A marine climate change adaptation blueprint for coastal regional communities

Frusher, S., Marshall, N., Tull, M., Metcalf, S., and van Putten, E. I.
FRDC 2010/542

TRANSLATING**NATURE**INTO**KNOWLEDGE**

A marine climate change adaptation blueprint for coastal regional communities

Frusher, S., Marshall, N., Tull, M., Metcalf, S., and van Putten, E. I.

November 2013

FRDC Project No 2010/542

Australian Government
Fisheries Research and Development Corporation

ISBN 978-1-86295-733-6

A marine climate change adaptation blueprint for coastal regional communities
Project No 2010/542

2013

Ownership of Intellectual property rights

This publication (and any information sourced from it) should be attributed to Frusher, S., Marshall, N., Tull, M., Metcalf, S., and van Putten, E. I., University of Tasmania, 2013, *A marine climate change adaptation blueprint for coastal regional communities*. Hobart, November.

Creative Commons licence

Disclaimer

The Fisheries Research and Development Corporation plans, invests in and manages fisheries research and development throughout Australia. It is a statutory authority within the portfolio of the federal Minister for Agriculture, Fisheries and Forestry, jointly funded by the Australian Government and the fishing industry.

Researcher Contact Details

Name: Stewart Frusher
Address: Private Bag 49
Hobart Tas 7001
Phone: 03 6227 7277
Fax: 03 6227 8035
Email: Stewart.Frusher@utas.edu.au

FRDC Contact Details

Address: 25 Geils Court
Deakin ACT 2600
Phone: 02 6285 0400
Fax: 02 6285 0499
Email: frdc@frdc.com.au
Web: www.frdc.com.au

In submitting this report, the researcher has agreed to FRDC publishing this material in its edited form.

Contents

Acknowledgments

The project was jointly funded by the Fisheries Research and Development Corporation (FRDC project 2010/542) and DCCC. We thank all the survey participants in the communities of St Helens, Bowen, and Geraldton. The project worked in close collaboration with Jenny Shaw's project "Climate change adaptation - building community and industry knowledge (FRDC-DCCEE 2011/503)" and we thank Jenny for all her support and input.

The following researcher and managers provided input and support at various stages of the project: Steve Blake, Rae Burrows, Nick Caputi, Jeff Dambacher, Marcus Haward, Alistair Hobday, Neil Holbrook, Sarah Jennings, Gretta Pecl.

We were grateful for the help received from the Oceanwatch (Seanet) and thank Lowri Pryce and the extension staff, in particular Anita, Jay, Dave, and Cassandra.

Elsa Gärtner provided project support.

We would also like to thank the anonymous reviewers for the time given to review the scientific papers that were produced as part of this project.

Executive Summary

Aims/objectives

1. Develop and trial a "blueprint" using three marine community case studies in southeastern, western and northern Australia, that objectively integrates a suite of adaptation assessment and evaluation tools for the provision of best choice marine climate change adaptation options to these coastal communities.
2. Compare and synthesise potential adaptation options across case studies to develop
   a) an understanding of the context dependence of adaptation in marine communities, and
   b) a portfolio of generic adaptation options for sub-tropical to temperate coastal and regional marine communities in Australia.
3. Based on the outcomes of 1 and 2, determine the broad representativeness of the blueprint to address the needs and priorities of coastal rural communities throughout Australia.
4. Develop capacity for inter-disciplinary research by training and mentoring two early career researchers.

Summary

An innovative methodological approach to developing adaptation options was tested in three Australian case study communities in Tasmania, Queensland, and Western Australia. Qualitative models were used to determine the effect of current marine climate and non-climate pressures on the regional coastal community's marine sectors. Recognising the combined role of climate and non-climate change pressures in shaping marine sectors in small coastal communities is important to allow a holistic overview to be developed and thus avoid potential unintended adaptation consequences.

The information for the qualitative models was gathered by means of semi-structured interviews. The semi-structured interview approach is a good alternative to, for instance, workshops or focus groups in communities where it is difficult to engage stakeholders or where the issue of interest are controversial or of a perceived political nature. We used a boundary organisation (Oceanwatch) to engage community members in the research. This engagement process was particular successful where Oceanwatch officers were locally resident or embedded in the local community.

The adaptation options, generated using the qualitative modelling approach, were mostly location and industry specific but some were generally applicable across the different communities. Some adaptations were in response to positive marine climate change impacts. Such positive impact arose, for instance, from income and labour opportunities for charter and recreational fishing associated with new range shifting species. Community level adaptations to negative impacts of marine climate pressures, like reduced abundance of commercial species due to increasing sea temperatures and range shifting pest species, were mainly in terms of finding species alternatives, diversification into other sectors, and having high mobility and flexibility.

The community consultation process not only generated information for the qualitative models and resulting adaptation options but also provided insight into the community's knowledge of, and concern about, marine climate change. In general marine climate change knowledge is present as it is readily observed through new species being caught by recreational, charter and commercial fishers. Programs like REDMAP (www.redmap.org) have significantly helped raise awareness of, for instance, range shifting species.

Knowledge of marine climate change is also gained though locally observed changing species abundance. However, community respondents were often less clear about the link between abundance and marine

climate change as abundance changes were perceived to be at least equally likely driven by fisher behaviour or fishery management. So, even though the impacts of marine climate change were known and observed, it often gained limited recognition due to the multitude of non-climate pressures on the marine sector (often referred to as the attribution problem). The attribution problem may lead to a lack of interest or perceived need to undertake adaptation planning for climate change as it is felt by industry and community that priority should be given to addressing non-climate pressure as they were short-term and more easily managed (e.g. change in abundance managed through input/output controls). Because the negative marine climate impacts were not perceived to be directly linked to climate change while the positive impacts were already being adequately captured, there was a seeming reluctance to address adaptation to marine climate change *per se*. In other words, there may be a certain level of inertia to overcome with respect to convincing communities to undertake marine climate change adaptation planning.

Even though there was considerable knowledge with respect to locally observed climate related phenomena, there appeared to be a lack of knowledge and awareness of flow-on consequences and knock-on economic effects of marine climate pressures. In contrast to the lack of interest in marine climate planning for individual marine sectors, these cumulative knock-on effects were considered to be an important issue for regional coastal communities with relatively high reliance on the different marine sectors. Comparative community level vulnerability assessment and impact analysis based on projected marine climate pressures is an area of interest that is often not captured in adaptation research.

In this project a web-based blueprint (coastalclimateblueprint.org.au) is developed that takes into consideration these case study findings. Firstly the aim of the blueprint is to raise awareness of marine climate change and the potential flow on effects into regional coastal communities. The general and locally specific information on marine climate adaptation as derived from the case studies will be useful in the web-based blueprint for illustrative purposes. Secondly, the blueprint provides a conduit for communities to undertake more detailed adaptation planning based on the knowledge and information garnered through the web-based blueprint. Using a Sustainable Livelihoods Analysis, an interactive assessment of community vulnerability to climate change allows community members or local governments to assess where their strengths and vulnerabilities may lie. For example, one community may have very high education levels and financial capital but be lacking in the necessary coastal infrastructure to allow commercial fisheries and aquaculture development. This interactive assessment provides each community with a first-step indication of where specifically adaptation may be needed to ensure they remain sustainable into the future.

Outcomes achieved to date

Regional coastal community residents and individuals associated with different marine sectors around Australia are intimate observers of local marine climate change phenomena. Even though often the impacts of marine climate change are already being felt, they are sometimes not given due recognition as a consequence of the multitude of non-climate pressures also impacting these marine sectors. Moreover, the cumulative flow on consequences and knock-on economic effects of marine climate pressures are rarely known or recognised.

The priority issue that needs to be addressed to encourage marine climate adaptation in regional coastal communities is not the lack of tools to plan for adaptation. There are currently many toolboxes and wizards freely available on the internet that detail planning- and risk assessment processes for developing climate adaptation plans. Rather, there is a need to make clearly worded and locally relevant marine climate change facts and data available and readily accessible. This type of information can provide a conduit for communities to determine relevant economic and social vulnerability factors, assess marine climate change knock-on effects and thus encourage them to prepare more detailed adaptation plans for their regional coastal communities. From understanding the background, context, community links, and potential community level implications it is more likely communities will be self-motivated and prepare a marine climate adaptation plan that, beside the common elements like sea level rise, also includes the issue of the impact on the marine environment *per se*.

A web-based blueprint, where much of the scientific information is not simply collated but communicated to create interest for non-science users, has been developed (coastalclimateblueprint.org.au). Enhancing the communication values of marine climate information, and the opportunity to update the information as it becomes available is intended to improve general acceptance of the potential impact of marine climate change. Aside from effective communication of marine climate information, the web-based blueprint also allows users to carry out a simple and high level vulnerability assessment and prepare their own simple adaptation plan online. The information provision and vulnerability assessment will require 'minimal user effort' but will, nevertheless, be informative and is primarily aimed at illustrating the value of adaptation planning and encouraging users to undertake more detailed adaptation planning in the future.

Aside from information included in the web-based blueprint, the case studies undertaken as part of this project provided much information on the community's marine climate observations and knowledge. The community consultation process contributed to scientific knowledge and testing of methodological applications. There are several scientific papers in review and development. The papers focus on different aspects of using qualitative information from community interviews in modelling community level climate and non-climate interactions and developing adaptations from this type of information. This project has contributed to scientific knowledge and helped illustrate the value of qualitative modelling in developing adaptation plans.

In summary, the project has had three clear outcomes: an insight into the community level understanding of marine climate change; a web-based blueprint communicating marine climate knowledge and information and also providing an opportunity for community level vulnerability assessments; and lastly, an increased understanding of the usefulness of qualitative approaches to modelling marine climate impacts at a community level.

Keywords

Coastal communities, climate change adaptation, marine sectors, qualitative modelling, web-based adaptation blueprint.

Introduction

Background

Changes in marine environments that are related to climate change have been occurring in many areas around the world (IPCC 2007; Smith et al. 1999; Burrows et al. 2011; Lough and Hobday 2011). Some areas have been identified as climate change hotspots, including regions around Australia, particularly in the southeast (Hobday and Pecl in review). Even though there are significant uncertainties associated with the timing, location and magnitude of future climate change (Hobday 2010), biological impacts from climate-driven change will include changes in marine species abundance (Simpson et al. 2011), distribution (Perry et al. 2005; Nye et al. 2009; Last et al. 2011), physiology (Somero 2010; Neuheimer et al. 2011) and phenology (Dufour et al. 2010). Changes will likely affect future fisheries catches and profitability (Hobday et al. 2008; Grafton 2010; Cheung et al. 2009), and challenge sustainability and food security (Rice and Garcia 2011). Climate change threatens to push some marine systems beyond their historical ranges of variability and uncertainty, creating a complex and unpredictable mix of challenges (Perry et al. 2005; Perry et al. 2011).

The ability of fishers, managers and marine resource-dependent communities to adapt to climate-induced change is the subject of much discussion and research (Berkes and Jolly 2001; Tompkins and Adger 2004; Hobday and Poloczansk 2010). In particular, small fishing communities with a heavy reliance on the marine environment are expected to be affected by climate-driven changes. Although not all fishing communities are the same, there are some general economic, social, cultural, and geographic characteristics that could make them particularly vulnerable (Clay and Olson 2007). At the economic level there are frequently multiple household- and family-level ties to fishing (Binkley 2000; Davis and Gerrard 2000; Badjeck et al. 2010). Communities that are heavily reliant on marine resources often have visible on-land and at-sea networks and infrastructure connections (i.e., boats, gear, fishing-related businesses) (Jacob et al. 2005; Olson and Clay 2001). Often the cultural connection to fishing and fishing communities persists despite continual changes from, for instance, commercial to recreational fishing and fishing-related tourism (Clay and Olson 2007). It is against this background, of a changing marine environment, fishing sector, and fishing community, that fisher and community adaptation to changes in the marine environment will, and are, taking place.

Different coastal communities are likely to be affected by different climate-driven processes. The magnitude of these processes may also vary. Some changes may not be substantial enough to induce adaptation or mitigation behaviour. However, overall it may be expected that households, firms, organisations, and governments must respond and adapt to the impacts of climate change as some climate-driven change cannot be avoided through mitigation efforts (Productivity Commission 2012). To plan for these inevitable adaptation requirements many adaptation plans are currently being developed at different scales. This may raise coordination problems between the plans of different agencies with overlapping scales as well as potential issues with path dependency (Liebowitz and Margolis 1995) that must be considered for the final implementation and communication of adaptation strategies. For instance, plans are developed at individual business and planning agency scale, as well as local, state and federal government levels. Yet, there is currently no generic framework that provides guidance as to the methods of data collection that may be used, or the skills and information necessary to successfully develop a climate adaptation plan. A generic tool will be of great benefit to small- to medium-sized coastal communities which have generally low resource and funding opportunities, but are nevertheless likely to be disproportionately impacted.

Needs

Meeting the challenge of preparing and adapting for climate change is arguably the most important task confronting the management of our national marine resources. Climate change is expected to result in significant impacts for marine ecosystems with flow on social and economic implications for resource users and communities. Importantly, regional coastal communities have high dependency on marine industries that provide social and economic benefits through fishing, aquaculture and tourism (e.g. recreational fishing and diving).

In the course of our study it became apparent that many communities do not appreciate the potential impact of marine climate pressures on their marine sector. This lack of appreciation is partly due to the opaqueness of the connectedness of the marine sector to other economic activities in the community and ultimately in its continued functioning. This was particularly important for small size communities in those Australian States with fewer alternative employment opportunities. An appreciation of the importance of the role of the marine sector (even though some areas like commercial fishing are currently in decline) could potentially increase awareness of marine climate pressures and the need to develop plans for adaptation. Raising awareness of relevant issues has thus become central to this project and is an important driver for the development of a web-based blueprint (coastalclimateblueprint.org.au).

At the time this project was developed it was obvious that the success of adaptation decisions in terms of meeting objectives, capturing opportunities and overcoming barriers, being cost effective and minimising negative flow on effects will be influenced by the level of understanding of the needs, priorities, perceptions and attitudes of stakeholders including knowledge of the social and economic consequences of adaptation options. Without such information, our ability to make timely and effective adaptation decisions will be limited. Developing the tools that provide the relevant information to reduce risks and increase capacity to cope with and benefit from change is urgently needed for these coastal communities. These tools need to cross discipline boundaries and provide linkages between the vulnerabilities of the biological system with the adaptive capacity and vulnerabilities of the human system.

An inter-disciplinary research approach that engaged stakeholders in the process of developing a suite of strategically targeted marine adaptations was implemented in this research. Even though this approach worked well, as is evident from the scientific papers that are in review and in preparation, it was obvious to the researchers that this scientific approach would not be the preferred path for all communities who are planning for adaptation to marine climate change. In fact, the scientific nature of the approach which requires a certain level of knowledge, may be perceived as too resource demanding or complex and be a disincentive for communities to develop the plan. This prompted the researchers to develop an adaptation blueprint that is a conduit to potentially more detailed and locally specific adaptation planning but initially is of use to marine stakeholders nationally by virtue of its simple nature.

The blueprint is web-based and will be a conduit that facilitates awareness and learning by regional coastal communities to marine climate change. The web-based blueprint provides information that allows regional coastal communities to develop adaptation plan containing different levels of detail. Regardless of the level of detail of the blueprint, all communities will be better able to make informed decisions based on a range of climate change adaptation options designed to minimise impacts and maximise opportunities.

Objectives

Number	Objective	Achieved	Narrative
1	Develop and trial a "blueprint" using three marine community case studies in southeastern, western and northern Australia, that objectively integrates a suite of adaptation assessment and evaluation tools for the provision of best choice marine climate change adaptation options to these coastal communities.	✓ (several papers planned and in preparation)	Adaption options were developed for case study communities using different evaluation tools. This is the subject of a scientific paper in review and in preparation.
2	Compare and synthesise potential adaptation options across case studies to develop	✓	Adaptation options were compared across case-studies and details are provided in the results section of this report
2a	an understanding of the context dependence of adaptation in marine communities, and	✓	The case study community context was the subject of a separate scientific paper and is discussed in this report
2b	a portfolio of generic adaptation options for sub-tropical to temperate coastal and regional marine communities in Australia.	✓	Some general adaptation options were identified on the basis of surveys carried out in the case study communities.
3	Based on the outcomes of 1 and 2, determine the broad representativeness of the blueprint to address the needs and priorities of coastal rural communities throughout Australia.	✓ (coastalclimateblueprint.org.au)	A web-based blueprint has been developed which will address the needs of regional coastal communities, raising awareness of marine climate change and also providing an opportunity for a first pass adaptation assessment
4	Develop capacity for inter-disciplinary research by training and mentoring two early career researchers.	✓	The two post-doctoral researchers have benefited from the opportunity to undertake this interdisciplinary research and have gained skills reflecting this.

Method

In this study a blueprint for regional coastal communities to marine climate change adaptation was developed. We used two different primary data collection methods to underpin the development of the blueprint. The two data collection methods were (i) an expert group workshop and (ii) semi-structured surveys in three case study locations. The blueprint also used secondary data based on a literature review. We first discuss the method used for the primary data collected at the workshop and the case studies. We then discuss how the primary data was used to develop the marine climate change adaptation blueprint (iii) and we discuss the steps in the blueprint.

(i) Workshop

A workshop was held in Hobart on the 8th and 9th of February 2012 attended by a group of 15 experts who are collaborators on this FRDC project. The aim of the workshop was to develop a preliminary and generic 'expert model' of the impact of marine climate change on marine sectors in coastal communities. The generic qualitative model of coastal impacts and adaptation was undertaken using a prioritisation technique (see ACERA (2010) for more information on the prioritisation method used at the workshop). The data collected as part of the expert group workshop is reported in the results.

The reason we developed a qualitative model at the expert workshop was because qualitative models depict cause-and-effect relationships amongst the most important variables in complex socio-ecological systems and can assess feedback and system stability (e.g. Dambacher et al. 2002; Dambacher and Ramos-Jiliberto 2007). Links between the system drivers can be based on verbal connections made by participants in a workshop but also by respondents in semi-structured interviews (see **Appendix 1**). Both workshops and semi-structured interviews can involve stakeholders who are increasingly involved in the complex system modelling processes to provide information regarding the integration of the different domains and also on potential adaptations. By facilitating stakeholder involvement in applied management problems, pre- and post-modelling results can be more easily communicated (van der Sluijs et al. 2003). In our study the results of the expert workshop informed the development of the questions for the semi-structured community interviews. The workshop and semi-structured interviews were used to develop the qualitative models of the impact of marine climate change, the first being a generic model, the second being case study specific respectively.

(ii) Case study survey

As part of the case studies component of this project key marine sector individuals were surveyed in three coastal communities (St Helens in Tasmania, Bowen in Queensland, and Geraldton in Western Australia) to establish community views of connections and feedback between climate change and marine activities in their community. Interviews sought community views on observed changes to date and how they have influenced the connections and feedback systems. Views were also collected on community understanding of the effect of predicted changes on the connections and feedback systems (see Appendix 3 for semi-structured interview questions).

The reason for applying a semi-structured survey approach was to investigate all change deemed relevant to individual respondents and avoided potential anchoring to climatic change issues. This was important in order to maximise participation by avoiding adverse reactions to participation in a study focussing solely on climate change, as climate change has become a very politically charged issue (Nursey-Bray et al. 2012). Applying this survey technique also avoided ‘tactical’ survey responses. For instance, fishers may be reluctant to link climate change to resource abundance, fearing the government may use this as an argument to reduce their individual quota allocation.

As mentioned above, the data collected in all three case study communities was through semi-structured interviews of community members and industry informants during 2012 (**Table 1**). Industry informants in this context are people who are networked and have privileged access to information about specific impacts, groups of persons or decision processes. Regional Oceanwatch (SeaNet) extension staff with existing contacts to the marine industries was used to facilitate contact with key community participants. A small number of individuals were attracted through snowball sampling (Goodman 1961) where a community survey respondent recommended another person of interest who was then approached.

Table 1: Timing of the survey process in each community, the number of surveys carried out and sectoral representation in the survey sample.

Case study particulars	***St Helens***	***Bowen***	***Geraldton***
Interview timing	February 2012	June 2012	September 2012
Surveys conducted	**35**	**23**	**25**
Fishing (all commercial)	✓	✓	✓
Tourism (dive)	✓	✓	-
Tourism charter	✓	✓ (past operator)	-
Recreational fishing	✓	✓	✓
Tackle (fishing related)	✓	✓	✓
Retail	✓	✓	✓
Real estate	✓	✓	-
Caravan parks	✓	✓	-
MAST (pilot)	✓	✓	✓
Accommodation	✓	✓	✓
Restaurants	✓	✓	✓
Aquaculture	✓	✓	✓
Education	✓	-	✓
Council	✓	-	✓
Processors	✓	✓	✓

It was considered appropriate to select experts as it was not feasible to survey large samples of the population (Ruhanen and Shakeela 2012). The majority of experts in our survey included individuals employed in fishing, aquaculture, charter fishing or dive sectors, or people who had connections to the marine industry. The indirect impacts of change in the marine environment on the community were assessed through interviews from a broader range of individuals including those working in restaurants, newsagencies, accommodation and general retail.

The survey was pre-tested with two local participants in the first case study area (St Helens) and minor changes were made to the survey questions. After completion of the first case study a review of the survey was undertaken resulting in minor adjustments being made to the survey prior to commencing surveys in the other 2 case study communities. A media release, a radio interview and an information sheet were available approximately one week prior to the survey to communicate the aim and focus of the study and garner interest in the community (see **Appendix 4** for a conference poster and other media releases).[1] The interviews were between 1 and 2 hours, as dictated by the participant, and was taped with the permission of each individual. The surveys were held in the participant's location of choice.

(iii) Blueprint

The development of the blueprint and determination of the steps in the blueprint is based on two parallel processes; the first is the interpretation and evaluation of the information collected as part of the expert workshop (i) and the community interviews (ii). The second is an extensive literature review and web-based search undertaken to supplement the empirically gathered information. The web-based search was focussed on existing adaptation support tools (see section in **references** for web-based toolkits). A review of the social aspects of community adaptation was also undertaken to inform the development of the blueprint (**Appendix 5 - Paper 1**).

[1] As the poster presented at the conference was early in the project, the steps have evolved from the original 9 steps and improved in 'logic'.

The blueprint is aimed at providing best choice marine climate change adaptation options. Due to the abundance of climate change adaptation toolkits already available (see **References**) it was perceived most useful to focus this project's efforts on providing a conduit for people to commence their marine climate change adaptation process by communicating simple summarised state based marine climate information. The blueprint is in essence a series of steps that will guide a user through all the aspects necessary to develop a marine climate change adaptation plan and the information necessary to base the plan on best available knowledge.

As the word blueprint suggests, all the information and methods the user needs to develop an adaptation plan are outlined in the 10 steps of the blueprint. The 10 steps that are required to develop a comprehensive, all-encompassing marine adaptation plan are based on established planning logic. Even though there are many ways to undertake a planning process (NOAA Office of Ocean and Coastal Resource Management 2010) the chosen 10 step process is flexible and allows for different resource input mixes to develop the plan and consequently different levels of detail in the final plan. The 10 step blueprint for marine climate change adaptation is shown in **Table 2** (shown schematically in the results section of this report). For each of the 10 steps of the blueprint an action item is listed and a stage identified.

Table 2: Ten steps, actions, items, and 8 stages involved in developing a blueprint for adaptation to climate change in the marine environment in regional coastal communities.

Step	***Action***	***Item***	***Stage***
1	Prepare	Resources & engagement method	Pre-planning
2	Characterise	Coastal regional community	Planning
3	Identify	Climate change pressures on marine sectors	Consultation
4	Identify	Non-climate pressures on marine sectors	Consultation
5	Identify	Pre-conditions for adaptation (resilience & adaptive capacity)	Consolidation
6	Develop	Climate change scenario	Evaluation & Scenarios
7	Assess	Potential adaptation strategies	Evaluation & Scenarios
8	Learn from	Examples and case studies	Comparison & learning
9	Develop	Regional coastal community marine adaptation plan	Finalising adaptation plan
10	Learn from	Refine and monitor	Refine & monitor

These steps are not dissimilar to the common steps in a risk-based assessment which are (Eyre et al. 2011):

- Establish the risk context
- Identify and describe the risk
- Analyse the risk
- Evaluate the risk
- Decide on the treatment.

As alluded to above, it was recognised in this project that not all regional communities have either the resources or the impetus to develop a plan with a high level of detail. This led to the development of a blueprint that follows the logic of the 10 steps but extracts the most essential information and simplifies this to allow all level of users to develop a plan of which some will be at a less detailed level. For this purpose relevant marine, climate, community, and case study information was condensed, reduced, and simplified (colloquially called the KISS approach) and a web-based blueprint was developed to allow first level entry to the adaption plan development process. The *web-based blueprint* (coastalclimateblueprint.org.au) provides succinct and simple climate change, marine, sector, and adaptation information to stakeholders and end-users. An important value of communicating simple marine, climate and community information by means of the web-based blueprint is that it will likely raise community awareness of marine climate change.

The web-based blueprint is an entry point for those wishing to carry out a first pass adaptation plan and also those who seek further detail about climate change in the marine environment. It is able to provide all users with a general adaptation assessment for their community and outlines the avenues for building on that general assessment through additional information gathering or community consultation. Depending on resources, time and skill, the users can expand the basic web-based blueprint and include different levels of detail and complexity. In total there are four different levels of adaptation blueprint that can be developed –

all starting with the web based tool. Level 1 is for users who have little time, have minimal community interaction, and no data gathering. Level 2 users – will be able to undertake some data gathering (which is entered into pre-prepared excel spreadsheets) to provide more detail and thus a deeper understanding of adaptation options. Level 3 and 4 require some level of community consultation and/or eternal contracting for a qualitative modelling component.

1 Resources & engagement method - *Pre-planning (stage A)*

The first step in the blueprint is the pre-planning stage, which is a common component of any process that leads to the preparation of a plan - in this case a marine climate change adaptation plan (NOAA Office of Ocean and Coastal Resource Management 2010). When undertaking an adaptation plan, there is a need to first identify goals and boundaries of the assessment, which takes place in the pre-planning stage (Schirmer and Casey 2005). In addition, part of the pre-planning process is to scope out the level of effort that will be put into generating the plan. In the pre-planning stage the people who will be responsible for carrying out the planning process will also need to be identified. The amount of effort often directly relates to resource availability (NOAA Office of Ocean and Coastal Resource Management 2010). In turn, resource availability is likely to determine the level of consultation in generating the plan, and also if primary and/or secondary data will be used. In situations where community consultation is planned there are many methods that can be applied, but the reason for the interaction, i.e. to obtain information, to establish community engagement, to promote community adaptation, will generally dictate the most appropriate avenue of interaction.

2 Coastal regional community - *Planning (stage B)*

The aim of step 2 is to collect and collate data to gain an understanding of the socio-economic characteristics (profile) of the coastal regional community for which the adaptation plan is being developed. Gaining a better understanding of the community's socio-economic characteristics will help inform the community's capacity to adapt. Empirical evidence suggests that adaptation is highly context-specific (Wolf 2011; Risbey et al. 1999) and therefore community characteristics, including demographics, and social and economic structures, must be understood. Moreover, it is essential in any planning process to understand the current situation before the effects of change can be understood and future actions can be planned.

We use a series of social and economic variables (indicators) to generate a community profile. The socio-economic variables that characterise regional coastal communities are often also indicators of sensitivity to marine climate change and adaptive capacity which in turn explains vulnerability (**see step 5 in Results**). The general socio-economic information collected in step 2 is thus used in step 5 to determine regional coastal community vulnerability to marine climate change (see also Huddlestone 2006). The inclusion of indicators was based on a survey of the literature and expert opinion inherent in the project team (see **Appendix 9** for a list of indicators).

Level 1 users of the web-based blueprint can 'estimate' the indicators for their communities based on information provided to them about State and National averages. For level 2, 3 and 4 users of the web-based blueprint an excel spreadsheet was developed that allows users to enter their specific community based 2006 and 2011 Census data (freely available at http://www.abs.gov.au/Census), thus providing a greater level of detail and accuracy. On entering the data in the excel spreadsheet, a number of social and economic indicators are automatically generated. The indicators are used in a vulnerability assessment (VA) and a sustainable livelihood analysis (SLA) (**see step 5 in Methods**).

3 Climate change pressures on marine sectors - *Consultation (stage C)*

While step 2 provides an understanding of community social and economic characteristics that ultimately affect adaptation (Wolf 2011; Wolf et al. 2009), in step 3 the climate change pressures on the marine environment that the community must adapt to are identified (e.g. Pecl et al. 2011; Hobday and Pecl in review). Effective adaptation strategies should be informed by a deeper understanding of the physical and ecological process relevant to adaptation. In step 3 the links are made between the marine climate change pressures, the marine environment, pressures on key species (from Pecl et al 2011 and FRDC project 2010-535 and FRDC project 2010-565), and the marine sectors. In addition to the pressures exerted on the marine sector, the flow-on effects on the regional coastal community are also considered (see **Appendix 6 – Paper 2**). In essence this step is analogous to what many other adaptation toolkits frame as understanding the risks (Australian Greenhouse Office 2006).

The web-based adaptation blueprint summarises the information on climate change pressures obtained from the science literature supplemented with the case study community consultation information. Scientific information from government websites (e.g., Bureau of Meteorology, CSIRO) with information on different climatic factors and scientific fact sheets (or similar) are summarised as well as referenced in the web-based blueprint (http://coastalclimateblueprint.org.au). The web-based blueprint provides and entry point for all level users to gain a basic understanding of the main marine climate change pressures and impacts, and also provides hyperlinks to additional and more detailed information.

In addition to information available on the web-based adaptation blueprint, locally specific marine climate change information can be gathered in step 3 through community consultation (the consultation phase for level 3 and 4 users). Where the public is consulted as part of the adaptation plan development, local community information can enrich adaptation strategies with locally specific information and thus increasing acceptance and effectiveness of the plan. The process of community consultation and information gathering can also serve a dual purpose, that is, community 'engagement'. There are several benefits associated with consulting the community and not relying exclusive on existing information. A number of studies demonstrate the relevance and validity of using local non-scientific knowledge in climate change studies (Orlove et al. 2000; Riedlinger and Berkes 2001; Berman and Kofinas 2004). Especially where data are limited, detailed observations of change as reported by local residents (related to specifics of timing, frequency, severity, etc.) can be of significant value in a formal scientific context (Martin et al. 2010). Kuruppu and Liverman (2011) found that changes in temperature and rainfall observed by local residents were consistent with historical trends. Many have been critical of the integration of local knowledge as decontextualised data within a scientific framework (Cruikshank 2001; Berkes 2002), and discussions remain over whether, and how, to overcome differences in epistemology as well as methodological, institutional and political challenges (Adger et al. 2009). However, a community member's sense of contribution to, and involvement in, climate science can provide increased cognitive understanding and thus enable adaptation decisions.

Consulting a wide variety of community members, including those working in marine industries but also more broadly within the community (e.g., local retailers, accommodation managers, restaurant managers, local councillors), is important to ensure a broad cross-section of opinions on impacts and relationships between the marine environment and the rest of the community is obtained. In particular, the importance of the institutional contexts of adaptation has also been demonstrated to be important in shaping adaptive responses (Adger 2000; McBeath 2003; Næss et al. 2005; Offermans et al. 2011). The sum of evidence underscores that unless institutional and decision structures are deliberately included in efforts to adapt, and the values that form the basis of decisions are made explicit, the barriers arising from governance mechanisms are unlikely to be addressed. For this reason, engaging resource managers in issues of climate change is necessary but insufficient to assess underlying vulnerabilities and prepare for impacts (Moser and Luers 2008; Moser and Tribbia 2008; Tribbia and Moser 2008).

4 Non-climate pressures on marine sectors - *Consultation (stage C)*

Aside from the marine climate pressures there are other pressures on the marine environment and marine sector. Climate change risks almost always interact with other risks faced by communities or organisations (Eyre et al. 2011). Often these other pressures loom larger in people's minds as they more directly impact on "todays" activities and adaptation to these non-climate pressures are part of daily operations. It is important to also explore these non-climate change pressures to contextualise the possibly compounding climate change effects. After all changes in climatic conditions and events are only one element in an often complex set of interactions (McLeman et al. 2011). Accordingly, climate impacts on the marine environment and marine industries may not be the most significant source of change in some communities and may operate on longer time-scales. As a result, if adaptation strategies are implemented for climate-related issues alone, they may not be effective. For instance, a decline in employment in the commercial rock lobster (*Jasus edwardsii*) fishing industry in St. Helens was suggested to have occurred due to an increased number of barrens cause by long-spined sea urchin (*Centrostephanus rodgersii*) grazing and a resultant reduction in preferred rock lobster habitat. However, there has also been a decline in the number of rock lobster boats in St. Helens for financial reasons and the availability of alternative employment opportunities. In addition, it is sometimes not possible to separate climate-related risks from the broader range of environmental stressors or socioeconomic changes to which adaptation is also required (Milne et al. 2008). The relative importance of these factors therefore needs to be assessed in parallel in the development of adaptation strategies (See **Appendix 7 – Paper 3**).

We consider the human domain alongside the biophysical using a whole of system approach, as adaptation to climate change does not occur in a vacuum but “ …rather in the context of ongoing economic, political, social and technological change” (Productivity Commission 2012, p. 51). Through analysing the reported changes in a whole of system context we gain an understanding of sectoral drivers of change and also drivers of participation and growth in the different marine sectoral activities.

Interviewing a wide range of community members as well as the use of expert opinion may help to clarify which stressors are present and their relative importance or impact, which is why step 4 is also part of the consultation phase.[2] For example, to understand the sectoral relevance of non-climate change pressures, we obtained ‘top of the mind’ responses in relation to observed changes in the three case study community. As mentioned above, our approach was aimed at avoiding respondents anchoring their answers to climatic change.

5 Pre-conditions for adaptation (resilience & adaptive capacity) - *Consolidation (stage D)*

In step 5 the information from the previous steps is combined to provide an overview, which we called the consolidation phase. This combined information provides the basis for a vulnerability assessment and Sustainable Livelihood Analysis for regional coastal communities. At the conceptual level, a resilient community is one that has the capacity and resourcefulness to effectively adapt. Resilient communities will take deliberate action to reduce risks with the goal of avoiding impacts and accelerating recovery (US Indian Ocean Tsunami Warning System Program 2007).

By providing knowledge of the relative vulnerability of different components of the socio-economic system, vulnerability assessments can enable decision-makers to prioritise their efforts and provide a basis for early engagement with community members. Adaptive capacity influences vulnerability to climate change effects and hazards (Adger 2006; Adger et al. 2005). There are two vulnerability concepts and they occur within the ecological (ecological vulnerability *EV*) and the social- and economic spheres (**Figure 1**). The potential impact of the ecological vulnerability is mediated through resource dependence (*RD*)

[2] Level 1 and 2 web based blueprint users may not be able to obtain information for Step 4 as they are not consulting with the community.

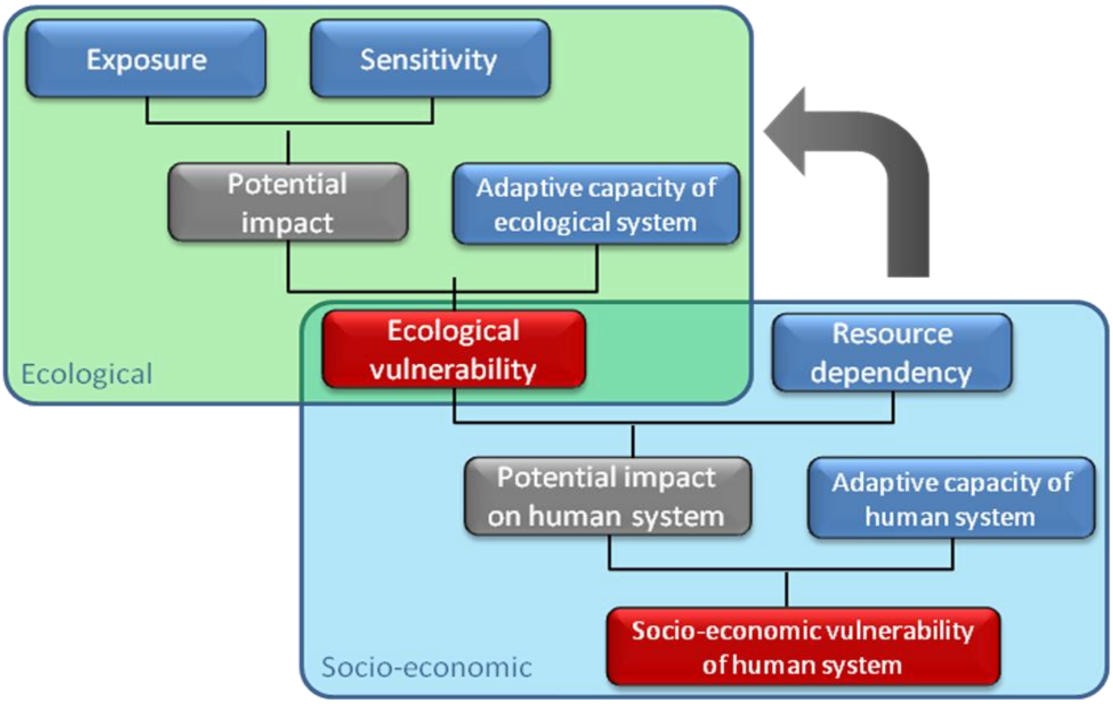


Figure 1. Vulnerability delineated by ecological and socio-economic system (adapted from Marshall et al. (2013).

A simple score for both the potential impact (of marine climate change) on the human system (*HPI*) and the socio-economic vulnerability of human system (*HV*) can be calculated for each community.

$$HPI = sum(EV) * sum(RD)$$

$$HV = HPI * sum(HAC)$$

$$HAC = sum(human + financial + social + physical)$$

Human adaptive capacity (*HAC*) is the sum of the adaptive capacity in the human, financial, social and physical domain. Potential impact (*HPI*) and vulnerability (*HV*) in the human domain is low if HAC =1; there is some impact and vulnerability if HAC >0.50 and <0.99, high impact and vulnerability if HAC <0.50)

Understanding the vulnerability of a coastal community will need to include the scale of the individual and community as well as an understanding of the vulnerability at the ecological sphere. Previous work has identified some important factors that can describe the sensitivity of individuals to changes in coastal resources. The premise for these factors is based on understanding how (and to what extent) people are dependent on the natural resources. For example, people are dependent on natural resources for economic purposes such as income and livelihood, and for a range of social and cultural purposes such as identity, lifestyle, family, networks, place attachment and meaning (Marshall et al. 2011). The more dependent people are on coastal resources, the more sensitive to change they are likely to be.

Previous work has also identified how potential impacts resulting from climate sensitivity might be moderated through adaptive capacity to fully understand the nature and magnitude of vulnerability. Adaptive capacity has been described at the individual level as comprising four essential elements i) the management of risk and uncertainty, ii) skills for planning, experimenting, reorganising, learning, iii) financial and psychological flexibility, and iv) an interest in adapting to change (Marshall et al. 2007; Marshall 2010). We assume that when adaptive capacity is high, resilience will be high and when sensitivity is high, resilience will be low.
There are many indicators that apply in the social domain that have been found to be important in the context of climate change. For instance, social capital offers another way of understanding the role of fundamental social attributes that contribute to the response and adaptation to climate change (Pelling and High 2005). Social capital offers a lens through which the role of social networks and norms in the production of adaptive capacity is studied (Pelling undated). Social capital is not only related to social

networks, it is a dynamic concept and is sensitive to changes in many observable community characteristics. For instance, social capital is a function of the demographic conditions of the community, especially in terms of age structure and cultural makeup.

Adaptive capacity is strongly influenced by social capital and social networks. Pelling (2003) distinguishes between informal and formalised social capital. The former can be found in neighbourliness, friendship or kin group support, and the latter in officially recognised civic associations. Informal social capital networks are particularly valuable in enabling critical thinking and alternative actions to be taken in the face of unexpected shocks. The position of individuals in social networks and institutions informs and influences adaptation behaviours (Crane et al. 2011). There are multiple pressures that lead to changes in the quality and quantity of formal and informal networks, and so to the building up or breaking down of access to external resources or capacity to mobilise internal community resources for adaptation. Adaptive capacity is continually being reshaped through the dynamics of social relationships. Where social capital is attuned to the imperative of adaptation it can offer a resource for reflexive adaptation.

The effects of social networks do not always contribute to positive outcomes with respect to adaptation. Investigating water use in Australia, Miller and Buys (2008) found that different aspects of social capital can have different implications, with some aspects having negative consequences on the community as a whole. Strong bonding ties can contribute to the vulnerability of a population rather than reducing it, as suggested by a recent study of elderly people’s responses to heat wave risk in the United Kingdom (Wolf et al. 2010).

We also use the Sustainable Livelihoods Approach (SLA), developed to help understand and analyse the livelihoods of the poor in order to improve the effectiveness of livelihoods-related development assistance (Carney 2002), to aid in understanding regional coastal community adaptation. The SLA is built on six core principles: it is people centred, holistic, dynamic, builds on strengths, considers macro and micro linkages and is based on sustainability (New Zealand's International Aid and Development Agency 2007). The SLA combines a conceptual framework with a set of operational principles to provide guidance on, for instance, policy formulation, development, and adaptive capacity building. The SLA has been widely used in coastal and fisheries development research and has informed the design of development programmes (Allison and Ellis 2001; Allison 2005; Allison and Horemans 2006). The SLA is just one tool for livelihoods analysis, and a wide range of other methods exits. It is important to acknowledge that the assessment of the five capital groups (**Table 3**) and the links between them will render a static picture of present sectoral activity. In the context of climate change adaptation in coastal communities it is important to investigate how the five capitals can be activated and operationalised for adaptation purposes. Determining how detailed and complete the SLA is for each of the communities will depend on resource availability and consultation effort.

Table 3. Definitions and descriptions for five capital assets (adapted from Moser 2007 from Spearman et al 2011)

Capital	***Description***
Natural	Natural capital refers to marine resources and their biodiversity (including, for instance, wetlands, mangroves, sea, lakes and rivers). Natural capital can be converted into financial capital (e.g. by selling fish), into physical capital (e.g. trees into buildings), and human capital (e.g. fish for a healthy diet).
Human	Human capital includes all things that allow a person to pursue a sustainable livelihood, such as skills, knowledge, ability to work and good health.
Financial	Financial capital, for example cash, savings, access to credit, and convertible assets, is used by people to achieve their livelihood strategies.
Social	Social capital is an intangible asset and includes the networks and relationships which exist in communities and groups, and which people make use of in their livelihoods. The intangible assets can be the rules, norms, obligations, reciprocity, and trust embedded in social relations, social structures, and societies' institutional arrangements.
Physical	Physical capital is the infrastructure and tools/equipment used to support livelihoods such as harbours and jetties, fish landing areas, gear stores, boats, nets, engines, processing equipment, and ice boxes.

The list of indicators used in this study to undertake both the VA and the SLA is shown in **Appendix 9**.

6 Climate change scenarios – *Evaluation & scenarios (stage E)*

In this 6th step of the blueprint the information collected in the previous steps is brought together and an holistic overview of the community, including interactions amongst sectors and the relevant impacts is produced. Without an overall picture of the community and its dynamics, important interactions between seemingly disparate parts of the community may be overlooked, increasing uncertainty (Botsford et al. 1997). In addition to the holistic overview of community interactions, scenarios of differing community interactions and feedbacks can be generated.

Scenarios are not predictions but plausible hypotheses about the future that guide strategic thinking. Scenario building generally involves a number of key steps including for instance, the identification of driving forces, selection of scenario logic, and the assessment of impacts (Preston 2010).

There are several ways to produce scenarios to exploring future development choices and pathways and the impacts of climate change and adaptation options (Bizikova et al. 2009; Varum and Melo 2010). The level of stakeholder and community engagement in producing these scenarios can vary. If community consultation is undertaken as part of the adaptation plan, scenario development will underpin the development of adaptation strategies in the next step (step 7).

We used a qualitative model approach to produce a representation of the coastal community and marine climate change pressures and used this model to explore adaptation scenarios. In qualitative models signed digraphs represent community dynamics, interactions and feedbacks. Signed digraphs are constructed according to the signs of interactions between variables in the system (in this case the regional coastal community). For example, direct negative effects such as the impact of a fishery on a fish stock are represented by •—, while direct positive effects such as the impact of an increase in stock abundance on fishery catches are represented by ←—. All direct interactions between variables (+, –, 0) can also be represented in a community matrix (**A**) and, following established mathematical protocol, can then be used to calculate predictions of response to perturbation using the adjoint of the negative community matrix (adj. (-**A**)) (Dambacher et al. 2003).

The qualitative modeling technique was used to assess different aspects of each case study as reported during surveys, including general community dynamics and fishery quota systems. Predictions of change, key drivers and variables were identified using an analysis of the community matrix (**Appendix 8 – Paper 4**). Model stability was also assessed to provide an indication of the reliability of the results. An unstable system will have a high likelihood of shifting to an alternative equilibrium that may not be adequately represented by the model. Model stability was measured using weighted feedback (*wFn*) where values of *wFn* close to +1 are perfectly stable and values close to -1 are totally unstable (Dambacher et al. 2003). A weighted feedback of 0 represents a system that is equally likely to be stable or unstable. Potential adaptation strategies were identified either by survey participants or through the analysis of model dynamics.

7 Potential adaptation strategies – *Evaluation & scenarios (stage E)*

This step is undertaken to 'test' potential strategies for adaptation, including specific actions. Without some form of testing different strategies, non-intuitive and seemingly unrelated impacts may occur as a result of their implementation. We used the qualitative modelling approach to test the adaptation strategies but there are other measures against which to measure the strategies (see step 9 in the results).

While no model will behave exactly as the natural system, investigation into the possible effects of adaptation strategies prior to their implementation, and any subsequent modifications that may be necessary, may improve the likelihood of success. Assessing potential management strategies using model simulations is a common occurrence in many different fields (Sainsbury et al. 2000; Lin et al. 2004).

In the context of qualitative modeling, adaptation strategies are favored that retain model stability at the same level or increased it. Additionally strategies are favored that predict benefits to variables of importance, such as a target species or struggling sector. For instance, in the St. Helens case study community, the potential adaptations resulted in markedly higher stability as well as predicting increased population size. Some adaptation strategies were represented in the qualitative models by the inclusion of new links or removal of existing links between variables. In the Geraldton qualitative model additional variables were added to represent adaptation strategies (detail provided in the results).

The community matrices from qualitative models representing the adaptation strategies were used to calculate conditional probabilities in Bayesian Belief Networks (BBNs) (Hosack et al. 2008). BBNs were used to provide semi-quantitative predictions of change following the implementation of the potential adaptation strategies. The use of this technique significantly reduces the time and effort required by experts and community members as their input is required only to develop the graphical structure and the links of a signed digraph. As specific quantitative data was not available for the model variables, this technique allowed the construction of more complex BBNs than would be possible if experts were required to provide conditional probabilities for all links in a model (Ticehurst et al. 2007). Probabilities larger or smaller than 0.333 have been recorded as they suggest the probability of observing an increase, decrease or no change was not equal (i.e., a change in one direction is more likely).

8 Examples and case studies – *comparison & learning (stage F)*

After developing realistic scenarios to represent the dynamics of regional coastal communities (step 6) and potential adaptation pathways (step 7) the users will now be able to develop their adaptation plan. Before developing and finalising the adaptation plan the blueprint user is provided with an opportunity to compare and assess adaptation strategies for similar coastal communities (i.e., in a similar location, with a similar sized population etc.) or communities (Penney 2011) with similar marine industries in this step. This will give the user of the blueprint a way to assess what is being tried in other places and why one strategy might be more practical or beneficial than another. Providing an opportunity to compare an adaptation plan to those developed by others will allow the users to ensure they have not overlooked certain issues. In the blueprint various council and government adaptation strategies and other resources currently available on the internet will be listed. The web-based blueprint will outline salient case study issues where relevant and useful (coastalclimateblueprint.org.au).

9 Regional coastal community marine adaptation plan – *Finalisation of adaptation planning (stage G)*

In Step 9, an outline is provided to the blueprint user on how to finalise the community marine climate adaptation plan from the information gathered in the consultation phase, consolidated in step 5, evaluated in Step 6 and 7, and compared to other adaptation plans in Step 8. The web-based blueprint will provide a (basic and high level) adaptation plan on the basis of the information provided by the web-based blueprint user. Level 3 and 4 users will be able to incorporate more specific and locally relevant information gathered as part of the modelling and community consultation process.

10 Refine and monitor – *refine and monitor (stage H)*

In order to determine whether the adaptation strategies are effective, sectoral and community monitoring must be undertaken after the preparation and implementation of the plan (e.g. http://pdf.wri.org/making_adaptation_count.pdf). As new issues arise, or old strategies are no longer effective, the adaptation plan must be modified. Those in positions of responsibility and those willing and able to implement change in communities must be able to continually adapt future strategies. This step essentially turns the blueprint into an adaptive management process (Walters 1986; Holling 1978) whereby a climate adaptation plan is periodically updated and revised to ensure it remains relevant and effective

Results/discussion

The analysis of the primary data gathered for this project (see Appendix 5 to 8 for the scientific papers that were prepared) and a review of the literature, formed the basis of the development of the marine climate change adaptation blueprint for regional coastal communities (**Table 2 in methods**). There are 10 steps in the blueprint which are distributed over 8 stages (**Figure 2**).

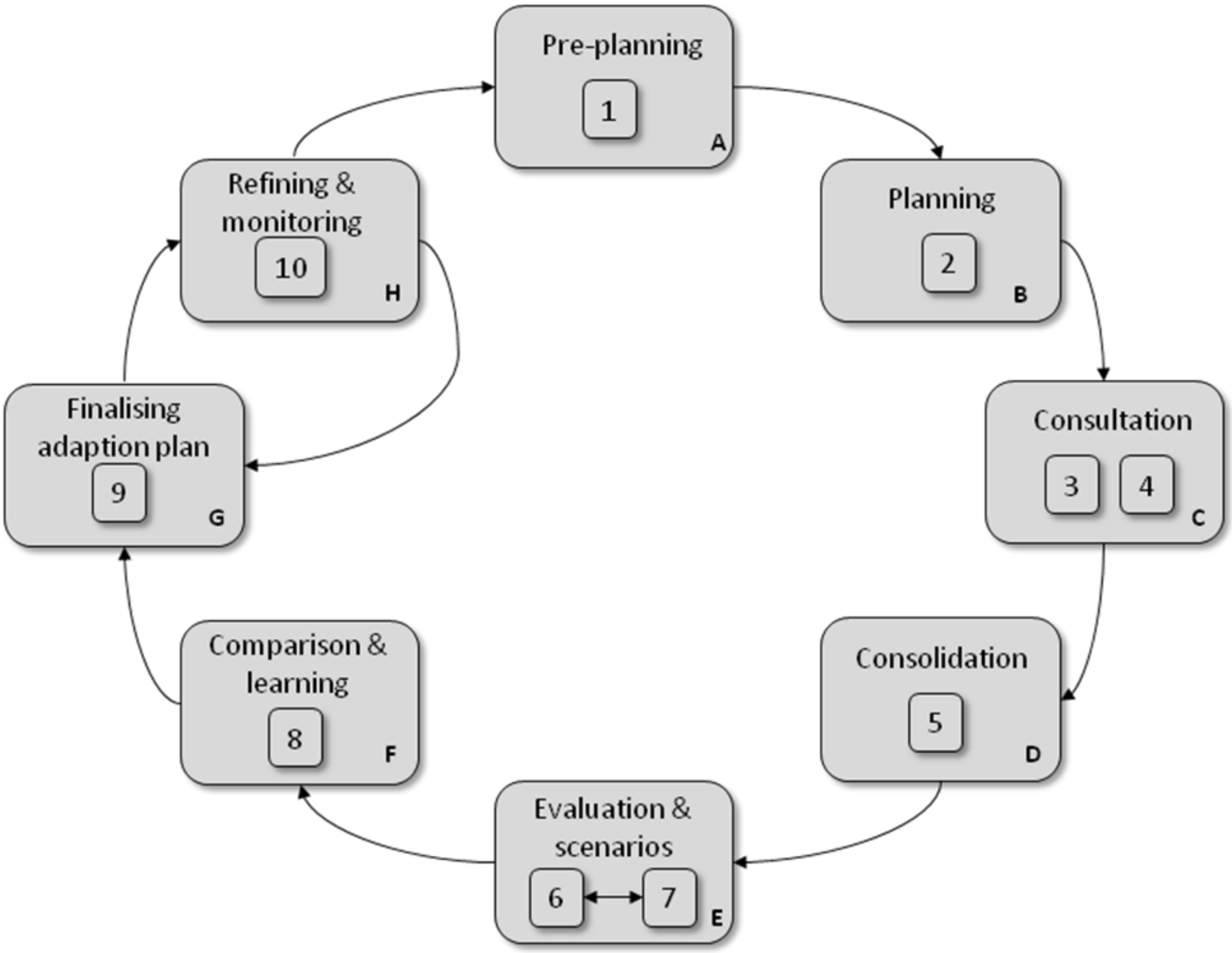


Figure 2: Ten steps distributed over 8 stages (A to H) involved in developing a blueprint for adaptation to climate change in the marine environment in regional coastal communities.

The 10-step blueprint was condensed into web-based blueprint (coastalclimateblueprint.org.au) to enhance the communication value and user friendliness. As described in the methods section, there are four levels at which users can complete an adaptation plan depending on several factors, including resources available. A level 1 blueprint is basic and requires minimal input but consequently is not very location specific. Level 1 and 2 blueprints are of value particularly for ‘extension purposes’ and to raise awareness about marine climate change. Level 3 and 4 adaptation plans rely on community consultation and will therefore be more location specific (**Table 4**).

Table 4: Ten steps to develop a blueprint for regional coastal community adaptation to marine climate change against the level of detail in the adaptation plan. Levels 2-4 require the user to fill out an excel (XLS) spreadsheet.

Step	***Item***	***Level 1*** *Web-based*	***Level 2*** *Web-based (including additional census info)*	***Level 3*** *Web- based and community consultation*	***Level 4*** *Web-based and community consultation by consultants*
1	Resources & engagement method	✓	✓	✓	✓
2	Coastal regional community	Basic	Detailed (XLS)	Detailed (XLS)	Detailed (XLS)
3	Climate change pressures on marine sectors	Pre-defined	Pre-defined	Locally refined through consultation	Locally refined through consultation
4	Non-climate pressures on marine sectors	×	×	✓	✓
5	Pre-conditions for adaptation (resilience & adaptive capacity)	General info automatically generated	More accurate auto generated info	more accurate auto generated info & potential for local refinement using consultation info	more accurate auto generated info & potential for local refinement using consultation info
6	Climate change scenario	Pre-defined	Pre-defined	Pre-defined	Modelled for local conditions
7	Potential adaptation strategies	Automatically generated	Automatically generated	Summarised for local conditions	Modelled for local conditions
8	Examples and case studies	Available on web-based blueprint	Available on web-based blueprint	Available on web-based blueprint	Available on web-based blueprint
9	Regional coastal community marine adaptation plan	Automatically generated	Automatically generated	Detailed	Locally refined
10	Refine and monitor	✓	✓	✓	✓

Following these 10 steps will help regional coastal communities develop an adaptation plan (at different levels of detail) to climate change in the marine environment

1

Resources & engagement method - *Pre-planning (stage A)*

There are a range of activities that need to be undertaken before starting the planning stage of adaptation planning. Regardless of the level of detail of the blueprint – all users will need to consider the pre-planning stage. In the pre-planning stage motivations for adapting to climate change are considered. Further objectives are defined, available resources assessed, teams assembled, and internal procedures or mechanisms are set in place to help complete the process. The decision tree (**Figure 3**) was developed to help regional coastal communities decide which level of the adaptation plan to complete.

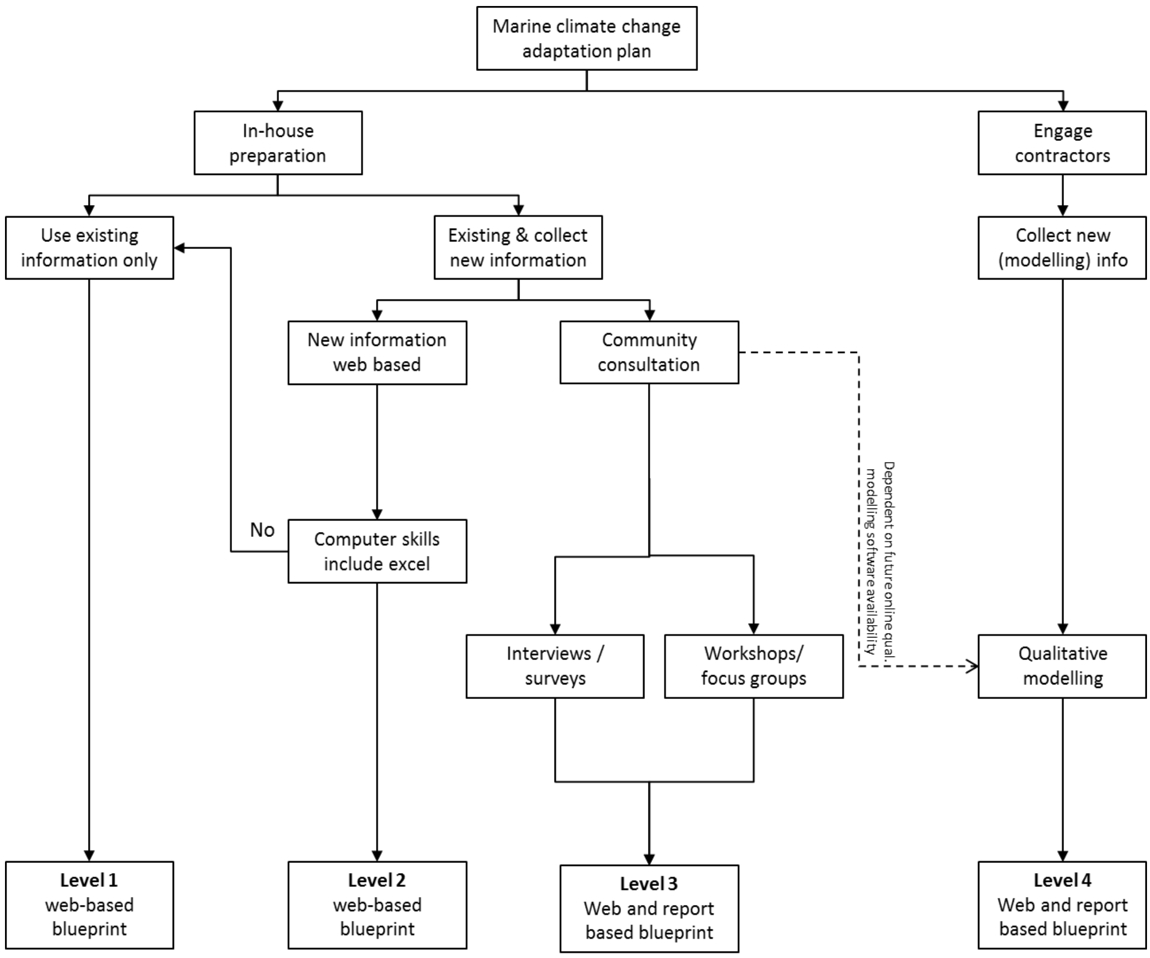


Figure 3 Different aspects of resource availability that users will need to consider and which will determine the level of detail in the adaptation blueprint (1 simple and high level, 4 complex and detailed)

2 Coastal regional community - *Planning (stage B)*

In step 2 of the blueprint a profile of the coastal community including population size, age structure, employment status, education, and employment in fishing and aquaculture is developed. As part of the community profile the types of marine industries that operate in the coastal community (e.g. commercial and recreational fishing, marine tourism) and the marine resources they rely upon are considered. For each of the case studies, a profile was developed (see also **Appendix 8 – Paper 4**). A number of socio- economic variables (also referred to as indicators) were selected to form the basis for developing the profile. Examples of the main indicators for the three case study communities are shown in **Appendix 9**.

3 Climate change pressures on marine sectors - *Consultation (stage C)*

In this step in the blueprint, climate impacts that influence the marine environment and marine industries are identified. We obtained information from the literature to outline the main marine climate change pressures around Australia. Detailed (species specific) information on ecological vulnerability was developed by Pecl et al (2011) for the southeast of Australia. The vulnerability assessment method is currently also implemented in Queensland (Walsh) and Western Australia (Caputi).[3]

This climate change and species specific information was supplemented by expert opinion and case study information. The positive and negative impacts of the main climate change pressures on marine species, ecosystems and marine sectors were thus identified (**Table 5**). A schematic figure of the links between the complete set of climate change pressures, marine environment (ecological groups) and the marine sectors is shown in **Appendix 10**.

Table 5: Examples of the positive (+ve) and negative (-ve) impacts of different climate change pressures on marine species, ecosystems and marine sectors

From	***Sign***	***Direct effect on other climate pressure***
Currents	+ve	Changes in currents will change mixing in the water column and in some places increase SST
Wind	+ve	Increased wind strength can increase current strength
From	***Sign***	***Direct effect on species (group)***
Ocean temperature	+ve	An increase in sea temperature can make some areas more suitable for species, including pests and diseases, that were not previously resident
Ocean temperature	-ve	An increase in sea temperature may reduce reproductive viability of resident target species or force range-shifts to cooler waters
Currents	+ve	Changes in currents may carry some species to areas where they have not previously been noted (could lead to eventual residence of the emergent species)
Rainfall	-ve	Extreme rainfall and flooding can increase bacterial and sediment loads and reduce salinity to an extent that ecosystem integrity is affected
Cyclones & storms	-ve	Storms and cyclones can damage the physical integrity of the ecosystem e.g., cyclones turning coral reefs into rubble.
Acidification	-ve	Increasing acidification can cause a weakening of calciferous structures including the shells and exoskeletons of shellfish (e.g., oysters) and crustaceans (e.g., rock lobster)
From	***Sign***	***Direct effect on marine sector***
Wind	+ve	Increased wind strength and reliability can increase the capacity for wind generated energy
Rainfall	-ve	Increased rainfall may reduce efficiency of production and quality of aquaculture species such as oysters, as a result of a decline in salinity
Cyclones & storms	-ve	Storms and cyclones may damage infrastructure and reduce production efficiencies including the number of fishing days or the ability to operate in shallower inshore grounds.
Cyclones & storms	+ve	Storms and cyclones can benefit the generation of renewable energy through increased wind and wave strength
Sea level rise	-ve	Rising sea levels may damage infrastructure, reduce production efficiencies and require movement to alternative locations (especially aquaculture)

There are significant uncertainties associated with prediction about changes in marine climate change pressures for 2030 and 2070.[4] However, it is very likely that SST around Australia will continue to warm through the 21st century. Robust projections of future changes in Australian SST depend on reliably capturing changes in major ocean current systems (Hobday and Lough 2011). The observational evidence for the intensification of the East Australian Current is strong and this trend is expected to continue into the future, leading to regionally enhanced warming off southeast Australia (Sen Gupta et al. 2009). How the smaller and more seasonal Leeuwin Current (Feng et al. 2009), which significantly affects marine

[3] There are some minor differences in the methodology applied in the Queensland and Western Australian studies which are detailed in FRDC 2010/535 and 2010/565.

[4] Climate change predictions can be found at (http://www.publish.csiro.au/?act=view_file&file_id=CSIRO_CC_Chapter%203.pdf)

ecosystems off the southwestern coast of Western Australia, is harder to model (http://www.oceanclimatechange.org.au/content/index.php/2012/report_card_extended/category/temperature) .

The general summary for the three regions central in this study is shown in **Table 6**. Note that the southeast and southwest of Australia are hotspot regions as they are warming at rates substantially faster than the global average.

Table 6: Predicted changes in marine climate change pressures for 2030-2070 and the estimated sensitivity to the marine climate change pressure for the southeast, northeast and west of Australia.

Marine climate change pressure	***Predicted change***	***Southeast****	***Northeast***	***West***
	↑	High	Medium	High
	More variable	Medium	High	Low
	↑	Medium	High	High
	↑ (pH ↓)	Medium	High	Medium

*Southeast includes Tasmania, Victoria, and New South Wales, northeast includes Queensland and the Northern Territory, and west includes Western Australia and South Australia.

On the basis of information gathered in the three case studies combined with expert opinion and a review of the literature the main climate pressures on the different marine sectors for three regions were identified (**Table 7**).

Table 7: The regional positive (+ve) and negative (-ve) impacts of four different climate change pressures on marine sectors. Data based on three case study communities (St Helens in Tasmania for the SE, Bowen in Queensland for the NE, and Geraldton in Western Australia for the W.

	SST#			RAIN			STORM			ACID		
Region based impact (marine sector / industry)	SE*	NE	W	SE	NE	W	SE	NE	W	SE	NE	W
Aquaculture (marine - rack)				-					-	-		
Aquaculture (marine - pen)									-			
Aquaculture (land based)								-				
Marine tourism Non extractive		-						-	-		-	-
Charter (game) fishing	+	-	-					-	-			
Commercial fishing	-	-	-									
Oil and gas												
Shipping, ports and marinas	-	-	-									
Recreational fishing	+	-	-									
Indigenous fishing		-										

SST includes sea surface temperature, current strength and current direction; Rain includes rainfall intensity and frequency; Storm includes wind intensity and cyclone and storm intensity and frequency; Acid is ocean acidification.
* SE includes Tasmania, Victoria, and New South Wales, NE includes Queensland and the Northern Territory, and W includes Western Australia and South Australia.

Even though there were similarities between some of the climate change drivers for the three case studies, reported changes varied considerably. For example, in both St. Helens and Geraldton sea temperature increases were reported. In St. Helens sea temperature increases were perceived to result in 'new' species abundance increases. This in turn had a positive effect on recreational fisheries and negative effect on ecosystem structure. In contrast, Geraldton respondents mainly focussed on the effect of the warming waters on declining aquaculture species survival and production. In Geraldton some respondents reported coral bleaching following a heatwave off Geraldton, however, there were few reports of substantial long-term ecosystem change as a result. Increased wind strength was also reported in Geraldton and is the basis for an increase in wind turbine construction and renewable energy production. There are hopes of selling this energy into the Perth metropolitan 'grid' in the future.

The marine sectors are vulnerable to different climate change pressures through the effects on marine species.

Three separate FRDC projects are undertaking risk assessments of impact of climate change for key marine species in their region (southeast Pecl et al. (2011), northeast FRDC Project Number: 2010/565[5], and west FRDC Project Number: 2010/535[6]). The preliminary risk categories for the key species are shown in **Appendix 11**.

The method used to assess the risk marine climate change poses to marine species are detailed in Pecl et al. (2011). In summary, the method is based on conceptual models of abundance, distribution and phenology and an estimate of the sensitivity of fishery species to climate change including key biological features of commercial species. These sensitivities to the direct effect of climate change may start at the cellular level

[5] At the time of writing only northeast coast species were available. For the northeast coast risk assessment a combination of sensitivity criteria as per Pecl et al (2011) were used as well as some fishery.

[6] Data is based on a preliminary risk screening of WA's commercial finfish and invertebrate species, based on criteria developed by Pecl et al. (2011).

(Hochachka and Somero 2002). Changes like, for instance, altered metabolic rates and other life-history traits, can cascade up to population levels (O'Connor et al. 2007). Moreover, from, for instance, the combined effect of changing temperatures and shifts in oceanographic processes (i.e. that affect dispersal and recruitment), population level changes may result in ecosystem-level changes (Doney et al. 2012) where the response can be unpredictable (Bernhardt and Leslie 2013; Folke C et al. 2004). In the study by Pecl et al. (2011) temperature was highlighted as the key underlying driver facilitating range shifts and changes in current-mediated larval transport was also identified as influencing range shift patterns

4 Non-climate pressures on marine sectors - *Consultation (stage C)*

Marine climate pressures are mostly 'observed' through increasing or decreasing species abundance and new species being caught. The climate pressures are felt through the economic impacts of abundance change on the marine sectors. In this study as well as others (Pecl et al. 2011), increasing ocean temperature is the most commonly cited climate change pressure. However there are many non-climate drivers that also affect marine sectors.

In the human domain, like in biology and ecosystem sciences, climate change risk assessments have to consider additional stresses on the species (Pecl et al. 2011). It is important to make these non-climate drivers explicit to address, for instance, potential attribution problems (Parmesan et al. 2011) where non-climate and climate pressures both have an impact but cannot be easily separated. The attribution issue frequently arises in discussions of climate change.

In this part of the consultation phase, detail on the non-climate drivers is collected. As part of the case studies a number of these non-climate pressures applied to all three areas (summarised in **Table 8**) while others were area specific. Considerable detail was collected in relation to non-climate pressures impacting commercial fishing (**Appendix 10)**.

Table 8: Main reported non-climate pressures on the marine sector in each of the case study locations.

Non-climate pressures on the marine sector	*St. Helens*	*Bowen*	*Geraldton*
Variability in tourism (mainly decline in recent past)	✓	✓	✓
Availability of (non-local) alternative sources of employment (increased labour cost)	✓	✓	✓
Volatility of prices (demand) for fish in the international market	✓	✓	✓
Increasing fishery costs (e.g. fuel) and influence of investors/ processors on the price of fish and lease quota cost	✓	✓	✓

Changing trends in tourism were reported at each location but different explanations for the change in tourism numbers applied in each case study area. For example, in Geraldton falling tourism numbers were partly explained by both the lack of accommodation and inadequate marketing. In Bowen, tourism had slowed due to lingering perceptions of bad weather and damaged infrastructure following cyclonic activity, as well as the high Australian dollar (AUD) and inadequate marketing. Both increases and falls in tourism number were reported in St. Helens. A decrease was explained by the high AUD but an increase was observed in the number of recreational fishers visiting the area because of the presence of 'new' and exciting recreational fish species.

The importance of tourism to the community as a whole also differed between the three locations. Tourism in Geraldton was currently not perceived to be of great concern; rather falling numbers may become a community issue in the future when the mining boom slows. In contrast, tourism in Bowen and St. Helens is currently very important and supports the local economy through retail sales, accommodation, tourist activities and employment.

The availability of alternative sources of employment had similar impacts in St. Helens and Bowen but differed in Geraldton. In general, workers in St. Helens and Bowen must leave the town to seek alternative employment, whereas the population of Geraldton has not been affected to the same degree. In Geraldton people who may have been redundant in one industry (such as fishing) have moved to other local jobs created by the port development, mining sector, and oil and gas sector.

All regions experienced increased uncertainty in their profits due to an increase volatility of prices in the international market place. Most of this was driven by the exchange rate and the opportunity for product replacement in international markets.

Both the increasing fuel costs, bait costs and labour costs were being experienced in all regions. Although the rock lobster fishers in Geraldton have only recently moved to a quota management system, they already had concerns (as expressed in Bowen and St Helens) that output controls were resulting in increased investor and processor purchase of quota and this was leading to increased control over the price of fish that a processor would offer, especially when having to lease quota from the processor.

5 Pre-conditions for adaptation (resilience & adaptive capacity) - *Consolidation (stage D)*

In step 5 the information gathered in steps 2 to 4 is consolidated. A simple score for the potential socio-economic vulnerability of human system (HV) can be calculated. Inevitably, by simplifying the complex subject of socio-economic vulnerability, some valuable details are sacrificed by using a simple and generally applicable and available set of data for analysis.

As well as a vulnerability analysis a community sustainable livelihood assessment can be carried out. This SLA can help identify how to increase adaptive capacity and reduce vulnerability in the human domain. For example, **Figure 5** (left panel) shows the maximum SLA with a score of 1 for all five capitals on the axes; the right panel provides an example of a community low in human capital and reduced physical- and natural capital.[7]

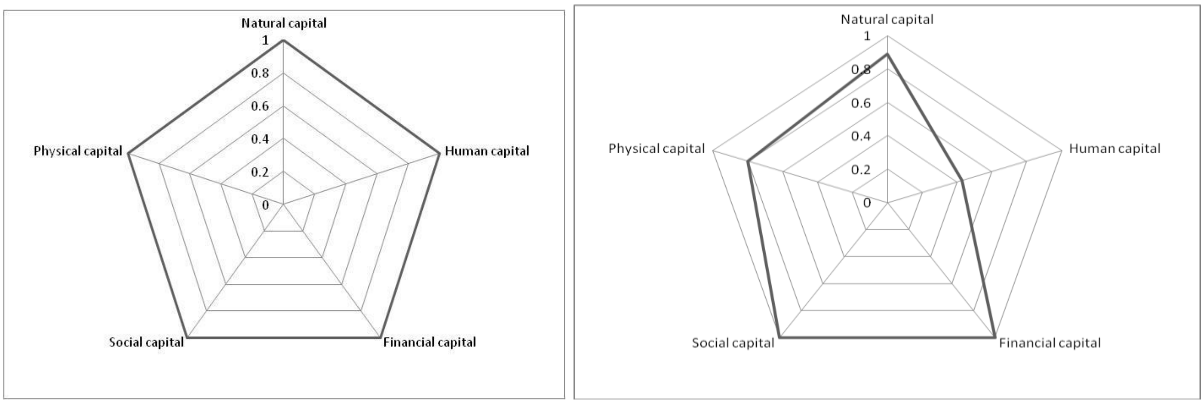


Figure 5: Example of SLAs for a community strong in all 5 capitals (left) and a community lower in human, physical and natural capital (right).

To address low human capital increased training, education, awareness raising, improved access to health and education facilities should be considered. To address low physical capital the community might wish to improve access to infrastructure, provide access to information on improved technology, and build capacity to improve the development of physical assets (Campbell 1999). Other examples of what can be done include encouraging communities to use their resources more sustainably, improve the post-harvest use of

[7] The interpretation of the SLA result is relative to the 'highest' possible scores (which is 1 for all 5 axes).

resources, and improve access to sectoral service provision to address low natural capital. To address low financial capital, access to formal credit can be increased and providing business training can improve the management of finances. Social capital can be improved through, for instance, strengthening community organisation skills and building up trust relationships.

By using a set of quantitative indicators that are easily and freely obtainable (Census data) the HV and the SLA can help identify the socio-economic vulnerability of regional coastal communities with respect to other coastal communities, state-wide and nationally. Information on the relative resource dependence of each community will also be useful to evaluate the potential flow on effects of change in marine sectors. Generic qualitative input output models, linking climate change pressures to relevant marine sectors, and subsequently to other sectors in the coastal community economy can give insight into the potential effect of marine climate change.

6 Climate change scenarios – *Evaluation & scenarios (stage E)*

If we know the climate and non-climate pressures and we have a model of the key dynamics in a coastal community, it is possible to identify possible adaptations. In our approach we used qualitative models to identify key dynamics in the community including the marine climate change pressures and non-climate pressures. By identifying key dynamics, the models help to identify adaptation opportunities. For most regional coastal communities it will not be possible to generate qualitative models due to resource investment and the technical knowledge needed to develop these models. For communities unable to develop qualitative models, other ways to visualise key community interactions (e.g. influence diagrams – see Shachter, 1988) that help gain an understanding of people's mental models may be used. A visualisation of relationships can help prioritise key dynamics and also identify community adaptations.

The qualitative models (signed digraphs) developed for the three case study communities are shown in **Appendix 13.** The models graphically show the relationship between key variables, for example, commercial fishing creates local employment. Commercial fishing also has a positive influence on the retail industry as people spend some of their money locally. Using qualitative models it is possible to identify key dynamics that drive the interactions and that currently shape the community (summarised in **Table 9)**. For instance in St Helens the increase in the sea urchin is creating barrens affecting commercial fishing for rock lobster but also providing local employment through the development of an urchin processing factory.

Table 9: Key dynamics and predictions perceived to have negative consequences for St Helens, Bowen, and Geraldton on the basis of the Community Models.

Location	Key dynamic/prediction
St. Helens	Increase in the sea urchin (*C. rodgersii* and associated barrens (Pr=0.552))
St. Helens	A fall in retail activity, dampens local employment – preventing people from moving to St Helens (population decline Pr=0.518)
Bowen	Decline in tourism (Pr=0.658) and flow-on impacts to accommodation (Pr=0.658), retail (Pr=0.804) and dive charters (Pr=0.590)
Bowen	Decline in population size (Pr=0.756), retail (Pr=0.804), local employment (Pr=0.811)
Geraldton	Declining commercial fisheries (Pr=0.821), aquaculture R & D investment and funding (Pr=0.939), tourism (Pr=0.906) and population size (Pr=0.905)

The changes that survey respondents observed are represented as 'perturbations' in the qualitative models. The inclusion of the perturbation variables in the models is based on the frequency of their mention in the interviews and if they were perceived to have broad community implications. The perturbations for each case study community are shown in **Table 10** (the signed digraphs are shown in **Appendix 13** with perturbations in the bottom left panel).

Table 10 Perturbations included in each Community Model and the reason for inclusion.

Perturbation	***Location***	***Reason***
↓ Commercial fishing	St. Helens	- rationalisation of the fleet after quota management; - less family transfer of quota; - declining abundance of target species (e.g, scallops, lobster); - alternative sources of employment (greater income in other industries); - declining access to port (due to increased siltation of entrance);
↓ Aquaculture (production)	St. Helens	- Climate change-induced flooding causes temporary stoppage of aquaculture (oysters) harvest and reduces production
↑ long spined sea urchin	St. Helens	- Residency and self-sustainability of *C. rodgersii* populations
↑ 'New' fished species	St. Helens	- Increased sightings of popular 'warmer water species' due to climate change-induced warming of ocean temperatures and increased extension of East Australian Current
↑ Tourism	St. Helens	- Good recreational fishing opportunities*
↓ Commercial fishing	Bowen	- fisheries management changes ('Green zones'); - concentration of fishing effort; - alternative sources of employment; - less family transfer of quota.
↓ Tourism	Bowen	- Perception that cyclones have damaged the reef and no regeneration has occurred yet; - perceived infrastructure damage from the cyclone was inhibiting visitors coming to the area for prolonged period; - Global financial crisis and high AUD exchange rate was reducing overseas and domestic tourists respectively.
↓ Ecosystem structure	Bowen	- Cyclones Hamish and Yasi caused 'rubbling' of coral reefs and destroyed habitat for reef dwelling fish.
↑ Mining (elsewhere, i.e., non-local)	Bowen	- Highly paid employment opportunities in mining sector in Bowen area.
↓ Commercial fishing	Geraldton	- rationalisation of the fleet after quota management; - alternative sources of employment (e.g. mining sector); - less family transfer of quota - declines in lobster recruitment
↓ Aquaculture (production)	Geraldton	-Insufficient R & D funding to support fledgling aquaculture businesses - inadequate marketing of benefits of aquacultured products
↓ Tourism	Geraldton	- Inadequate marketing of tourism opportunities in Geraldton - lack of affordable accommodation (as most placed are booked out by mining sector and oil & gas industry
↓ Target species	Geraldton	- Low abundance of rock lobster puerulus expected to cause a decline in breeding stock in the future
↓ Funding (aquaculture)	Geraldton	- Inadequate marketing of the benefits of aquacultured products - GFC induced financial strain causing reduced investment in 'high risk' industries
↓ Aquaculture (cool water) species	Geraldton	- Climate change induced increase in ocean temperatures and greater southerly extent of the Leeuwin Current increase stress and causes higher

		mortality of ‘cool water’ aquacultured species
↑ Aquaculture (warm water) species	Geraldton	- Climate change-induced increase in ocean temperatures and greater southerly extent of the Leeuwin Current increase aquaculture potential of ‘warm water’ species

* Although the survey respondents often indicated there had been a general decline in tourism in the past two years, the State tourism survey did not indicate this downward trend. However, most respondents recognised there had been an increase in recreational fishing and fishing based tourism.

* Although the survey respondents often indicated there had been a general decline in tourism in the past two years, the State tourism survey did not indicate this downward trend. However, most respondents recognised there had been an increase in recreational fishing and fishing based tourism.

Some of the perturbations variables, like the decrease in commercial fishing activity, are common across the case studies. However, the community survey respondent’s perceived reasons for the decline differ between the case studies.

7 Potential adaptation strategies – *Evaluation & scenarios (stage E)*

All models developed in Step 6 are based on the information obtained during interviews with community members. After incorporating the main perturbations (**Table 10**) into the community models the main impact to the community can be assessed (**Table 11)**. The benefit of using qualitative models to assess these perturbations is that they can be climate and non-climate driven (as identified in steps 3 and 4) and adaptation can focus on impacts already experienced or projected future impacts. For instance, the decrease in aquaculture production in St Helens (**Table 10**) is driven by the already experienced increase in rainfall events requiring production to stop due to runoff events and contamination potential. Other perturbations may be driven by some climate pressure according to scientists (e.g. decline in commercial rock lobster fishing in St Helens) but the community’s perception of the reasons for the decline may not include climate change as a driver. Despite the differing views, the overall effect can be accurately represented in the model.

Table 11: Results from the adaptation models for each of the case study communities using both qualitative models and BBNs. Results for marine sectors are shown in bold.

Model and Qualitative stability metric (*wFn*)	**Predictions (direction of response and probability of change after perturbing the community models)**
St. Helens model 0.78	↑ Population size (Pr=0.370), ↑ **Charter and recreational fishing (Pr=0.739)**, ↓ **Oyster aquaculture (Pr=0.966),** ↓ **Commercial fishing (Pr=0.876)** ↓ Retail (Pr=0.446) ↓ Tourism (Pr=0.417) ↓ Local employment (Pr=0.508)
Bowen model 1.00	↑ Tourism (Pr=0.665), ↑ **Recreational fishing (Pr=0.753)**, ↑ Retail (Pr=0.697), ↑ Local employment (Pr=0.592), ↑ Population size (Pr=0.756), ↑ **Dive charters** (Pr=0.590) ↑ Tourism accom. (Pr=0.665) ↓ **Commercial. fishing (Pr=0.657)** ↓ Ecosystem structure (Pr=0.746) (due to shift away from fishing to alternative employment and impact of recreational fishing)
Geraldton model -0.80	↑ **Aquaculture profits (Pr=0.964),** ↑ **Recreational fishing (Pr=0.527)**, ↑ Tourism (Pr=0.444), ↑ Target species (Pr=0.516), ↑ Retail (Pr=0.835), ↑ Local employment (Pr=0.833), ↑ Population size (Pr=0.833), ↑ **Funding (for aquaculture) (Pr=0.939)**, ↑ **Aquaculture (warm water) species (Pr=0.939)**, ↑ Renewable energy (Pr=0.939) ↓ **Commercial fishing (Pr=0.914)** (due to shift to alternative employment, CC impacts and management arrangements)

On the basis of the perturbed models it is possible to identify the most obvious and likely adaptations. While the details and reasoning behind each adaptation are unique in all locations, there are a number of similarities across all coastal communities. For example, encouraging and maintaining a local market for fish is a useful adaptation in all locations. In addition, the maintenance and development of Chinese (and other international markets) in addition to local markets will provide a higher level of income and stability to the fishing industry. Diversification of overseas markets is important as it helps to insulate the industry from market disturbances such as; for example, the temporary 'ban' placed by the Chinese on Australian rock lobster imports in November 2010 (http://www.radioaustralia.net.au/international/2010-11-29/china-bans-australian-rock-lobster-imports/174846).

Similarly, increasing the output and function of aquaculture is an adaptation strategy in all three locations. This can be a useful adaptation because aquaculture provides employment as well as an alternative source of fish products which may support the local population and associated industries (e.g., processors, retail) if a decline in commercial fishing continues to occur. Some conditions in aquaculture production, such as water temperature and light (land-based aquaculture), can be controlled and are therefore not subject to the same climate change impacts as wild fisheries and ocean-based aquaculture. The capacity to control some environmental aspects of aquaculture determines that it may provide a sustainable source of employment and fish products despite the impacts of climate change.

Increasing tourism is a potential adaptation in each location to assist with the provision of local employment through tourism-related businesses (i.e., charter fishing, dive charters, eco-tours) and associated business, such as accommodation and retail sales. The reasoning for increasing strictly regulated eco-tourism at the Abrolhos islands is slightly different because in addition to increasing local employment, it allows increased tourism to occur without damaging the fishers' 'connection' to the Islands or the ecosystem itself and may help maintain infrastructure.

The two smaller communities, St. Helens and Bowen will benefit from increases in the size of the population. The retail sector drives large parts of the economy in these small regional coastal communities. Support of local retail leading to greater employment opportunities can lead to improvement in the sustainability of community services, such as healthcare and education. Population size in Geraldton was not a key determinant of community stability and viability, with in essence, a self-sustaining retail sector.

A number of unique potential adaptations also exist for each location. These are due to differences in the size, types of employment opportunities and industries available, and types of climate change impacts. For instance, the adaptation to increase urchin factory production was only relevant in St. Helens due to the presence of the invasive urchin species, *C. rodgersii*, while the closure of cyclone-damaged reefs was only relevant in Bowen, the only tropical case study. Unique adaptations in Geraldton tend to focus on improving higher-level conditions, such as education and communication, which can improve employment opportunities, fisheries management and aquaculture.

Table 12: Similar and unique adaptations identified.

Location	Similar adaptations	Unique adaptations
St. Helens	- Encourage and maintain a local & domestic market for commercial captured fish - Increase aquaculture output/function - Encourage increased tourism - Increase population size	- Increase urchin factory production - Give fishers more influence on fish prices, - Separate processors from investors - Improve regulation, compliance with rules and policing of recreational fishing
Bowen	- Encourage and maintain a local & domestic market for commercial captured fish - Increase aquaculture output/function - Encourage increased tourism - Increase population size	- Closure of cyclone-damaged area and shift of fishing effort elsewhere to enable rebuilding of stocks
Geraldton	- Encourage and maintain a local & domestic market for commercial captured fish - Increase aquaculture output/function - Encourage increased tourism (Abrolhos Islands)	- Improve/increase research (renewable energy, aquaculture and fisheries) and education (commercial fisheries compliance) - Communication (benefits of aquacultured products and renewable energy). - Increase renewable energy production & sales - Provide incentives for deckhands to take up employment in the fishing industry. - Encourage rock lobster fishers to take up new opportunities on the islands when they finish annual fishing operations - Maintain fishing quota system

A series of adaptations that were not inherent in the qualitative models but were raised in the consultation process are shown in **Appendix 13**.

8 Examples and case studies – *comparison & learning (stage F)*

The case studies that are part of this report (and any literature and available internet resources) provide insight into some of the common marine climate change pressures and the potential impact on the marine sectors and the community as a whole. The modelling of the community systems and the interactions within allow the identification of some general perturbations currently observed in regional coastal communities. Moreover, some general adaptation options could be identified by means of the survey information gathered in the three local case study communities. The findings in the case study communities combined with coastal and marine ecosystem adaptation management suggested by other studies can help communities that are planning to develop their own adaptation plan. Adaptations identified by other studies include ecological buffers zones, open space preservation and conservation, ecosystem protection and maintenance (facilitating wetland migration, managing for ocean acidification), ecosystem restoration creation and enhancement (wetlands, coral artificial reefs), aquatic invasive species management (NOAA Office of Ocean and Coastal Resource Management 2010). These other examples of adaptations are available on the website (coastalclimateblueprint.org.au).

9 Finalising regional coastal community marine adaptation plan – *Finalising adaptation plan (stage G)*

In the first 5 steps of the blueprint the community's socio-economic vulnerability was evaluated. The likely climate change pressures on the marine sectors were identified and the non-climate pressures were described. The community's perceptions of the effect of both the climate and non-climate driven change was modelled using a qualitative approach. The power of the qualitative model is that it can attribute probabilities to the outcomes. But qualitative models are high level and smaller scale actions are not so easily identified using the models. The impacts on marine sector, informed by the qualitative model, were then described and adaptation actions were developed. The possible adaptation actions were selected with enough background knowledge to allow the user to now evaluate and prioritise actions. The action plan that is built on the information gathered so far will in fact be the final adaptation plan.

The initial stage of this step is to determine what sort of adaptation actions have been developed which will help firm up the reasoning behind the adaptation.

Table 13: Types of adaptations and description (UK Climate Impacts Program 2006).

Adaptation category	***description***
Accepting the impacts and bearing losses	A decision not to act can be a valid option. This could either recognise that sufficient procedures are already in place to deal with the risk, or that the relevant assets/systems are not worth the effort or cost associated with protecting them.
Loss prevention	Actions to reduce vulnerability to climate change (through impacting **exposure**, **sensitivity** or **adaptive capacity**). This occurs prior to experiencing the impact. The most extreme form of this would be to move vulnerable populations or systems away from the hazards introduced by climate change – however, this will not always be viable.
Loss sharing	Spreading the risk of loss among a wider population. This occurs after the impacts have been experienced (e.g. through insurance).
Behaviour modification	Eliminating the activity or behaviour that causes the **exposure** or **sensitivity**. Again, this must occur prior to experiencing the impact.
Exploiting positive opportunities	This recognises that there may be benefits to new activities, behaviours, practices or species arising out of climate change impacts or adaptation activities. 'New opportunities may also be exploited by moving activities to a

	new location to take advantage of changed climatic conditions.' Actions should not be constrained by this list. There are also other options available, such as focusing on recovery efforts after experiencing an impact, either through the organisation acting alone, or by establishing community networks for action.

Also the following terms are found throughout the climate change literature and are useful in prioritising the action given the uncertainty of climate change (**Table 14**).

Table 14: Types of adaptation actions (NOAA Office of Ocean and Coastal Resource Management 2010; Eyre et al. 2011; UK Climate Impacts Program 2006)

Adaptation type	***Prioritisation***
Win-win options	Adaptation measures that have the desired result in terms of minimising the climate change risks or exploiting potential opportunities but also have other social, environmental or economic benefits. Within the climate change context, win-win options are often associated with measures or activities that address climate impacts but which also contribute to mitigation or other social and environmental objectives.
No-regret options	These types of adaptations deliver benefits that exceed their costs, whatever the extent of climate change.
Low regrets (or limited regrets options)	Adaptive measures for which the associated costs are relatively low and for which the benefits, although primarily realised under projected future climate change, may be relatively large.
Flexible adaptation options	These adaptation options involve putting in place incremental adaptation actions, rather than undertaking large-scale adaptation in one fell swoop. This approach reduces the risks associated with being wrong, since it allows for incremental adaptation. Measures are introduced through an assessment of what makes sense today, but are designed to allow for incremental change, including changing tack, as knowledge, experience and technology evolve.

In the finalising stage the evaluation of the adaptation measures should be considered according to the following principles (adapted from NOAA Office of Ocean and Coastal Resource Management (2010):

1. Socially acceptable
2. Technically feasible
3. Administratively implementable
4. Politically acceptable
5. Legally enforceable
6. Economically effective and efficient
7. Environmentally sustainable

Some obvious decision tools can be used to prioritise adaptation actions (Eyre et al. 2011): Cost benefit analysis, multi-criteria analysis and cost efficiency analysis. Cost benefit analysis is useful where quantitative monetary information is available. In cases where little quantitative information is available, cost efficiency analysis may be more useful. Multi-criteria analysis is useful if there are multiple objectives and complex judgement is required (Eyre et al. 2011; World Bank 2010). A summary of methodologies for the economic evaluation of adaptation can be found in the World Bank (World Bank 2010) publication.

Please note that it is not the intention of the blueprint to determine an adaptation strategy but to enable users to obtain broad information across a range of areas: physical, biological, social and economic so that the appropriate decision makers are in the best position to determine an adaptation strategy.

10 Refine and monitor – *refine and monitor (stage H)*

Monitoring plays a vital role in climate change adaptation (NOAA Office of Ocean and Coastal Resource Management 2010). It allows you to track the ecological and socio-economic consequences and responses of your action, practice adaptive management, and adjust polices.

Implications

The main benefit resulting from the integrated research approach and development of a 10 step process is the increased understanding of the important role of the marine sector in regional coastal communities, and the significant potential for both negative and positive marine climate change impacts to occur. Regional coastal communities will benefit directly from being able to access marine climate change information and the opportunity to carry out a first pass adaptation assessment.

Even though some of the scientific papers that provide an overview of the community marine climate change impacts are still in preparation, it was obvious that residents in the case study coastal communities were observing change and able to relate some of these changes directly to marine climate change. Marine climate change was not always a high priority issue when considered in the context of other climate and non-climate issues, however, it was clear from case study interviews that the cumulative community level impacts were of interest and relevance. Residents in coastal communities are often keen observers of change (and increasingly reporters of change through REDMAP (www.redmap.org)), yet they were often less well informed of the potential scale of the flow on effects of change in their marine sectors to their communities. From the rigorous interview process in the case study communities it became obvious that there is a need to raise awareness and understanding of both the effects of marine climate change at the local level as well as the flow on effects into the community. It is also informative for coastal communities to comparing their climate change situation and potential impacts and adaptations to other regional coastal communities.

The case studies clearly showed regional differences in current perceived impacts and the specificity of marine climate change impacts on different marine sectors. Regional differences in marine climate change and impacts need to be clearly communicated (through the web-based blueprint). Importantly, even though there are regional differences in marine climate pressures, there are also national similarities in the impacts on marine sectors, providing opportunities to compare and learn from others.

The methodological approach to developing the adaptation scenarios taken in this research (using a qualitative modelling technique) provided a holistic overview of current marine climate and non-climate pressures and allowed comprehensive adaptation options to be developed. Even though qualitative modelling is a powerful approach (as proven in this research) it is not easily transferred or available for use by non-scientists. Until software is developed that allows the adoption of this modelling technique by non-scientists and community members other conceptual or mental models of the links and feedback systems have to be applied. The scientific implications of using qualitative models for community adaptation planning are significant which will be borne out in the eventual publication of the scientific papers.

It is difficult to attribute any direct monetary benefits of the research but it is expected that the community use of the web-based blueprint (coastalclimateblueprint.org.au), will bring benefits through increased awareness of marine climate change issues and the potential impact on marine sectors Australia wide. Wise adaptation planning should lead to increased efficiency in the long-term planning and use of marine resources and improved health of the community. Summarised, "quasi-generic", clearly communicated, and relevant marine climate change information will be accessible to all marine stakeholders and end-users and thus increase the knowledge and understanding of regional coastal community's vulnerability to marine climate change. Communities that use the web-based blueprint will benefit from the transparent process which does not depend on biological models only but also takes account of the social and economic dimensions. Over time, information collected through the blueprint will provide rich detail and an increasing amount of marine climate change context for users as more communities use the tool to assess their own situation.

Recommendations

Further development

1. Modelling tool

There are a number of research and other activities that could be undertaken to add-value to this current project. The first is that the qualitative modelling approach applied in the case studies (in steps 6 and 7) currently requires a scientist or expert to develop. However, as qualitative modelling is conceptually simple and easy to explain and understand, it would seem to lend itself to a web-based development tool or application that communities could use themselves. This would significantly reduce the cost of developing adaptation plans that are regionally specific and contain a high level of detail. There are a number of other instances where this self-guided development of qualitative models has been raised as desirable in future developments.

2. New information

The web-based blueprint has up-to-date state based and national information on climate pressures, species and commercial fisheries and aquaculture (coastalclimateblueprint.org.au). However, there is a lack of information on the other marine sectors – in particular charter fishing, non-extractive charters (e.g. whale watching) and the marine based renewable energy sectors. Generating spatially explicit maps that indicate where all the marine sector operate should be a priority.

3. Updating webpage (coastalclimateblueprint.org.au)

The interactions with community members as part of the case study component of this research suggested that members of regional coastal communities are often very interested in contrasting their own situation to that of other comparable communities; they felt that they can not only learn from others but it makes their own unique situation clearer. The web-based blueprint allows for users to submit their own data estimates and, as use of the web-based blueprint increases and data is generated, this comparing and contrasting of communities will become more sophisticated. The generation of web-based marine climate change and vulnerability information will also allow users to learn from others with respect to marine climate change adaptation planning.

4. Use as a communication tool

The web-based blueprint can be used as a communication tool in conjunction with other successful projects like REDMAP. For instance, the web-based blueprint can provide opportunities for users to report any observed social and economic impacts from marine climate change that is affecting their community. The ability to submit observations could, at a later stage, be an extension to be added to the web-based blueprint.

Planned outcomes

An important and tangible outcome of this FRDC/DCCEE project is a web-based blueprint for marine climate change adaptation for regional coastal communities. It is a simple tool intended to create a greater understanding of marine climate change and adaptation planning. Through use of the web-based blueprint, decision makers in coastal communities and marine based industries will be able to improve their knowledge and awareness of marine climate change issues regionally. In turn, this will lead to a greater understanding of the potential impact on marine sectors Australia wide. Summarised, clearly communicated and relevant marine climate change information will be easily accessible to all marine stakeholders and end-users. Over time the web-based blueprint will increase the level of knowledge and understanding of regional coastal community vulnerability to marine climate change, in particular in terms of the flow-on effects.

The issue of marine climate change is currently not central to adaptation and aside from sea level rise (not the subject of this report) is often overlooked. It is important to clearly communicate the potentially significant flow on impacts of marine climate change in regional coastal communities, especially as non-analogue futures and surprises are predicted.

As much research has been done to develop wizards and toolkits that outline how to develop, structure, and create a climate adaptation plan – it was not considered useful to make this the focus of this FRDC/DCCEE project. The most useful of these wizards and toolkits are referenced in this report and were used to inform this study and thus provided a structured and well established approach taken here.

Even though we used a more or less traditional approach to undertaking the adaption planning for the three case study coastal communities that were central to this study, we applied an innovative, conceptually simple, yet sophisticated way to describe the key community marine climate and non-climate pressures. Importantly we focused on frameworks to link the biophysical and human systems and to gain a clearer representation of the multitude of both climate and non- climate impacts that occur across the combined marine sectors. Through developing the qualitative models on the basis of the community interviews we were able to showcase a method for identifying a comprehensive set of adaptation options.

Through the three case studies we were able to document the current state of the marine sectors in each of the regions and the communities' observations, understanding and knowledge of climate change.

Conclusion

We used three case study communities to showcase a 10 step planning process to gather community level information and investigate marine climate and non-climate pressures on marine sectors in regional coastal communities. The information gathering process used for the case studies showed that many community members and in particular people associated with marine sectors have significant local knowledge and are keen observers of local change in the marine environment. Moreover, most members of the coastal communities show interest in learning the explanation for the changes they observe. Providing climate related explanations for change, while acknowledging the co-contributing role of non-climate pressures, provides a holistic perspective.

A holistic perspective on change can be incorporated into the development of an adaptation plan using qualitative information in a qualitative modelling framework. When applying a qualitative modelling approach to detail adaptations to the combined climate and non-climate pressures, probabilities can also be attributed to the potential adaptation outcomes.

The qualitative models revealed there were several high level marine climate change adaptations that appeared to be generally applicable to regional coastal communities but were also influenced by locally specific factors. For instance, new charter fishing opportunities were created by range shifting species. However, these opportunities were potentially more difficult to exploit in smaller coastal communities due to the seasonal nature of the tourism industry and the need to cross subsidise with other forms of income. It could therefore be challenging to gain momentum and benefit fully from this climate driven change and some industry facilitation could be appropriate in these smaller coastal communities. Even though the qualitative modelling approach adopted in this study to determine adaptation options is useful, the adaptations identified using this method are sometimes high level and can appear general.

From the case study interviews it was apparent that many people observe change in the marine environment. However, there appears to be a general lack of interest in developing adaptation option in response to these marine climate change pressures *per se*. Marine climate change is often perceived to be ‘inevitable’ and, therefore, manageable. This is particularly because people in marine sectors like commercial fishing are continuously adapting to change and this see climate as one more process of adaptation. Nevertheless, in this study we found there to be little extant knowledge of the potential flow-on implications of marine climate change in regional coastal communities. The consequences and impact of marine climate change on one marine sector may be readily observable, but the knock-on effects are not so evident and can in fact be very significant at the community level. It is, therefore, essential that these effects are more carefully considered. In the web-based blueprint these knock-on effects are illustrated and thus provide a conduit for individual communities to consider their own situation in more detail.

Appendices

Appendix 1 - Intellectual property

No commercially valuable intellectual property resulted from this research. Results are provided with no protection or confidentiality.

Appendix 2 – Staff

The following table lists personnel involved in the project

Name	**Government / organisation**
Steve Blake	WAMSI
Rae Burrows	Department of Fisheries
Nick Caputi	Department of Fisheries
Jeff Dambacher	CSIRO
Stewart Frusher	University of Tasmania
Marcus Haward	University of Tasmania
Alistair Hobday	CSIRO
Neil Holbrook	University of Tasmania
Sarah Jennings	University of Tasmania
Nadine Marshall	CSIRO
Gretta Pecl	University of Tasmania
Malcolm Tull	Murdoch University
Sarah Metcalf	Murdoch University
Anita Paulsen	Oceanwatch
Ingrid van Putten	CSIRO
Cassandra Price	Oceanwatch
Lowri Price	Oceanwatch
Jenny Shaw	WAMSI
Jay Shoesmith	Oceanwatch
David Schubert	Oceanwatch

Appendix 3 – Semi-structured interview questions

This is a face-to-face survey. The interviewer(s) will be able to probe the interviewee for detailed information for each question (and also explain the question to the interviewee if not understood).

Establish which business you're in that depends on marine resources
Which marine dependent economic activity are you engaged in?
How did you get involved in this activity (*prompt* – family business)
How long do you think you'll keep doing it?
Is your work in this job seasonal? i.e. do you do any other type of work throughout the year? (If yes, what type of work)?
How much of your income is dependent on this activity?
How many people do you employ? (and how many are family members)?
How much of you/your family time do you spend on this activity that is unpaid (*prompt* – average number of days you spend doing the books or repairs)
Has your income from this activity increased or decreased over the past 5 years?
Is your income from this activity susceptible to much yearly fluctuation?
Approximately how much did you turnover in the last 12 months
Which particular local goods and services your business depends on and supplies to
Which sectors do you buy from for your business (*prompt* diesel – tackle – boat slipping) Ask how much
Which sectors do you sell to (*prompt* fish restaurant – processors) Ask how much
Aside from your own business activity, can you tell me which other local sectors are directly dependent on marine resources (*prompt* commercial fishing – tourism)
Sorts of things the affect your business in the SHORT term
Which factors affect your business activity in the SHORT term? (*prompt* price of fuel – exchange rate – price of fish – cold storage – offloading facilities)
Can you tell me which of these short term factors are likely to *most affect* your business?
Can you tell me *how* changes in the short term factors will affect your business?
Have any of the changes in short term factors affected your business in the past?
Do you expect they will affect you in the future?
Is there anything that can be done now to prevent these things from affecting you in the future?
Is there anything that local or state government can do now to prevent these things?
Things that you think will affect your business in the LONG term (
Which factors affect your business activity in the long term (*prompt* government regulations – fish abundance – roads – offloading & processing facilities)
Can you tell me which of these long term factors are likely to most affect your business
Can you tell me *how* changes in the long term factors will affect your business
Have any of the changes in long term factors affected your business in the past
Do you expect they will affect you in the future?
Is there anything that you can do now to prevent these things from affecting you in the future
Is there anything that local or state government can do now to prevent these things
Things that affect you in the short and long term will have flow on effects in the local community (not only economic but also social)
Can you tell me how/why the things that affect your business will affect others and other sectors in the community?
Is there anything that you/local/ state government can do to prevent these things from affecting the rest of the community?

Appendix 4 – Project related media

Conferences:

- *Observations of change in the Marine Sector: preliminary results of a case study in St Helens, Tasmania*. Estuaries Science Forum, Hobart, Tasmania, May 2012.

- *A blueprint for adaptation to climate change in coastal communities. On Climate,* 5th Annual International Climate Change Conference, University of Washington, Seattle, July 2012.

- *Coping with change – adaptation in coastal communities.* NCCARF Conference, Perth

- *From physics to folk via fish – connecting the socio-ecological system to understand the ramifications of climate change on coastal rural communities*. International symposium on Climate Variability and Change on Marine Resources and Fisheries in the South Pacific, 7 – 10 January, 2013. Concepcion, CHILE.

- *From climate change to economic and social adaptation in coastal communities*. Oceans Past IV, 7 - 9 November 2012. University of Notre Dame, Fremantle, Australia

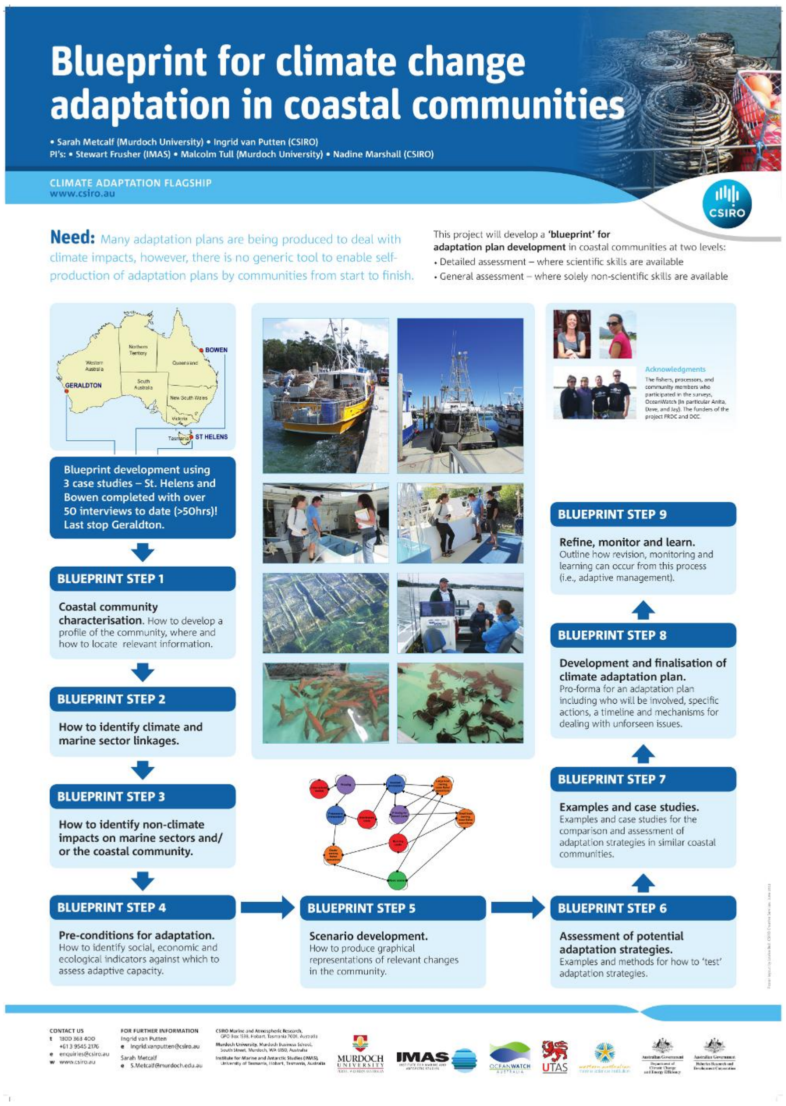
- *Adaptation Options for Coastal Communities: an Australian case study*. People and the Sea VII: Maritime Futures, 26 - 28th of June, Amsterdam.

Industry articles:

- Van Putten, I, Metcalf, S, Gartner, EA, Frusher, SD, *Are coastal communities in Australia ready for change?* Fishing Today 25, Feb/Mar, p. 25. (2012).
- Metcalf, S, Paulsen, A and Van Putten, I, *Change in coastal communities – St Helens Interviews Concluded*. Fishing Today.

Radio interviews:	ABC Radio country hour (Ingrid van Putten)
	Western Australian local Radio (Sarah Metcalf)
Community presentations:	St Helens councillors
	NRM group (Tasmania)

Conference poster NCCARF conference (Melbourne)



Flyers:

An adaptation blueprint for coastal regional communities

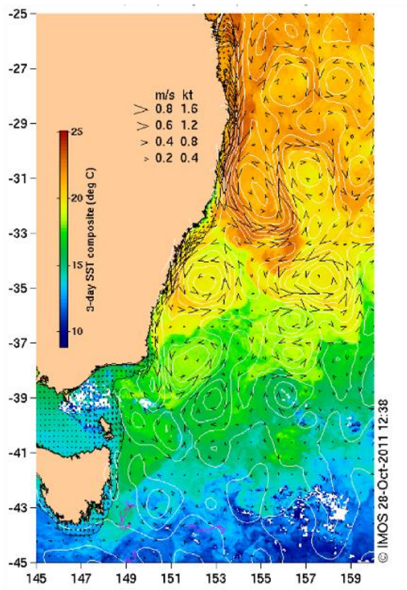
Coastal communities

Tourism

Commercial fishing

WHAT IS THE PROBLEM?

Commercial and recreational fishing, tourism, aquaculture, fish processing, as well as transport and other associated industries all depend on the marine environment. These marine dependent sectors contribute to the economic wellbeing of communities and impact the way the community operates. The economic health of marine dependent sectors has significant flow-on effects to other parts of the economy which affects the social fabric of the community.



Changes in the marine environment are expected to significantly impact small- to medium-sized rural coastal communities with marine-dependent sectors. Consequently, the need for effective adaptation in these coastal communities has been recognised.

WHAT NEEDS TO BE DONE?

Developing tools to reduce risks and increase capacity to cope with, and benefit from, change is urgently needed. These tools can't be developed unless we understand the needs, priorities, perceptions, and attitudes of people in the communities. Without such information, the ability to make timely and effective adaptation decisions will be limited.





What this project proposes to do?

St. Helens, Geraldton and Bowen have been selected to collect information on:

- the role of marine dependent industries in communities
- the connection of marine dependent industries to other economic activities
- the role of marine dependent industries in the social fabric of communities
- the predicted effects of change

Community consultation dates

St Helens (Tasmania): February and March
Bowen (Queensland): June and July
Geraldton (Western Australia): September and October

The outcomes of the project will enable industries, governing bodies, communities and individuals to make informed decisions to maximise opportunities for the future. What we learn from this project could also address the needs and priorities of coastal rural communities throughout Australia.

We will spend time in each community to give you an opportunity to have your say.

To register your interest or for more information please contact your local Oceanwatch representative or the researchers listed below:

OceanWatch

St. Helens, Tasmania:
Anita Paulsen, (03) 6224 2890, 0407 135 637
anita@oceanwatch.org.au

Geraldton, Western Australia:
Jay Shoesmith, (08) 9432 7777, 0401 838 436
jay@oceanwatch.org.au

Bowen, Queensland:
Dave Schubert, (07) 4773 7226, 0409 347 495
dave@oceanwatch.org.au

Sarah Metcalf (Murdoch University)
(08) 9360 7833
s.metcalf@murdoch.edu.au

Ingrid van Putten (University of Tasmania, CSIRO)
(03) 6232 5048
ingrid.vanputten@csiro.au

Project leadership team:
Stewart Frusher (University of Tasmania), Nadine Marshall (CSIRO), Malcolm Tull (Murdoch University)

Photo credits: Tony Cooper, IMAS, OceanWatch

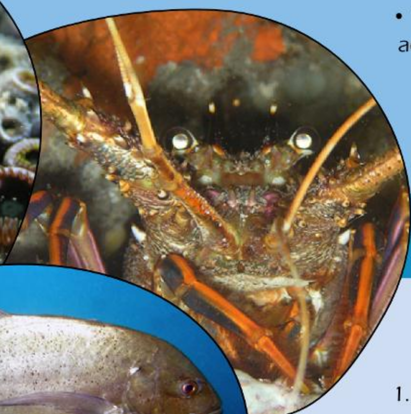
FRDC 2010/542

An adaptation blueprint for coastal communities

Project Background

Commercial and recreational fishing, tourism, aquaculture, fish processing, as well as transport and other associated industries all depend on the marine environment. These marine dependent sectors contribute to the economic and social wellbeing of communities and impact the way the community operates. The economic health of marine dependent sectors has significant flow-on effects to other parts of the economy which affects the social fabric of the community. Changes in the marine environment, such as those expected from climate change, are likely to significantly impact small- to medium-sized rural coastal communities with marine-dependent sectors. Consequently, the need for effective adaptation in these coastal communities has been recognised. Developing tools to reduce risks and increase capacity to cope with, and benefit from, change is urgently needed. These tools can't be developed unless we understand the needs, priorities, perceptions, and attitudes of people in the communities. Without such information, the ability to make timely and effective adaptation decisions will be limited.

Project Outline



St. Helens in Tasmania, Geraldton in Western Australia and Bowen in Queensland have been selected to collect information on:

- the role of marine dependent industries in communities;
- the connection of marine dependent industries to other economic activities;
- the role of marine dependent industries in the social fabric of communities; and
- the potential impacts on the community from changes in the utilisation of marine resources due to a changing climate.

Outcomes

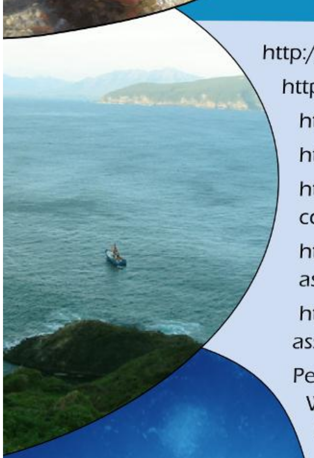
From the information collected, the project will develop a 'blueprint' for adaptation plan development in coastal communities at two levels:

1. A detailed assessment – where scientific input is available.
2. A general assessment – where scientific input is not readily available.

Benefit to the Community

The outcomes of the project will assist industries, governing bodies, communities and individuals to make informed decisions to maximise opportunities for the future. The location and case studies (i.e. size of town and types of industries) were chosen to enable our results to also address the needs and priorities of coastal rural communities throughout Australia. We are spending time in each community to learn about their marine industries. To register your interest or for more information please contact your local OceanWatch representative or the researchers listed below.

More Info



http://www.oceanclimatechange.org.au

http://www.climatechange.gov.au/publications/coastline/east-coast-rock-lobster.aspx

http://www.redmap.org.au/

http://nccarf.edu.au/marine

http://www.daff.gov.au/fisheries/environment/climate_change_and_fisheries/cc-action-plan-fish-aquaculture

http://www.imas.utas.edu.au/__data/assets/pdf_file/0019/221923/Risk-assessment-report_Part1-Fisheries-and-Aquaculture-Risk-Assessment.pdf

http://www.imas.utas.edu.au/__data/assets/pdf_file/0017/222092/Risk-assessment-report_Part2-Species-profiles-02.pdf

Pearce A, Lenanton R, Jackson G, et al (2011) The "marine heat wave" off Western Australia during the summer of 2010/11. Fisheries Research Report No. 222. Department of Fisheries, Western Australia. 40pp.

Contact

Dr Stewart Frusher, University of Tasmania.
Email: stewart.frusher@utas.edu.au; Ph (03) 6226 1771

Dr Nadine Marshall, CSIRO Townsville.
Email: Nadine.Marshall@csiro.au; Ph (07) 4753 8537

Dr Malcolm Tull, Murdoch University.
Email: M.Tull@murdoch.edu.au; Ph (08) 9360 2397

Photo credits: G. Carlos, T. Cooper, G.Pecl, Institute for Marine and Antarctic Studies (IMAS).

The National Climate Change Adaptation Research Plan (NARP) for Marine Biodiversity & Resources identifies research priorities in five sectoral areas: marine aquaculture, commercial & recreational fishing, conservation management, tourism & recreational uses, and cross-cutting issues.

Australian Government
Department of Climate Change and Energy Efficiency

Australian Government
Fisheries Research and Development Corporation

NCCARF National Climate Change Adaptation Research Facility

NCCARF National Climate Change Adaptation Research Facility
Adaptation Research Network MARINE BIODIVERSITY AND RESOURCES

OCEANWATCH AUSTRALIA

western australian marine science institution

UTAS

IMAS INSTITUTE FOR MARINE AND ANTARCTIC STUDIES

CSIRO

Murdoch UNIVERSITY

Other media

News article in Geraldton newspaper

> Geraldton is this week playing host to the third stage of The National Climate Change Adaption Research Plan for Marine Biodiversity and Resources.
>
> In a joint venture with Murdoch University, the University of Tasmania and the CSIRO, a team of researchers have travelled here to work on 'an adaption blueprint for coastal regional communities'.
>
> Dr Sarah Metcalf of Murdoch University and Ingrid Van Putton from the CSIRO have been joined by Jay Shoesmith from OceanWatch Australia to study the Midwest region.
>
> They are here wanting to talk to anyone involved in the marine industry, whether that's commercial or recreational fishing, marine tourism or aquaculture to find out what changes these people have seen, either in the environment or in management practises.
>
> They are also interested in talking to local businesses to see how changes in the marine sector might flow through to them as well as seeing how they have coped with other changes such as in mining and tourism.
>
> This is part of a two year project funded by the Department of Climate Change and Energy Efficiency and the Fisheries Research and Development Corporation which started in November of 2011.
>
> The intent of this is to make a comparative case study between the three geographical locations under investigation.
>
> The first of these is St Helens in north east Tasmania which is a town of about 3000 people and largely fishing oriented.
>
> The second is Bowen in Queensland, just south of Townsville with a population of around 10,000 and a fishing industry based around reefline fishing.
>
> OceanWatch are involved with this because of their connections into local communities, they are an extension service for the commercial fishing industry and enable researchers to gain easier access to the industry players.
>
> Dr Metcalf says they are trying to connect the environmental changes to social and economic changes within the towns.
>
> 'Fisheries have all declined in the different areas for different reasons and they have all experienced different types of climate events or climate drivers, whether that's increased rainfall events or in Queensland, the cyclone sequences that cause a change'.
>
> Scientists have been working on these patterns they're seeing in the oceans and are recording a rise in water temperature.
>
> On the east coast of Tasmania a 4 degree average temperature increase has been noted over the past fifty years.
>
> The consequences of this have been noticed by people and it is fishermen who are really aware of this because they are on the ocean all the time.

Media releases

Tasmanian project media release (adapted for Bowen and Geraldton)

MEDIA RELEASE

NEWS FROM THE UNIVERSITY OF TASMANIA

DATE: TUESDAY 7 FEBRUARY 2012

ATTENTION: Chiefs of Staff, News Directors

UTAS

Preparing coastal regional communities for changes in the marine environment

Coastal regional communities will be given a helping hand to adapt to changes in the marine environment with a new research project.

The project is titled *A climate change adaptation blueprint for coastal regional communities*.

Researchers from the University of Tasmania, Murdoch University and CSIRO are to visit and study the consequences of change in St Helens in Tasmania, Geraldton in Western Australia and Bowen in Queensland.

Principal Investigator, Associate Professor Stewart Frusher, from the Institute for Marine and Antarctic Studies (IMAS), said researchers will travel to each town to identify what changes are already occurring, as well as those that might occur in the future.

"Marine-dependent sectors contribute to the economic wellbeing of communities and impact the way the community operates.

"Industries such as commercial and recreational fishing, tourism, aquaculture, fish processing, transport and other associated industries may be affected by changes to nearby marine ecosystems.

"Consequently, coastal communities are expected to be significantly affected by marine-related changes," Prof Frusher said.

Prof Frusher said they would like to gather information from people working in local industries, as well as general community members to develop a comprehensive picture of the contribution and flow-on effects of marine industries to the local economy and social fabric of the community.

"We're interested in finding out about changes people have observed in their local community and how it has affected them," he said.

"We're also interested in what community members expect will change in the future, and to identify ways to both benefit from opportunities and deal with threats in the context of climate change."

1

Data collection will occur in St Helens from mid-February to mid-March and researchers would like to speak to a broad range of people from fishers, to those working in related industries, local government workers as well as community members interested in the future wellbeing of the community, local industries, climate and science.

"Those interested are encouraged to meet with the researchers to share their opinions on the various subjects," Prof Frusher said.

The key aim of the project is to develop tools to identify risks to the community and increase the capacity to cope with and benefit from change in coastal communities. The researchers will spend an extended period of time in each community to make sure everyone gets a chance to have their say.

"The research will enable industries, governing bodies and individuals to make informed decisions based on the best information available so as to maximise opportunities for the future," he said.

This study has been funded by the Department of Climate Change and Energy Efficiency and the Fisheries Research and Development Corporation.

Media opportunity:

Associate Professor Stewart Frusher, Dr Sarah Metcalf and Dr Ingrid van Putten are available for interview on Wednesday from 12.30 to 1.30pm at CSIRO's Freycinet Room in Hobart. Dr Metcalf and Dr van Putten will be undertaking the research in communities.

Anyone living in the designated coastal communities who wants to be involved should contact their local Oceanwatch representative: Ms Anita Paulsen (6224 2890, 0407 135 637), or the researchers Dr Ingrid van Putten (6232 5048) or Dr Sarah Metcalf (08 9360 7833) to register their interest.

Information Released by:
The Communications and Media Office, UTAS
Phone: (03) 6226 2124 or 0438 510 616
Email: Media.Office@utas.edu.au

Appendix 5 – Paper 1: A literature review of the social aspects of community adaptation

1. Introduction

A realisation that behavioural changes are required to mitigate climate change effects has developed since the 1970s when the warming of our climate was first linked to human activities (e.g. Bryson 1974; Bryson and Wendland 1970). Since this time, considerable efforts have been placed on investigating the ecological, economic, and social impacts of climate change (e.g. Pattiaratchi and Buchan 1991, Watson et al. 1998, Hoegh-Guldberg 1999, Hughes et al. 2003, Marshall et al. 2010). In Australia, mitigation measures have been applied to achieve behavioural change including the implementation of strategies and policies at all levels of government that will lead to emission reductions (Productivity Commission 2012). However, there is also a realisation that some level of climate change is inevitable irrespective of emission reduction strategies (IPPC 2001; Productivity Commission 2006). Households, firms, organisations, and governments have to respond and adapt to the impacts of climate change that cannot be avoided through climate change mitigation efforts, such as the gradual warming of our climate and increases in sea level (Productivity Commission 2012). Adaptation involves all levels of community and society and requires processing information about climate change, assessing risks and selecting adaptation responses. Climate risk should ideally become a normal part of short- and long-term planning and decision making (Productivity Commission 2006; 2012).

The need for society to adapt is reflected in the attention given to the subject in a governance framework (e.g. Pielke et al. 2007, Kern and Alber 2008) and by the exponential growth in scientific research published on climate change adaptation (Eakin and Patt 2011; Preston and Westaway 2010; Preston et al. 2011b; Yuen et al 2012). There has been an increasing focus on individual and societal adaptation to climate change, although the theoretical construct or empirical reality is not new (Adger et al. 2009). Humans have lived with adaptation to climate change and variability for a long time and developed ways of coping (Glantz 1988; Burton et al. 2002; Ford and Smit 2004; Smit and Wandel 2006; Dovers 2009; Ford et al. 2010b; Ford and Berrang-Ford 2011). However, the window of opportunity for adaptation to predicted future climate change and variability may be somewhat narrower due to shorter expected time frames for future impacts in comparison to the past (Adger and Barnett 2009; Parry et al. 2009b; Ford and Berrang-Ford 2011).

A large proportion of adaptation to climate change will occur autonomously, much as it has in the past. For instance, adaptation may occur through pricing and market signals. However, barriers to adaptation are evident and likely to arise in the future (e.g. Härtel and Pearman 2010). Barriers may become apparent due to certain market characteristics, institutional and governance arrangements, or government policies (Productivity Commission 2012). At the same time as these seemingly external factors, barriers may simply be cognitive and result from the way people make decisions. The significant behavioural component to adaptation will require the development of pathways, strategies and policies that enable and assist adaptation (Productivity commission 2012).

There is a need to better understand the variables that contribute to autonomous and facilitated adaptation and the barriers that may arise. In other words, there is a need understand the variables that explain the capacity of individuals, communities, businesses and governments to adapt. Gaining this understanding is by no means simple, firstly due to the scale at which the capacity to adapt can be assessed. The scales range from the individual (Marshall and Marshall 2007), household and community levels of organisation (Adger 2000, Berkes and Folke 1998, Berkes and Jolly 2001; Cinner et al. 2009) to national assessments (Adger and Vincent 2005; Nelson et al. 2007). Moreover, as indicated above, behaviours at the individual and societal levels are contingent upon a wide variety of barriers (Adger et al. 2009). It is however, important to gain a comprehensive understanding of this complex issue as adaptive capacity influences, and reduces, vulnerability to climate change effects and hazards (Adger 2006; Adger et al. 2005; Rapport et al. 1998).[8] When communities are resilient they will take deliberate adaptation action to reduce risks with the goal of avoiding impacts and accelerating recovery (U.S. Indian Ocean Tsunami Warning System Program 2007). At the conceptual level, a resilient community is one that has the capacity and resourcefulness to develop effective ways of coping positively with adversity and with change (Marshall et al 2010).

In this paper we review the literature on the social variables that contribute to community adaptation to climate variability and climate change. In addition, we provide reasoning for the methods we have applied in the project "A climate change adaptation blueprint for coastal regional communities" (Blueprint Project), based on documented scientific evidence. Even though the social component of community adaptation is of primary interest it is inextricably linked to the behavioural and cognitive aspects of individual decision making. There are many examples of individual cognitive biases and anomalies in decision making that will affect adaptation to climate change (e.g. Productivity commission 2012), such as availability bias, anchoring, choice overload, dealing with low probability events, framing present bias, loss aversion, and status quo bias (Camerer and Kunreuther 1989; Iyengar and Lepper 2000; Johnson and Goldstein 2004; Kahneman, Knetsch and Thaler 1991; Thaler 1981; Tversky and Khaneman 1973, 1974, 1986). Given the breadth of literature on these subjects we do not discuss them in detail but refer to them where appropriate.

There are three other components of the adaptation literature we do not explicitly review here. Firstly, the importance of the institutional contexts of adaptation has been demonstrated to be important in shaping adaptive responses (Adger 2001; McBeath 2003; Næss et al. 2005). The sum of evidence underscores that unless institutional and decision structures are deliberately included in efforts to adapt, and the values at the foundation of the decisions are made explicit, the barriers arising from governance mechanisms are unlikely to be addressed. At the policy level, adaptation policies, like many other areas of public policy, are constrained by inertia, cultures of risk denial, and other phenomena well known in policy sciences (Adger et al. 2009; McLeman et al 2011). Engaging resource managers in issues of climate change is necessary but insufficient to assess underlying vulnerabilities and barriers (Moser and Dilling 2007; Moser and Luers 2008; Moser and Tribbia 2008; Tribbia and Moser 2008). In this review we acknowledge the importance of the institutional context to adaptation but we do not explore the governance component further. Secondly, in this review we also do not detail any of the well-known economic variables, for example, profitability, assets, equity, markets, product diversity that contribute to explaining resilience at an individual and community level. Lastly, the review also does not explicitly consider the resource component of resilience and adaptive capacity. There is a well-established literature that indicates that overdependence on a small set of resources and activities reduces resilience and adaptive capacity (e.g. Leman et al. 2011).

2. Community adaptation to climate change

There is a history of both theoretical and empirical research on adaptation. Empirical evidence suggests that adaptation is highly context-specific (e.g., Risbey et al. 1999; Eriksen et al. 2005 quoted in Wolf 2011). Community characteristics, including demographics and social and economic community structures, must be understood alongside other variables that explain adaptation. The differences between communities can sometimes provide insight into why some are better able to adapt than others. These differences can also provide insight into variables that prevent adaptive behaviour or barriers to adaptation. Understanding the variables that explain adaptive capacity provides an opportunity to identify pathways that enhance adaptation strengths and diminish the barriers. The use of case studies is a well recognised and appropriate methodological approach for better understanding context specific adaptation variables and allows the development of generic adaptation strategies.

At a general level, behaviours at the individual and social levels are contingent upon a wide variety of factors (Adger et al. 2009) and research explaining adaptation behaviour originates in multiple disciplinary fields including sociology, psychology, anthropology, and economics. To gain an overview and understanding of all factors and interactions that explain adaptation behaviour at the community level is by no means simple. For example, characteristics that operate at the individual level include beliefs,

[8] Adaptive capacity and resilience both refer to the ability to deal with uncertain future impacts. Vulnerability can be defined as resulting from those "characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist, and recover" from an impact (Wisner et al. 2004)

preferences, perceptions of risk, knowledge, experience, habitual behaviour, and norms and values. Societal adaptation behaviour is known to be contingent on ethics, knowledge, attitudes to risk (Adger et al. 2009), perception of vulnerability and impacts, social and institutional context, and values (Wolf 2011). Research on the social dimensions of adaptation highlights aspects of local context, such as social capital and cultural norms, which are important in the context of adaptation because they determine how societies interact with climate change and variability (Adger 1999, 2003; O'Brien et al. 2006; Moser and Tribbia 2008; Wolf et al. 2009 quoted in Wolf 2011). The variables that operate at the community level are likely to be a combination of the above mentioned and include the capacity to learn; capacity to reorganise; community assets; flexibility; gender relations; environmental institutions and social norms; culture of corruption; and markets (Marshall et al 2010).

The relationships between variables that explain adaptation behaviour at the individual, community, and societal level are not always linear or positive. For instance, perceptions, values and norms may enable or constrain action, thus either encouraging or limiting adaptation (Adger et al. 2009). The interactions between the variables that explain adaptation are even more complex in that the principals of multi-collinearity apply. For instance, there are multiple aspects to the internal relationship between demographic changes in coastal communities and adaptation. Around the world coastal communities are experiencing an unprecedented rate of change due to population growth in coastal areas (U.S. Indian Ocean Tsunami Warning System Program 2007). Previously small coastal communities have experienced an influx of older residents which changes the community structure and demographics. Age structure in itself has been linked to social capital, in that increases in average age are associated with greater social capital, which has, in turn, been linked to increasing adaptive capacity (Wolf 2011). However, an ageing population often also means a greater need for service provision which places demands on the government funding system, which in turn may detract from the community's adaptive capacity. At the same time, higher levels of wealth are sometimes brought into small coastal communities by a growing population of relatively wealthy retirees. Economic resilience of communities can increase with more wealth. But some authors question the relationship between presumed high adaptive capacity associated with wealth (O'Brien et al. 2006; Pielke et al. 2007; Moser and Luers 2008 quoted in Wolf 2011). It is evident from this demographic example that explaining community adaptation, even if only considering demographic variable age distribution, is by no means simple.

Nevertheless, effective adaptation strategies should be informed by a deeper understanding of the variables that contribute to individual, community, and social process of adaptation. Identification and assessment of the range of barriers to adaptation can further aid the development of effective adaptation strategies (Wolf et al 2009; 2011). Such information must be garnered directly from the community to ensure the identified adaptation strategies are effective. In the sections below we review the literature on the social and behavioural variables that explain community adaptation to climate-driven change and barriers to adaptation. We then identify pathways that enhance positively contributing variables and diminish barriers to adaptation. However, the description of these pathways is necessarily general as specific communities information must also be considered for useful and practical adaptation pathways to be identified.

We commence our review focussing on the role of access to information in the adaptation process. We review the information access literature to provide a solid basis for the remainder of the review even though information access is not central to the Blueprint project but is the main focus of a related FRDC project, the 'Knowledge Project'. The Knowledge Project has the role of determining current climate change knowledge levels and climate change information provision to coastal communities. Fundamentally the Knowledge Project and the Blueprint Project are linked as information, knowledge, and awareness are correlated. After all if the information is provided in an appropriate and accessible format it will create knowledge and awareness of climate risks which in turn creates recognition of the need to adapt.

2.1 Information

There is a clear recognition of the important role information plays in adaptation behaviour. Information can improve the understanding of the consequences of a changing climate and both the challenges and opportunities it presents (Boyd et al 2011). Information informs risk management decisions about when and how to best adapt, and allow adaptation actions to be prioritised (Productivity Commission 2012). Leadership and community members need to use risk information when making decisions about adaptation (Productivity Commission 2012). Lower levels of knowledge and awareness reduce the likelihood of autonomous or assisted adaptation to climate change.

Effective adaption requires individuals to absorb complex scientific evidence on the impacts of climate change and to choose between different adaptation options based on their perceptions of the costs and benefits. This necessitates individuals to incorporate the uncertainties of climate change into these decisions. Research has shown that cognitive aspects will impact on these complex decision making processes. For instance, people can struggle to gather and process complex information and as a result take short cuts, such as simply deciding to repeat past behaviour, in order to make decisions, either consciously or subconsciously (Crowle and Turner 2010). Decisions that are chosen out of habit could result in sub-optimal adaptation.

Simply providing more information on complex climate change impacts or adaptation options may not improve matters (Nicholls 1999). For already complex issues it is cognitively difficult to assimilate multiple sources of information and make sense of them. Shafir (2008) noted that the existence of multiple choices may reduce the likelihood of a rational decision, and may lead to the decision maker delaying an adaptation decision indefinitely (Productivity commission 2012).

Too much information may create problems but imperfect and inadequate information can also lead to inadequately-informed decision making and have direct negative effects (Productivity Commission 2012). Inconsistencies in information can also create problems as it could, for instance, entrench the divide on the cause of climate change found by Leviston and Walker (2011) who find that, while most of the 5036 Australian survey respondents believe climate change is happening, they are divided on the cause: approximately half think that it is human-induced and half that it is solely attributable to natural causes.

Research on public understanding of global warming has focused mainly on the inadequacies in understanding (Stamm et al. 2000). Kuruppu and Liverman (2011) point out that a vast knowledge requirement related to climate science and adaptation in general exists among the grassroots. Just as better weather forecasting could improve the ability of the community to manage current climate risks, better information about climate change could improve the community's ability to plan for future climate risks.

There is a need for consistent, ongoing and diverse education programmes, as adaptation is a continuous process of learning and reflection (Folke, 2006). In order to combat information issues, communities need to be equipped with skills and tools on how to deal with information that is relevant for adapting to a changing climate (Boyd et al. 2011). These skills and tools crucial to effectively adapt to climate change and to manage risks can include models - such as those developed in the Blueprint Project - that help put the aspects of information into context.

2.1.1 Downscaling, local knowledge, and experience

A variable that makes information more meaningful and thus significantly contribute to adaptation is the provision of information at the local level (Kuruppu and Liverman 2011). Local level information makes it easier to conceptualise the impacts of climate change and thus be open to adaptation. Especially in the absence of accurate schematic representations of climate science, observations of existing local pressures, for which schemas had been developed, make it easier for people to assimilate and associate climate science (Kuruppu and Liverman 2011). It is easier to digest 'observed' secondary drivers of climate change and their impact (e.g. local sea level rise) than 'climate science *per se*. The limited availability of local climate change information and the lack of knowledge of impacts at a local level are often highlighted as a cause of concern.

Individual and community knowledge of local level climate impacts are created though directly experiencing extreme climate events, which tends to shape the perceptions of future climate (Cruikshank 2001; Huntington and Fox 2005). The perception of risk associated with climate change is generally considered remote and removed from direct personal experience (e.g., Bord et al. 1998; Kirby 2004; Lowe et al. 2006; Stamm et al. 2000) but its cognitive presence increases through more immediate extreme experience (e.g., Germany, Höhle 2002). Direct and often catastrophic experiences of extreme climate events are likely to have a significant impact of adaptive behavioural responses.

As mentioned above, behavioural change follows the processing of information about a concept, understanding it and being able to relate to it (Hughes, 2006). Translating the complexities and uncertainties of global climate change science 'into the language of popular culture' is a challenging task (Lorenzoni and Pidgeon 2006, p. 74; Trumbo and Shanahan 2000). The general public frequently struggles to interpret the scientific jargon, conceptualise the risk and relate global scenarios to their personal experience (Swim et al.

2011; Weber and Stern 2011). This is one problem faced by the Knowledge Project, in particular, but also the Blueprint Project if the adaptation strategies that will be identified are to be of use in the case study communities. Downscaling the impacts to the local and linking them to people's existing circumstances and experiences (Kuruppu and Liverman 2011) in many cases increases cognitive accessibility (Buys et al 2012). This again illustrates the need for case study specific information prior to the development of generic strategies for change and suggests the use of educational tools that link climate impacts to the local level will enhance the final outcome through a greater willingness to adapt.

Even though the localised impacts are easier to fit into a cognitive framework, thus contributing to adaptive behaviour, local knowledge and direct experience do not always make it easier to conceptualise climate change and thus be open to adaptation. In examining perceptions of drought and climate change among Australian farmers, Milne et al. (2008) found that most farmers attribute drought conditions to local stresses rather than climate change alone. Farmers were also reluctant to attribute local climatic changes to the global climate change (Kuruppu and Liverman 2011). It is sometimes not possible to separate climate-related risks from the broader range of environmental stressors to which adaptation is also required. Moreover it is difficult to separate the impacts of environmental and socioeconomic changes. Changes in climatic conditions and events are only one element in this complex set of interactions (McLeman et al. 2011). The daily challenges that contemporary farmers face have been identified as key barriers limiting their acceptance and willingness to act on climate change (Fleming and Vanclay 2009; Nursey-Bray et al 2012). Additionally, a barrier to adaptation is created through the need for convincing evidence that climate change will be more extensive and intensive than the previously observed climatic variability (Fleming and Vanclay 2009).

Even though there is some evidence to indicate the contrary, there largely is support for the notion that the likelihood of adaptation to climate change is greater through the provision of information with greater relevance to the local scale, conceptualising the information through an observable process, and direct (sometimes extreme) experience. Additionally, personal participation in gathering local information that underpins climate science creates a sense of contribution to and involvement in the scientific process and provides increased cognitive understanding and thus enables adaptation decisions.

There are clear benefits of using local non-scientific knowledge in climate change studies (Orlove et al. 2000; Riedlinger and Berkes 2001; Berman and Kofinas 2004). Especially where data are limited, detailed observations of change as reported by local residents (related to specifics of timing, frequency, severity, etc.) can be of significant value in a formal scientific context (Marin, 2010). Kuruppu and Liverman (2011) found that changes observed by local resident of temperature and rainfall changes were consistent with the historical trends. However, many have been critical of the integration of local knowledge as decontextualised data within a scientific framework (Cruikshank 2001; Berkes 2002), and discussions remain over whether and how to overcome differences in epistemology as well as methodological, institutional and political challenges (Adger et al. 2009).

As part of the Blueprint project local non-scientific knowledge and evidence of local change is gathered from local residents. Local change as observed by community residents includes climate related changes in the marine environment (a central topic of the Blueprint project) but also social, economic and governance changes that affect their community. The applied project methodology allows climate induced changes to be put into a whole of system context – at the same time allowing the researchers to develop an understanding of the perceived role of climate change in the community and elicit adaptation pathways that consider other relevant changes and thus take a more holistic and systems approach.

2.2. Risk perception

Similar to the effect of information at a local scale, direct experience, and conceptualisation through an observable process on adaptation behaviour, risk perception and a person's own perceived adaptive capacity also contribute to individual-level proactive adaptation. Perception of risk operates at individual decision-making levels but also constrains collective action.

There is a long history of studying decision making under risk. The topic has been dealt with perhaps most famously in the economic literature (e.g., Kahneman and Tversky 1979) but is equally important to research originating in the psychological, social, and anthropological sciences (e.g., Edwards 1954, Slovic 1987).

Individual adaptation hinges on whether an impact, anticipated or experienced, is perceived as a risk and whether it should (and can) be acted upon. Accepting that one is at risk of exposure to an impact of climate change is not simply a function of information, awareness, or knowledge. Direct experience, like information access, also influences risk perception and individual acceptance of personal risks (Keller et al. 2006) and the recognised need to adapt. However, direct experience has also been shown to have the opposite effect and reduce adaptation response where there is a belief the risk is inevitable and cannot be prevented (Wong and Zhao 2001; Wolf 2011).

There is a growing amount of research into the way individuals process the disparate information they receive concerning risks for which the underlying science is uncertain. Indications are that the subjective risks vary across types of people (Cameron 2005). Risk perception interacts with underlying value systems, translating into risk types. Value systems and risk perceptions shape adaptive behaviour (Adger et al. 2009). Divergent goals for adaptation emerge, in part, from different attitudes to risk (risk-takers versus the risk-averse), to disposition (a progressive versus conservative ethos) and to the adaptive capacity of future generations (optimistic versus pessimistic) (Adger et al. 2009).

The process of assessing risks with respect to adaptation also includes the psychological dimension of efficacy of beliefs (Narayan 2006) and the cognitive perception of whether the process of adaptation and interventions are likely to be effective. An individual's belief in their own abilities to manage climate impact and thus reduce risk will have an effect on their perception of the likely effectiveness of adaptation and thus plays a crucial role in driving intentions to adapt. Kuruppu and Liverman (2011) point out there is a need for greater attention to be placed on understanding the underling drivers shaping such beliefs. Bandura (1995, p. 8) indicates that "people's beliefs in their coping capabilities affect how much stress and depression they experience in threatening or difficult situations, as well as their level of motivation" can explain adaptive behaviour (Kuruppu and Liverman 2011).

The provision of integrated investigative tools to community members that allows them to simulate the changes they expect will happen in their locality and to assess the effectiveness of likely adaptation responses may be a valuable tool in increasing understanding and adaptive capacity, and making explicit the risks associated with climate change. This type of tool can be developed using programs such as Vensim or Stella which can include risk assessments. An integrated assessment tool, with the capacity for community-specific data input, can form the basis for the identification of potential adaptation strategies in other coastal communities (a central theme of the Blueprint Project). The collection of case study specific data to underpin the development of such integrative tools must be undertaken prior to the assessment of potential adaptation strategies.

2.3 Beliefs, attitudes and values

Case study specific data collection must be undertaken prior to the production of any generic adaptation decision tool because many of the variables that explain adaptation behaviour are related to individual cognition. When conceptualising adaptation as a social process it becomes apparent that values are inherently embedded in how climate risk is perceived (Adger 2009). Values translate into action because they frame how societies develop rules and institutions to govern risk and how they manage social change (Ostrom 2005) all of which are relevant to adaptation.[9]

Values in society are not held in isolation and are different for the various stakeholders. Values that underpin adaptation decisions become more diverse and contradictory moving up from small-scales and single agents to larger-scales and multiple agents (Adger et al 2009). The variation in values translates into the existence of diverging goals of adaptation to climate change. These goals will differ within a sector, a society, between nation states and, most intractably, between different generations. Adaptations that address concerns of one set of values may not address those of a different and competing set of values. The bottom line is that unless there is support for the values that lead to proactive adaptation initiatives, the practical implementation of broader adaptation activities remains questionable (Adger et al. 2009).

---

[9] Values are central, core ideals about how people conduct their lives. Values are much more stable (and difficult to influence) than beliefs and attitudes. Values reflect a person's sense of right and wrong or what "ought" to be. Beliefs are what people personally "know" to be true. They are 'convictions'. Attitudes evaluate and express opinion on an issue comprising likes or dislikes.

There is no easy way to change people's values and related goals. Particularly because people tend to ignore, and not seek out, information that is inconsistent with their current views, and additional information can tend to cement their pre-existing views (Kahneman 2011; Nicholls 1999). Despite this difficulty changing values is an important issue particularly as there is a growing literature around environmental attitudes and the fact that a stewardship ethos reduces vulnerability (Leman et al 2011) and increases the likelihood of adaptation. A stewardship ethos sees the combined social and environmental well-being of the community for the long-term as being preferable to short-term economic gains (McLeman et al. 2011). Related to this is a current recognition of the linkages between environmental stewardship and capacity building.

2.4 Social capital

Similar to the fact that information accessibility and risk perception explain adaptation, social capital offers another way of understanding the role of fundamental social attributes that contribute to the response and adaptation to climate change (Pelling and High 2005). Social capital offers a lens through which the role of social networks and norms in the production of adaptive capacity is studied (Pelling undated).

Adaptive capacity is strongly influenced by social capital and social networks. Pelling (2002, 2003) distinguishes between informal and formalised social capital. The former can be found in neighbourliness, friendship or kin group support, and the latter in officially recognised civic associations. Informal social capital networks are particularly valuable in enabling critical thinking and alternative actions to be taken in the face of unexpected shocks. The position of individuals in social networks and institutions informs and influences adaptation behaviours (Crane et al. 2011). There are multiple pressures that lead to changes in the quality and quantity of formal and informal networks, and so to the building up or breaking down of access to external resources or capacity to mobilise internal community resources for adaptation. Adaptive capacity is continually being reshaped through the dynamics of social relationships. Where social capital is attuned to the imperative of adaptation it can offer a resource for reflexive adaptation.

The effects of social networks do not always contribute to positive outcomes with respect to adaptation. Investigating water use in Australia, Miller and Buys (2008) find that different aspects of social capital can have different implications, with some aspects having negative consequences on the community as a whole. Strong bonding ties can contribute to vulnerability of a population rather than reduce it, as suggested by a recent study of elderly people's responses to heat wave risk in the United Kingdom (Wolf et al. 2010).

Social capital is not only related to social networks, it is a dynamic concept and is sensitive to changes in many observable community characteristics. For instance, social capital is a function of in the demographic conditions of the community, especially in terms of its age structure and cultural makeup.

There remains a range of unresolved issues in the literature that limit the explanatory power of social capital. Perhaps most important is the lack of clarity over whether social capital is a dependent, independent or intermediary variable. This is an important concern in using social capital as an indicator of vulnerability and as a focus for policy attention to enhance adaptive capacity. For policy makers, the question remains whether to build social capital on the basis of top-down and bottom-up strategies (Williams, 2003).[10]

3. Communicating climate change

Adaptation responses to climate change are influenced by both psychological and socio-cultural factors (Leiserowitz 2006). Information presented at a local scale and conceptualisation through an observable process affect the likelihood of community adaptation. Direct experience will impact risk perception which in turn will have an effect on the adaptation response. While it is important to learn more about the variables that explain adaptation (as per the peer reviewed literature) there is an equivalent need to understand how to best gather this type of information from the community and more importantly how to then use and present this information to enhance their adaptive capacity and adaptation needs. This raises the topic of community engagement and communication.

---

[10] Top-down strategies suggest social capital is an outcome of society-state relations and existing civic associations, bottom-up strategies stress the importance of social norms (Williams 2003).

In general there appear to be significant issues around communication and engagement with communities, particularly concerning the topic of climate change. A lack of awareness of the problem or starting point; and how to structure and integrate adaptation planning in the context of the many other coastal management and planning activities has been pointed out by many (e.g. Fernandez-Bilbao 2009; Booth 2012).

In the context of communicating climate change issues, much has been written about the psychology of climate change communication (e.g Center for Research on Environmental Decisions 2009; Leiserowitz 2006; 2007 Weber and Stern, 2011). It is well know that climate change issues are difficult to communicate due to, for instance, confirmation bias and framing, and single action bias (Center for Research on Environmental Decisions 2009). The psychology of communicating climate change information is important in the context of community adaptation.

As it is often scientists who communicate climate change information there is a need to look at the methods they use to communicate. Campbell (2011) indicates that it is important scientists develop their methods deliberatively, involving their target audiences; and that they avoid undue dependence on traditional media and public authorities for such communication. It is best to develop multiple channels, including Internet-based and social network media.

As much of climate science is uncertain the approach to communicating aspects of uncertainty should depend on the context but transparency is generally important. It is also important for scientists to extend their communication over longer time periods and to have support in doing so, and to persist in public engagements even when this seems difficult (Campbell 2011).

3.1 Social learning

Deliberative methods that involve active participation by an audience can be useful in communicating climate issues (even though attracting participants in the first place can be very challenging indeed). The productivity commission (2012) indicates that where opportunities to participate in and influence decision-making processes are not widely available to the community, adaptation policy and options may not match the community's views on risk, nor may these policies protect highly valued community assets. Moreover these deliberative processes are increasingly popular due to the perception that social learning develops as part of this process. Social learning theory explains and describes the social processes that can lead to adaptation, where people learn within a social context through for instance modelling or other interactive forms of group conceptualizations.

Social learning takes place when groups of multiple stakeholders with a diversity of values get together to discuss, model, and find solutions to problems (Martin et al. 2010; Ison 2009). This approach is particularly useful when the problem is complex and uncertainty is high (Walters and Holling 1990). Social learning is increasingly gaining interest over more traditional methods of information dispersal and expert-based teaching (Pahl-Wostl 2009; Pahl-Wostl 2002; Muro and Jeffrey 2008; Blackmore et al. 2007). Observed social learning outcomes include gains in substantive knowledge (e.g. on climate change impacts), procedural knowledge (e.g. on alternative adaptation strategies), understanding of different perspectives, as well as social and technical skills, enhanced awareness, altered agendas, and better social relations (Albert et al 2012). The sharing of experiences in group discussions provides rich outcomes in terms of for instance, the ability to process uncertainty information (Marx et al 2007).

Social learning frameworks have been used in a climate adaptation context mainly in the context of case study applications, for instance, water resources (Martin et al. 2010; Wilder et al. 2010) wildlife management (Armitage et al. 2011) and agriculture (Martin et al. 2010; Yuen et al 2012). Adaptation processes have also been evaluated using social learning approaches (Cundill and Fabricius 2009; Eakin and Patt 2011) including learning between members of the Intergovernmental Panel on Climate Change (Siebenhüner 2006). Gidley et al. (2009) considered social learning in participatory futures methodologies. Fabricius (2009) indicated that social learning is an essential part of adaptation and adaptive management. The process of undertaking the adaptation assessment plays an important role in catalysing social learning and collective action. Empirical evidence suggests that the ability of societies to adapt is determined, in part, by the ability to act collectively (Adger 2003).

The assessments in themselves provide the platform upon which social learning occurs and are of value irrespective of whether assessments are able to prescribe optimal management responses or provide objective information. (Yuen et al 2012). To maintain transparency, the community can be provided with an opportunity to check that their voice has been captured accurately.

4. Community adaptation and engagement

There are a multitude of projects, both in Australia and overseas, which have developed frameworks, or road maps, for different organisations on how to engage with communities over climate change issues and how to develop adaptation plans (e.g. Fernandez-Bilbao 2009; Booth 2012). Community engagement is "any process that involves the public in solving problems or making decisions, and uses public input to make decisions" (International Association for Public Participation, http://www.iap2.org.au/).

There are many methods that can be applied to interact with communities, but the reason for the interaction, i.e. to obtain information, to establish community engagement, to promote community adaptation, will generally dictate the most appropriate avenue of interaction. Fernandez-Bilbao (2009) base the type of engagement for community adaptation planning and engagement on three types of adaptation decisions: (1) low conflict, controversy or uncertainty about the adaptation, (2) need for buy in from a number of stakeholders, or (3) high conflict, controversy and uncertainty about the need to adapt and/or the way to adapt.

For instance, surveys and questionnaires are appropriate in most contexts, while communities meeting and forum which bring together interested people for information and discussion of an issue would serve a different purpose. New and innovative techniques for community engagement are continually being developed to attract more participants and create better outcomes. For instance, the creation of a relaxed atmosphere is central to the principals of World Café (http://www.theworldcafe.com/about.html). Charettes also rely on the setting of the workshop but in this case they are 'on-location' and undertaken in a pressure environment with an aim to produce plans and designs by the end of the workshop. The cultural techniques integrates the skills and creativity of (often local) artists, including visual and performing arts, video and film production, graphic design and computer imagery, to unearth community ideas. Community panels rely on recruited participants who are regularly consulted and thus continuously engaged. Increasingly E-consultation such as email, listserv, discussion boards, and chat-rooms are used for communication and to derive information.

The diversity of communities is a crucial consideration in the context of adaptation planning. Community profiling is important to gain an understanding of demographic profile and the various interest or stakeholder groups. There are many hard to reach groups, with a range of barriers that inhibit participation, ranging from personality types, age, mobility, language, pressure groups, and access. There does not seem to be an easy and ready method or technique that encourages the participation of the harder to get groups. In many reports on adaptation planning, the lack of participation is mentioned as a problem (e.g. Booth 2012). The lack of participation and survey fatigue it is a well known phenomena to social scientists.

Summary

In this report we reviewed the literature on the variables that explain community adaptation to climate change. We also focussed on the role of access to information in the adaptation process mainly to provide a solid basis for understanding related variables. We undertook to review the role of information even though information access is not central to the Blueprint project but is the main focus of a related FRDC project, the 'Knowledge Project'. The Knowledge Project has the role of determining current climate change knowledge levels and climate change information provision to coastal communities. Fundamentally the Knowledge Project and the Blueprint Project are linked as information, knowledge, and awareness are correlated. After all if the information is provided in an appropriate and accessible format it will create knowledge and awareness of climate risks which in turn creates recognition of the need to adapt.

From the review it is obvious that information is one of many variables that impact on community adaptation. In order to combat information issues, communities need to be equipped with skills and tools on how to deal with information that is relevant for adapting to a changing climate (Boyd et al. 2011). These skills and tools crucial to effectively adapt to climate change and to manage risks can include models - such as those developed in the Blueprint Project - that help put the aspects of information into context.

As part of the Blueprint project local non-scientific knowledge and evidence of local change is gathered from local residents. Local change as observed by community residents includes climate related changes in the marine environment (a central topic of the Blueprint project) but also social, economic and governance changes that affect their community. The applied project methodology allows climate induced changes to be put into a whole of system context – at the same time allowing the researchers to develop an understanding of the perceived role of climate change in the community and elicit adaptation pathways that consider other relevant changes and thus take a more holistic and systems approach.

The provision of integrated investigative tools to community members that allows them to simulate the changes they expect will happen in their locality and to assess the effectiveness of likely adaptation responses may be a valuable tool in increasing understanding and adaptive capacity, and making explicit the risks associated with climate change. This type of tool can be developed using programs such as Vensim or Stella which can include risk assessments. An integrated assessment tool, with the capacity for community-specific data input, can form the basis for the identification of potential adaptation strategies in other coastal communities (a central theme of the Blueprint Project). The collection of case study specific data to underpin the development of such integrative tools must be undertaken prior to the assessment of potential adaptation strategies.

References

Adger, W.N., Barnett J., 2009. Four reasons for concern about adaptation to climate change. Environ Plan A 41, 2800–2805.

Adger, W.N., 2000. Social and ecological resilience: are they related? Progress in Human Geography 24, 347‐ 364.

Adger, W.N., 2006. Vulnerability. Global Environmental Change 16, 268‐ 281.

Adger, W.N., Arnell, N.W., Tompkins, E.L., 2005. Adapting to climate change: perspectives across scales. Global Environmental Change 15, 75‐ 76.

Adger WN, Dessai S, Goulden M et al (2009) Are there social limits to adaptation to climate change? Clim Change 93(3–4):335–354

Adger, W. N. and Vincent, K. (2005) Uncertainty in adaptive capacity. (IPCC Special Issue on 'Describing Uncertainties in Climate Change to Support Analysis of Risk and Options') Comptes Rendus Geoscience 337(4), 399-410.

Albert, C., Zimmermann, T., Knieling, J., von Haaren, C., 2012. Social learning can benefit decision-making in landscape planning: Gartow case study on climate change adaptation, Elbe valley biosphere reserve. Landscape and Urban Planning Volume 105(4), 347–360.

Bandura, A., 1995. In: Bandura, A. (Ed.), Self-Efficacy in Changing Societies. Cambridge University Press, Cambridge, pp. 1–45.

Below, T.B., Mutabazi, K.D., Kirschke, D., Franke, C., Sieber, S., Siebert, R., Tscherning, K., 2012. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Global Environmental change – Human and policy dimensions, 22 (1), 223-235, DOI:0.1016/j.gloenvcha.2011.11.012

Berkes, F., 2002. Epilogue: making sense of Arctic environmental change? In: Krupnik, I., Jolly, D. (eds) The earth is faster now: indigenous observations of arctic environmental change. Arctic Research Consortium of the United States and Smithsonian Institution, Fairbanks AK, pp 335–349.

Berkes F, Folke C (1998) Linking Social and Ecological Systems for Resilience and Sustainability. In 'Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience'. (Eds F Berkes, C Folke) pp. 1-25. (Cambridge University Press: Cambridge).

Berkes F, Jolly D (2001) Adapting to climate change: social-ecological resilience in a Canadian Western Arctic community. Conserv Ecol 5(2):18–39

Berman, M., Kofinas, G., 2004. Hunting for models: grounded and rational choice approaches to analyzing climate effects on subsistence hunting in an Arctic community. Ecological Economics, 49, 31–46.

Blackmore, C., Ison, R., Jiggins, J., 2007. Social learning: an alternative policy instrument in the context of Europe's water. Environmental Science and Policy, 10(6), 493–498.

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, School of Civil and Environmental Engineering, University of New South Wales, Sydney available at http://www.nccarf.edu.au/wwwold/settlements-infrastructure/sites/www.nccarf.edu.au.wwwold.settlements-infrastructure/files/file/ACCARNSI_STAGE%201%20REPORT_Case%20Studies%20of%20Adaptation%20Tools_Final_May%202012.pdf

Bord, R.J., Fisher, A., O'Connor, R.E., 1998. Public perceptions of global warming: United States and international perspectives. Climate Research, 11(1), 75–84.

Boyd, E., Street, R., Gawith, M., Lonsdale, K., Newton, L., Johnstone, K., Metcalf, G., 2011. Leading the UK Adaptation Agenda: A Landscape of Stakeholders and Networked Organizations for Adaptation to Climate Change, Chapter 6

Bryson, R. A., 1974. A perspective on climatic change. Science, 184, 753–760.

Bryson, R. A., Wendland, W.M., 1970, Climatic effects of atmospheric pollution. Global Effects of Environmental Pollution, S. F. Singer (ed.), Springer-Verlag/D. Reidel, 130–138.

Burton, I., Huq, S., Lim, B., Pilifosova, O., Schipper, E.L., 2002. From impacts assessment to adaptation priorities: the shaping of adaptation policy. Climate Policy 2(2), 145–159.

Buys. L., Miller, E., van Megen, K., 2012. Conceptualising climate change in rural Australia: community perceptions, attitudes and (in) actions. Regional Environmental Change, 12, 237–248. DOI 10.1007/s10113-011-0253-6

Camerer, C.F., Kunreuther, H., 1989. Decision processes for low probability events: Policy implications. Journal of Policy Analysis and Management, 8(4), 565–592.

Campbell, P. 2011 Understanding the receivers and the reception of science's uncertain messages *Phil. Trans. R. Soc. A* (2011) 369, 4891–4912 doi:10.1098/rsta.2011.0068

Center for Research on Environmental Decisions. (2009). *The Psychology of Climate Change Communication: A Guide for Scientists, Journalists, Educators, Political Aides, and the Interested Public*. New York. Available at http://cred.columbia.edu/guide.

Cinner, J.M., McClanahan T., Graham N.A.J., Pratchett M., Wilson S.K., Raina J.B., 2009. Gear-based fisheries management as a potential adaptive response to climate change and coral mortality. Journal of Applied Ecology, 46, 724-732.

Coastal Communities and Industries. Gland, Switzerland, IUCN. v + 36 pp.

Crane, T.A., Roncoli, C., Hoogenboom, G., 2011. Adaptation to climate change and climate variability: The importance of understanding agriculture as performance. Journal of Life Sciences, 57, 179–185.

Cruikshank, J., 2001. Glaciers and climate change: perspectives from oral tradition. Arctic 54, 377–393.

Dessai, S., Adger, W.N., Hulme, M., Turnpenny, J., Köhler, J., Warren, R., 2004. Defining and experiencing dangerous climate change. Climate Change 64, 11–25.

Dovers, S., 2009. Normalizing adaptation. Global Environmental Change 19(1), 4–6.

Eakin, H.C., Patt, A., 2011. Are adaptation studies effective, and what can enhance their practical impact? Wiley Interdisciplinary Reviews: Climate Change 2(2), 141–153.

Edwards, W., 1954. The theory of decision making. Psychological Bulletin, 51(4), 380-417.

Fernández-Bilbao, A., Woodin, S., Richardson, J., Zsamboky M., Bose, S., Orr, P., Twigger-Ross, C., Colbourne L. 2009 Understanding the Processes for Community Adaptation Planning and Engagement (CAPE) on the Coast R&D Technical Report FD2624/TR, available at http://evidence.environment-agency.gov.uk/FCERM/Libraries/FCERM_Project_Documents/FD2624_Final_Technical_Report.sflb.ashx

Few, R., Brown, K., Tompkins, E.L., 2007. Climate change and coastal management decisions: insights from Christchurch Bay, UK. Coastal Management, 35(2–3), 255–270.

Fleming, A., Vanclay, F., 2009. Using discourse analysis to better inform the practice of extension. Extension Farming Systems Journal, 5(1), 1–10.

Ford, J.D., Berrang-Ford, L., 2011. Climate Change Adaptation in Developed Nations From Theory to Practice Advances. Global Change Research, 42, DOI: 10.1007/978-94-007-0567-8

Ford, J.D., Berrang-Ford, L., 2011. Introduction Chapter 1 in J.D. Ford and L. Berrang-Ford (eds.), *Climate Change Adaptation in Developed Nations: From Theory to Practice*, Advances in Global Change Research 42

Ford, J.D., Keskitalo, E.C.H., Smith, T., Pearce, T., Berrang-Ford, L., Duerden, F., Smit, B., 2010. Case study and analogue methodologies in climate change vulnerability research. Wiley Interdisciplinary Review: Climate Change, 1(3), 374–392.

Ford, J.D., Smit, B., 2004. A framework for assessing the vulnerability of communities in the Canadian arctic to risks associated with climate change. Arctic, 57(4), 389–400.

Glantz, M., 1988. Societal responses to climate change: forecasting by analogy. Westview Press, Boulder, CO, USA, 428pp.

Grothmann, T., Patt, A., 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. Global Environmental Change Part A 15, 199–213.

Gurran, N., Norman, B., Gilbert, C., Hamin, E. 2011 Planning for climate change adaptation in Coastal Australia: Report No. 4 for the National Sea Change Taskforce November 2011, available at http://www.seachangetaskforce.org.au/Publications/Planning%20for%20climate%20change%20in%20coastal%20Australia%20%20State%20of%20Practice.pdf

Härtel, C.E.J., and Pearman, G.I. 2010 Understanding and responding to the climate change issue: Towards a whole-of-science research agenda. *Journal of Management & Organization* **16**: 16–47.

Hoegh-Guldberg, O., 1999. Climate change, coral bleaching and the future of the world's coral reefs. Mar. Freshwater Res. 50, 839–66.

Hohle, E., 2002. 'Global climate change as perceived by the public'. In: Zwick, M.M. and Renn, O. (eds.), *Perception and Evaluation of Risks. Findings of the "Baden-W¨urttemberg Risk Survey 2001*. Joint working report by the Centre of Technology Assessment in Baden-W¨urttemberg and the University of Stuttgart, Sociology of Technologies and Environment, Germany, pp. 115–130.

Hughes, T.P., Baird, A.H., Bellwood, D.R., Card, M., Connolly, S.R., Folke, C., Grosberg, R., Hoegh-Guldberg, O., Jackson, J.B.C., Kleypas, J., Lough, J.M., Marshall, P., Nystrom, M., Palumbi, S.R., Pandolfi, J.M., Rosen, B., Roughgarden, J., 2003. Climate change, human impacts, and the resilience of coral reefs. Science, 301, 929-933.

Huntington, H., Fox, S., 2005. The changing arctic: indigenous perspectives. In: Arctic climate impact assessment. Cambridge University Press, Cambridge.

IPCC (Intergovernmental Panel on Climate Change), 2007. 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 and New York.

Ison, R.L., 2009. How to act in a climate change world. Systems practice, systemic inquiry and action research. Springer, London.

Iyengar, S.S., Lepper, M.R., 2000. When choice is demotivating: Can one desire too much of a good thing? Journal of Personality and Social Psychology, 79(6), 995–1006.

Johnson, E.J. and Goldstein, D.G., 2004. Defaults and donation decisions. Transplantation, 78(12), 1713–1716.

Kahneman, D., Knetsch, J.L. and Thaler, R.H., 1991. Anomalies: The endowment effect, loss aversion, and status quo bias. Journal of Economic Perspectives, 5(1), 193–206.

Kahneman, D., Tversky, A, 1979. Prospect theory: An analysis of decision under risk. Econometrica, 47(2), 263-292.

Kern, K., Gotelind, A., 2008. Chapter 8 - Governing Climate Change in Cities: Modes of Urban Climate Governance in Multi-level Systems, (ed.) OECD, OECD Conference Proceedings, Paris, pp. 171. www.oecd.org/dataoecd/12/38/42554913.pdf#page=172

Kirby, A., 2004. Britons unsure of climate costs – polling results. BBC News Online. http://news.bbc.co.uk/2/hi/science/nature/3934363.stm. Cited 20 Jan 2008

Kuruppa, N., Liverman, D., 2011. Mental preparation for climate adaptation: The role of cognition and culture in enhancing adaptive capacity of water management in Kiribati. Global Environmental Change, 21, 657–669.

Leiserowitz, A. (2006) Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change*, 77, 45-72. DOI: 10.1007/s10584-006-9059-9

Leiserowitz, A. (2007) "Communicating the risks of global warming: American risk perceptions, affective images and interpretive communities," in S. Moser and L. Dilling, eds. *Creating a Climate for Change: Communicating climate change and facilitating social change*. Cambridge University Press.

Leviston, Z., Walker, I.A., 2011. Baseline survey of Australian attitudes to climate change: preliminary report, CSIRO National Research Flagships Climate Adaptation.

Lorenzoni, I., Jordan, A., O'Riordan, T., Kerry Turner, R., Hulme,M., 2000. A co-evolutionary approach to climate change impact assessment—part II: a scenario-based case study in East Anglia (UK). Global Environmental Change 10, 145–155.

Lorenzoni, I., Pidgeon, N.F., 2006. Public views on climate change: European and USA perspectives. Climate Change, 77, 73–95. doi: 10.1007/s10584-006-9072-z

Lowe, T., Brown, K., Dessai, S., de Franca Doria, M., Haynes, K., Vincent, K., 2006. Does tomorrow ever come? Disaster narrative and public perception of climate change. Public Understanding of Science, 15(4), 435–457.

Mandler, G., 1990. In: Fisher, S., Cooper, C. (Eds.), On the Move: The Psychology of Change and Transition. John Wiley and Sons, West Sussex, England, pp. 13–32.

Marshall, N.A., Marshall, P.A., 2007. Conceptualising and Operationalising Social Resilience within Commercial Fisheries in Northern Australia. Ecology and Society, 12, http://www.ecologyandsociety.org/vol12/ iss11/art11/.

Marshall, N.A., Marshall, P.A., Tamelander, J., Obura, D., Malleret-King, D., Cinner, J.E., 2009. A Framework for Social Adaptation to Climate Change; Sustaining Tropical

Martin, J., Rogers, M., Winter, C., 2010. Social Learning and Adaptation. Centre for Sustainable Regional Communities. Climate Change in Regional Australia, Bendigo.

McBeath J (2003) Institutional responses to climate change: the case of the Alaskan transportation system. Mitig Adapt Strateg Glob Change 8(1):3–28

McLeman, Robert A. Brklacich, Michael Woodrow, Maureen Vodden, Kelly Gallaugher, Patricia and Sander-Regier, Renate 2011 Opportunities and Barriers for Adaptation and Local Adaptation Planning in Canadian Rural and Resource-Based Communities, Chapter 33 in J.D. Ford and L. Berrang-Ford (eds.), *Climate Change Adaptation in Developed Nations: From Theory to Practice*, Advances in Global Change Research 42

Milne, M., Stenekes, N., Russell, J., 2008. Climate Risk and Industry Adaptation. Canberra, Australian Bureau of Rural Sciences, 108pp.

Moench, M., Dixit, A., 2004. The Institute for Social and Environmental Transition. International, CO, 211pp.

Moser SC, Dilling L, eds (2007) Creating a Climate for Change: Communicating Climate Change and Facilitating Social Change (Cambridge Univ Press, Cambridge, UK).

Moser, S.C., Ekstrom, J.A. 2010. A framework to diagnose barriers to climate change adaptation, Proceedings of the National Academy of Science, 107(51), 22026-22031.

Moser, S.C., Luers, A.L., 2008. Managing climate risks in California: the need to engage resource managers for successful adaptation to change. Climate Change, 87(1), 307–322.

Moser, S.C., Tribbia, J., 2008. Vulnerability to inundation and climate change impacts in California: coastal managers' attitudes and perceptions. Marine Technological Society, 40(4), 35–44.

Muro, M., Jeffrey, P., 2008. A critical review of the theory and application of social learning in participatory natural resource management processes. Journal of environmental planning and management, 51(3), 325–344.

Narayan, D., 2006. In: Narayan, D. (Ed.), Measuring Empowerment: Cross-Disciplinary Research. Oxford University Press, Oxford, pp. 3–38.

Næss LO, Bang G, Eriksen S et al (2005) Institutional adaptation to climate change: floodresponses at the municipal level in Norway. Glob Environ Change Part A 15(2):125–138

Nelson DR, Adger WN, Brown K (2007) Adaptation to environmental change: contributions of a resilience framework. Annual Review of Environmental Resources 32:395–419

Nicholls, R., 1999. Cognitive illusions, heuristics, and climate prediction. Bulletin of the American Meteorological Society, 80, 1385–1397.

Nursey-Bray, M.J., Pecl, G., Frusher, S., Gardner, C., Haward, M., Hobday A., 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.

O'Brien, K.L., Eriksen, S., Sygna, L., Naess, L.O., 2006. Questioning complacency: climate change impacts, vulnerability and adaptation in Norway. AMBIO: A journal of the human environment, 35(2), 50–56.

Orlove, B.S., Chiang, J.C.H., Cane, M.A., 2000. Forecasting Andean rainfall and crop yield from the influence of El Nino on Pleiades visibility. Nature 403, 68–71.

Pahl-Wostl, C., 2009. A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Global Environment Change, 19(3), 354–365.

Parry, M., Lowe, J., Hanson, C., 2009. Overshoot, adapt and recover. Nature 458, 1102–1103.

Pattiaratchi, C.B., Buchan, S.J., 1991. Implications of long-term climate change for the Leeuwin Current. Journal of the Royal Society of Western Australia, 74, 133–140.

Pelling (undated) Social Capital and Institutional Adaptation to Climate Change RCC working paper 2, http://www.rcc.rures.net/documents/WP2.pdf

Pelling, M., 2003. The vulnerability of cities: natural disaster and social resilience, Earthscan: London.

Pielke, R.A. Jr, Prins, G., Rayner, S., sarewitz, D., 2007. Lifting the taboo on adaptation. Nature, 445, 597–598.

Preston, B., Westaway, R., 2010. A critical look at the state of climate adaptation planning. In: P,N., Holper, W., Cai (eds.) Greenhouse 2009 Conference. CSIRO.

Preston, B.L., Yuen, E.J., Westaway, R.M., 2011. Putting climate vulnerability on the map: a critical look at approaches, benefits, and risks. Sustainability Science Productivity Commission 2012, *Barriers to Effective Climate Change Adaptation*, Draft Report, Canberra.

Putten, van E.I., Gorton, B. Fulton, B., Thebaud, O. (in review). The impact of fisher's risk profile on fishery outcome and catch variability in an end-to-end ecosystem model, ICES Journal of Marine Science.

Reeson, A. Dunstall, S., 2009. Behavioural Economics and Complex Decision- Making: Implications for the Australian Tax and Transfer System, CSIRO, http://taxreview.treasury.gov.au/content/html/commissioned_work/downloads/CSIRO_AFTS_Behavioural_economics_paper.pdf (accessed 30 January 2012).

Riedlinger, D., Berkes, F., 2001. Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. Polar Record 37, 315–328.

Risbey, J.S., Kandlikar, M., Dowlatabadi, H., Graetz, D., 1999. Scale, context, and decision making in agricultural adaptation to climate variability and change. Mitigation and adaptation strategies for global change, 4, 137–165.

Slovic, P., 1987. Perception of risk. Science, 236, 280-285.

Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Global Environment Change, 16(3), 282–292.

Stamm, K.R., Clark, F., Eblacas, P.R., 2000. Mass communication and public understanding of environmental problems: the case of global warming. Public Understanding of Science, 9(3), 219–237.

Swim, J.K., Stern, P.C., Doherty, T.J., Clayton, S., Reser, J.P., Weber, E.U., Gifford, R., Howard, G.S., 2011. Psychology's contributions to understanding and addressing global climate change. American Psychologist, 66(4), 241–250.

Thaler, R. 1981. Some empirical evidence on dynamic inconsistency. Economics Letters, 8(3), 201–207.

Tompkins, E.L., Few, R., Brown, K., 2008. Scenario-based stakeholder engagement: incorporating stakeholders preferences into coastal planning for climate change. Journal of environmental management, 88(4), 1580–1592.

Trumbo, C., Shanahan, J., 2000. Social research on climate change: where we have been, where we are and where we might go. Public understanding of science, 9(3), 199–204. doi:10.1088/0963-6625/9/3/002

Tversky, A., Kahneman, D., 1973. Availability: A heuristic for judging frequency and probability. Cognitive Psychology, 5(2), 207–232.

Tversky, A., Kahneman, D., 1974. Judgment under uncertainty: Heuristics and biases. Science, 185(4157), 1124 –1131.

Tversky, A., Kahneman, D., 1986. Rational choice and the framing of decisions. The Journal of Business, 59(4), S251–S278.

U.S. Indian Ocean Tsunami Warning System Program, 2007. How Resilient is Your Coastal Community? A Guide for Evaluating Coastal Community Resilience to Tsunamis and Other Coastal Hazards. U.S. Indian Ocean Tsunami Warning System Program supported by the United States Agency for International Development and partners, Bangkok, Thailand. 144 p.

UNDP (United Nations Development Programme), 2004. Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures. Cambridge University Press, Cambridge.

Walters, C.J., Holling, C.S., 1990. Large-scale management experiments and learning by doing. Ecology and society, 71 (6), 2060–2068.

Watson, R.T., Zinyowera, M.C., Moss, R.H., Dokken, D.J. (Eds.), 1998. The regional impacts of climate change. An assessment of vulnerability. Special Report of IPCC Working Group II. Cambridge University Press, Cambridge, 517 pp.

Weber, E., 1997. In: Bazerman, M., Messick, D., Tenbrunsel, A. (Eds.), Psychological Perspectives to Environmental and Ethical Issues in Management. Jossey-Bass, San Francisco, CA, pp. 314–341.

Weber, E.U., Stern, P.C., 2011. Public understanding of climate change in the United States. American Psychologists, 66(4), 315–328. doi:10.1037/a0023253

Weber, Elke U.; Stern, Paul C. American Psychologist, Vol 66(4), May-Jun 2011, 315-328. doi: 10.1037/a0023253

White, G., 1974. Natural Hazards: Local, National, Global. Oxford University Press, Oxford, UK.

Wolf, J., 2011. Climate Change Adaptation as a Social Process, Chapter 2. in J.D. Ford and L. Berrang-Ford (eds.), *Climate Change Adaptation in Developed Nations: From Theory to Practice*, Advances in Global Change Research 42

Wolf, J., Adger, W.N., Lorenzoni, I., Abrahamson, V., Raine, R., 2010. Social capital, individual responses to heat waves and climate change adaptation: an empirical study of two UK cities. Global Environment Change, 20(1):44–52.

Wolf, J., Lorenzoni, I., Few, R., Abrahamson, V., Raine, R., 2009. Conceptual and practical barriers to adaptation: an interdisciplinary analysis of vulnerability and adaptation to heat waves in the UK. In: Adger WN, Lorenzoni I, O'Brien K (eds.) Adapting to climate change: governance, values and limits. Cambridge University Press, Cambridge.

Appendix 6 – Paper 2: Fishing for the impacts of climate change in the marine sector: A case study.

(van Putten EI, Metcalf S, Frusher S, Marshall N, Tull M (In press) Fishing for the impacts of climate change in the marine sector: A case study. *International Journal of Climate Change Strategies and Management*.)

Abstract

Essential elements of climate change research include taking a whole of systems approach, which entails a socio-ecological perspective, and considering climate challenges alongside other challenges faced by resource users. In this paper a case study based research approach is developed to investigate the role of climate and non-climate drivers in shaping three commercial marine sectors: fishing, aquaculture, and marine tourism. The analysis is based on information gained using in depth semi-structured interviews in a coastal community in southeast Australia. Even though climate drivers differ, the economic sectors of this community are representative of many similar coastal communities around the Australia.

Results show that at a community level people involved in, or associated with marine sectors are aware of climate change impacts on the marine environment. Even though many may not see it as a pressing issue, the potential effect of climate change on business profitability was recognised. Both the profitability of commercial fishing and aquaculture (oysters) was affected through mostly a downward pressure on product price, while marine tourism profitability was mainly affected through changes in the number of visitors. A number of positive impacts from climate-driven change, mainly from windfall economic benefits of range shifted species, were reported for commercial- and charter fishing. However, no positive impacts were reported for the aquaculture- and dive sectors.

In the aquaculture sector climate drivers were of great significance in industry participation, while participation in commercial fishing was mainly driven by socio-economic factors. Combining the different domains with climate drivers allows for identification and assessment of targeted adaptation needs and opportunities and sets up a comprehensive approach to determine future adaptation pathways.

Keywords: Ocean warming, fisheries, marine tourism, aquaculture, climate change

Appendix 7 – Paper 3: Adaptation options for marine-industries and coastal communities using community structure and dynamics

(Metcalf SJ, van Putten EI, Frusher SD, Tull M, Marshall N (2014) Adaptation options for marine-industries and coastal communities using community structure and dynamics. *Sustainability Science*, 9 (1). pp. 1-15. DOI 10.1007/s11625-013-0239-z)

Abstract

Identifying effective adaptation strategies for marine resource dependent coastal communities impacted by climate change can be a difficult task due to the dynamic nature of marine ecosystems. The task will be even more difficult if current and predicted shifts in social and economic trends are also considered. Information about social and economic change is often limited to qualitative data thus requiring research methods that can deal with such data characteristics. A combination of qualitative and quantitative models provide the flexibility that allows the assessment of current and future ecological and socio-economic risks and can provide information on alternative adaptations.

Based on stakeholder input, qualitative models and Bayesian Belief Networks (BBN) are used in this study to holistically assess climate and non-climate driven change in a coastal community in south-east Australia. Semi-quantitative predictions of key dynamics are calculated using these two modelling techniques. The direct and indirect effects of change are evaluated and alternative adaptation strategies developed which assists with effective communication of information between stakeholders and researchers.

A continued decline in the coastal community population was predicted due to reduced local employment and retail spending. Diversification of employment opportunities and attracting residents of a more evenly spread age range are potential high level adaptation strategies. Combating excessive removal of popular range-shifted species can be achieved through bag- or size-limits and monitoring of currently unmanaged stocks. Our results demonstrate that combining BBNs and qualitative models can provide a dynamic, learning-based, semi-quantitative approach to the assessment of combined climate and socio-economic impacts and identify potential adaptation strategies.

Keywords: Climate change, qualitative modelling, Bayesian Belief Network, fisheries, marine industries, coastal communities

Appendix 8 – Paper 4: Transformation of coastal communities: Where is the marine sector heading?

(van Putten EI, Metcalf S, Frusher S, Marshall N, Tull M (In press) Transformation of coastal communities: Where is the marine sector heading? Australian Journal of Regional Studies.)

Abstract

Much has been said about migration to coastal areas and the consequent change in coastal community demographics. Even though coastal communities are changing they are often still colloquially referred to according to the presumed dominant economic activity, such as 'fishing towns'. However, the commercial fishing sector is contracting and communities are re-orienting to other marine sectors such as marine tourism and aquaculture, and some non-marine sectors. Our aim is to examine the additional pressure of climate change on coastal communities typically referred to as 'fishing towns' as climate change may prove to be the 'tipping point' for both the fishing fleet and coastal fishing towns. The purpose of this paper is not to examine the details of climate change- which have been documented elsewhere- but to identify the effects on fishing towns. Our approach is to consider a coastal community's vulnerability to climate change in the marine environment in the context of its size, demographics, and economic characteristics. Small coastal communities characterised by an older demographic, high unemployment, a declining commercial fishing fleet, high participation in the marine sector, and limited local sea-based or land-based employment opportunities are assumed to be especially vulnerable to the effects of climate change in the marine environment. Together with qualitative survey results from 87 community members in three typical coastal communities across Australia, we provide insight into trends and change in our coastal communities. Our results suggest that small coastal communities that were previously fishing towns are unlikely to be resilient to the effects of climate changes such as declines in fish abundances and coastal inundations where transformations of structure and function of communities are likely to occur as the fishing component of communities decline. The future of coastal communities in Australia is likely to look very different indeed.

Appendix 9 – Indicators used in Vulnerability and Sustainable Livelihood Assessments

Indicators that estimate ecological vulnerability

***Natural** capital* *(SLA category)*	***Narrative***	***Scoring (better is higher score)***
Marine climate change hotspot	If the area is in a marine climate change hotspot means higher exposure, greater potential impact and increased ecological vulnerability	Not in hotspot =1 Yes in hotspot =0
Number of fisheries overfished	More overfished fisheries means a greater chance of compounding effects of climate change (as the system is already stressed)	No overfished =1 One or more overfished =0
Ecosystem condition	Better ecosystem condition (i.e. absence of pests and diseases) means lower ecosystem vulnerability	good=2 fair=1 bad=0
Number of climate change sensitive commercial fish species	Higher number of sensitive commercial species means lower resilience (Pecl et al 2011)	No sensitive spp =1 More than 1 sensitive spp =0

Indicators that estimate resource dependence

***Natural** capital* *(SLA category)*	***Narrative***	***Scoring (better is higher score)***
Proportion of people employed in the agriculture, forestry & fisheries sector	Higher proportion of people who work in these sectors means higher dependency on these natural resources	< state average=1 >state average=0
Proportion of people employed in fishing	Higher proportion of people who work in fishing means higher marine resource dependency	< state average=1 >state average=0
Proportion of people employed in aquaculture	Higher proportion of people who work in aquaculture means higher marine resource dependency	< state average=1 >state average=0
Proportion of people employed in accommodation & restaurants	Higher number in tourism related sectors (40% assumed marine tourism) means higher marine resource dependency	< state average=1 >state average=0

Indicators that estimate adaptive capacity

***Human** capital* *(SLA category)*	*Narrative*	*Scoring (better is higher score)*
Education level	Higher education levels means greater adaptive capacity	> state average=1 <state average=0
Unemployment level	Lower unemployment levels means greater resilience (leading to greater adaptive capacity)	< state average=1 >state average=0
Proportion of population over the age of 15 with no qualifications	Lower proportion of over 15 year olds without qualifications means greater resilience (leading to greater adaptive capacity)	< state average=1 >state average=0
Proportion of females employed (full-, and part time)	A greater proportion of women employed means greater adaptive capacity (due to potentially higher family incomes)	> state average=1 <state average=0
Proportion of population in need of social assistance	A lower need for social assistance means higher resilience (leading to greater adaptive capacity)	< state average=1 >state average=0
Proportion of population whose current place of usual residence is different to the residence one year ago	A less mobile population can mean higher resilience as local knowledge does not move away (leading to greater adaptive capacity)	< state average=1 >state average=0
Proportion of total population who are indigenous	A lower indigenous population can mean higher resilience as there is likely to be a lesser demand on the health system and parts of the social system	< state average=1 >state average=0

***Financial** capital* *(SLA category)*	*Narrative*	*Scoring (better is higher score)*
Median income	Greater personal wealth indicates more disposable income and a greater capacity to adapt	> state average=1 <state average=0
Median mortgage	Lower mortgages means more disposable income available which means greater adaptive capacity	< state average=1 >state average=0
Age dependency (<19 and >65 as a proportion of 20-64 year olds)	Lower dependency ratio means higher resilience (leading to greater adaptive capacity)	< state average=1 >state average=0
Median rental	Lower rental prices means more disposable income available which means greater adaptive capacity	< state average=1 >state average=0

***Social** capital* *(SLA category)*	*Narrative*	*Scoring (better is higher score)*
Proportion of dwellings that are unoccupied	a lower number of unoccupied houses means there is likely to be less of a "shack' or seasonal population increasing adaptive capacity	< state average=1 >state average=0
Proportion of households that are single parent household (with children <15)	A lower proportion of single parent households will increase resilience (leading to greater adaptive capacity)	< state average=1 >state average=0
Average number of people per household with children	Smaller families are likely to have more disposable income and make less use of services like education and health increasing resilience	< state average=1 >state average=0
Index of disadvantage	Areas of greater disadvantage will have less adaptive capacity	Top 20% =2 middle 60%=1 bottom 20%=0

People who do volunteering activity as proportion of residents	Greater involvement in volunteering indicates a more socially active community increasing adaptive capacity	> state average=1 <state average=0
Travel time to work	Lower travel time to work means more likely that local work can be found in the community increasing resilience (leading to greater adaptive capacity)	< state average=1 >state average=0
Change in population size	A growing population means greater adaptive capacity (although it may put pressure on the ecological system)	growing =1 declining=0

***Physical** capital* *(SLA category)*	*Narrative*	*Scoring (better is higher score)*
Houses owned outright	A higher proportion of people who own their homes means greater resilience (leading to greater adaptive capacity)	> state average=1 <state average=0
Proportion of residents who rent their house	A lower proportion of people who rent their homes indicates higher home ownership increasing resilience (leading to greater adaptive capacity). Also people who rent are generally less affluent or more transient	< state average=1 >state average=0
Accessibility / remoteness index	Areas that are remote will have less easy access to resources lowering adaptive capacity	bottom 20%= 2 middle 60%=1 top 20% =0
Proportion of the population who are owner business managers	A higher proportion of owner business managers means greater adaptive capacity	> state average=1 <state average=0

Appendix 10 – Schematic of climate pressures on marine sectors

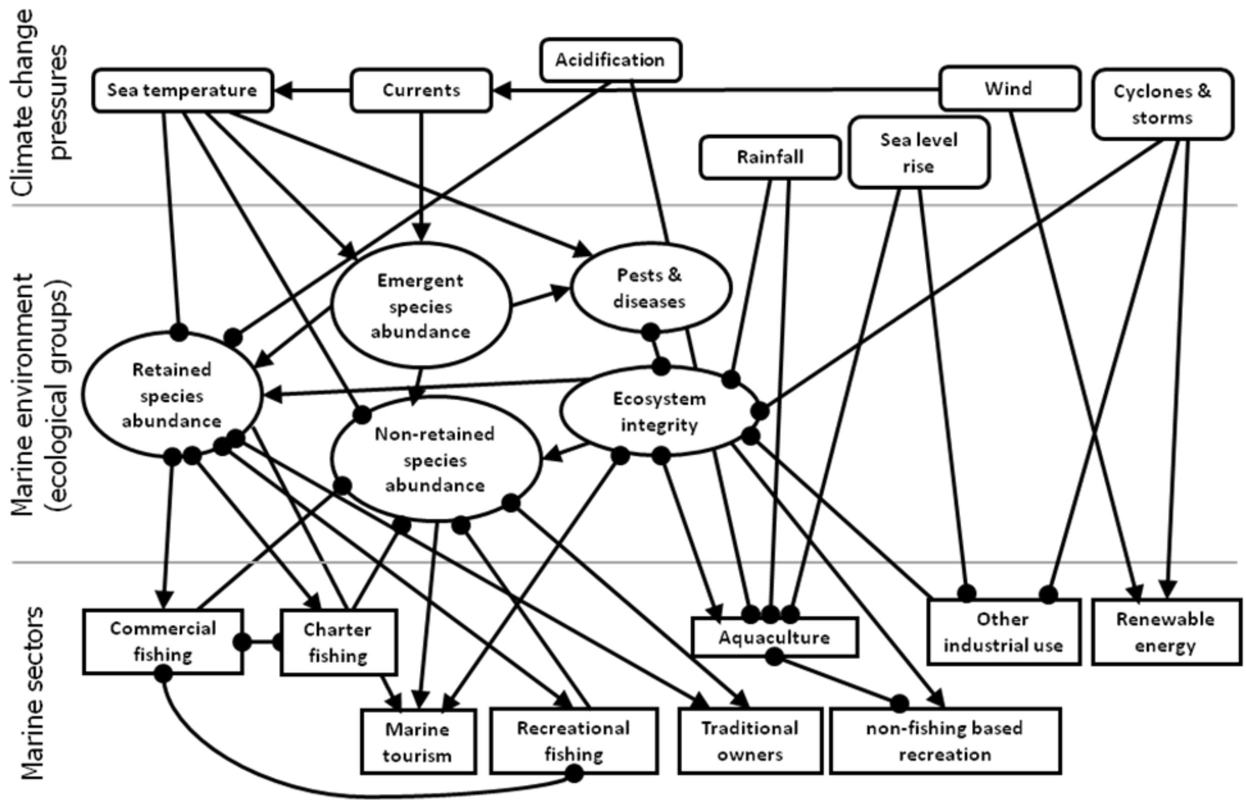


Figure 10.1: Schematic showing the links between climate change pressures, marine environment (ecological groups) and marine sectors. A positive effect is shown by (→) and a negative effect by (—●).

Table 10.1: Description of climate change pressures, marine environment (ecological groups) and marine sectors.

Climate drivers	***Variable description***
Sea temperature	The degrees in centigrade of the oceans top layer (i.e., Sea Surface Temperature)
Currents	The strength of surface ocean water flow in a prevailing direction
Rainfall	The amount of rainfall occurring within the region
Mean sea level rise	The mean level of the ocean's surface at the coast
Wind	The strength of wind blowing from a particular direction
Cyclones & Storms	Frequency of cyclones and storms
Acidification	Change in the pH of the ocean, which is affected by the uptake of carbon dioxide from the atmosphere and impacts hard-shelled organisms
Marine environment (ecological groups)	***Variable description***
Commercial species	Abundance of marine species that are kept for sale and/or food (e.g. Rock lobster, abalone, coral trout, crabs)
Non-commercial species	Abundance of marine species that are returned to the water after being caught, or are not caught at all. (e.g. Some recreational spp; bycatch species)
Emergent species	Abundance of marine species that are new (or have not been recorded) to a certain geographic location (e.g. long spinned urchin, jellyfish, northern shark

	spp)
Pests & diseases	Abundance of marine species that are pest and diseases (e.g. Green slime)
Ecosystem integrity	Level of biodiversity, structure (i.e., rocky reefs, coral reefs) and sustainable functioning of ecosystems (e.g. Healthy abalone habitat, kelp forests, seagrass beds)
Marine sectors	***Variable description***
Commercial fishing	Amount of catch for sale, barter or trade (e.g. Reef-line fishery, wet-line fishery, shark fishery, trawl fishery)
Charter fishing	Level of fishing from a vessel carrying paid passengers (e.g. Georges Bay fishing trip)
Marine tourism	Level of recreational activities (except fishing) for which payment is received which have as their host or focus the marine environment (e.g. Dive trip to the GBR, swimming with dolphins in WA)
Recreational fishing	Amount of fishing for sport or pleasure (e.g. Catching YTK in northeast Tasmania, angling off a jetty)
Aquaculture	Amount of farming of aquatic (marine) organisms which involves cultivating saltwater populations (some larval and juvenile stages of marine fish live in freshwater) under controlled conditions (e.g. Oyster, Barramundi, prawns, pearls)
Traditional owners	Number of people who, through membership in a descent group or clan, have responsibility for caring for particular Country (e.g. Torres strait islander line fishery)
Non-fishing based recreation	Level of recreational activities (other than fishing) which have as their base the marine environment (e.g. Snorkelling, Swimming, Sailing)
Other industrial use	Amount of industrial activities that take place in the marine environment other than fishing, marine tourism and aquaculture (e.g. Gas & oil industry, transportation)
Renewable energy	Energy generation in the marine environment or immediately adjacent coastal areas (e.g. Wave energy, wind energy, solar energy farms)

Four different climate drivers were identified in the St Helens case study, affecting five relevant marine sectors. By far the most obvious climate driver to commercial fishers, recreational fishers, and marine tourism was the increase in sea temperature. In the aquaculture industry the effect of changes in rainfall intensity and frequency were considered most important.

Only two different climate drivers were identified in the Bowen case study, which affected four marine sectors. Cyclones and storms were most mentioned and are the obvious climate driver for that region. Sea temperature was mentioned mainly in relation to the observed coral bleaching events.

Wind in combination with currents and sea temperature were climate drivers for the Geraldton case study. There were seven sectors affected by climate change in this region. The main difference to the other two case studies was the negative effect of wind on recreational fishing, charter and marine tourism. Moreover there was a perceived negative effect of sea temperature on aquaculture (as currently ‘cool’ water species provide aquaculture potential and the waters are warming).

Appendix 11 – Key marine species climate change risk assessment

Table 11.1: Sensitivity range and risk score for key marine species for three Australian regions (southeast, northeast, and west)

Species	*Risk score*	*sensitivity*	*Region*
Banana prawn	6.25	high	Northeast
Beche de mer (sand fish)	7.38	high	Northeast
Black bream	6.5	high	Southeast
Blacklip abalone	6.75	high	Southeast
Blacktip sharks	6.5	high	Northeast
Blue grenadier	6.25	high	Southeast
Blue threadfin	6.08	high	Northeast
Brownlip abalone	6.75	high	West
Commercial scallop	6.5	high	Southeast
Coral trout	6.13	high	Northeast
Greenlip abalone	7	high	Southeast
Greenlip abalone	6.5	high	West
King George whiting	6.25	high	Southeast
King threadfin	6.25	high	Northeast
Pigeye shark	6.63	high	Northeast
Red spot king prawn	6.17	high	Northeast
Red throat emperor	6.25	high	Northeast
Roe’s abalone	6.5	high	West
Scalloped hammerhead	6.63	high	Northeast
School mackerel	6.25	high	Northeast
School prawn	6.5	high	Southeast
Silver lipped pearl oyster	6.25	high	West
Southern rock lobster	6.75	high	Southeast
Southern saucer scallop	6.25	high	West
Spot tail shark	6.5	high	Northeast
Tiger prawn	6.17	high	Northeast
Tropical lobster	7.25	high	Northeast
Whiskery shark	6.25	high	West
Australian herring	6	medium-high	West
Australian salmon	5.5	medium-high	Southeast
Barramundi	5.94	medium-high	Northeast
Barred javelin	5.78	medium-high	Northeast
Black jew	5.83	medium-high	Northeast
Black spot cod	5.88	medium-high	Northeast
Blue sprat	5.75	medium-high	Southeast
Blue swimmer crab	5.5	medium-high	Southeast
Blue swimmer crab	5.75	medium-high	West
Bugs	5.92	medium-high	Northeast
Crimson snapper	5.75	medium-high	Northeast
Deep-water redfish	5.75	medium-high	West
Dusky flathead	5.67	medium-high	Northeast
eastern king prawn	6	medium-high	Southeast
Eastern king prawn	6	medium-high	Northeast
Gold spot cod	5.88	medium-high	Northeast
Goldband snapper	5.63	medium-high	Northeast
Golden snapper	5.75	medium-high	Northeast
Grass emperor	5.92	medium-high	Northeast
Grey mackerel	5.92	medium-high	Northeast
Gummy shark	6	medium-high	Southeast
Jack mackerel	5.75	medium-high	Southeast
Mangrove jack	5.67	medium-high	Northeast
Mud crab	5.75	medium-high	West
Mud crab	6	medium-high	Northeast
Pikey bream	5.83	medium-high	Northeast
Pink snapper	6	medium-high	West

Red emperor	5.92	medium-high	Northeast
Redbait	5.5	medium-high	Southeast
Rock flathead	5.5	medium-high	Southeast
Saddle tail snapper	5.75	medium-high	Northeast
Sand flathead	5.75	medium-high	Southeast
Sandfish	5.5	medium-high	West
Sandy sprat	5.75	medium-high	Southeast
Scallops	5.92	medium-high	Northeast
Snapper	5.5	medium-high	Southeast
Southern calamari	6	medium-high	Southeast
Southern garfish	5.5	medium-high	Southeast
Spangled emperor	5.92	medium-high	Northeast
Spanner crab	5.92	medium-high	Northeast
Spotted mackerel	5.69	medium-high	Northeast
Whiting	5.5	medium-high	Northeast
Yellowtail kingfish	5.5	medium-high	Southeast
Dusky flathead	5.25	medium	Southeast
Southern bluefin tuna	5.25	medium	Southeast
Spanish mackerel	5.25	medium	West
Spanish mackerel	5.33	medium	Northeast
Spanner crab	5.25	medium	Southeast
Striped marlin	5.25	medium	Southeast
Tiger flathead	5.25	medium	Southeast
Western king prawn	5.25	medium	Southeast
Yellowtail scad	5.25	medium	Southeast
Australian anchovy	5	medium-low	Southeast
Australian sardine	5	medium-low	Southeast
Bigeye tuna	5	medium-low	Southeast
Billfish	5.13	medium-low	Northeast
Blue mackerel	5	medium-low	Southeast
Blue swimmer crab	5	medium-low	Northeast
Bluespot flathead	5	medium-low	Southeast
Gloomy octopus	4.75	medium-low	West
Yellowfin tuna	4.75	medium-low	Southeast

Based on Pecl et al 2011, Welch et al (unpublished), Caputi et al (unpublished)

Appendix 12 – Case study non-climate pressures

Table 12.1: Price related non climate drivers of fishing behaviour in the three case study communities, St Helens (H), Bowen (B), and Geraldton (G).

Price factors	***Effect***	***H***	***B***	***G***	***Current development***
Species catchability#	If species are abundant (not abundant) and easy (hard) to catch prices will be lower (higher).	✓	✓	✓	(↑↓)
Seasonality of effort	Quota management allows fishers to seasonally allocate effort and 'fish to market' at times when prices are high.	✓		✓	(↑) in seasonal fishing
Exchange rate	Unfavourable exchange rates will make product more expensive to import which affects demand, prices, and profitability	✓	✓	✓	(↑) in exchange rate
Fish Imports	Fish imports will compete with local produce and put downward pressure on prices.	✓	✓	✓	(↑) in fish imports
Local & import market restrictions	Supermarket chains imposing a ban on some fish products would put a downward pressure on price. Restrictions by importing countries for some fish products also put a downward pressure on price.			✓	(↑) in market restrictions
MSC certification	MSC certification can create access to new markets and retail outlets resulting in increased prices. Absence of certification can cause the opposite.			✓	(↓) limited MCS certification
Illegal international market access	Illegal access to export markets can cause price fluctuations (e.g. when borders are unexpectedly closed prices fall).	✓		✓	(↑) illegal market access
Processor availability	Adequate fish will allow multiple processors to operate and create competition, driving prices up (while processors can also 'dump' fish on the market to reduce prices for other processors).		✓	✓	(↑) availability in Geraldton (↓) in Bowen
Buyer & seller licences	Cost and availability of licences will affect competition between processors reducing the fish prices paid to fishers.		✓	✓	(↑) in licence cost

Species catchability is the factor also affected by climate drivers not shown here.

The following factors were found to affect the cost of labour in the three locations. All three locations were experiencing labour cost increases due to employment opportunities in other industries.

Table 12.2: Labour related non climate drivers of fishing behaviour in the three case study communities, St Helens (H), Bowen (B), and Geraldton (G).

Labour factors	***Effect***	***H***	***B***	***G***	***Current development***
Age	Younger fishers are more likely to pursue alternative income earning options (especially if no quota is owned)	✓	✓	*	(↑) young fishers looking for other employment
Oil & gas industry development	Skill compatible (sea going jobs) job opportunities in high income earning oil & gas sector	✓		✓	(↑) development
Mineral resource sector	Alternative high income earning opportunities by growth in job opportunities in the mineral resources		✓	✓	(↑) development
Port development	Growing mineral resource sector creates demand for port development also creating local jobs		✓	✓	(↑) development
Rail development	Growing mineral resource sector creates demand for rail development creating job alternatives		✓		(↑) development

* Because the alternative jobs were available locally there did not seem to be an age related effect for Geraldton.

The following factors were found to affect the variable cost structure of commercial fishing in the three locations.

Table 12.3: Variable cost related non climate drivers of fishing behaviour in the three case study communities, St Helens (H), Bowen (B), and Geraldton (G).

Variable cost factors	*Effect*	*H*	*B*	*G*	*Current development*
Quota ownership characteristics	If the fisher doesn't own quota they incur lease costs thus increasing variable cost	✓			(↑) lease quota fishing
Bank lending rules	Inability to borrow money from banks prevents some fishers buying quota thus increasing their longer term variables costs	✓			(↓) bank lending for fish quota purchase
Pass quota down to family member	If quota is (not) passed down in a family this will increase (reduce) quota ownership thus reducing (increasing) lease quota (variable) costs	✓			General trend (↓) quota passed down
Retirement funding options/alternatives	If quota is intended to fund retirement this will reduce the likelihood that it will be passed down, reducing quota ownership and thus increasing lease quota (variable) costs	✓			General trend (↑) hang onto quota for retirement purposes
Family fishing history and family quota	If the family has a fishing history it often means that family quota is owned thus reducing lease quota (variable) costs	✓			(↓) families with fishing history
Lease quota cost	High lease quota cost increase variable costs which squeezes profit margins.	✓		✓	(↑) lease cost
Method of lease quota trade	Availability (unavailability) of 'non-binding' lease quota at reasonable prices reduces (increase) variable costs and also increase 'speculation' on quota prices	✓		✓	(↑) binding lease quota trade
Administrative & monitoring requirements	Costliness and time consuming effort to obey the management rules increases variable costs	✓	✓		(↑) requirements and reporting
Investor licences	Concentration of licence ownership by investors	✓	✓		(↑) increase investor owners
Communication and technology (phones)	Technology allows greater communication & information sharing (stealing) which increases effort in some fishing locations #		✓	✓	(↑) increase in technology
General costs	Fluctuations in petrol prices, maintenance costs etc.	✓	✓	✓	General trend (↑)

mentioned in association with marine reserves and reduced fishing area availability.

The following factors were found to affect the fixed cost structure of commercial fishing in the three locations.

Table 12.4: Fixed cost related non climate drivers of fishing behaviour in the three case study communities, St Helens (H), Bowen (B), and Geraldton (G).

Fixed cost factors	***Effect***	***H***	***B***	***G***	***Current development***
Vessel ownership	Vessel ownership characteristics affects fixed cost overheads	✓			General trend (↑↓)
Vessel size	Larger size vessels have different efficiency and associated costs and limit (increase) access to some fishing areas/harbours.	✓			General trend (↑) larger size vessels
Licence (access) cost	Fisher's yearly cost paid to government for access to fishery that pays for monitoring, research etc. is high.	✓	✓	✓	General trend (↑) cost

There are a range of other non-climate variables that are not directly price or cost related that also affect participation in the commercial fishing sector.

Table 12.5: Fisheries management, resourcing, other industry impact, fishing, and family and community related non climate drivers of fishing behaviour in the three case study communities, St Helens (H), Bowen (B), and Geraldton (G).

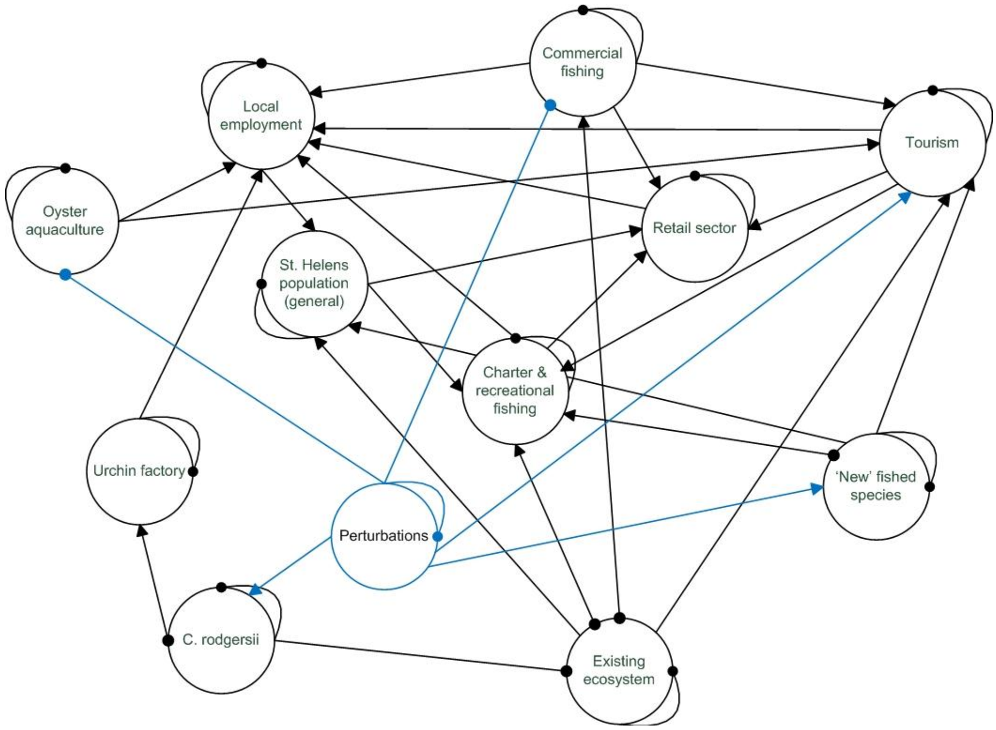
Fishery management	***Effect***	***H***	***B***	***G***	***Current development***
Management & co-management arrangements	Unbalanced or mis-representative committee membership	✓	✓		(↑) unrepresenta-tiveness
Exploratory licence rules	Extreme difficulty (cumbersome) in getting approval	✓			(↑) difficulty
Resourcing	***Effect***	***H***	***B***	***G***	***Current development***
Government department resources	Cuts in government resources imply reduced exploratory licence processing and reduced capacity for research and monitoring.	✓		✓	(↓) resources
Public works funding	Availability of resources will affect access to fishing grounds and harbour.	✓			(↓) public funding
Access to Georges Bay	Unclear institutional responsibility & reduced availability of resources affects access through shallow bay entry/exit to fishing grounds and harbour.	✓			(↓) access for large vessels
Other industry impact	***Effect***	***H***	***B***	***G***	***Current development***
Marine transport activity	Boating activity can cause pollution and introduction of pest species.	✓	✓	✓	(↑) transport activity
Harbour activity	Dredging of harbour & boating activity from growing mineral resource sectors can lead to suspended sediments & spills.		✓	✓	(↑) activity
Coastal infrastructure development	Some coastal development has negative effect on ecosystem integrity.			✓	(↑) development activity
Commercial fishery diversification options	Availability of exploratory licences allows fishers to diversify.	✓			(↓) diversification options
Fishing	***Effect***	***H***	***B***	***G***	***Current***

					development
Under- and over-sized fish catch	Recreational or commercial fishers can cause sustainability issues mostly by over size catches.	✓	✓	✓	(↑↓) occurrence
Second job opportunities	Quota management reduces fishing time due to increased efficiency in catching. In some regions increased available time created opportunities to have more than one job (where jobs were more readily available).			✓	(↑) opportunities
Family & community	***Effect***	***H***	***B***	***G***	***Current development***
Family dynamics	Reduced time allocated to fishing can increase home time and affect family dynamics.			✓	(↑↓) both good & bad reported
Lifestyle	Quota management has meant more flexibility in the timing and the amount of time fishers spend fishing and thus being away from their family. In some cases this meant that they could choose to remain home at times of celebrations or need.	↑		✓	(↑↓) lifestyle enjoyment
Community spirit	Changes in timing of fishing with quota means less time together as a 'fishing community'*.			✓	(↓) community spirit

* mentioned in Geraldton due to the nature of the Abrolhos island. Although the process of community decline had been happening for some time prior to quota introduction.

Appendix 13 – Qualitative models for three case study communities

a)



b)

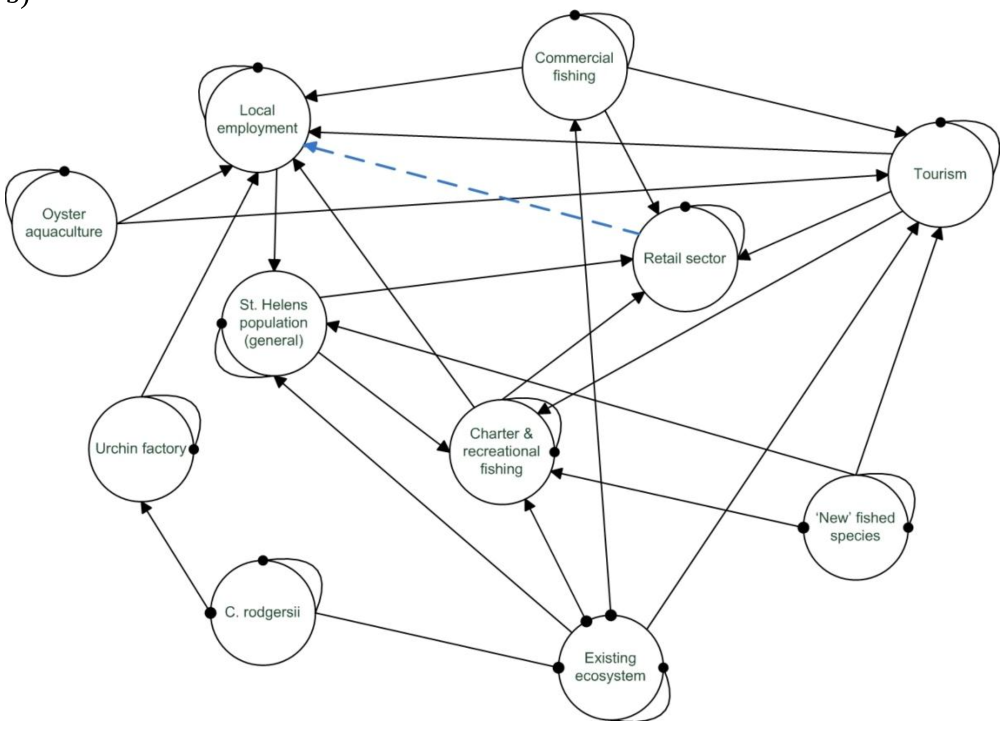
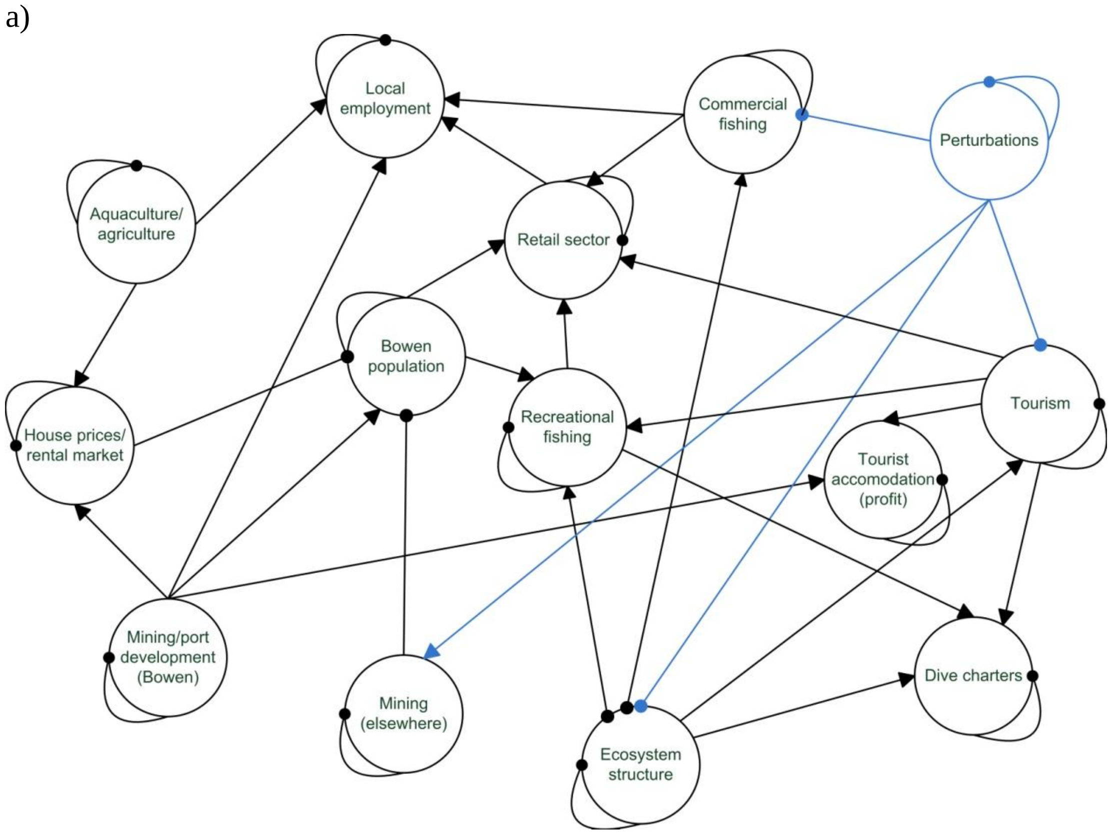


Figure 13.1 Coastal community model representing the dynamics of marine-dependent sectors and the marine environment in St Helens, Tasmania. a) Current St Helens community model including changes and impacts (perturbations) as perceived by local survey participants (Table 1), b) Alternative coastal community model with the adaptation of removing the link (blue arrow) from the retail sector to local employment to increase stability by removing the short positive feedback cycle (destabilising) between local employment, the St Helens population and the retail sector, which in real terms can be seen as a reduced reliance on retail for local employment.

a)



b)

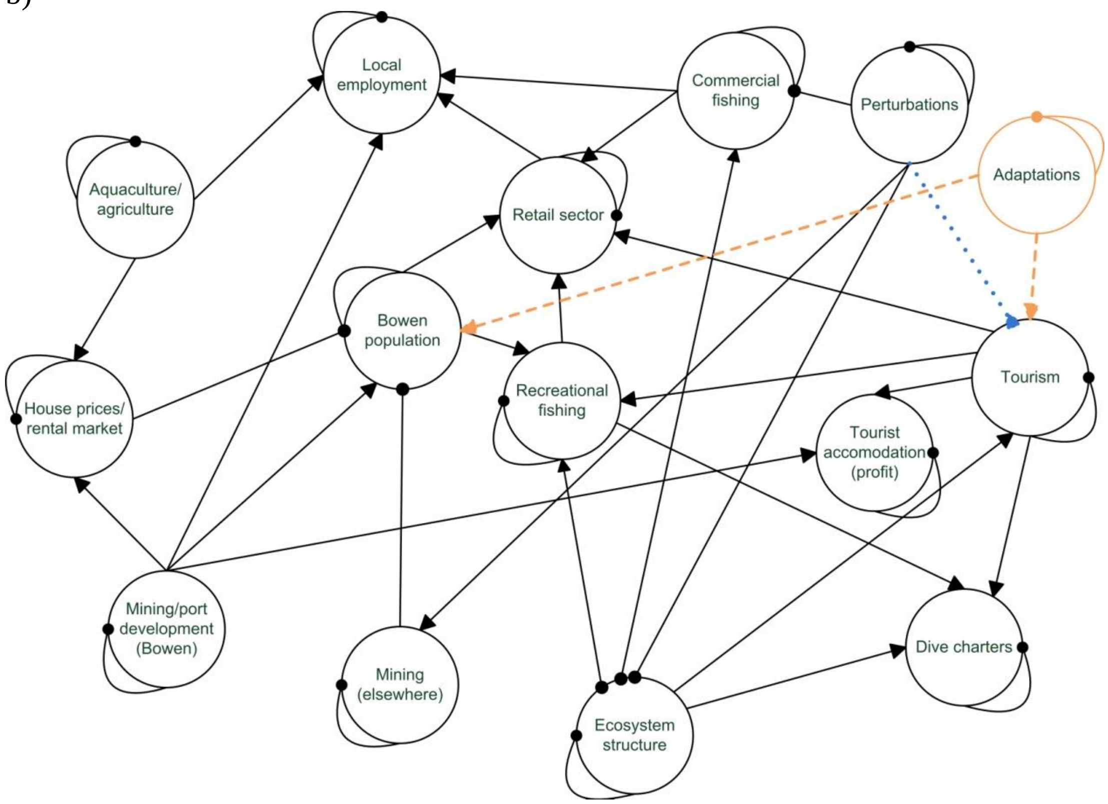
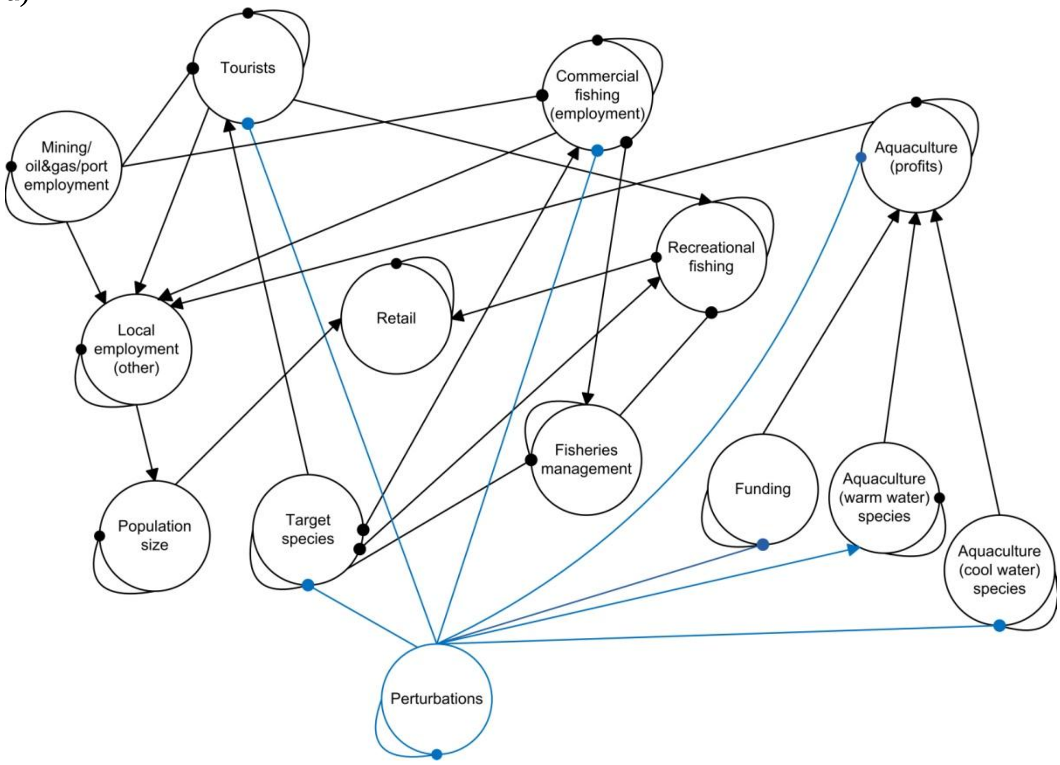


Figure 13.2 Coastal community model representing the dynamics of marine-dependent sectors and the marine environment in Bowen, Queensland. a) Current Bowen community model including changes and impacts (blue) as perceived by local survey participants (Table 1), b) alternative coastal community model with perturbation causing a decline in tourism removed (blue dashed line) and replaced by an adaptation to increase tourism in Bowen as well as the Bowen population.

a)



b)

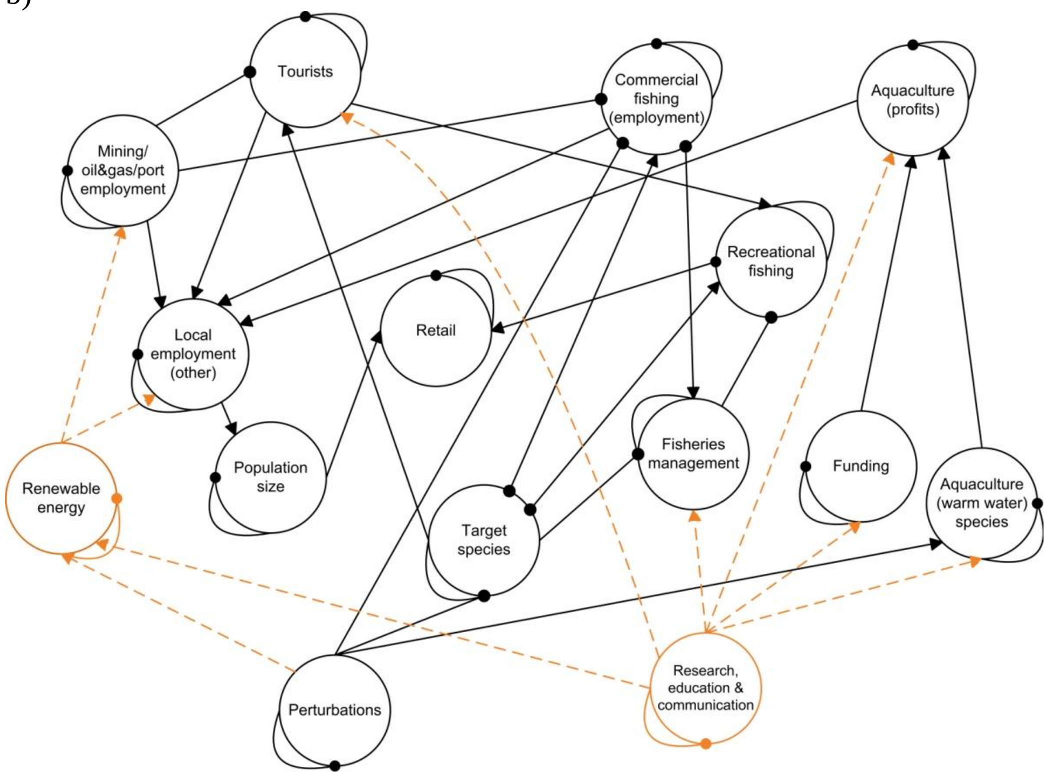


Figure 13.3 Coastal community model representing the dynamics of marine-dependent sectors and the marine environment in Geraldton, Western Australia. a) Current Geraldton community model including changes and impacts (blue) as perceived by local survey participants (Table 1), b) alternative coastal community model with adaptations (dashed lines) to increase research, education and communication, and renewable energy production. These adaptations remove perturbations to tourism, aquaculture and funding seen in a).

Appendix 14 – New species identified in case study locations

Information gathered in the case study locations provided observations of new species and potential pests in the marine environment as observed by the survey respondents. This is not an exhaustive list and many more species and more detailed information on new species sightings can be found on Redmap (www.redmap.org.au).

Table 14.1: New marine species and potential pest sightings in the case study areas.

Sighted new species	***Status***	***Marine sector***	***Case study***
Dolphin fish	Confirmed (?)	Rec	St Helens
Striped Marlin	Confirmed	Rec	St Helens
Easter Rock Lobster	Confirmed	Comm, Rec	St Helens
Stripy Tuna		Rec	St Helens
Bluefin Tuna		Comm, Rec, tourism	St Helens
Yellow fin Tuna		Rec, tourism	St Helens
King George Whiting	Confirmed	Rec, tourism	St Helens
Broadbill		Rec	St Helens
Yellow Tail Kingfish	Confirmed	Rec, tourism	St Helens
(northern) shark species	Abundance increase	None	Geraldton
Whales	Abundance increase	Tourism	Geraldton
Sea snake	Abundance increase	None	Geraldton
Dugong	Individual(s) sighted	Traditional	Geraldton
Threat species (potential pest)	***Status***	***Marine sector***	***Case study***
Jelly fish	Confirmed increase	None	St Helens
Blue bottles	Confirmed	None	St Helens
Starfish	Confirmed	None	St Helens
Potato Cod	Unconfirmed	None	St Helens
Jelly fish	Increase in shark nets	None	Geraldton
Weed (Lion's mane?)	Increase in shark nets	None	Geraldton

Appendix 15 – Other adaptation options

Table 15.1: New marine species and potential pest sightings in the case study areas.

Topic	***Marine sector***	***Action*** ***Climate change related***	***Reason***
Information (CC)	Community	Develop good information dispersal methods to inform public about access and local conditions after severe weather events.	Access to towns affected by recent climate driven events should be mediated immediately to ensure that tourist travel patterns are not affected for too long (e.g. re-opening roads after rainfall events and avoid 'extended' impact of cyclones)
Information (CC)	Commercial fishing	Develop courses that inform fishers about the potential financial implications of species disappearing or entering local waters	Fishers may wish to learn how to develop investment plans to investigate if investing in, for instance, a larger vessel is worthwhile – or purchase more quota
Information (CC)	Commercial fishing	Develop information sessions on the implications on changing species abundance on quota	Planning for the future is important to ensure fisheries remain viable. Fishers may wish to find out the implications of selling or buying quota if species are impacted by climate change
Monitoring (CC)	Recreational fishing	Improve monitoring of recreational catch to reduce conflict between commercial and recreational fishing especially considering predicted abundance changes	A more frequent official 'count' of participation and catch estimates is necessary. Although difficult to estimate, illegal catches should/could be better accounted for and incorporated into catch estimates.
Development (CC)	Aquaculture	Encourage investigation of closed on land systems to ensure development of aquaculture into the future.	Aquaculture is constrained by available farming space and only limited expansion is possible in the majority of situations
Development (CC)	Aquaculture	Encourage the development of combined aquaculture and tourism attractions	Direct sale outlets and other aquaculture related tourism opportunities could assist with enabling continued sustainable aquaculture development. Linking tourism to aquaculture would also provide a learning opportunity to demonstrate the benefits of sustainable aquaculture development.
Development (CC)	Aquaculture	Support local aquaculture by increasing collaboration with local research institutions to enhance new species development (and diversification in anticipation of marine climate pressures)	High development costs associated with new aquaculture enterprises can be partly assisted by close collaboration with research institutions.
Markets (CC)	Commercial fishing	Diversification of markets - re-establishing local and domestic fish sales	Diversification buffers producers against failure in a specific single market which has occurred for rock lobster on several occasions. Increasing local and domestic outlets can help promote tourism as tourists often associate "fishing" towns with fresh local produce. Increased marketing of the benefits of fresh local seafood both in health and local employment.

Topic	*Marine sector*	*Action* *Non- climate related*	*Reason*
Management	Recreational fishing	Flexible and adaptive rule development for 'unmanaged' species	When new (commercial) species appear in local waters management decisions have to be prompt and flexible to avoid a 'gold rush'.
Management	Commercial fishing	Renewal of representation on co-management committees and industry bodies through better 'rotation times' and 'term limitations'	In all locations the issue of balanced representativeness and renewal was mentioned with respect to industry bodies and the co-management decision committees.
Management	Commercial fishing	Incentives to better balance representation on co-management committees and industry bodies.	There is generally low incentive for participation due to entrenched interests but importantly, time demands and cost of interactions (i.e. loss of fishing time). Adequate monetary reimbursements are required and more locally held meetings.
Information	All	Encourage opportunities for increased participation (local community/tourists/commercial and recreational marine industries) in "scientific research" or monitoring programs.	Local participants and tourists often have considerable knowledge of the marine domain and are often eager to assist in science by either supporting scientists or collecting "citizen science". Citizen science is rapidly increasing globally.
Information	Commercial fishing	Develop information sessions on succession planning	Provide information sessions on the value of different way of encouraging young people to enter the industry and provide information to quota owners on the impacts of retaining or selling quota
Supply chain	Commercial fishing	Encourage more transparent pricing systems in processing industry	Improved transparency in prices between fishers and processors would help build trust and stronger co-operation to explore alternative processing options or markets.
Markets	Commercial fishing	Facilitating supply of 'locally caught' fish to local restaurants	This affects the local restaurants who want to serve locally caught fish especially if in tourist locations (related to climate rations action mentioned above)
Labour	Commercial fishing	At times of significant alternative employment in other sectors – labour shortages in fishing could be addressed by providing incentives to retain skill base and labour in fishing and short term shortages could be addressed through temporary visa for overseas labour	High wages in the mining and oil & gas sectors mean fishers have trouble retaining (reliable) deckhands.
Infrastructure	Recreational fishing	Keep infrastructure provisions in step with growth in participation in recreational fishing.	Access to jetties and avoiding 'boat ramp rage' is increasingly important especially if recreational fishing participation continues to grow.
Services	Community	Maintain local engineering and support services to fishers and aquaculture to maintain fishery contribution to local economy	With a declining commercial fishing sector in small local communities, the infrastructure and service provision to remaining fishers becomes increasingly problematic.

References

(ACERA), A. C. o. E. f. R. A. 2010. *Process manual: Elicitation tool*. Melbourne: ACERA.

Adger, W. N. 2000. Social and ecological resilience: are they related? *Progress in Human Geography* 24: 347-364.

Adger, W. N. 2006. Vulnerability. *Global Environmental Change* 16: 268-281.

Adger, W. N., T. P. Hughes, C. Folke, S. R. Carpenter, and J. Rockström. 2005. Social -ecological resilience to coastal disasters. *Science* 309: 1036-1039.

Adger, W. N., S. Dessai, M. Goulden, M. Hulme, I. Lorenzoni, D. R. Nelson, L. O. Naess, J. Wolf, and A. Wreford. 2009. Are there social limits to adaptation to climate change? *Climate Change* 93(3-4): 335-354.

Allison, E. H. 2005. The fisheries sector, livelihoods and poverty reduction in eastern and southern Africa. In *Rural livelihoods and poverty reduction policies*, edited by F. H. Ellis F. London: Routledge.

Allison, E. H. and F. Ellis. 2001. The livelihoods approach and management of small-scale fisheries. *Marine Policy* 25(5): 377-388.

Allison, E. H. and B. Horemans. 2006. Putting the principles of the Sustainable Livelihoods Approach into fisheries development policy and practice. *Marine Policy* 30: 757-766.

Australian Greenhouse Office. 2006. *Climate Change Impacts and Risk Management, A Guide for Business and Government*. Canberra: Australian Greenhouse Office.

Badjeck, M. C., E. H. Allison, A. S. Hall, and N. K. Dulvy. 2010. Impacts of climate variability and change on fishery-based livelihoods *Marine Policy* 34: 375-383.

Berkes, F. 2002. Epilogue: making sense of Arctic environmental change? In *The earth is faster now: indigenous observations of arctic environmental change*, edited by I. Krupnik and D. Jolly. Fairbanks AK: Arctic Research Consortium of the United States and Smithsonian Institution.

Berkes, F. and D. Jolly. 2001. Adapting to climate change: social-ecological resilience in a Canadian western Arctic community. *Conservation Ecology* 5(2): 18.

Berman, M. and G. Kofinas. 2004. Hunting for models: grounded and rational choice approaches to analyzing climate effects on subsistence hunting in an Arctic community. *Ecological Economics* 49: 31-46.

Bernhardt, J. R. and H. M. Leslie. 2013. Resilience to climate change in coastal marine ecosystems. *Annaul Review of Marine Science* 5(1-8): 1-22.

Binkley, M. 2000. Getting by in Tough Times: Coping with the Fisheries Crisis. *Women's Studies International Forum* 23(3): 323-332.

Bizikova, L., T. Dickinson, and L. Pintér. 2009. Participatory scenario development for translating impacts of climate change. In *Participatory Learning and Action 60: Community-based adaptation to climate change*, edited by H. Reid, et al. London: International Institute for Environment and Development (IIED).

Botsford, L. W., J. C. Castilla, and C. H. Peterson. 1997. The management of fisheries and marine ecosystems. *Science* 277: 509-515.

Campbell, J. 1999. *Linking the sustainable livelihood approach and the code of conduct for responsible fisheries*. Exeter, UK: The Innovation Centre University Of Exeter Campus.

Carney, D. 2002. *Sustainable livelihoods approaches: Progress and possibilities for change*. Ontario, Canada: Deparment for International Development.

Cheung, W. W. L., V. W. Y. Lam, J. L. Sarmiento, K. Kearney, R. Watson, and D. Pauly. 2009. Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries* 10(3): 235-251.

Clay, P. M. and J. Olson. 2007. Defining fishing communities: Issues in Theory and Practice, edited by A. A. Association.

Crane, T. A., C. Roncoli, and G. Hoogenboom. 2011. Adaptation to climate change and climate variability: The importance of understanding agriculture as performance. *Journal of Life Sciences* 57: 179-185.

Cruikshank, J. 2001. Glaciers and climate change: perspectives from oral tradition. *Arctic* 54: 377-393.

Dambacher, J. M. and R. Ramos-Jiliberto. 2007. Understanding and predicting effects of modified interactions through a qualitative analysis of community structure. *Quart. Rev. Biol* 82(3): 227-250.

Dambacher, J. M., H. W. Li, and P. A. Rossignol. 2002. Relevance of community structure in assessing indeterminacy of ecological predictions. *Ecologia Aplicada* 83: 1372-1385.

Dambacher, J. M., H. Luh, H. W. Li, and P. A. Rossignol. 2003. Qualitative stability and ambiguity in model ecosystems. *American Naturalist* 161: 876-888.

Davis, D. and S. Gerrard. 2000. Gender and Resource Crisis in the North Atlantic Fisheries. *Women's Studies International Forum* 28(3): 279–286.

Doney, S. C., M. Ruckelshaus, J. Duffy, J. Barry, F. Chan, C. A. English, H. M. Galindo, J. M. Grebmeier, A. B. Hollowed, N. Knowlton, J. Polovina, N. N. Rabalais, W. J. Sydeman, and L. D. Talley. 2012. Climate change impacts on marine ecosystems. *Annu. Rev. Mar. Sci* 4: 11-37.

Dufour, F., H. Arrizabalaga, X. Irigoien, and J. Santiago. 2010. Climate impacts on albacore and bluefin tunas migrations phenology and spatial distribution. *Progress in Oceanography* 86: 283-290.

Eyre, S., S. Niall, F. Silke, and S. Young. 2011. *Climate change adaptation toolkit user guide: A comprehensive guide to planning for climate change adaptation in three steps*. Geelong: City of Greater Geelong, RMIT University, NetBalance Foundation.

Feng, M., E. Weller, and K. Hill. 2009. The Leeuwin Current. In *Report Card of Marine Climate Change for Australia; detailed scientific assessment*, edited by E. S. Poloczanska, et al. Canberra: NCCARF Publication 05/09.

Folke C, Carpenter S, Walker B, Scheffer M, and Elmqvist T. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. *Annu. Rev. Ecol. Evol. Syst.* 35: 557-581.

Goodman, L. A. 1961. Snowball sampling. *Annals of Mathematical Statistics* 32(1): 148-170.

Grafton, Q. R. 2010. Adaptation to climate change in marine capture fisheries. *Marine Policy* 34(3): 606-615.

Hobday, A. J. 2010. Ensemble analysis of the future distribution of large pelagic fishes in Australia. *Progress in Oceanography*.

Hobday, A. J. and E. S. Poloczansk. 2010. *Adapting agriculture to climate change: Preparing Australian agriculture, forestry and fisheries for the future*. Melbourne: CSIRO Publishing**:** 205-228.

Hobday, A. J. and J. M. Lough. 2011. Projected climate change in Australian marine and freshwater environments. *Marine and Freshwater Research* 62: 1000-1014.

Hobday, A. J. and G. T. Pecl. in review. Identification of global marine hotspots: sentinels for change and vanguards for adaptation. *Reviews in Fish Biology and Fisheries*.

Hobday, A. J., E. S. Poloczanska, and R. J. Matear. 2008. *Implications of Climate Change for Australian Fisheries and Aquaculture: a preliminary assessment*. Canberra: Report to the Department of Climate Change, Canberra, Australia.

Hochachka, P. W. and G. N. Somero. 2002. *Biochemical Adaptation: Mechanism and Process in Physiological Evolution*. Oxford, UK: Oxford University Press.

Holling, C. S. 1978. *Adaptive environmental assessment and management*. London, England: John Wiley and Sons.

Hosack, G. R., K. R. Hayes, and J. M. Dambacher. 2008. Assessing uncertainty in the structure of ecological models through a qualitative analysis of system feedback and Bayesian belief networks. *Ecological Applications* 18: 1070-1082.

Huddlestone, V. 2006. *Assessment of Western rock lobster strategic management options: A social assessment of coastal communities hosting the Western rock lobster fishing fleet*. Perth, WA: Fisheries Management Paper.

Jacob, S., M. Jepson, and F. L. Farmer. 2005. What You See Is Not Always What You Get: Aspect Dominance as a Confounding Factor in the Determination of Fishing Communities. *Human Organization* 64(4): 374-385.

Kuruppu, N. and D. Liverman. 2011. Mental preparation for climate adaptation: The role of cognition and culture in enhancing adaptive capacity of water management in Kiribati. *Global Environmental Change* 21: 657-669.

Last, P. R., W. T. White, D. C. Gledhill, A. J. Hobday, R. Brown, G. J. Edgar, and G. T. Pecl. 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.

Liebowitz, S. J. and S. E. Margolis. 1995. Path dependence, lock-in and history. *Journal of Law, Economics and Organisation* 11(1): 205-226.

Lin, C. C., H. Peng, and J. W. Grizzle. 2004. A stochastic control strategy for hybrid electric vehicles. *Proceedings of the American Control Conference* 0743-1619(5): 4710.

Marshall, N. A. 2010. Understanding social resilience to climate variability in primary enterprises and industries. *Global Environmental Change* 20: 36-43.

Marshall, N. A., D. M. Fenton, P. A. Marshall, and S. G. Sutton. 2007. How Resource Dependency Can Influence Social Resilience, within a Primary Resource Industry. *Rural Sociology* 72(3): 359-390.
Marshall, N. A., P. A. Marshall, A. Abdulla, T. Rouphael, and A. Ali. 2011. Preparing for climate change: recognising its early impacts through the perceptions of dive tourists and dive operators in the Egyptian Red Sea. *Current Issues in Tourism* 14(6): 507-518.
Marshall, N. A., R. C. Tobin, P. A. Marshall, M. Gooch, and A. J. Hobday. 2013 Vulnerability of marine resource users to extreme weather events. *Ecosystems,*.
Martin, J., M. Rogers, and C. Winter. 2010. *Social Learning and Adaptation*. Bendigo: Centre for Sustainable Regional Communities.
McBeath, J. 2003. Institutional responses to climate change: the case of the Alaskan transportation system. *Mitigation and Adaption Strategies for Global Change* 8(1): 3-28.
McLeman, R. A., M. Brklacich, M. Woodrow, K. Vodden, P. Gallagher, and R. Sander-Regier. 2011. Opportunities and barriers for adaptation and local adaptation planning in Canadian rural and resource-based communities. In *Climate change adaptation in developed nations: From theory to practice*, edited by J. D. Ford and L. Berrang-Ford: Springer Science and Business Media B.V.
Miller, E. and L. Buys. 2008. The impact of social capital on residential water-affecting behaviors in a drought-prone Australian community. *Society and Natural Resources* 21(3): 244-257.
Milne, M., N. Stenekes, and J. Russell. 2008. *Climate Risk and Industry Adaptation*. Canberra: Australian Bureau of Rural Sciences.
Moser, S. C. and J. Tribbia. 2008. Vulnerability to inundation and climate change impacts in California: coastal managers' attitudes and perceptions. *Marine Technological Society* 40(4): 35-44.
Moser, S. C. and A. L. Luers. 2008. Managing climate risks in California: the need to engage resource managers for successful adaptation to change. *Climate Change* 87(1): 307-322.
Næss, L. O., G. Bang, S. Eriksen, and J. Vevatne. 2005. Institutional adaptation to climate change: flood responses at the municipal level in Norway. *Global Environmental Change* 15(2): 125-138.
Neuheimer, A. B., R. E. Thresher, J. M. Lyle, and J. M. Semmens. 2011. Tolerance limit for fish growth exceeded by warming waters. *Nature Climate Change* 1: 110-113.
New Zealand's International Aid and Development Agency. 2007. *NZAID Sustainable Livelihoods Approach Guideline* New Zealand: NZAID.
NOAA Office of Ocean and Coastal Resource Management. 2010. *Adapting to climate change: A planning guide for state coastal managers*. Silver Springs, MD: NOAA.
Nursey-Bray, M., G. T. Pecl, S. Frusher, C. Gardner, M. Haward, A. J. Hobday, S. Jennings, A. E. Punt, H. Revill, and E. I. van Putten. 2012. Communicating climate change: Climate change risk perceptions and rock lobster fishers, Tasmania. *Marine Policy* 36: 753–759.
Nye, J. A., J. S. Link, J. A. Hare, and W. J. Overholtz. 2009. Changing spatial distribution of fish stocks in relation to climate and population size on the Northeast United States continental shelf. *Marine Ecology Progress Series* 393: 111-129.
O'Connor, M. I., J. F. Bruno, S. D. Gaines, B. S. Halpern, S. E. Lester, B. Kinlan, and J. M. Weiss. 2007. Temperature control of larval dispersal and the implications for marine ecology, evolution, and conservation. *Proceeding of the National Acadamy of Science USA* 104(4): 1266-1271.
Offermans, A., M. Haasnoot, and P. Valkering. 2011. A method to explore social response for sustainable water management strategies under changing conditions. *Sustainable Development* 19: 312-324.
Olson, J. and P. M. Clay. 2001. An Overview of the Social and Economic Survey Administered During Round II of the Northeast Multispecies Fishery Disaster Assistance Program. Woods Hole, MA: National Marine Fisheries Service, Northeast Fisheries Science Center.
Orlove, B. S., J. C. H. Chiang, and M. A. Cane. 2000. Forecasting Andean rainfall and crop yield from the influence of El Nino on Pleiades visibility. *Nature* 403: 68-71.
Parmesan, C., C. Duarte, E. Poloczanska, A. J. Richardson, and M. C. Singer. 2011. Overstretching attribution *Nature Climate Change* 1: 1-4.
Pecl, G. T., T. J. Ward, Z. Doubleday, S. Clarke, J. Day, C. Dixon, S. Frusher, P. Gibbs, A. Hobday, N. Hutchinson, S. M. Jennings, K. Jones, X. Li, D. Spooner, and R. Stoklosa. 2011. *Risk Assessment of Impacts of Climate Change for Key Marine Species in South Eastern Australia. Part 1: Fisheries and Aquaculture Risk Assessment*. Canberra: Fisheries Research and Development Corporation.
Pelling, M. 2003. *The vulnerability of cities: natural disaster and social resilience*. London: Earthscan.
Pelling, M. undated. Social capital and institutional adaptation to climate change.
Pelling, M. and C. High. 2005. Understanding adaptation: what can social capital offer assessments of adaptive capacity? *Global Environmental Change* 15(4): 308-319.

Penney, J. 2011. *Guide to Writing Community Climate Change Adaptation Case Studies Clean Air Partnership Toronto*. Tononto, Canada: Clean Air Partnership

Perry, A. L., P. J. Low, J. R. Ellis, and J. D. Reynolds. 2005. Climate Change and Distribution Shifts in Marine Fishes. *Science* 308(5730): 1912-1915.

Perry, R. I., R. E. Ommer, M. Barange, S. Jentoft, B. Neis, and U. R. Sumaila. 2011. Marine social-ecological responses to environmental change and the impacts of globalization. *Fish and Fisheries* 12: 427-450.

Preston, B. L. 2010. Scenarios for Climate Adaptation: An International Perspective. In *Presentation to VCCCAR Scenarios for Climate Adaptation Stakeholder Workshops*. Melbourne.

Productivity Commission. 2012. *Barriers to Effective Climate Change Adaptation*. Canberra:

Rice, J. C. and S. M. Garcia. 2011. Fisheries, food security, climate change, and biodiversity: characteristics of the sector and perspectives on emerging issues. *ICES Journal of Marine Science* 68: 1343-1353.

Riedlinger, D. and F. Berkes. 2001. Contributions of traditional knowledge to understanding climate change in the Canadian Arctic. *Polar Record* 37: 315-328.

Risbey, J. S., M. Kandlikar, H. Dowlatabadi, and D. Graetz. 1999. Scale, context, and decision making in agricultural adaptation to climate variability and change. *Mitigation and Adaptation Strategies for Global Change* 4: 137-165.

Ruhanen, L. and A. Shakeela. 2012. Responding to Climate Change: Australian Tourism Industry Perspectives on Current Challenges and Future Directions. *Asia Pacific Journal of Tourism Research*.

Sainsbury, K. J., A. E. Punt, and A. D. M. Smith. 2000. Design of operational management strategies for achieving fishery ecosystem objectives. *ICES Journal of Marine Science* 57: 731-741.

Schirmer, J. and A.-M. Casey. 2005. *Social Assessment Handbook: A guide to methods and approaches for assessing the social sustainability of fisheries in Australia*. Canberra: Fisheries Research and Development Corporation.

Sen Gupta, A., A. Santoso, A. S. Taschetto, C. C. Ummenhofer, J. Trevena, and M. H. England. 2009. Projected changes to the Southern Hemisphere ocean and sea ice in the IPCC AR4 Climate Models. *Journal of Climate* 22: 3047-3078.

Shachter, R. D. 1988. Probabilistic inference and influence diagrams. *Operations Research* 36: 589-604.

Simpson, S. D., S. Jennings, M. P. Johnson, J. L. Blanchard, P.-J. Schon, D. W. Sims, and M. J. Genner. 2011. Continental Shelf-Wide Response of a Fish Assemblage to Rapid Warming of the Sea. *Current Biology*.

Somero, G. N. 2010. The physiology of climate change: how potentials for acclimatization and genetic adaptation will determine ‘winners’ and ‘losers’. *The Journal of Experimental Biology* 213: 912-920.

Ticehurst, J. L., L. T. H. Newham, D. Rissik, R. A. Letcher, and A. J. Jakeman. 2007 A Bayesian network approach for assessing the sustainability of coastal lakes in New South Wales, Australia. *Environmental Modelling and Software* 22: 1129-1139.

Tompkins, E. L. and W. N. Adger. 2004. Does adaptive management of natural resources enhance resilience to climate change? *Ecology and Society* 9(2): 10.

Tribbia, J. and S. C. Moser. 2008. More than information: what coastal managers need to prepare for climate change. *Environmental Science and Policy* 11(4): 315-328.

UK Climate Impacts Program. 2006. *Identifying adaptation options*. London: UK Climate Change Program.

US Indian Ocean Tsunami Warning System Program. 2007. *How Resilient is Your Coastal Community? A Guide for Evaluating Coastal Community Resilience to Tsunamis and Other Coastal Hazards*. Bangkok, Thailand: U.S. Indian Ocean Tsunami Warning System Program supported by the United States Agency for International Development and partners.

Varum, C. and C. Melo. 2010. Directions in scenario planning literature - A review of the past decades. *Futures* 42: 355-369.

Walters, C. J. 1986. *Adaptive management of renewable re-sources*. New York, New York, USA: McGraw-Hill.

Wolf, J. 2011. Climate Change Adaptation as a Social Process. In *Climate Change Adaptation in Developed Nations: From Theory to Practice,* edited by J. D. F. a. L. Berrang-Ford: Advances in Global Change Research.

Wolf, J., W. N. Adger, I. Lorenzoni, V. Abrahamson, and R. Raine. 2010. Social capital, individual responses to heat waves and climate change adaptation: an empirical study of two UK cities. *Global Environment Change* 20(1): 44-52.

Wolf, J., I. Lorenzoni, R. Few, V. Abrahamson, and R. Raine. 2009. Conceptual and practical barriers to adaptation: an interdisciplinary analysis of vulnerability and adaptation to heat waves in the UK. In *Adapting to climate change: governance, values and limits*, edited by A. W.N., et al. Cambridge: Cambridge University Press.

World Bank. 2010. *Economic Evaluation of Climate Change Adaptation Projects. Approaches to the Agricultural Sector and Beyond*. Washington D.C.: World Bank.

Web-based climate adaptation toolkits

http://climate-adapt.eea.europa.eu/web/guest/home,

http://www.careclimatechange.org/tk/cba/en/step_by_step_guidance/design/strategies.html,

http://www.parc.ca/saskadapt/assets/images/docs/saskadapt-self-assessment-offline.pdfhttp://climate-adapt.eea.europa.eu/web/guest/adaptation-support-tool/step-1)

http://www.ukcip.org.uk/wizard/about-the-wizard/)

http://www.geelongaustralia.com.au/community/environment/article/item/8cf7e8cfb9bad9d.aspx

http://www.geelongaustralia.com.au/common/public/documents/8cf8a428e29d1fd-Climate_Change_Toolkit_User_Guide.pdf

http://www.climatechange.gov.au/community/~/media/publications/local-govt/risk-management.ashx

http://www.ukcip.org.uk/wordpress/wp-content/PDFs/ID_Adapt_options.pdf

http://siteresources.worldbank.org/ENVIRONMENT/Resources/DevCC1_Adaptation.pdf

The Institute for Marine and Antarctic Studies (IMAS), established in 2010, comprises the University of Tasmania's internationally recognised expertise across the full spectrum of temperate marine, Southern Ocean, and Antarctic research and education.

IMAS - Waterfront
20 Castray Esplanade
Battery Point Tasmania Australia

Postal address:
Private Bag 129, Hobart TAS 7001

IMAS - Taroona
Nubeena Crescent
Taroona Tasmania Australia
Telephone: +61 3 6227 7277

Postal address:
Private Bag 49, Hobart TAS 7001

www.imas.utas.edu.au