lough J M & Hobday A J (2011) 'Observed climate change in Australian marine and freshwater environments', *Marine and Freshwater Research* 62: 984-999.
- Loughnan M E, Tapper N J, Phan T, Lynch K & McInnes J A (2012) *A spatial vulnerability analysis of urban populations to extreme heat events in Australian capital cities*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

- Lyth A, Allchin R, Bell E & Holbrook N J (2013) *Ross River Virus in Tasmania in a Changing Climate: a vulnerability assessment A Preliminary Assessment of Ross River Virus Risk and Vulnerability in a Changing Climate*, a report prepared for the Tasmanian Government Climate Connect program (UTAS: Hobart, Tasmania), available from http://www.climatechange.tas.gov.au/grants/climateconnect_grants/previous_rounds/project_reports_-_round_four.
- Lyth A, Nichols S & Tilbury D (2007) *Shifting towards sustainability: Education for climate change adaptation in the built environment sector*, a report prepared by the Australian Research Institute in Education for Sustainability (ARIES) (ARIES: New South Wales) 54. .
- Macintosh A, Foerster A & McDonald J (2013) *Limp, Leap or Learn? Developing legal frameworks for climate change adaptation planning in Australia: Spatial Planning Instruments for Climate Change Adaptation*, Final Project Report (NCCARF: Gold Coast, Queensland).
- Madin E M P, Ban N, Doubleday Z A, Holmes T H, Pecl G T & Smith F (2012) 'Socio-economic and management implications of range-shifting species in marine systems', *Global Environmental Change* 22: 137-146.
- Maia A & Meinke H (2010) 'Probabilistic methods for seasonal forecasting in a changing climate: Cox-type regression models', *International Journal of Climatology* 30(15): 2277-2288 DOI: 10.1002/joc.2042.
- Mair J (2011) 'Events and Climate Change: An Australian Perspective', *International Journal of Event and Festival Management* 2 (3): 245-253.
- Mallon K & Hamilton E, Black M, Beem B, Abs J (2013) *Adapting the Community Sector for Climate Extremes* (NCCARF: Gold Coast, Queensland) 286.
- Martin H (2013) 'Hello world, it's Tassie calling', article published in *The Mercury* (3 February 2013), available from: http://www.themercury.com.au/article/2013/02/03/371593_tasmania-news.html.
- Marzloff M, Dambacher J M, Johnson C R, Little L R & Frusher S D (2011) 'Exploring alternative states in ecological systems with a qualitative analysis of community feedback', *Ecological Modelling* 222: 2651-2662.
- Materia C (2008) *Local Government Climate Change Forum Summary Paper, May 2008* (Local Government Association of Tasmania: Hobart, Tasmania).
- Matthews T (2011) *Climate Change Adaptation in Urban Systems: Strategies for Planning Regimes*, Urban Research Program Research Paper 32, available from: http://www.griffith.edu.au/__data/assets/pdf_file/0004/275107/urp-rp32-matthews-2011.pdf.
- McEvoy D, Mullett J, Millin S, Scott H & Trundle A (2013) *Understanding Future Risks to Ports in Australia: Enhancing the Resilience of Seaports to a Changing Climate* (NCCARF: Gold Coast, Queensland).
- McInnes K L, Church J A, Pattiarachi C, Greenslade D, White N & Sexton J (2012a) *Sea Level and Coastal Impacts from Climate Change, Weather and Seismic Disturbances: a Review of Research Activities and Observational Requirements*, paper delivered at the Integrated Marine Observing System Conference 3-4 October 2012, Canberra, available from: www.imos.org.au.

- McInnes K L, Macadam I, Hubbert G D, & O'Grady J G (2009a) 'A Modelling Approach for Estimating the Frequency of Sea Level Extremes and the Impact of Climate Change in Southeast Australia', *Natural Hazards* 51: 115-137 DOI 10.1007/s11069-009-9383-2.
- McInnes K L, O'Grady J G, Hemer M, Macadam I & Abbs D J (2012b) *Climate Futures for Tasmania: Extreme Sea Levels along Tasmania's Coast and the Impact of Climate Change*, Climate Futures for Tasmania Technical Report (ACE CRC: Hobart, Tasmania) 44.
- McLeod D J, Hallegraef G M, Hosie G W & Richardson A J (2012a) 'Climate-driven range expansion of the red-tide dinoflagellate *Noctiluca scintillans* into the Southern Ocean', *Journal of Plankton Research* 34: 332-337.
- McLeod D J, Hobday A J, Lyle J M & Welsford D C (2012b) 'A prey-related shift in abundance of small pelagic fish in eastern Tasmania?' *ICES Journal of Marine Science* DOI: 10.1093/icesjms/fss069.
- McMichael A, Weaver H J, Berry H, Beggs P, Currie B, Higgins J, Kelly B, McDonald J, Tong S (2009) *National Climate Change Adaptation Research Plan for Human Health* (National Climate Change Adaptation Research Facility: Gold Coast, Queensland) 64.
- McMichael A, Woodruff R & Hales S (2006) 'Climate change and human health: Present and future risks', *The Lancet* (UK edition) 367(9513): 859-69 DOI:10.1016/S0140-6736(06)68079-3.
- McNeill I M, Dunlop P D, Heath J B, Skinner T C Morrison D L (forthcoming 2013) 'Expecting the Unexpected: Predicting Physiological and Psychological Wildfire Preparedness from Perceived Risk, Responsibility, and Obstacles', *Risk Analysis: An International Journal* DOI: 10.1111/risa.12037.
- Meinke H & Stone R C (2005) 'Seasonal and inter-annual climate forecasting: the new tool for increasing preparedness to climate variability and change in agricultural planning and operations', *Climatic Change* 70: 221-253.
- Meinke H, Howden S M, Struik P C, Nelson R, Rodriguez D & Chapman S C (2009) 'Adaptation science for agricultural and natural resource management – urgency and theoretical basis', *Current Opinion in Environmental Sustainability* 1: 69-76 DOI:10.1016/j.cosust.2009.07.007.
- Meinke H, Nelson R, Kokic P, Stone R, Selvaraju R & Baethgen W (2006) 'Actionable climate knowledge – from analysis to synthesis', *Climate Research* 33: 101-110, available from: http://www.int-res.com/articles/cr_oa/c033p101.pdf.
- Middelmann M H (ed.) (2007) *Natural Hazards in Australia: Identifying Risk Analysis Requirements* (Geoscience Australia: Canberra, ACT).
- Ministerial Council for Police and Emergency Management (2009) *Climate Change Adaptation Action Plan*, available from: <http://www.em.gov.au/Documents/ClimateChangeActionPlan%20EndorsedbyMCPEM.pdf>.
- Mokany K, Harwood T D & Ferrier S (2013) 'Comparing habitat configuration strategies for retaining biodiversity under climate change', *Journal of Applied Ecology* 50: 519-527.
- Morrison C & Pickering C M (2011) *Climate change adaptation in the Australian Alps: impacts, strategies, limits and management*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

- Morrongiello J R, Beatty S J, Bennett J C, Crook D A, Ikedife D N E E, Kennard M J, Kerezszy A, Lintermans M, McNeil D G, Pusey B J & Rayner T (2011) 'Climate change and its implications for Australia's freshwater fish', *Marine and Freshwater Research* 62: 1082-1098.
- Moser S & Ekstrom J (2010) 'A framework to diagnose barriers to climate change adaptation', *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* 107(51): 22026-22031 DOI: 10.1073/pnas.1007887107.
- Mount R E, Lacey M J & Hunter J R (2010) *Tasmanian Coastal Inundation Mapping Project Report Version 1.2* [Consultants Report] (Tasmanian Planning Commission: Tasmania).
- Mount R E, Lacey M J & Hunter J R (2011) *Tasmanian Coastal Inundation Mapping Project Report Version 2.0* [Consultants Report] (Tasmanian Planning Commission: Tasmania).
- Mukheibir P, Gero A & Herriman E J (2012a) *Cross-scale barriers to climate change adaptation in local government, Australia - Workshop Three report*, prepared for National Climate Change Adaptation Research Facility (NCCARF) (Institute for Sustainable Futures, University of Technology: Sydney, New South Wales) 1-27.
- Mukheibir P, Kuruppu N, Gero A & Herriman J (2012b) *Cross-Scale Barriers to Adaptation in Local Government, Australia*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Murta J, Gero A, Kuruppu N & Mukheibir P (2012) *Enhancing Adaptive Capacity of Small to Medium Enterprises – Background Report*, report prepared for NCCARF (Institute for Sustainable Futures, University of Technology: Sydney, New South Wales).
- Nelson D R, Adger W N & Brown K (2007) 'Adaptation to environmental change: contributions of a resilience framework', *Annual Review of Environment and Resources* 32: 395-419 DOI: 10.1146/annurev.energy.32.051807.090348.
- Nelson R, Kokic P, Crimp S, Martin P, Meinke H, Howden S M, de Voil P & Nidumolu U (2010b) 'The vulnerability of Australian rural communities to climate variability and change: Part II - Integrating impacts with adaptive capacity', *Environmental Science and Policy* 13(1): 18-27 DOI:10.1016/j.envsci.2009.09.006.
- Nelson R, Kokic P, Crimp S, Meinke H & Howden S M (2010a) 'The vulnerability of Australian rural communities to climate variability and change: Part I—Conceptualising and measuring vulnerability', *Environmental Science & Policy* 13(1): 8-17 DOI:10.1016/j.envsci.2009.09.006.
- .
- Nichols N (2008) *Australian Climate and Weather Extremes: Past, Present and Future*, a report for the Department of Climate Change (Department of Climate Change: Canberra, ACT).
- Norman-Lopez A, Pascoe S & Hobday A J (2011) 'Potential economic impacts of climate change on Australian fisheries and the need for adaptive management', *Climate Change Economics* 2: 209-235 DOI: 10.1142/S2010007811000279.
- Nursey-Bray M, Pecl G, Frusher S, Gardner C, Haward M, Hobday A J, Jennings S, Punt A, Revill H & van Putten I (2012) 'Communicating climate change: climate change risk perceptions and rock lobster fishers, Tasmania', *Marine Policy* 36: 753-759 DOI:10.1016/j.marpol.2011.10.015.
- O'Neill C, Green D & Lui W (2012) 'How to Make Climate Change Research Relevant for Indigenous Communities in Torres Strait, Australia', *Local Environment: The International Journal of Justice and Sustainability* 17(10): 1104-1120.

- Page L & Thorp V (2010) *Tasmanian Coastal Works Manual: A Best Practice Management Guide for Changing Coastlines* (DPIPWE: Hobart, Tasmania).
- Park S E, Marshall N A, Jakku E, Dowdd A M, Howden S M, Mendham E & Fleming A (2012) 'Informing adaptation responses to climate change through theories of transformation', *Global Environmental Change* 22: 115-126 DOI:10.1016/j.gloenvcha.2011.10.003.
- Pecl G T, Frusher S, Gardner C, Haward M, Hobday A J, Jennings S, Nursey-Bray M, Punt A, Revill H & van Putten I (2009) *The east coast Tasmanian rock lobster fishery – vulnerability to climate change impacts and adaptation response options*, report to the Department of Climate Change (DCC) (DCC: Australia).
- Pecl G T, Ward T, Doubleday Z, Clarke S, Day J, Dixon C, Frusher S, Gibbs P, Hobday A J, Hutchinson N, Jennings S, Jones K, Li X, Spooner D & Stoklosa R (2011) *Risk Assessment of Impacts of Climate Change for Key Marine Species in South Eastern Australia. . Part 1: Fisheries and Aquaculture Risk Assessment*, Fisheries Research and Development Corporation, Project 2009/070.
- Pecl G, Frusher S, Sauer W & Hobday A J (2010) 'Networking across Global Marine Hotspots', report from workshop in Sendai, Japan, in *Climate change effects on fish and fisheries* 18: 26-28.
- Petheram L, Zander K K, Campbell B M, High C & Stacey N (2010) "Strange changes": Indigenous perspectives of climate change and adaptation in NE Arnhem Land (Australia)', *Global Environmental Change* 20: 681-692.
- Phelan D, Bridle K, Parsons D, Ball P, Prior S, Brown C A & Mohammed C (2012b) *Impact of climate change on irrigated pastures – opportunities for dairy farmers*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8V27CL?open>.
- Phelan D, Parsons D, Bridle K, Prior S Brown C, Holz G & Mohammed C (2012a) *Impact of climate change on Meander Valley – opportunities for agricultural enterprises*, available from:
- Phelan D, Parsons D, Bridle K, Prior S, Brown C & Mohammed C (2012c) *Impact of climate change overview – opportunities for Tasmanian agriculture*, available from: <http://www.dpipwe.tas.gov.au/inter.nsf/Attachments/LBUN-8V277F?open>.
- Pitt & Sherry (n.d.) *ClimateAsyst@: Climate Susceptibility, Analysis & Communication tool*, available from: <http://www.pittsh.com.au/documents/climateasyst.pdf>.
- Pitt N R, Poloczanska E S & Hobday A J (2010) 'Climate-driven range changes in Tasmanian intertidal fauna', *Marine and Freshwater Research* 61: 963-970.
- Poloczanska E S, Booth T, Carter W, Dekeyser S, Roiko A, Wang X, Wong C & Martin T (2012b) *iClimate: Final Report to the National Climate Change Adaptation Research Facility*, (CSIRO: Australia).
- Poloczanska E S, Hobday A J, & Richardson A J (eds.) (2009) *Report Card of Marine Climate Change for Australia*, NCCARF Publication 05/09 ISBN 978-1-921609-03-9.
- Poloczanska E S, Hobday A J, & Richardson A J (eds.) (2012a) *Marine Climate Change in Australia, Impacts and Adaptation Responses*, 2012 Report Card ISBN 978-0-643-10927-8.
- Prince B (2007) 'How Should We Manage the Impact of Climate Change on Coastal Aboriginal Cultural Heritage in the Tasmanian Wilderness World Heritage Area?' [Conference abstract] *Sixth World Archaeological Congress*, Dublin, Ireland 29 June to 4 July 2008, available from: <http://www.ucd.ie/wac-6/>.

- Prober S M & Dunlop M (2011) 'Climate change: a cause for new biodiversity conservation objectives but let's not throw the baby out with the bathwater', *Ecological Management and Restoration* 12: 2-3.
- Prober S M, Hilbert D W, Ferrier S, Dunlop M & Gobbett D (2012) 'Combining community-level spatial modelling and expert knowledge to inform climate adaptation in temperate grassy eucalypt woodlands and related grasslands', *Biodiversity Conservation* 21:1627-1650.
- Productivity Commission (2012) *Barriers to Effective Climate Change Adaptation: Productivity Commission Inquiry Report No. 59*, Final Report released 14 March 2013 (Australian Government: Canberra, ACT), available from: <http://www.pc.gov.au/projects/inquiry/climate-change-adaptation/report>.
- Rao K, Lopoukhine N & Jones K (2008) *Tasmanian Wilderness (Australia) Report of the Reactive Monitoring Mission*, 15 to 20 March 2008 (UNESCO: Paris, France).
- Reser J P, Bradley G L, Glendon A I, Ellul M C & Callaghan R (2012) *Public Risk Perceptions, Understandings, and Responses to Climate Change and Natural Disasters in Australia, 2010 and 2011*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Ridgway K R (2007) 'Long-term trend and decadal variability of the southward penetration of the East Australian Current', *Geophysical Research Letters* 34: 1-5.
- Risbey J & O'Kane T (2011) 'Sources of knowledge and ignorance in climate research', *Climatic Change* 108(4): 755-773.
- Robson B J, Chester E T, Allen M, Beatty S, Close P, Cook B, Cummings C R, Davies P M, Lester R, Lymbery A, Matthews T G, Morgan D & Stock M (2013) *Novel methods for managing freshwater refuges against climate change in southern Australia*, report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Roemmich D, Gilson J, Davis R, Sutton P, Wijffels S & Riser S (2007) 'Decadal spin-up of the South Pacific subtropical gyre' *Journal of Physical Oceanography* 37(2): 162-173.
- Rudman T, Horton B M & Balmer J (2008) *Monitoring Dry Coastal Vegetation in the Tasmanian Wilderness World Heritage Area, Part 1 Monitoring Priorities*, Nature Conservation Report 2008/1 (Department of Primary Industries and Water: Hobart, Tasmania).
- SGS Economics & Planning (2012a) *Tasmanian Coastal Adaptation Pathways Project, Kingston Beach – Public Interim Report*, Tasmanian Coastal Climate Adaptation Pathways Project: January 2012 (SGS Economics & Planning, Melbourne, Victoria).
- SGS Economics & Planning (2012b) *Tasmanian Coastal Adaptation Pathways Project Documentation of Methodology* [Final Report] (Local Government Association of Tasmania: Hobart, Tasmania).
- SGS Economics & Planning and UNSW Water Research Laboratory (2009) *Climate Change Impacts on Clarence Coastal Areas*, report prepared for Clarence City Council [Final Report] (Clarence City Council: Hobart, Tasmania).
- Sharples C (2004) *Indicative Mapping of Tasmanian Coastal Vulnerability to Climate Change and Sea Level Rise: Explanatory Report*, Consultant Report to Department of Primary Industries & Water (DPIW: Hobart, Tasmania).

- Sharples C (2006) *Indicative Mapping of Tasmanian Coastal Vulnerability to Climate Change and Sea-Level Rise: Explanatory Report (Second Edition)*, Consultant Report to Department of Primary Industries & Water (DPIW: Hobart, Tasmania).
- Sharples C (2010) *Technical Report: Shoreline Change at Roches Beach, South-Eastern Tasmania 1957-2010* (ACE CRC: Hobart, Tasmania).
- Sharples C (2011) 'Potential climate change impacts on geodiversity in the Tasmanian Wilderness World Heritage Area: A management response position paper', *Nature Conservation Report Series 11/04* (DPIPWE: Hobart, Tasmania).
- Steffen W & Hughes L (2011) *The Critical Decade: Tasmanian Impacts and Opportunities* (The Climate Commission: Canberra, ACT), available from: http://climatecommission.gov.au/wp-content/uploads/Tasmanian-impacts-report_web.pdf.
- Stokes C J & Howden S M (eds.) (2010) *Preparing Australian agriculture, forestry and fisheries for the future* (CSIRO Publishing: Melbourne, Victoria).
- Stokes C J, Howden S M, Gifford R G, Meinke H, Bange M, McRae D, Roth G, Gaydon D, Beecher H G, Reinke R, Crimp S, Park S, Inman-Bamber G, Webb L, Barlow E W R., Hennessy K, Whetton P H, Booth T H, Kirschbaum M U F, Battaglia M, Stone G, Cobon D, Ash A, McKeon G, Miller C J, Jones R N, Hobday A J & Poloczanska E S, edited by Stokes C J & Howden S M (2008) *An Overview of Climate Change Adaptation in Australian Primary Industries – Impacts, Options and Priorities*, a report prepared for the National Climate Change Research Strategy for Primary Industries (CSIRO: Australia).
- Stone R C & Meinke H (2006) 'Weather, climate, and farmers: an overview', *Meteorological Applications* 13(Supplement S1): 7-20 DOI:10.1017/S1350482706002519. .
- Sullivan K (2008) 'Policy Implications of Future Increases in Extreme Weather Events due to Climate Change', *Australian Journal of Emergency Management* 23(4): 37-42.
- Tasmanian Government (2011) 'Tasmanian Government Submission: Barriers to Effective Climate Change Adaptation', a submission to the Productivity Commission's Inquiry into Barriers to Effective Climate Change Adaptation, December 2011, CA405923: 1-17.
- Thom B, Cane J, Cox R, Farrell C, Hayes P, Kay R, Kearns A, Low Choy D, McAneney J, McDonald J, Nolan M, Norman B, Nott J & Smith T (2010) *National Climate Change Adaptation Research Plan for Settlements and Infrastructure*, (National Climate Change Adaptation Research Facility: Gold Coast, Queensland).
- Thompson P A, Baird M E, Ingleton T & Doblin M A (2009) 'Long-term changes in temperate Australian coastal waters: implications for phytoplankton' *Marine Ecology Progress Series* 394: 1-19.
- Tilden J (2011) *How Vulnerable are Circular Head Coastal Habitats to Sea Level Rise?* (Cradle Coast NRM: Burnie, Tasmania).
- Turton S, Dickson T, Hadwen W, Jorgensen B, Pham T, Simmons D, Tremblay P & Wilson R (2010) 'Developing an Approach for Tourism Climate Change Assessment: Evidence from Four Contrasting Australian Case Studies', *Journal of Sustainable Tourism* 18(3): 429-447.
- Verdon-Kidd D (2012) *Bridging the gap between end user needs and science capability: dealing with uncertainty in future scenarios* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).

- Watson R A, Nowara G B, Tracey S R, Fulton E A, Bulman C M, Edgar G J, Barrett N S, Lyle J M, Frusher S D & Buxton C D (2012) 'Ecosystem model of Tasmanian waters explores impacts of climate-change induced changes in primary productivity', *Ecological Modelling* (in press) DOI.org/10.1016/j.ecolmodel.2012.05.008.
- Wayte S (2012) 'Management implications of including a climate-induced recruitment shift in the stock assessment for jackass morwong (*Nemadactylus macropterus*) in south-eastern Australia', *Fisheries Research* 142: 47-55 DOI.org/10.1016/j.fishres.2012.07.009.
- Wenger C, Hussey K & Pittock J (2012) *Living with floods: key lessons from Australia and abroad* [Draft], report for the National Climate Change Adaptation Research Facility (NCCARF: Gold Coast, Queensland).
- Werner A K, Goater S, Carver S, Robertson G, Allen G R & Weinstein P (2012) 'Environmental Drivers of Ross River Virus in South-Eastern Tasmania, Australia: Towards Strengthening Public Health Interventions', *Epidemiology and Infection* 140(2): 359-371.
- West J & Brereton D (2013) *Climate Change Adaptation in Industry & Business – Climate Change Adaptation: A Framework for Best Practice in Financial Risk Assessment, Governance and Disclosure*, Final Report (NCCARF: Gold Coast, Queensland).
- West J (2013) 'Obstacles to progress', *Griffith Review* 38, available from: <https://griffithreview.com/edition-39-tasmania-the-tipping-point/obstacles-to-progress>.
- White C J, Fox-Hughes P, Grose M R, Corney S, Bennett J C, Holz G K, Gaynor S & Bindoff N L (2010b) *Climate Futures for Tasmania, Discussion document: implications for fire danger in bushfire prone areas of Tasmania* (ACE CRC: Hobart, Tasmania).
- White C J, Grose M R, Corney S P, Bennett J C, Holz G K, Sanabria L A, McInnes K L, Cechet R P, Gaynor S M & Bindoff N L (2010a) *Climate Futures for Tasmania: extreme events technical report* (ACE CRC: Hobart, Tasmania).
- Whitehead J (2011) *Climate Change Mitigation - Natural Coastal Assets: Derwent Estuary Program Planning Tool Discussion Paper for Tidal Wetlands & Saltmarshes*, (Derwent Estuary Program: Hobart, Tasmania).
- Williams A L, Wills K E, Janes J K, Vanderschoor J K & Newton P C D (2007) 'Warming and free-air CO₂ enrichment alter demographics in four co-occurring grassland species', *New Phytologist* 176: 365-374.
- Wolf J, O'Neill N R, Rogers C A, Muilenberg M L & Ziska L H (2010) 'Elevated Atmospheric Carbon Dioxide Concentrations Amplify *Alternaria alternata* sporulation and total antigen Production', *Environmental Health Perspectives* 118(9): 1223-8 DOI:10.1289/ehp.0901867.
- Zeppel H (2011) 'Collaborative Governance for Low-Carbon Tourism: Climate Change Initiatives by Australian Tourism Agencies', *Current Issues in Tourism* 15(7): 603-626.

APPENDIX 1: STAKEHOLDER AND RESEARCHER REFERENCE GROUPS MEMBERSHIP

Researcher Reference Group

Associate Professor Leon Barmuta	School of Zoology, UTas
Associate Professor Erica Bell	Department of Rural Health, UTas
Associate Professor Stewart Frusher	Institute for Marine and Antarctic Studies, UTas
Associate Professor Neil Holbrook	Institute for Marine and Antarctic Studies, UTas NCCARF Marine Adaptation Network Convenor
Associate Professor Marcus Haward	School of Government, UTas
Associate Professor Mark Hovenden	School of Plant Science, UTas
Professor John Hunter	ACE-CRC, UTas
Dr Sarah Jennings	Head, School of Economics and Finance, UTas
Professor Ted Lefroy	Centre for Environment, UTas
Dr Michael Lockwood	School of Geography and Environmental Studies, UTas

Stakeholder Reference Group

Andrew Scanlon	Hydro-Tasmania
Melanie Brown	Local Government Association of Tasmania
Kathleen Broderick	NRM South
James McKee / Andrew Baldwin	NRM North
Roger Jaensch	Cradle Coast Authority
Derek LeMarchant	Northern Tasmanian Development
Katrina Graham	Southern Tasmanian Councils Authority
Luke Martin	Tourism Industry Council of Tasmania
Phil Bayley	Tasmanian Chamber of Commerce and Industry
Mary Massina	Property Council of Australia
Terry Long	Tasmanian Minerals Council
Brigid Morrison	Tasmanian Farmers and Graziers Association
David Sanderson	Wine Industry Association
Lucy Gregg	Fruit Growers Tasmania and Biosecurity Action Alliance
Neil Stump / Julian Harrington	Seafood Industry Council
Peter McGlone	Tasmanian Conservation Trust
Dr Sally Bryant	Tasmanian Land Conservancy
Kath McLean	Tasmanian Council of Social Services
Todd Houstain	Sustainable Living Tasmania
Heather Sculthorpe, Andry Sculthorpe & Sharnie Everett	Tasmanian Aboriginal Centre

Louise Gilfedder	Department of Primary Industries, Parks, Water and Environment
Caroline Brown	Department of Primary Industries, Parks, Water and Environment
Claire Jansen	Department of Premier and Cabinet

National Climate Change Adaptation Research Facility
Griffith University Gold Coast Campus
Parklands Drive, Southport
QLD 4222, Australia
Telephone 07 5552 9333
Facsimile 07 5552 7333
www.nccarf.edu.au



Australian Government
Department of Climate Change
and Energy Efficiency



Queensland
Government



USQ UNIVERSITY OF
SOUTHERN QUEENSLAND
fulfilling lives

