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Climate Change Adaptation Strategies to Support Australia's Estuarine and Coastal Marine Ecosystems

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Abbreviations

CAS: Climate Change Adaptation Strategy

CSIRO: Commonwealth Scientific and Industrial Research Organisation

ECME: Estuarine and Coastal Marine Ecosystems

FRDC: Fisheries Research and Development Corporation

GU: Griffith University

JCU: James Cook University

OEU: Optimum Expected Utility

PA: Precautionary Approach

RDM: Robust Decision Making

RS: Robust Strategy

SES: Socio-Ecological Systems

Executive Summary

What the report is about

Scientists from James Cook University, CSIRO and Griffith University collaborated to develop a process for planning Climate Change Adaptation actions to support the resilience and productivity of Australia's estuarine and coastal marine ecosystems into the future. This 3 year project involved extensive review of Climate Change Adaptation strategies from across the world and evaluated their usefulness under Australian conditions through reviewing case studies, through interviews with workers from all levels of science and management from across Australia, and by reviewing modelling tools and using advanced qualitative modelling. The project was developed in response to the threats to the fisheries values, biodiversity and ecosystem functions posed by Climate Change on Australia's estuarine and coastal marine ecosystems that are already heavily impacted by changes in land and water use. This was undertaken in the recognition that large-scale strategy thinking was necessary for a country with a great diversity of estuary and coastal marine ecosystems, plant and animal assemblages, climates, and region-specific threats and matters of contention. The project developed a set of general principles to help direct estuarine and coastal adaptation strategies whatever the particular situation – to help guide, but not constrain, the development of informed adaptation policies, plans and actions.

Background

Australia's estuarine and coastal marine ecosystems (ECMEs: estuaries, nearshore marine waters, and coastal wetlands) support important biodiversity and fisheries values. They are critical transition zones between terrestrial, freshwater and marine ecosystems, providing key ecosystem functions (e.g. high productivity, and nutrient exchange and cycling) and associated services (e.g. nursery ground provision). Their high value to fisheries means healthy ECMEs are needed to support the economic prosperity of many regional centres and marine based industries across Australia. ECMEs are already heavily impacted by changes in land (e.g. urbanisation and agriculture) and water use (e.g. extraction). These pressures will increase as the effects of Climate Change become more evident. In the face of these increasing pressures there are significant challenges in maintaining the resilience and functioning of ECMEs, and in reconciling the actions required to protect the values of ECMEs with the needs to protect human infrastructure. Addressing these challenges will provide managers with a vision and understanding enabling effective prioritisation of adaptation strategies and management interventions.

Aims/objectives

The project aimed to synthesize and integrate current knowledge for the development of adaptation strategies for management of Australia's ECMEs in the face of Climate Change that takes account of bioregional differences and differences among estuary types, and to develop tools and guidelines to support the development of adaptation strategies.

Methodology

We reviewed current knowledge, data, tools and processes for the development of adaptation strategies for management of ECMEs under Climate Change, and evaluated key adaptation strategy approaches used around the world. Based on this evaluation we produced a comprehensive resource identifying tools and methods available for adaptation strategy development, together with advice on their values for specific purposes. We also conducted studies investigating (i) the roles of current governance structures in the way adaptation strategies

are developed, (ii) the current state of development of adaptation planning across Australia, and (iii) the lessons that could be learned, from the experiences of managers at all levels involved in Climate Change adaptation, about what has and hasn't worked in adaptation strategy development and implementation. Finally, we combined all the sources of information developed in the study to produce a set of general principles to help direct adaptation strategies whatever the particular situation.

Results/key findings

We found that successful adaptation strategies needed to be developed in a broad context, focussing on whole-of-systems, long-term outcomes. In seeking approaches to achieve these goals, we determined that traditional Climate Change adaptation frameworks were too rigid for use across Australia's diverse estuary and coastal marine systems. In fact, no single approach is suitable given the range of plant and animal assemblages, climates, and region-specific threats and matters of contention. As a result the project developed a set of general principles to help direct adaptation strategies regardless of the particular situation – to help guide, but not constrain, the development of informed adaptation policies, plans and actions. In addition, to assist those tasked with adaptation strategy delivery, the project produced a review of available tools and frameworks, together with recommendations for the situations they are useful in, and a checklist of components that need to be considered when developing effective adaptation strategies.

Recommendations

1: Successful adaptation strategies need to be developed in a broad, holistic context

2: Focus on whole-of-system, long-term transformative outcomes for socio-ecological systems

3: Employ robust strategies that minimise harm across human and natural systems

4: Acknowledge a multi-scale vision and incorporate a multi-scale approach

5: Ensure fair, representative and equitable stakeholder engagement

6: Harmonise legislation, policy and actions to achieve large-scale, long-term public benefits

7: Effective governance that is clear, consistent and complementary

8: Focus on achievable and realistic delivery of adaptation strategy outcomes and outcome-support tools

9: Optimise outcomes by employing adaptive feed-back cycles appropriately

Implications for relevant stakeholders

Successful Climate Change Adaptation requires engagement by all sectors of the population – stakeholders from every walk of life during all stages of the process. All need to be included, so those charged with facilitating change need to focus on engagement and education. In particular, it is critical that all players understand the levels of uncertainty involved and the consequences of that pervasive uncertainty. Prescriptions will not solve the diverse problems presented by climate change – flexibility and open minded approaches to achieving big picture goals to support the public good, and extensive and intimate common sense engagement by the whole community provide the pathway that will need to be followed to achieve effective Climate Change adaptation in the ECME.

Keywords

Climate Change • Adaptation Strategy • Resilience • Estuary • Wetland • Nursery Ground • Productivity

Introduction

Australia's estuarine and coastal marine ecosystems (ECMEs: estuaries, nearshore marine waters, tidal wetlands and coastal freshwater systems) support important biodiversity and fisheries values and ecosystem functions. ECMEs are already heavily impacted by changes in land (e.g. urbanisation and agriculture) and water use (e.g. extraction). These pressures will be exacerbated by Climate Change impacts, particularly sea level rise and altered hydrology. There are significant challenges in: (i) maintaining resilience and facilitating adaptation in estuarine and nearshore environments to maintain critical ecosystem functions and connectivity; (ii) implementing robust, ecologically-based solutions for optimally managing interactions between coastal ecosystems and human responses to Climate Change; and (iii) providing healthy functioning ecosystems that support the economic prosperity of many regional centres and marine based industries across Australia. Addressing these challenges will provide managers with a vision and understanding that enables refinement and prioritisation of adaptation strategies and management interventions.

ECMEs are critical transition zones between terrestrial, freshwater and marine ecosystems, providing key ecosystem functions (e.g. nutrient exchange and cycling) and associated services (e.g. nursery ground provision). Impacts of sea-level rise, altered hydrology and increasing temperatures will be compounded by interactions with human assets and management interventions to protect those assets. Consequently, there is a strong need to assess the relative importance of Climate Change impacts versus those associated with other pressures, and to identify priorities and strategies for adaptation that support clear and consistent goal setting by policy and management agencies. There is also a need to build on the large body of ecological and Climate Change impact work already done, and focus on developing a suite of strategies to support the adaptive management of biodiversity and fisheries/aquaculture values in ECMEs.

The underlying goal of publically developed adaptation strategies must be to manage the impacts of Climate Change and sea level rise to optimise overall public benefits. This trade-off is particularly complex in ECMEs because of their diverse environmental values and extensive human utilisation, and the complex socio-ecological systems (SESs) they support.

The estuarine and coastal marine space is complex environmentally, economically and socially. Much of the world's population is concentrated along coasts and around estuaries – this is particularly true of Australia. Along with that goes extensive agricultural, urban, industrial and port development. At the same time, ECMEs are areas of high conservation and biodiversity values. Sites of high ecological value, like Kakadu and Hinchinbrook Island National Parks, demonstrate the direct conservation value of ECMEs, but the values of ECMEs extends far beyond this. They occupy a pivotal location between land and sea and perform important roles in moderating seaward flows of nutrients (Ford *et al.*, 2005, Webster *et al.*, 2005) and pollutants (Brodie *et al.*, 2003, Haynes *et al.*, 2007), making them vital to the health and wellbeing of offshore natural assets such as the Great Barrier Reef. In addition, the high productivity and nursery value of coastal aquatic ecosystems means they are critical to the resilience and long-term health of Australia's coastal fisheries, with many commercially and recreationally valuable fisheries occurring in and around ECMEs, and many offshore fisheries depend on ECME nursery grounds and productivity.

These vital roles mean that damage to estuaries and coastal wetlands threatens key linkages in life-cycle and productivity chains, threatening the robustness and resilience of both fisheries and biodiversity assets of national and international significance. Here we focus on the issue of ***developing adaptation strategies that aim to optimise the ecosystem services provided by ECMEs, while harmonising with other facets of the public benefit***. Of particular importance is recognition that Climate Change adaptation occurs in an environment of pervasive uncertainty; potential threats are based on predictions that become more uncertain the further they are projected into the future, and in most cases there will be considerable uncertainty about the outcomes of particular adaptation actions. Furthermore, there can be a miss-match between climate change projections that are in the decades or centuries and very large spatial scales, but management objectives that apply at the scale of years to decades and catchments or smaller.

We address ***adaptation strategies*** (the large-scale conceptual vision of alternative adaption pathways) rather than the adaptation plans or actions that are informed by adaptation strategies. This strategic view is aimed at supporting decision makers at all levels to make Climate Change adaptation decisions that support overall public good and support the long-term resilience and productivity of estuaries and coastal marine natural resources in an uncertain world. The focus here is on producing a final product that is communicable to, and useable by, stakeholders across the range of needs and at all levels of sophistication. In particular, to ensure that adaptation strategies are developed in a way that means estuarine and coastal ecosystems continue to provide for the SESs they support into the future; that the resources they support, are as resilient and robust as possible (Folke *et al.*, 2010).

This report culminates in nine key principals for developing adaptation strategies for Australia's estuarine and coastal marine ecosystems. These are included in a stand-alone form in Appendix 4: "*Adaptation strategies for optimised public benefits from Australia's estuarine and coastal marine ecosystems: 9 principles*". These principals are aimed at supporting the long-term resilience and productivity of estuaries and coastal marine natural resources, and are intended to be sensitive to and applicable across (a) different conceptual scales of desired outcomes, (b) different typologies of the systems in question, and (c) different local issues, needs and constraints.

Objectives

Objective 1: Synthesize and integrate all current knowledge, data, tools and processes for the development of a national assessment of impacts and adaptation strategies for management of estuarine and coastal marine ecosystem under Climate Change that takes account of bioregional differences and differences among estuary types.

Objective 2: Evaluate the key adaptation strategies recognising that there needs to be a process to harmonise adaptation strategies for the public benefit.

Objective 3: Develop tools and guidelines, at a National level, for developing adaptation strategies for the estuarine environment that take account of bioregional and typological differences among estuaries.

Method

Objective 1: *Synthesize and integrate all current knowledge, data, tools and processes for the development of a national assessment of impacts and adaptation strategies for management of estuarine and coastal marine ecosystem under Climate Change that takes account of bioregional differences and differences among estuary types.*

The work for this objective involved a review aimed at providing the necessary background information to underpin Project 2011/040. In synthesising and integrating knowledge, data, tools and processes we first reviewed currently available information beginning with the recent comprehensive review of Hadwen *et al.,* (2011) "*The Coastal Ecosystems Responses to Climate Change synthesis report*". This work synthesises and integrates relevant information into a broad-scale assessment of Climate Change threats to multiple coastal ecosystem types (e.g. reefs, mangroves, seagrass, sand dunes, etc.) and their vulnerabilities, as well as identifying potential adaptation actions across Australia. Given this recent comprehensive work, we concentrated on expanding the details in Hadwen *et al.*, (20011) to cover areas specific to the objectives of project 2011/040, and in particularly to address Objective 1: *synthesize and integrate all current knowledge, data, tools and processes for the development of a national assessment of impacts and adaptation strategies for management of estuarine and coastal marine ecosystems under Climate Change that takes account of bioregional differences and differences among estuary types*.

Our review was developed in a series of project meetings where issues relevant to the project were discussed and developed. In between meetings the ideas developed during the previous meeting were fed back through managers in DERM and GBRMPA for comment. The review structure and its components were developed and refined during three initial meetings. In a fourth review meeting (2 days), each team member presenting their compilation of one section of the review, in their area of expertise, to the group, followed by a group review of the material. The review was then constructed using a quasi-Delphi process, where one team member was responsible for a component of the review and the draft sections were fed back through the other team members for review and updating.

To ensure broad cover and relevance, the review utilised international literature, reports from other relevant Climate Change projects (including other NARPs) and grey literature. The review includes four sections: (1) Current Understanding of Climate Change Impacts on Australia's estuaries, (2) Key Vulnerabilities to Climate Change, (3) Underpinning Issues for Adaptation Strategy Development, and (4) Integrated Regional & Typological Differences in Estuaries.

Objective 2: *Evaluate the key adaptation strategies recognising that there needs to be a process to harmonise adaptation strategies for the public benefit.*

The work for this objective involved evaluation and review of adaptation strategies aimed at providing the background to inform Objective 3 of FRDC-DCCEE Project 2011/040. In particular, key adaptation strategies were reviewed in the light of recognition of the need for a process to harmonise adaptation strategies for the public benefit.

The evaluation was developed in a series of project meetings where issues relevant to adaptation strategies were discussed and developed. The discussions were based on in-depth

investigation of the issues by all team members, with members focussing particularly on their areas of expertise, and served as a forum to bring together information and integrate it into a common understanding. In between meetings the ideas developed during the previous meeting were fed back through managers in DERM and GBRMPA for comment. The review was then constructed using a quasi-Delphi process, where one team member was responsible for a component of the review and the draft sections fed back through the other team members for review and updating. To ensure broad cover and relevance, the review utilised international literature, reports from other relevant Climate Change projects (including other NARPs) and grey literature. The review covered three areas: (1) Major Adaptation Strategy Types, (2) Frameworks and Associated Tools, and (3) Relationship between Governance and Adaptation Strategies.

Objective 3: *Develop tools and guidelines, at a National level, for developing adaptation strategies for the estuarine environment that take account of bioregional and typological differences among estuaries.*

The development of tools and guidelines occurred in two phases: (i) the stepwise development of a *Purpose-Designed Mechanistic Climate Change Adaptation Framework* targeted for use in Australia's estuarine and coastal ecosystems, and its testing and evaluation, and (ii) the development of *Principles of Operational Adaptation Strategies* targeted for use in Australia's estuarine and coastal ecosystems.

Phase 1: Step-Wise Development of the Guideline Toolbox Framework

The first phase of work for this objective involved the development and testing of a framework for potential use to assist development of Climate Change Adaptation Strategies (CAS) for Australia's estuarine and coastal ecosystems. This work was informed by material developed for the first two objectives.

Initial review of existing frameworks identified a diversity of frameworks (see Results and Discussion section 2.2; also review by Mawdsley *et al.*, 2009). Rather than developing a completely new framework, the existing frameworks were evaluated for use in the current context. This was achieved through a step-wise process (outlined below) culminating with the development of a refined framework model tuned to the Australian estuary/coastal ecosystem context.

1. An initial case study (a generic Burdekin Delta estuary) was selected as a "stalking horse" for evaluating model structures and testing and comparing alternative models. Key components of the system were modelled using a signed digraph qualitative modelling approach, focussing on one impactor; bund walls. The signed digraph was developed in a one-day workshop conducted by Dr Jeff Dambacher; [CSIRO Mathematics, Informatics and Statistics]. The model assumptions for the case study system were: key environmental asset - nursery provision; target of management - bund walls as the thing to be managed; primary Climate Change factors - sea level rise and alteration in extended dry cycle (≅ El Niño).

2. To prevent model development from being constrained by a particular structure, a conceptual model of framework components was developed based solely on logical linkages informed by group knowledge, the review of available frameworks and the qualitative modelling in step 1.

3. To ensure a deep understanding of the model components and their implications for framework development, the components of the conceptualisation framework were investigated in the context of the generic Burdekin Delta estuary case study and published adaptation frameworks.

4. Based on previous components of the study (Objectives 1 and 2), qualitative modelling (Step 1), framework conceptualisation (Step 2), and contextual development (Step 3), the Klein *et al.,* (1999) adaptation model was selected as a "standard" base adaptation model for framework development.

5. The "standard" Klein *et al.,* (1999) model framework was developed into a more detailed and functional framework appropriate for Australia's ECMEs. This involved specifying and elaborating the components of the framework to make them explicit and therefore able to inform actions specific to the needs and circumstances of Australia's ECMEs.

6. As a final step in developing the Guideline Toolbox Framework, the completed framework was evaluation in a step-by-step empirical "case study" test situation, asking the questions "what would actually happen in each step and how would they relate to each other?" This was based on a "Fisheries in Clarence River" case study, a situation familiar to most of the project team.

7. Adjustment of the model after Step 6 culminated in a 'final' model but this model could only be valuable in a general sense if it performed successfully for typologically different situations. Consequently, the model was applied to a series of specific case studies (Kakadu, Barratta Creek, and Tully Delta case studies) with different characteristics.

Phase 2: Developing Principles of Operational Adaptation Strategies

Testing the performance of the framework in Phase 1 led to the conclusion that a general one-stop-shop guideline framework is too restrictive, inflexible, and prescriptive to provide an overall focus for Australia's estuarine and coastal Adaptation Strategy needs. Consequently, in Phase 2 we concentrated on producing flexible operational adaptation strategy principles and tool that could be adapted to support strategy development across the varied situations presented by Australia's diverse ECME. The aim was to produce a final product that is communicable to, and useable by, stakeholders across the range of needs and at all levels of sophistication.

The development of the adaptation strategy principles was informed by the knowledge developed for Objectives 1 and 2, Phase 1 of Objective 3, and by three specific studies: (i) an investigation of environmental governance in Australia, (ii) a series of interviews with managers and scientists involved in adaptation planning and actions across all levels, and (iii) an investigation of the current status of adaptation planning and action across Australia.

(i) **Environmental Governance:** This comprised a desktop study analysing documentary sources, in particular; legislation, agreements, policy and strategy documents, and government reports. Data derived from interviews conducted within the scope of the project and personal communications were also used to assist with the analysis of documentary sources. Two major limitations should be noted: (a) Australian environmental governance is

highly complex and dynamic comprising three tiers of government having different regulatory powers and a large number of management bodies both governmental and private performing different environmental planning and management functions. Consequently, rather than reporting on each jurisdiction in detail, the work concentrated on a series of examples illustrating how respective management problem(s) have been approached in one or several jurisdictions. (b) A wide range of pressures affect coastal fisheries but because of the objectives of the project, evaluation focused on governance problems related to the protection of marine, tidal and riverine habitats, and maintenance of catchment-to-coast habitat connectivity. Other problems requiring governance responses such as overfishing, pest eradication, and point and non-point source chemical and nutrient pollution are not addressed in this report.

(ii) **Using Expert Opinions to Elicit Enablers and Limitations for the Adaptive Management of Estuaries and Waterways under Climate Change:** We surveyed senior individuals from across the governance spectrum charged with managing and conducting applied research on Australia's estuaries, waterways and coastal systems under threat from climate variability. We conducted a targeted semi-structured person-to-person set of interviews with interviewees across a range of organisational (federal, state, council, academic, private, etc.) and spatial scales (national, regional, local), and from a variety of governance layers within these systems.

The aim of this process was to elicit and synthesize the practical knowledge and personal experiences on waterways management from a range of cross-governance layers of managers, researchers and practitioners. We gathered information about their perspectives on the drivers of success of Climate Change plans and actions based on their individual experiences, and on knowledge from past and present activities. This produced a nationally-relevant qualitative (and semi-quantitative) knowledge-base that could be used to inform and guide the future development of adaptive management strategies for estuaries, wetlands, and ecosystems.

A total of 20 interviews were conducted in Queensland (11), Tasmania (6) and Western Australia (3). Prior to each interview, an information and consent letter was sent to targeted interviewees explaining the aims and objectives. The interview consisted of one senior project member meeting and interviewing one person at a time, using a 5 theme template to guide the interview and digitally recording the event in an audio file, for quality and transcription uses. All audio material was deleted at the end of its use in the project.

The interviews focused on 5 general themes and sub-topics:

1. The high-level motivations of the protagonists, including their own professional and career experiences. The purpose of this was to identify the high-level drivers that trigger adaptive management, whether they are top-down (regulatory and jurisdictional) or bottom-up (public pressure, individual champions, etc.) processes.

2. The factors and conditions that could act as enablers or constraints for successful management, including resourcing levels, political networks, information basis, etc. Particular emphasis was given to eliciting the roles of strategic planning and tactical responses to management.

3. The experiences of the protagonists and specific examples of waterways and estuarine system management that illustrate their contributions to the points (1) and (2) above.

Here we focused specifically on the instruments (plans, projects, and directions) and the outputs and outcomes out of these examples, particularly what did and did not work.

4. The explicit or implicit inclusion (or non-inclusion) of Climate Change and variability of the systems and examples of their management and research experiences. Here we asked whether Climate Change was addressed, how and what instruments or information basis was considered or not. Important here was the elicitation of personal preferences on how to deal with Climate Change for such systems.

5. The protagonists' views and experiences about the roles of the likely adaptive management strategies for estuaries, wetlands, and ecosystems. Here we elicited the roles of institutions, their strengths and weaknesses, resource levels and more importantly, their own opinion on how adaptive management for Climate Change in estuaries should happen and reside.

(iii) **Current Status of Adaptation Planning**: We systematically examined the international peer reviewed literature and official adaptation plans of coastal local governments relating to marine Climate Change along representative stretches of Australia's coastline to evaluate 'adaptation progress' (Moser & Ekstrom 2010). This meta-analysis of official local government documentation and publicly available information provided a rapid assessment of adaptation progress. Stretches of Australian coastline, approximately 500-1,000km in length, were selected that included a variety of council sizes (with at least one large urban centre) and different demographic and economic characteristics. Care was also taken to include a wide variety of the coastal environments and conditions. The selected areas were in southern West Australia (from Perth to Albany), eastern Tasmania (from Hobart to Dorset), and eastern Queensland (from Brisbane to Townsville). Western Australia, Tasmania and Queensland were also the subject of another Climate Change related study (See Metcalf *et al.*, (2014) and van Putten *et al.*, (in press)), and this aided in the interpretation of result.

A total of 67 councils present along these stretches of coastline were included in the study. For each local council, all official documentation (such as strategic plans, management plans) that mentioned the words 'climate' and/or 'change' were identified (using a whole domain word search of the official council website). These documents were then searched for specific statements related to coastal marine Climate Change adaptation. Only official documentation was used as these are a functional part of the adaptation process, whereas other council published sources such as newsletters and web pages describing council activities are not.

The information garnered was used to determine the adaptation phase of each council and the nature of the adaptations being planned. To this end, specific statements made by an individual council related to marine Climate Change adaptation were assessed according to: (i) the Climate Change drivers that were addressed, with the following categories; a) changing sea surface temperatures b) ocean acidification c) simple sea level rise (a change in the position of the coastline due to sea level rise) and d) sea level rise complex (addressing at least one of the associated effects of sea level rise such as salt-water intrusion or increased storm surge height) (ii) what phase of the adaptation process a council was in, with the following categories; a) whether the gathering of understanding for potential future adaptive action was planned, or b) actual adaptive action was planned (iii) whether these plans related to; a) economic or b) infrastructural adaptation.

In addition to the above data, a range of council characteristics were recorded in order to perform analyses to determine factors important in the development of adaptation plans. Information on income from 2011/2012 rates and total expenditure were gathered from individual council budgets. Information on membership by councils of associations facilitating adaptation was gathered from individual council websites or the website representing the regional, state, or international organisation. Information for each local council was also retrieved from the Australian Bureau of statistics 2011 census database, including population size, percent of the population involved in the agriculture, forestry and fishing industries. Finally, whether drought (related to climate variability) featured as the main driver in their adaptation plans was also recorded.

An aspect that could not be measured as part of this analysis was the quality and appropriateness of the adaptation response, because that would have required an in-depth understanding of each local situation. The purpose of this study was to provide a rapid assessment and give a proxy for the current adaptation status, it is unable to provide detail or analysis of the process each council had undergone in the development of their adaptation plans. Therefore, we have simply measured a council's present stage in the adaptation process, and the results should not be understood as a judgment of the quality of a council's response.

Final Development of *Principles of Operational Adaptation Strategies*: The overarching direction of the final development of the Operational Adaptation Strategy Principles was informed by stakeholder needs articulated during the *Using Expert Opinions to Elicit Enablers and Limitations for the Adaptive Management of Estuaries and Waterways under Climate Change* (Appendix 2). For the 'Operational Adaptation Strategy' approach to be useful, and valid and applicable across Australia, the advice it provides needs to have a high level conceptual focus.

To achieve this we concentrated on developing adaptation strategy principles aimed at (i) optimising the ecosystem services provided by ECMEs, while harmonising with other facets of the public benefit, (ii) addressing adaptation at a strategic level (the large-scale conceptual vision of alternative adaption pathways) rather than the level of adaptation plans or actions that are informed by adaptation strategies, and (iii) being sensitive to and applicable across different conceptual scales of desired outcomes, different typologies of the systems in question, and different local issues, needs and constraints.

To ensure the "strategy principles" were firmly based in established methods we grounded their development in the diverse materials formulated during the project; bringing together the material produced during Objectives 1 and 2, and Phase 1 of Objective 3, and the three studies specific to Phase 2 of Objective 3. These are reported in detail in the following supporting documents:

- Appendix 1: *Environmental Governance: Barriers and Bridges to the Long Term Protection of Coastal Fisheries.*
- Appendix 2: *Using Expert Opinions to Elicit Enablers and Limitations for the Adaptive Management of Estuaries and Waterways under Climate Change*.
- Appendix 3: *Assessment of Local Government Progress in Marine Climate Change Adaptation in Australia.*

As well as the *Strategy Principles* (detailed in Appendix 4: *Adaptation Strategies for Optimised Public Benefits from Australia's Estuarine and Coastal Marine Ecosystems: 9 Principles*) we developed two key supporting materials: Appendix 5: *Draft Review and Assessment of Tools to Support Climate Adaptation for Estuaries, and* Appendix 6: *A Checklist for the Process of Developing an Effective Adaptation Strategy*.

Results and Discussion

Objective 1

Objective 1: *Synthesize and integrate all current knowledge, data, tools and processes for the development of a national assessment of impacts and adaptation strategies for management of estuarine and coastal marine ecosystem under Climate Change that takes account of bioregional differences and differences among estuary types.*

1.1: Current Understanding of Climate Change Impacts on Australia's estuaries

More than three quarters of Earth's land surface is connected to the ocean by rivers, with juxtaposed estuaries, deltas and tidal wetlands ecosystems (Ludwig & Probst, 1998). Over the past 50 years, these ecosystems have experienced increasing pressures from multiple-uses by an ever increasing human population, severely affecting rivers, estuaries and deltaic systems through enhanced fertilizer usage, damming, deforestation, and many other land-use pressures (Svitski *et al.*, 2005; Meybeck & Vorosmarti, 2005). These ecosystems occur at the interface between continents and oceans, and the consequent biodiversity interconnections and material fluxes have a global impact on coastal-marine biogeochemistry (Bianchi & Allison, 2009). Estuarine and coastal ecosystems have historically been altered by human pressures, however the rate of change is accelerating due to global Climate Change (Lotze *et al.*, 2006).

The 4th Assessment Report (AR4) on the expected impacts and vulnerabilities from global climate and ocean changes for coastal and low-lying aquatic land-sea ecosystems established that these systems are exposed to increasing risks of extreme events and sea level rise changes, which in turn will be further exacerbated by human-induced pressures (IPCC, 2007). In particular, coastal estuaries and wetlands are expected to be negatively affected by extreme events in combination with sea-level rise especially if their natural ability to migrate landward is limited by human structures or sediment availability (Nicholls *et al.*, 2007).

Further post-AR4 research on the nature, extent and trends of the changes in climate extremes, and their impacts on the coastal-marine environment (IPCC, 2012; Seneviratne *et al.*, 2012) conclude that there is a high likelihood that anthropogenic influences have contributed to increasing extreme coastal high water levels via mean sea level changes. There is low confidence that changes in extreme wave heights can be directly attributed to anthropogenic influences (because of insufficient literature). However, there are strong linkages between wave height, and wind and storms meaning that any anthropogenically influenced alterations in wind strengths, or storm frequencies and intensities, are likely to result in changes in significant wave height (SWH). Additionally, both recent coastal assessments at the national and regional scale and process-based studies have provided further evidence of the vulnerability of low-lying coastlines to rising sea levels and erosion. As a result, in the absence of adaptation, there is high confidence that locations currently experiencing adverse impacts, such as coastal erosion and inundation, will continue to do so in the future due to increasing sea levels, even in the absence of changes to other contributing factors (IPCC, 2012; Seneviratne *et al.*, 2012).

Table 1: Summary of observed and projected Climate Change in Australia, summary based on Hadwen *et al.,* (2011) and literature research.

Terrestrial Coastal Climate		
	Observed	**Projected**
Temperature	• Surface temp. rose by nearly 1°C between 1910- 2009 • Last decade warmest on record • 2010 one of the hottest years recorded • Decrease frequency of extreme hot & cold weather	• Mean annual temp. to warm between 0.8-2.1°C by 2030 • By 2070, mean annual temp. to rise by either 1.8-3.9°C (A1B scenario) or 2.4-6.4°C (A1FI scenario) • Max temp. of the warmest week of the year to warm • Min temp. of the coldest weeks of the year to warm at a greater rate • Decrease in annual temp. range in the west, while increase temp. range in the south and east.
Rainfall	• Declines in rainfall since 1950 in south-western Australia (excluding 2011) • Rainfall increased in northern Australia	• Projected decline in annual mean precipitation. • By 2030 decline in annual mean rainfall by a min of 4% and max 37% (A1B) or min 5% and max 58% (A1FI) • Wettest periods to increase in north Queensland and SW Western Australia • Driest periods to decrease in precipitation
Tropical cyclones and lows	• No significant trends in total number of cyclones or proportion of intense cyclones. • Frequency and intensity declined significantly since 1980s south of 20° on east coast	• Projections are uncertain • Possible increase in tropical cyclones in categories 3-5 • Potential decline in numbers • Poleward shift of cyclones • Associated extreme winds may increase • Southward extension of the warm East Australian Current could lead to extinction of east coast lows, extreme wave conditions and more southerly cyclone tracks
Solar radiation		• Annual mean solar radiation expected to increase by 0.1-0.3J/m^2 by 2030 • By 2070 will increase by 0.2-1.0 J/m^2 • Increases larger in the east than west • Mean radiation in the warmest quarter of the year will increase north and north-east but decrease south west and south east (except for Tasmania) • Mean radiation of the coldest quarter will increase – strongest in the south
Soil Moisture		• Annual mean soil moisture index projected to decline by up to 25% (A1B) or 28% (A1FI) by 2030. • Annual index to decline by 29% (A1B) or 58% (A1FI) by 2070 • Moisture projected to decline across all coastal regions in warmest and coldest quarters

Table 1 (cont.): Summary of observed and projected Climate Change in Australia, summary based on Hadwen *et al.,* (2011) and literature research.

Marine Coastal Climate		
	Observed	**Projected**
Ocean Temperature	• Global Average sea surface temp increased by 0.7°C since 1900 • Surface waters around Australia warmed about 0.9°C (0.4°C in the last 50 years) • 6 of the 10 warmest years since 1910 have occurred in the last decade • South east shows greatest rate of warming (0.23°C/decade) • Tropical Australia 0.11-0.12°C/decade • South western waters increased by 0.6-1°C over the last 50 years • Southward shifts in annual mean sea surface temp. climate	• Sea surface temp. to warm by 0.2-1.2°C by 2030 and 0.5-2.8°C (A1B) or 0.6-3.8°C (A1FI) by 2070. • North-west and south-east have greatest projected warming • Little difference seasonally
Ocean Acidification	• Ocean surface pH fallen by 0.1 since around 1750 (8.2 to 8.1) • Increasing trend towards ocean acidification • Atmospheric CO2 increased from 280ppm (pre-industrial) to 380ppm	• Atmospheric CO2 predicted to reach 540-979 ppm by end of the century • Oceanic pH to drop a further 0.3 to 0.4 units (more acidic than in the past 800 000 years) • Greatest declines in pH predicted for north-east Australia
Wave Climate	• Positive trend in frequency and intensity of large wave events across southern coastline	
Sea surface salinity	• Increase in salinity in south-east coasts. • A mean trend of 0.036psu/decade in the Tasman Sea between 1944-2002	• Southern and north-eastern Australian marine waters to become slightly fresher by 2030 (-0.1 g/l) • West, north-west and south-east slightly saltier (+0.1 g/l) by 2030 (more intense by 2070)
Sea level rise	• Variability in rate of rise • Average for Australian coasts between 1920 and 2000 is 1.2mm/yr • The 2 longest sea level rise records (from Sydney and Freemantle) show relative rise of 0.9±0.2mm/yr over 1914-2007 and 1.4±0.2 mm/yr over 1897-2007	• Regions with highest proportion of inundation tend to occur on northern Australia, particularly in the gulf and estuarine systems. • Coastal inundation projected to increase up to 38 – 107% by 2100. • See inundation pattern table for specific regions (p52)

Observed and predicted Climate Change around Australia is summarised in Table 1, and by region in Table 2. Higher oceanic temperatures are predicted to occur around Australia, particularly in south-eastern Australia (Poloczanska *et al.*, 2009). The East Australia Current is predicted to transport greater volumes of water southward, whereas the Leeuwin Current on the western coast may weaken. On land, projections suggest that air temperatures will rise and rainfall will decline across much of Australia in the coming decades. Together, these changes will result in reduced runoff and hence reduced stream flow and lake storage. Predictions from current climate models are particularly limited with regard to coastal and freshwater systems, making them challenging to use for biological-impact and adaptation studies (Hobday & Lough, 2011). The key predictions for coastal-marine systems suggest that; (i) Australian ocean temperatures have warmed, with south-west and south-eastern waters warming fastest, (ii) the flow of the East Australian Current has strengthened, and is likely to

strengthen by a further 20% by 2100, (iii) marine biodiversity is changing in south-east Australia in response to warming temperatures and a stronger East Australian Current, and (iv) declines of over 10% in growth rates of massive corals on the Great Barrier Reef are likely due to ocean acidification and thermal stress (Poloczanska *et al.,* 2009).

Interconnected land-sea aquatic systems, such as tidal wetlands, mangroves and salt marshes (i.e. ECMEs), are likely to be influenced by a number of key forcing factors, such as increases in sea level rise, changes in precipitation patterns and changes in estuarine hydrology, which will affect the distribution, biodiversity and productivity of ECMEs (Lovelock *et al.,* 2009). It is likely that the combined effects of climate and ocean changes will have a strong impact on these habitats because their position exposes them to a multitude of oceanic and atmospheric climate drivers, making them highly vulnerable to Climate Change. Tidal wetlands are extremely sensitive to sea level rise and extreme events, with historical expansions of mangroves into salt marsh habitats observed in south-east Australia, and into freshwater wetlands in northern Australia, mainly as a result of soil subsidence associated with reduced rainfall (Lovelock *et al.*, 2009).

Anthropogenic Climate Change is already apparent and will have significant, ongoing impacts on Australian fishes and their habitats (Gillanders *et al.*, 2011). Even with immediate actions to reduce greenhouse gases, there will be sustained environmental changes. Therefore, it is necessary to consider appropriate adaptive management strategies to minimise the inevitable detrimental impacts for both fishes and the human populations that rely on them (Koehn *et al.*, 2011). Biologically, Climate Change will have a range of direct effects on the physiology, fitness, and survivorship of Australia's marine, estuarine and freshwater fishes, but also indirect effects via habitat degradation and changes to ecosystems. Effects will differ across populations, species and ecosystems, with some impacts being complex and leading to unexpected outcomes.

From the biophysical perspective, Climate Change impacts on estuaries, tidal wetlands and low-lying coastal systems will vary at a regional scale similar to riverine and marine ecosystems that are biogeographically distinct (Kroon *et al.,* 2011). Despite natural variations, changes in global temperature are likely to be reflected in equivalent changes in water temperatures of streams, lakes, estuaries and coastal wetlands. Also, there is expected to be intensification of coastal winds, changes in cyclonic activity, increase shore erosion, alterations to mixing patterns, all of which will lead to changed salinity conditions in coastal lakes, tidal wetlands and estuaries. Thus, the likely climate and ocean changes are expected to have major consequences for Australian estuaries and associated fish and biotic communities, but their responses will vary according to the local-to-regional context and the nature of natural and human-induced impacts (Gillanders *et al.,* 2011).

Table 2: Distribution of observed and predicted Climate Change across Australia, summary based on Hadwen *et al.,* (2011) and literature research.

		Observed	Predicted
Northern Australia	Gulf of Carpentaria	• Rates of ocean temp warming in tropics around 0.11-0.12°C • Ocean surface pH fallen by 0.1 since 1750	• Mean annual temperature to increase • Wettest period to increase rainfall • Driest period to decrease rainfall • Large increase in solar radiation • Soil moisture to decrease • Decline in pH • Predicted highest proportions of coastal inundation
	North East	• Declines in rainfall since 1950 • Rates of ocean temp warming in tropics around 0.11-0.12°C • Suggested southward shift in annual mean sea surface temp climate of >200km between 1950-2007 • Ocean surface pH fallen by 0.1 since 1750	• Mean annual temperature to increase • Wettest period to increase rainfall • Driest period to decrease rainfall • Large increase in solar radiation • Soil moisture to decrease • Predicted decrease in salinity (-0.1 g/l by 2030) • Greatest declines in pH
	North West	• Rates of ocean temp warming in tropics around 0.11-0.12°C • Suggested southward shift in annual mean sea surface temp climate of >100km between 1950-2007 • Ocean surface pH fallen by 0.1 since 1750	• Mean annual temperature to increase • Driest period to decrease rainfall • Moderate increase in solar radiation • Soil moisture to decrease • High projected ocean warming • Projected increase in salinity (+0.1 g/l by 2030) • Decline in pH
Southern Australia	South East	• Declines in rainfall since 1950 • Increased salinity (0.036 psu/decade) from 1944 -2002 • Sea surface temp. warming 0.23°C/ decade • Intensification of EAC • Ocean surface pH fallen by 0.1 since 1750 • Positive trend in frequency and intensity of large wave events	• Mean annual temperature to increase Driest period to decrease rainfall • Large increase in solar radiation • Soil moisture to decrease • High projected ocean warming • Projected increase in salinity (+0.1 g/l by 2030) • Decline in pH
	South West	• Declines in rainfall since 1950 • Sea surface temp. warming 0.20°C/ decade • Increase water temp of around 0.6-1°C in past 50 years • Ocean surface pH fallen by 0.1 since 1750 • Positive trend in frequency and intensity of large wave events	• Mean annual temperature to increase • Wettest period to increase rainfall • Driest period to decrease rainfall • Moderate increase in solar radiation • Soil moisture to decrease • Projected increase in salinity (+0.1 g/l by 2030) • Decline in pH
	Great Australian Bight	• Ocean surface pH fallen by 0.1 since 1750 • Positive trend in frequency and intensity of large wave events	• Mean annual temperature to increase • Driest period to decrease rainfall • Soil moisture to decrease • Predicted decrease in salinity (-0.1 g/l by 2030) • Decline in pH

In a synthesis conducted for Queensland but relevant for other regions, Kroon *et al.*, (2011) proposed a range of impacts derived from climate and ocean changes, which also combined current human-derived threats such as overexploitation, pollution, modification of water

flows and hydrology, habitat destruction and degradation, and invasion by non-native species. The main expected impacts were:

Ecological Change

- Changes in species behaviour and physiology due to changing environmental envelopes,
- Changes in species abundance, distribution and resilience to climate variability due to changes in habitat availability and connectivity,
- Changes in species resistance, resilience and exposure to extreme events and diseases,
- Changes in overall ecosystem productivity and nutrient status due to changes in phenology,
- Geographic changes in ecosystem types due to more frequent and/or more intense extreme events, and
- Changes in overall estuarine landscape function and structure, and its derived ecosystem services.

Ecosystem Services

- Changes to the services provided by estuarine, wetlands and low-lying ecosystems including: provisioning, regulatory, cultural and supporting services for natural, urban and production systems (although the maintenance of freshwater and marine biodiversity contributes to the delivery of these ecosystem services, no linear relationship exists between the two),
- Climate Change is expected to affect the delivery of ecosystem services, in particular through changes in flow regime, carbon sequestration and (terrestrial and freshwater) biodiversity.

Regional Variation

On a regional scale, the main changes for Australia's estuaries, wetlands, and low-lying ecosystems will most likely include:

- Extension of arid and semi-arid regions in an easterly direction,
- Some arid and semi-arid tidal wetlands will most likely change their frequency and duration of inundation, possibly dry out permanently,
- Coastal and sub-coastal swamps might decrease in water inflow in South-East Queensland and the eastern Murray-Darling region during the dry season,
- Decrease in hypo-limnetic oxygen levels in coastal and sub-coastal lakes during stratification periods,
- State-wide increasing problems with cyanobacteria in lakes due to increasing temperatures,
- Coastal lakes, especially coastal dune lakes, and salt-marshes might suffer from saltwater intrusion.

1.2: Key Vulnerabilities to Climate Change

The IPCC defines vulnerability of coastal zones as "the degree of incapability to cope with the consequences of Climate Change and accelerated sea-level rise" and recommended a conceptual framework for coastal vulnerability assessment (Klein and Nicholls, 1999). It distinguishes between natural-system vulnerability and socio-economic vulnerability to Climate Change, although they are clearly related, and proper analysis of socio-economic vulnerability requires prior understanding of how the natural system would be affected. Hence, analysis of coastal vulnerability always starts with some notion of the natural system's susceptibility to the biogeophysical effects of Climate Change, and of its natural capacity to cope with these effects (resilience and resistance). This section focuses on this first step. Four categories of estuarine natural values are presented, which cover most of the ecosystem services contributed to human communities by estuaries as identified in Hadwen et al (2011, p 116).

Water quality

Water quality is described by a series of biogeochemical parameters such as turbidity, nutrient content, oxygen content, etc., aiming at characterising the "health" of the aquatic environment in the sense of its biogeochemical balance (absence of eutrophication/anoxia), and its subsequent ability to sustain a healthy ecosystem (e.g. phytobenthic habitats). It relates to many of the estuarine ecosystem services listed in Hadwen et al (2011): ornamental resources, recreation and tourism, spiritual and aesthetic values, nutrient cycling. Water quality and primary production are the results of complex interactions between those biogeochemical parameters as well as other attributes of the estuary (Fig. 1). It involves many feedback loops, as well as "qualitative" interactions (black arrows) which tend to make generalisation impossible, even within an estuary type.

Habitats

Saltmarshes, mangroves, seagrass and macroalgae are critical habitats sustaining unique assemblages of fish and aquatic invertebrates, as well as migratory shorebirds. Many commercially important fish species may use these habitats for their juvenile development. They also help to stabilise the shorelines and sediment, and play a significant role in the recycling of nutrients. Finally, they contribute highly to the aesthetic and cultural values of estuaries, and to make them attractive to tourism and recreational activities (e.g. DCC, 2011a)

Mangroves and saltmarshes are already facing extensive degradation and loss throughout the world, mostly as a result of agricultural and urban development, drainage and river channelization. The greatest effect of Climate Change on those intertidal habitats is expected to arise as a result of increasing sea levels. Sea-level rise will lead to either the redistribution or the disappearance of intertidal and shallow coastal habitats (Koehn et al, 2011). Mangroves are able to enhance surface accretion and compensate sea-level rise up to a certain rate (DCC, 2011a). Mangroves, and saltmarshes to a lesser extent (Hadwen *et al.*, 2011) are able to "migrate" inland, provided that they have access to suitable substrates, and that no human infrastructures act as a barrier to this migration (DCC, 2011a; Hadwen et al, 2011; Gillanders et al, 2011). Furthermore, increased extreme temperatures may increase the frequency and severity of bushfires, affecting the composition of riparian vegetation (Hadwen et al, 2011).

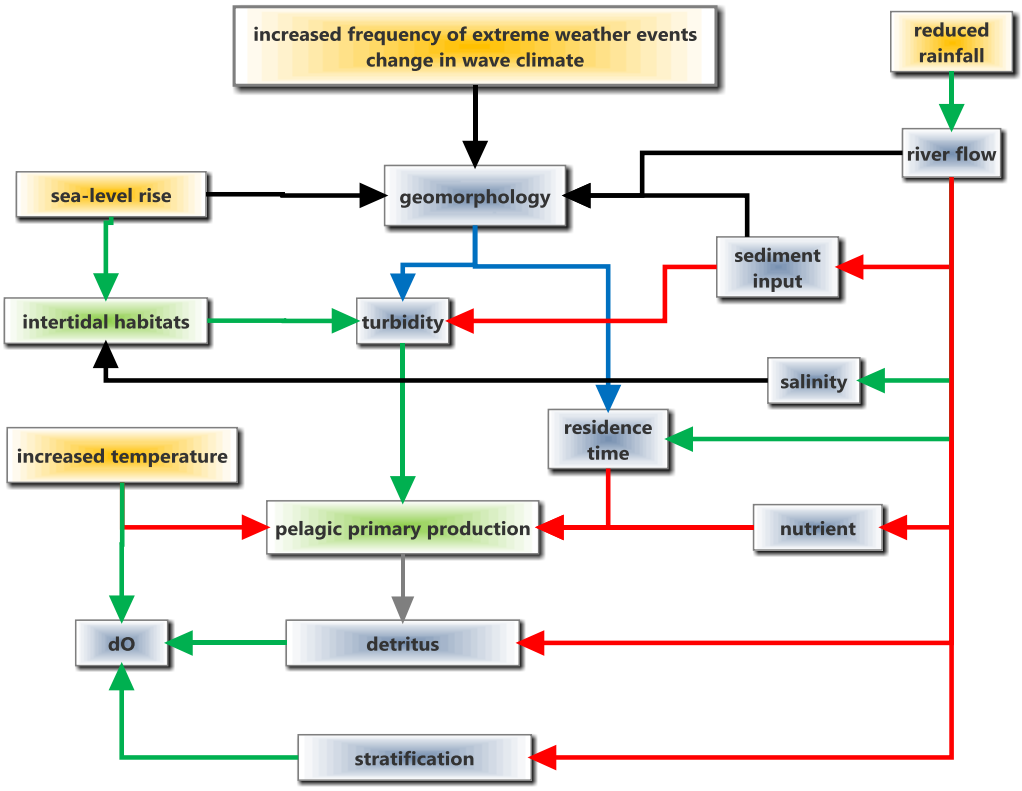


Figure 1: Potential effect of Climate Change on estuarine water quality and primary production.

Orange squares correspond to physical parameters directly affected by Climate Change; blue-grey squares to estuarine non-living attributes, and green squares to estuarine primary producers. Red arrows correspond to positive effects, green ones to negative effects, blue ones to undefined effects (in this general case) and finally black arrows to qualitative effects.

Seagrass and kelp forests face eutrophication, sedimentation or increases in local abundance of destructive herbivores. Sensitivity of these habitat-forming plant species to chronic disturbances is likely to be exacerbated by physiological stress associated with increasing temperature, as well as climate-change induced changes in other parameters such as salinity and pH (Koehn et al, 2011). Seagrass beds are likely to be negatively affected by rising sea levels, as light penetration will be compromised at the deeper sites. Seagrass ability to colonise new shallower substrates will depend on a combination of factors including nutrient concentrations, water temperature, consumers and patterns of river flows and catchment runoffs. Extreme events have been shown to be particularly devastating for seagrass communities, with associated run-off and sediment loads typically resulting in large local and regional losses of seagrasses in many areas around the world. If water quality impacts persist, they are more devastating to seagrass communities than are the physical impacts of moderate tropical cyclones. The run-off related impacts from cyclones on seagrasses will ultimately be determined by the timing, volume and persistence of the event, particularly with respect to the normal seasonal runoff patterns for any given estuary.

Biodiversity

Biodiversity relates to many of the estuarine ecosystem services identified in Hadwen *et al.*, (2011): genetic resources, ornamental resources, recreation and tourism, education and

knowledge, spiritual and aesthetic values. Climate Change is likely to impact on estuarine biodiversity through:

Loss of habitat and connectivity: Saltwater intrusion will displace freshwater species, which eventually may disappear from river systems where suitable habitat is not available above the saltwater wedge. Similarly, reduced river flows limit access to drought refuges and threaten the viability of many species (Turak et al, 2011).

Invasive species: Species, either alien or native to other regions of Australia, might be able to occupy new habitats, leading to unanticipated ecosystem impacts (not necessarily negative). For example, the climate-mediated arrival of a new sea urchin species to Tasmania has led to disruption of ecosystem structure and a decline in abundance of other species, including fish (Ling et al, 2009). Although some species may be able to adapt, the rapid rate of Climate Change and likely short-term variability in water availability, combined with reduced access to refugial habitats, make local extinctions of many taxa probable. At the same time, changing conditions could lead to new, successful colonisations, potentially increasing the richness of biological assemblages (Turak et al, 2011).

Fish stocks

Recreational and commercial fisheries not only contribute substantially to the Australian economy, but are also socially and culturally important. Recreational angling is an important leisure activity in Australia, with an annual participation rate higher than for the rest of the world (Koehn et al, 2011).

Table 3 summarises the potential impacts of climate-change on fish and commercial invertebrates. It does not include the indirect effects of Climate Change in fish habitats and food.

Fish are able to swim away from unfavourable environments so it might be argued that changes in salinity, temperature, oxygen, etc., would cause changes in distribution rather than their disappearance. Changes in distributions could include latitudinal changes, i.e. moving southwards to other estuaries, or "longitudinal" changes, i.e. reduced use of estuarine waters. Two limitations exist though: (1) southward migration is not always possible (limited connectivity between estuaries due to the distance or ocean circulation, absence of estuaries southward); (2) some species depend on estuaries for reproduction or completion of specific life stages, and therefore cannot migrate longitudinally. It is also important to note that whilst from a global perspective, a mere change in commercial fish distribution might be considered as acceptable, it would not be the case from a regional perspective, as it would lead to potentially significant economic losses (Trakhtenbrot et al. 2005).

Another key mechanism allowing species to cope with warming (other than shifting biogeographic ranges) is phenological alteration (the synchronous timing of ecological events) to accommodate spatial and seasonal changes in ambient temperature (Burrows *et al.*, 2011). Therefore, the so-called perturbation of reproductive behaviour mentioned by some authors (Table 3) can actually also be defined as a coping mechanism.

Many authors mention strong correlations between river discharge and the productivity of several estuarine fisheries around the world. Such correlations are positive most of the time, but can also be negative sometimes and it may not be consistent between regions (see review

in Ives et al, 2009). Most of those studies are based on catch time series analysis, and therefore are strongly influenced by the species catchability. For example it is now suggested that the higher catches of eastern school prawns following large river discharges (due to heavy rain events) could be related to an increased seaward movement of both mature and immature school prawns, rather than to variations in abundance (Ives et al, 2009).

Table 3: Impacts of Climate Change on fish and invertebrates; synthesised from Neuheimer et al, (2011); Gillanders et al, (2011); Koehn et al, (2011); Fabry et al, (2008); Hadwen et al, (2011), and literature research.

Environmental parameters affected by Climate Change	Groups concerned	Details
Increased temperature	All	Within species thermal tolerance limits: faster growth potentially leading either to increased survival or to greater susceptibility to starvation because of higher metabolic rates. Also potentially perturbation of the reproductive behaviour. Near the upper limit of thermal tolerance: increased metabolic costs leading to reduced growth and eventually to major dysfunctions and death
Salinity	All	Affects osmoregulation and oxygen consumption of fish outside their salinity tolerance range and leads to impaired growth and reproduction and in extreme cases death.
Reduced Oxygen	All	Reduces growth and increases mortality
Reduced pH	Marine calcifiers	Reduced growth and enhanced mortality due to reduced calcification rates and shell dissolution
	Fish	Potential effect on fish behaviour, including sensory ability, indirect effect through reduction of food availability
Reduced flows	All	Loss of habitats / reduced connectivity between floodplain habitats and main channel
	Marine migrants / diadromous species	Loss of connectivity between freshwater and oceans Reduced export of larvae from the estuary
Entrance-channel openings	Marine migrants / diadromous species	Loss of connectivity: depending on the timing and duration of estuarine closure, those fish may be unable to move between freshwater, estuaries and oceans (movements related to spawning and colonisation of larval/juvenile/adult habitats)

Interactions with existing human-induced threats

Because of the high level of connectivity (both hydrological and biological) between estuaries and the adjacent freshwater, terrestrial and marine realms, it is likely that Climate Change may interact with other anthropogenic stressors to produce synergistic and/or cumulative impacts on biodiversity and ecosystem functioning in estuaries.

Table 4 lists the potential interactions between non-climatic anthropogenic stresses and climate-induced changes on estuaries.

It is also worth noting that Climate Change can also lead to changes in the human-use of estuaries: e.g. a drier climate may cause changes to crop selection, irrigation practices, environmental water allocations and rural population demographics, leading to further changes on water extraction and nutrient and sediment run-off. Similarly, recreational anglers may change fishing locations or the species targeted (e.g. from cold-water salmonids to warm-water native species), resulting in changes to population take rates (Koehn et al, 2011).

Table 4: Potential interactions between climate-induced changes and human-induced existing threats in estuaries. Synthetised from Kingsford (2011); DCC (2009); Koehn *et al.,* (2011); Turak *et al.,* (2011).

Human-induced threats	Potential synergistic interactions	Potential impacts
Habitat loss and degradation (land-use, dredging, bank stability works)	Reduced freshwater flows (due to reduced rainfall)	Loss of wetlands / loss of connectivity between floodplain and channel habitats / loss of biodiversity
	More frequent storms and floods	Increased erosion
Water extraction/ diversion/retention	Reduced freshwater flows – saline intrusion (due to sea-level rise)	High salinities – loss of connectivity (freshwater/ocean)
Invasive species	All Climate Change impact likely to jeopardize the survival of a given local species	Local species outcompeted / loss of biodiversity
Pollution (including nutrients)	Reduced freshwater flows	Increased exposure to the pollutant due to higher residence time in the estuary
Infrastructures	Sea-level rise	"Coastal squeeze"/contraction in habitat area (infrastructure preventing inland migration of estuarine habitats e.g. mangroves and wetlands)
	Saline intrusion (from sea-level rise and/or reduced freshwater flows)	Loss of freshwater ecosystems and biological assemblages because urban and agricultural development restricts movement into more suitable areas
	More frequent floods	Increased height and duration of floods and associated impacts due to outflow restriction (settled river mouth)
Overharvesting	All Climate Change impact likely to jeopardize the survival of harvested species or species impacted by harvesting activities	Species extinction / loss of biodiversity

1.3: Underpinning Issues for Adaptation Strategy Development

1.3.1. The Critical Need to include Connectivity in Adaptation Planning

Traditionally, environmental policy, valuation, legislation, planning and management have been designed and organised around frameworks that value individual components or units of the environment (Dale *et al.,* 2010). This *spatial component centred* approach to valuing and managing (Dale *et al.,* 2010) involves splitting the landscape into spatial units that contain an item or factor of interest (e.g. 'rarity') and working with those. Recently, there has been increasing recognition that few spatially distinct units operate in isolation, and that connections to other units are usually critical to allow necessary ecological processes to operate (Amezaga *et al.,* 2002; Lawler, 2009; QWP 2011). The fact of a highly connected world makes a traditional *spatial component centred* view untenable for rational management and long-term viability because it divorces governance from the landscape patterns and processes that generate and maintain the units of interest (Amezaga *et al.,* 2002; Dale *et al.,* 2010).

Recognition of the need to understanding connectivity and incorporate it into planning, policy, legislation and management was the driver for the recently completed Queensland Wetland Program project "*Understanding Aquatic Ecosystem Connectivity*" (QWP, 2011).

The acceptance and utility of this approach, and the understanding it has engendered clearly indicate the need for a parallel framework for incorporating connectivity into CAS. Connectivity is particularly important in a Climate Change Adaptation context because, as well as playing a crucial role in ecosystem functioning, connectivity is also an important consideration with respect to governance structures (see section 5).

What is connectivity?

The term "connectivity" is widely used, but more often in the form of a buzz-word than as a clearly defined concept (Sheaves, 2009). Connectivity has seen a multitude of situation-specific definitions, which are valid in specific contexts (Calabrese & Fagan, 2004). However, in a general sense connectivity can be thought of as "*An empowering mechanism that facilitates the movement of materials or effects between spatio-temporal units and enables events in one spatio-temporal unit to influence events in another unit*" (Sheaves *et al.*, in prep). In essence, connectivity is a mechanism for joining objects, locations, events or effects for the fulfilment of processes (QWP, 2011). It is an integral component of many scientific endeavours and theories, including genetics (Broquet *et al.*, 2010), metapopulation dynamics (Matthiessen *et al.*, 2007), reserves/protected area theory (Ortiz-Lozano *et al.*, 2009), etc.

Specific properties and features of connectivity

Connectivity is a dynamic process that underpins a diverse range of functional outcomes because it allows spatio-temporal separation to be overcome at particular points in space-time (Sheaves, 2009). In allowing distant entities to interact, connectivity provides the glue facilitating spatio-temporally dispersed functions and defining "real" boundaries of functional units (including "real" ecosystem boundaries [e.g. Box 1]). Thus, connectivity allows functional understanding in a world that is operationally a mosaic of interacting entities (Sheaves, 2009). By allowing understanding of functioning not afforded by a purely spatial view connectivity is a key in understanding complex systems.

Box 1. Ecosystem boundaries.

Many ecosystems are defined by physical or geomorphological boundaries. For instance, the definitions of estuaries commonly used by biologists (e.g. Pritchard, 1976; Day, 1980; Potter *et al.*, 2010) are purely physio-geomorphological, with estuaries identified by the degree to which they are enclosed, the extent of their connection to sea and their internal salinity gradients. No reference is made to any biological or ecological parameters. Where the lives of organisms that are the focus of study are limited by these parameters (e.g. salinity tolerance), and those limits match the definition of an estuary, then using a physio-geomorphological definition of an estuary as a spatial framework for biological or ecological study biology is appropriate. However, where connectivity is important in facilitating functions that operate across the physio-geomorphological of the estuary the "real" boundary of the functional ecosystem unit can only be defined by incorporating connectivity.

Potential and Realised Connectivity: Connectivity comprises more than a simple physical connection between two entities; it requires that the connection culminates in a functional outcome relating to a particular situation (e.g. facilitating an ecological process, a management response to a policy, a link between governance and ecological process). So connectivity comprises two components; *potential* and *realised* connectivity (QWP, 2011). For example, for fish nursery ground utilisation a flood event may provide *potential* connectivity but this will only result in *realised* nursery ground value if competent-to-settle larvae are available at the time the connection occurs.

Relationship between Potential and Realised Connectivity: The relationship between potential and realised connectivity is *dynamic*, and *situation-*, *question-*, *perspective-* and *conceptual scale*-specific. It is *dynamic* because the relationship changes across a variety of spatial and temporal scales, to the extent that connectivity is likely to have a different realised outcome at two different places or times (Thomaz *et al.*, 2007). It is *situation-specific* because many factors can intervene to modify the potential realised relationship (King *et al.*, 2003; Albanese *et al.*, 2009). For instance, realised nursery ground value can be disrupted if the connection becomes inhospitable or untenable (e.g. because of low DO or the presence of predators). It is *question-* and *perspective*-specific, because the functional outcome of connectivity differs depending on the purpose of understanding and the point of view of the observer (Calabrese & Fagan, 2004). This nursery ground value example takes on a completely different character if the question is refocussed on the nutritional support provided to predator populations through the ability to ambush recruiting juveniles when they are migrating into nursery habitats. The relationship is *conceptual scale*-specific because the same connectivity relationship can have different meanings depending on the observer's conceptual standpoint; connectivity for an ecosystem, for a nursery ground, for animal movements, for nutrient cycling, at a theoretical level, for particular applied purposes, to understand a single type of event etc.

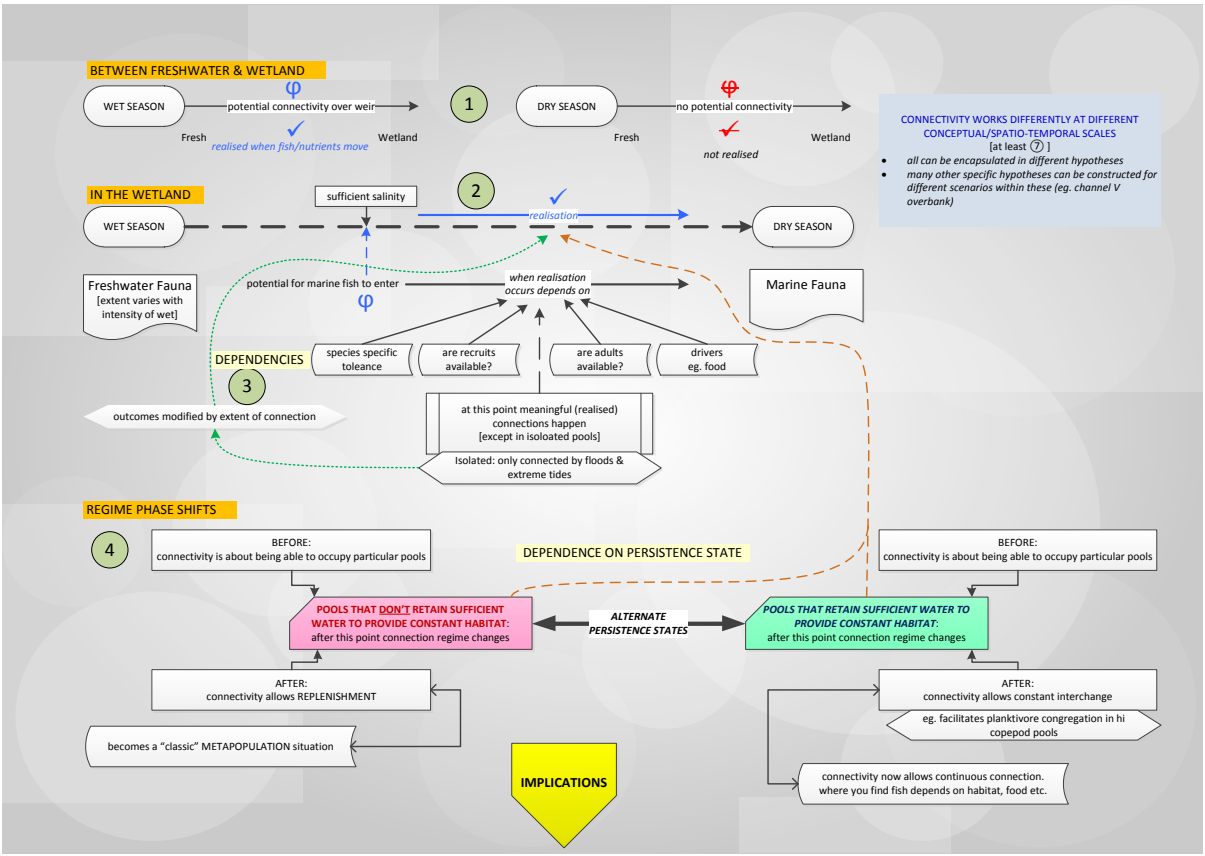


Figure 2: The complexity of connectivity: the example of a tropical tidal salt-couch wetland.

Connectivity is subject to a variety of modifiers (1) seasonal changes in potential connectivity, (2) seasonal change in the conditions necessary to convert potential to realised connectivity, (3) species- and situation-specific dependencies, (4) regime phase shifts where pattern of realisation depends on the natures of the connectivity end members.

The Complexity of Connectivity: Connectivity is complex, with outcomes in any particular situation subject to a variety of modifiers (e.g. Fig. 2). In fact, all the modifiers of connectivity, and the relationship between potential and realised connectivity, produce a convoluted connectivity landscape, the complexities and implications of which need to be understood and accounted for if connectivity is to be included in CAS (Sheaves, 2009; Vos *et al.*, 2010).

Although the examples used here have concentrated on ecological connectivity, each of the properties and features of connectivity have direct equivalents in all other Climate Change Adaptation related activities (Box 2).

Box 2: Examples of the role of connectivity in Climate Change Adaptation related activities.

A. Biological and ecological
- Movements of organism at any stage of their life history (migration, emigration) (Sheaves, 2009)
- Nutrient, biomass and energy flows and subsidies (one and two-ways) (Dittmar & Lara, 2001)
- Biophyisical processes that are spread spatio-temporally across many units (production, cycling, enthropy) (Lamberti *et al.*, 2010)

B. Physics and chemical
- Translocation of chemophysical units, like water quality, thermohaline circulation, or runoffs effects (Lamberti *et al.*, 2010)
- Translocation of impacts and downstream impact effects (Freeman *et al.*, 2007; Gilman *et al.*, 2008)

C. Management and governance
- Impacts of adaptation measures on humans (social, economic etc.) (Mapstone *et al.*, 2010)
- Links between legislation, policy, planning, management, jurisdiction and other governance issues (See section 6)
- Modification of vulnerabilities through off-site impacts on a vulnerable asset or reduced vulnerability due to connectivity to multiple units
- Links between management and ecosystem outcomes
- Links between adaptation measures and off-site outcomes

How does considering Connectivity influence Climate Change Adaptation Strategies?

In allowing action at a distance, connectivity is crucial in facilitating ecosystem function, and so a key factor in successful Climate Change Adaptation. The pervasive influence of connectivity on both ecological (Sheaves, 2009) and governance (Amezaga *et al.*, 2002) outcomes complicates adaptation plans; few actions or effects can be contemplated that won't have far reaching consequences. Adaptation and mitigation activities that address one ecosystem, ecological problem or one spatial unit will almost invariably have a variety of consequent off-site impacts, both on other ecological units, and on human activities, industries, and governance structures (Gilman *et al.*, 2008). Adaptation planning and subsequent management actions will have a similar diversity of impacts both on the environment and on human activities (Mapstone *et al.*, 2010). Without consideration of connectivity these complex outcomes have the potential to produce a variety of unexpected consequences. As a result, it is crucial that a clear understanding of connectivity underpins adaptation strategy thinking, with effective adaptation strategies requiring new management concepts and rethinking of the relationships between ecological, institutional, social, and socio-ecological systems, as well as their relationship to integrated natural resource management, integrated catchment management and coastal management.

1.4: Integrated Regional & Typological Differences in Estuaries

The importance of typologies in coastal zone research and management

Typologies provide simple frameworks which enable organised studies of complex systems. They are particularly pertinent to research and management of estuaries and other inherently dynamic and varying coastal zone ecosystems. Coastal and estuarine ecosystems are influenced by a complex of environmental variables (Wetland*Info*, 2012). Furthermore, Australia is also a large continent covering the tropics to sub-Antarctic. Around Australia estuaries vary in geomorphology, tidal influence, wave influence, climate, and the available pool of biological components, which are in turn influenced by factors such as climate as well as biological and biogeographic factors. Therefore, estuaries are likely to display distinctly different characters on key environmental and biological axes, respond differently to Climate Change and as a result require different adaptation strategies. Although there may only be a relatively small suite of realistic adaptation strategy categories (Klein *et al.*, 1999; Burton *et al.*, 2006), the nature and consequences of them are likely to vary substantially from setting to setting and region to region. Australia's diversity of climates, geologies, geomorphologies and regional settings mean that specific adaptation strategy alternatives need to be developed and validated for functionality across a wide variety of situations. Consequently, an appropriate typological understanding is needed to ensure the development of adaptation strategies at a national level will capture the fundamental axes of variability, and that case study tests of models will have broad relevance. Achieving broadly relevant results means this typology needs to provide a simple, but representative, framework. Any complex schema will be too unwieldy to serve as a major spatial structuring framework for the project. The challenge is to select a typology that represents the important differences among estuaries, but is simple enough to allow adaptation strategies to be developed for, and tested in, a manageable set of case study scenarios.

Typologies

Typologies need to be appropriate to the scale at which they will be applied and the purpose for which they will be used. Consequently, there is no single "correct" typology; rather typologies need to be tailored to particular situations and needs. Typologies are ensembles of classifications, established from a variety of criteria relevant to a particular situation, assembled into groups for particular purposes (ANAE, 2012). As a result, the type and quality of the underpinning classification systems, and the ways they are combined, need to be carefully managed to produce a typological scheme most appropriate to a particular situation.

Many "global" typologies have been suggested, but most are either attuned to a specific set of regional conditions that don't apply particularly well across Australia at a national level (e.g. Harrison & Whitfield, 2006), or are too narrowly focussed for testing adaptation strategies (e.g. Laruelle *et al.*, 2010; Dürr *et al.*, 2011). Harrison and Whitfield (2006) proposed a typological scheme based on open and closed estuaries that performed well across a large range of South African estuaries. Although this scheme fits well for south-western Australian estuaries (Potter *et al.*, 1990) where tidal and wave conditions are similar to those in South Africa, it is not appropriate for the bulk of Australian estuaries where a wider range of tide/wave relationships exist (OzCoasts, 2012). Laruelle *et al.*, (2010) and Dürr *et al.*, (2011) suggest schemas based mainly on geomorphology, but these fail to account for many of the factors that influence Australian estuaries. Other Australian classification schemes are often

dated or lacking in the estuary-specific information needed for estuary classification (e.g. IMCRA, 1998).

Typologies will also differ depending on the use to which they are put. For example, a very simple typology, that "averages over" small scale complexity, might be appropriate for developing broadly applicable simulation models. However, the same schema would probably be inappropriate for testing the models because it would not allow the impact of smaller scale variation to be evaluated.

Two detailed classification schemes show promise for the development of typologies appropriate to Australian estuaries; OzCoasts (2012) and ANAE (2012).

OzCoasts

OzCoasts (OzCoasts 2012) provides a variety of classification tools and has served as a basis for most Australian estuary typologies over the last decade. It has seen widespread use, and has become the "default" typology for Australia's estuaries. For instance, it was the classification scheme used in the recent "Climate Change Responses and Adaptation Pathways" report (Hadwen *et al.,* 2011). However, OzCoasts is not designed as a definitive source for typological development. As stated under the heading "Estuarine Typology" in OzCoasts (2012); "*Currently there is no comprehensive typology of Australian estuaries, however, the geomorphic classification presented here is an initial start and is currently the national default typology*".

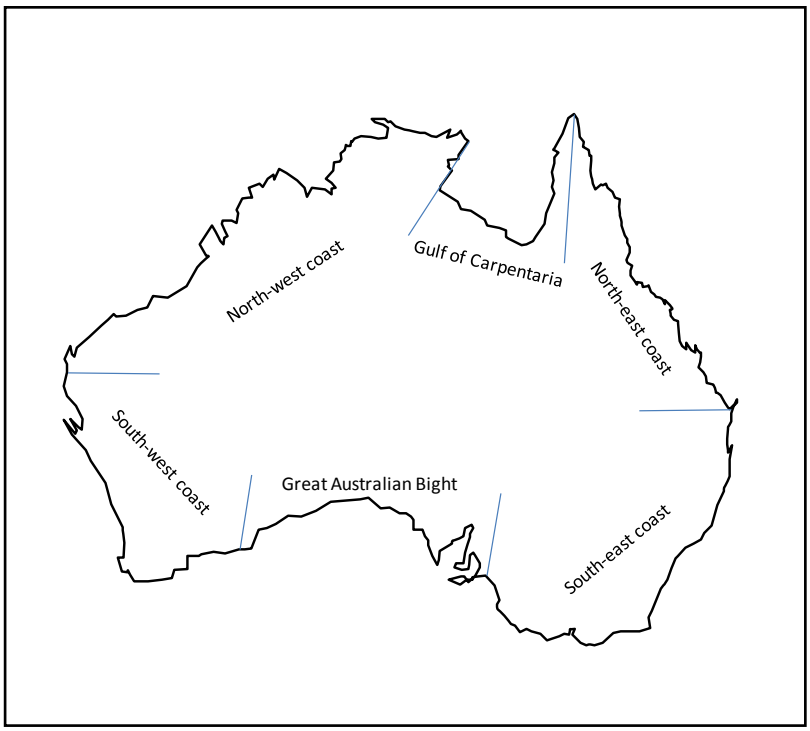


Figure 3: OzCoast regions (after OzCoasts 2012)

The OzCoasts (2012) schema is based on 6 regional zones (Fig. 3) providing a simple spatial structure. An additional layer of complexity is accounted for by a ternary classification based

on wave, tide and river influences (after Dalrymple *et al.,* 1992; Boyd *et al.,* 1992). This combination results in 17 major zones X classification categories (Table 5).

Table 5: Regions X geomorphic classifications based on data presented in OzCoasts (2012). Only classification categories comprising at least 10% of a region's estuaries are included.

		Tide dominated				Wave dominated		
	REGION	Delta	Estuary	Creek	Embayment	Delta	Estuary	Coastal lagoon/strandplain
tropical	north-west coast		27%	50%	10%			
	Gulf of Carpentaria	17%		48%				14%
	north-east coast	16%		41%		17%		
temperate	south-east coast					10%	42%	35%
	Great Australian Bight			31%				53%
	south-west coast					11%	66%	17%

OzCoasts was initially developed during the first National Land and Water Resources Audit (NLWRA, 2000) to incorporate the Australian Estuarine Database and estuarine datasets compiled at that time (OzCoasts, 2012). Despite more recent updates it is becoming a little dated. Additionally, although OzCoasts has been used widely it is not fully developed for biological or impact related applications. It mainly focuses on regional divisions and wave, tide and river influences, and although the site contains information on some biological factors they are neither comprehensive nor easy to integrate into a typological framework. Similarly, there is no comprehensive information on impact or Climate Change classifications. However, its landform and topography classifications provide important inputs to the more recent ANAEC classification framework.

ANAEC

Recently, there has been a concerted effort to produce a comprehensive aquatic ecosystem classification framework for Australia in the form of the Interim Australian National Aquatic Ecosystem Classification Framework (ANAE, 2012). The ANAE Framework has been developed in response to the requirements of the National Water Initiative as part of the Aquatic Ecosystem Toolkit.

ANAE is a broad-scale, semi-hierarchical, attribute-based, biogeophysical framework (ANAE, 2012) developed in recognition that many assessments will relate to areas with low density and quality of biological data. The ANAE includes 3 hierarchical scales; level 1, regional scale; level 2, landscape scale; level 3, classes of aquatic systems and habitat scale. Levels 1 and 2 are most relevant to developing and Australia-wide estuary typology. They relate to national regionalisations for landform, climate, hydrology, topography and water influence. They are based on collated, existing datasets, with the development data sets for particular applications suggested in the ANAE documentation (Table 6).

Table 6: Data sets suggested in the ANAE documentation relevant to developing an Australian estuarine typology

	Hydrology	**Geofabric CSIRO AWR 2005**	**Surface water: Marine currents: Groundwater**
Level 1: Regional scale	Climate Köppen based	BOM Climate Classification	Full Köppen: http://www.bom.gov.au/climate/environ/other/koppen_explain.shtml BOM Temperature/humid: http://www.bom.gov.au/jsp/ncc/climate_averages/climate-classifications/index.jsp
	Landform	IMCRA	Provincial scale: http://www.environment.gov.au/coasts/mbp/publications/imcra/pubs/map1-pb.pdf meso-scale: http://www.environment.gov.au/coasts/mbp/publications/imcra/pubs/map2-msb.pdf
Level 2: Landscape scale	Water influence		Nothing in the document but catchment area relative to estuary area might be useful
	Landform	assign biophysical estuary types and catchment source	OzCoasts, Smartline
	Topography	Tide, Wave, River dominated	OzCoasts, Smartline
	climate	Köppen subdivisions	http://www.bom.gov.au/climate/environ/other/kpn.jpg
Level 3: Habitat scale	Nothing really needed in this space beyond "estuary". ANAE level 3 covers estuary limit identification and estuary-level attribution.		

Given its detailed and comprehensive formulation and links to appropriate existing classifications, ANAE provides a useful resource on which to base an Australian National estuary typology. Additional useful data sets relative to Climate Change applications are available from the Worldwide Coastal Warming Assessment project website (WCWA, 2012). However, there are still substantially gaps in comprehensive classifications of Australia's estuarine biotic assemblages; although there is good information on marine and intertidal plant communities there is no comprehensive classifications of Australia's estuarine nekton, benthic, plankton or microphytobenthos assemblages.

Objective 2

Objective 2: *Evaluate the key adaptation strategies recognising that there needs to be a process to harmonise adaptation strategies for the public benefit.*

2.1: Major Adaptation Strategy Types

The IPCC defined Climate Change adaptation as the "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC 2001). Adaptation actions are aimed at reducing vulnerability to Climate Change and can take the form of changes in practices, processes or structures in response to projected or actual changes in climate (Watson *et al.,* 1996), and is aimed at reducing or delaying the consequences of Climate Change rather than the prevention of impacts (Smit and Pilifosova, 2001). Adaptation contrasts to "mitigation", the other major category of responses to Climate Change which involves preventing or reducing Climate Change by reducing greenhouse gas emissions (Klein *et al.,* 1999; Burton *et al.,* 2006).

Adaptation can be in response to observed climate impacts, or in anticipation of future Climate Change, and can be proactive, aimed at reduction of exposure to future risks, or reactive, aimed at alleviating impacts that have occurred (Carter *et al.,* 1994; Burton *et al.,* 2006). Proactive adaptation generally requires a greater initial investment but is usually more effective at reducing future risk and cost (Burton *et al.,* 2006). However, reactive strategies are important to deal with risks that remain after the implementation of proactive adaptation, or due to unexpected or unavoidable impacts.

Table 7: Major adaptation responses and categories of action (two left hand columns) and their relationships to selected literature sources.

		Literature Categories			
Type of Response	***Category of Action***	***Klein et al., 1999***	***Burton et al., 1993***	***Millar et al., 2007; Lawler 2009***	***Burton et al., 2002***
Sit-it-out responses	No need for action				
	Abandon				
	Self-adaptation				
Active responses	Retreat	Retreat	Change location		Adaptation for Accommodation
	Protect	Protect	Prevention of loss	Improve resistance	
	Accommodate	Accommodate	Tolerate loss Spreading loss	Improve resilience Facilitate change	
	Alternative		Change use	Facilitate change	
	Restore		Repair		

Developing effective CAS is a complex process. However, there is a relatively restricted suite of adaptation strategies available. These have been defined and discussed in many ways by

various authors but can be distilled into eight categories of adaptation actions (Table 7). Most authors have concentrated on 'active responses'. These have been stated in a variety of ways but can be grouped into five categories of action (Table 7). For example, Burton *et al.*, (1993) identified and detailed six generic types of active adaptation strategies (Table 8), but tolerating and spreading loss can be subsumed into the 'accommodate' category of Klein *et al.*, (1999) and interpreted as actions to improve resistance, improve resilience or facilitate change (Millar *et al.,* 2007; Lawler 2009).

Table 8: Generic types of behavioural adaptation strategies (modified after Burton *et al.,* 1993).

Prevention of loss	anticipatory actions to reduce the susceptibility of an exposed component or function to the impacts of climate
Tolerating loss	adverse impacts are accepted in the short term because they can be absorbed by the exposed unit without long term damage
Spreading or sharing loss	actions to distribute the burden of impact over a larger region or population beyond those directly affected
Changing use or activity	switching of activity or resource use from one that is no longer viable to another that is
Changing location	where preservation of an activity is more important than its location and the activity is migrated to an area that is more suitable under Climate Change
Restoration	aims to restore a system to its original condition following damage or modification

Although taking no action is generally not seen as adaptation, there are many situations where active adaptation is not needed or not warranted (

Table 9). Consequently, the sit-it-out strategy is an option that needs to be explicitly considered during adaptation planning, and may be the most critical decision made in adaptation trade-offs as management is forced to prioritize actions and balance up the needs of different sectors (Lawler, 2009). In extreme cases, managers will be forced to make decisions such as letting species go extinct or "lose" low-lying land. These decisions will need to be made carefully and the full impact of different decisions evaluated. For example, Lawler (2009) suggests 'triage' with decisions about active response versus abandonment based on the severity of the impact and the value of the resource. However, the likely success of different actions needs to be considered; it might be better to prioritise scarce resources to deal with "low impact" first because there is a reasonable certainty of success or because this provides the most useful outcomes. Similarly, in-depth consideration is needed even when there is apparently no need for action because of apparent inherent capacity to deal with Climate Change impacts. This is because the mere existence of capacity is not itself a guarantee that the capacity will be used (Burton and Lim, 2001).

The three sit-it-out actions and five active responses represent the general types of actions that decision makers can take (Table 9). However, the exact details of what each action requires and how it will be operationalized will vary case-by-case depending on the specific location, the specific nature of the threats, local issues, governance requirements, and social, ecological and economic imperatives.

Table 9: Details of categories of action.

Type of Response	*Category of Action*	*Details*
Sit-it-out responses	No need for action	
	Abandon	*Do nothing, there is no value in any action because loss is inevitable over the specific strategic horizon* *OR* *Costs outweigh value of action*
	Self-adaptation	*Let natural change occur: the system is able to self-adapt*
Active responses	Retreat	*Change the location of the activity*
	Protect	*Impose protection* *reduce other pressures*
	Accommodate	*Tolerate loss* *Spread loss* *System state change*
	Alternative	*Utilise and alternative resource*
	Restore	*Repair/restore functionality*

2.2: Frameworks and Associated Tools

A framework is here defined as a process that identifies clear steps with which to develop climate adaptations for estuarine systems. Each step should comprise a set of tools that can be used to complete that step. It is likely that more than one tool would be available for each step as the framework should be useful for both data poor and rich situations. Wherever possible, existing frameworks and methods would be used and only if there is a gap, should these be identified.

From the literature reviewed, there are many different frameworks used (see review by Mawdsley *et al.,* 2009) but, for illustration purposes, these have been divided roughly into three classes:

1. IPCC and derived frameworks,
2. Risk-vulnerability-adaptation frameworks, and
3. Modelling methods that include the steps within them.

IPCC and derived frameworks

The best known IPCC climate impact and adaptation framework is that by Carter *et al.*, (1994) developed during IPCC II. It links Impacts and Adaptation in a generic framework of seven high level steps - a) define the problem, b) selection of method, c) testing of method, d) selection of scenarios, e) assessment of biophysical and socio-economic impacts, f) assessment of autonomous adjustment and g) evaluation of adaptation strategies. Within the seventh step, are seven sub-steps, being a) define objectives, b) specify the climatic impacts of importance, c) identify the adaptation options which can be classified as prevention of loss, spreading/sharing loss, changing use/activity, changing location, and restoration, d) examine the constraints, e) quantify measures and formulate alternative strategies, f) weight objectives and evaluate trade-offs, and g) recommend adaptation measures. A modification of the adaptation steps of Carter *et al.*,(1994) for the coastal zone is described in Klein *et al.*, (1999)

where they prefer a multi-stage iterative approach with fewer steps – a) information collection and awareness raising (mostly from the IPCC Steps 1 -6), b) planning and design, c) implementation, and d) monitoring and evaluation (Fig. 4).

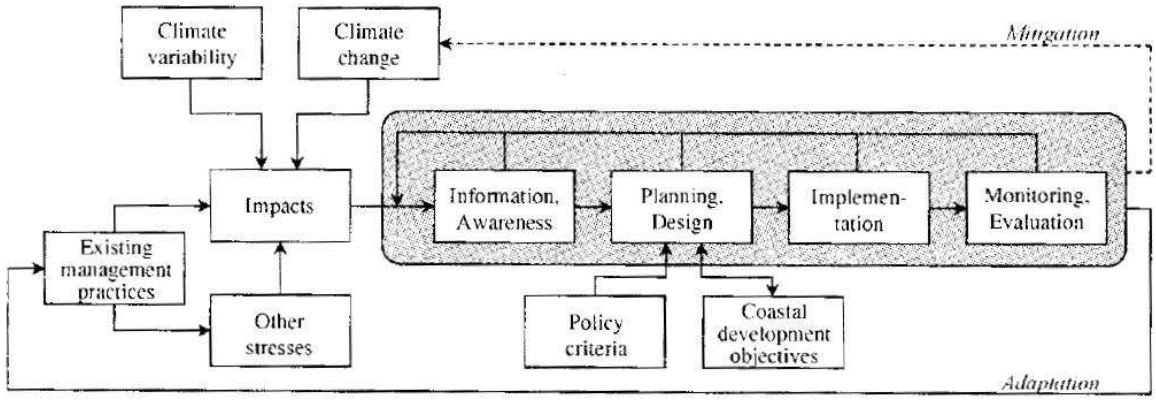


Figure 4: The conceptual framework of Klein *et al.,* (1999) showing in the shaded area the iterative steps involved in coastal adaptation variability and change.

In both these papers (Carter *et al.,* 1994; Klein *et al.,* 1999), several missing elements are described, which combined can be summarised as:

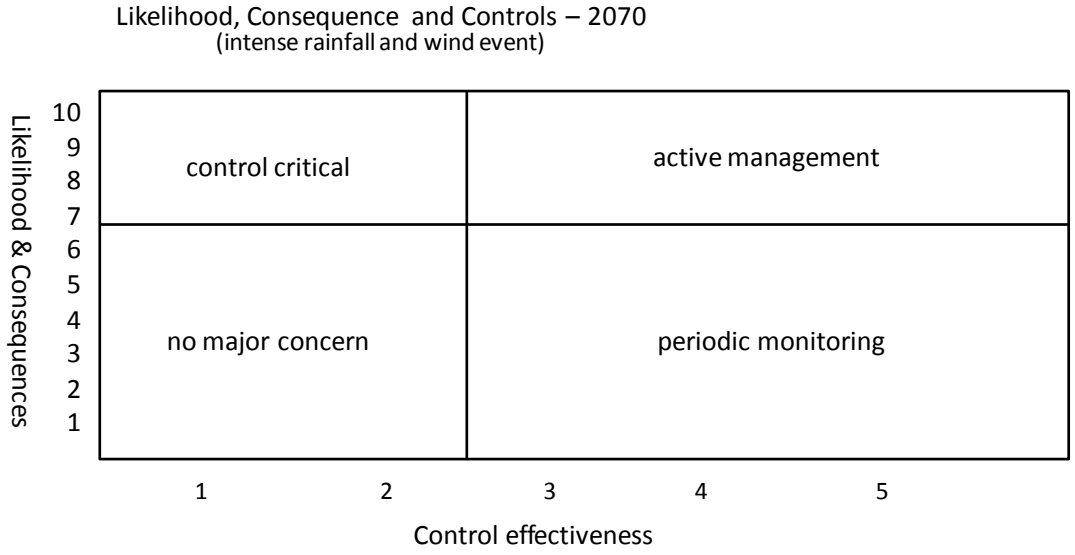
- Interaction between Climate Change and other impacts,
- Public perceptions and awareness,
- Spatial and temporal planning of adoption measures,
- Mechanisms for public involvement,
- Non-technical aspects (e.g. legal, institutional) aspects of adaptation,
- Tools and procedures to evaluate adaptation performance, and
- Policy and governance.

Risk-vulnerability-adaptation frameworks

The bulk of frameworks fall within these steps of undertaking a risk assessment, a vulnerability assessment and then developing adaptation strategies. The most data poor methods rely on stakeholder engagement processes, such as Cobon *et al.*, (2009) – a method developed for the grazing industry but now more widely applied. Here the steps are a) define context – area and timescale, b) identify climate variables, c) assign likely changes in climate patterns, d) identify key elements for your organisation, e) copy climate variable and organisation elements to impact matrix, f) describe impacts for each climate variable and element, g) determine likelihood categories, h) determine consequence categories, i) assign impact risk, j) describe adaptation responses, k) determine adaptive capacity, l) assign level of vulnerability, m) prepare risk or vulnerability statements, and n) prepare action plans. The utility of this framework is that it provides the tools in the forms of look-up tables or matrices to fill in at each step, making learning the process reasonably easy.

Central to all these methods is identifying the major risks and impacts, and concentrating adaptation strategies on these. However, most of the methods still tend to ignore many of the

issues identified by Carter *et al.*, (1994) and Klein *et al.*, (1999). For example, few methods seem to include steps beyond developing the adaptation strategies, with some notable exceptions such as the FAC4T method of Mukheibir (2006), who emphasises the latter part of the process. Their steps are a) assessment of current climate trends and future projections, b) undertaking a vulnerability assessment, c) identify current vulnerabilities (in each sector and for cross-cutting themes) based on current climate risks and trends, d) identify future vulnerabilities based on future climate scenarios and risks, e) strategy formulation, f) development of adaptation options, g) evaluation of priority adaptation strategies, h) programme and project scoping and design – (CAPA), i) implementation, and j) monitoring and evaluation of interventions. The City of Melbourne (DCC, 2009b) developed their adaptation strategies that also included the government entity to which the strategy applies e.g. municipal, council, municipal and council (Fig. 5). Furthermore, they rank the strategies



by the likelihood and consequence, and control effectiveness.

Figure 5: The "City of Melbourne" schema showing different strategies against a likelihood and consequence versus control effectiveness matrix (modified after DCC, 2009b).

The Heinz Centre (2007) is a good example of a survey of Climate Change adaptation planning that also classifies different frameworks using informative comparison criteria, such as whether the method has sufficient detail for policy construction.

Semi-quantitative methods include Monte Carlo methods, Bayesian Belief Networks (BBN) (Lam & Bacchus, 1994), multi-criteria decision analysis (Mendoza & Martins, 2006) (and some a combination of those). Bayliss *et al.*, (2012) undertook a quantitative ecological risk assessment (called QERA) of the Magela floodplain in Kakadu National Park, Australia. This risk assessment method was then incorporated into a BBN to evaluate different adaptation strategies. This therefore combines stakeholder and quantitative methods to assess adaptation strategies. Off the shelf, risk assessment packages such as BestFit or @Risk (Palisade Corporation) are also used. Despite the semi-quantitative nature of the methods, the frameworks still tend to follow the risk-vulnerability-adaptation steps.

Quantitative methods

Different to the above methods are those that address the development of adaptation strategies directly within integrated models such as Atlantis (http://atlantis.cmar.csiro.au/ for method and references) or EcoPath with EcoSim (http://www.ecopath.org/ for method and references). These methods follow the adaptive management loop of developing objectives, defining and modelling the system (including the human elements), management options and the performance measures for the different strategies. These methods are extremely complex and require a certain degree of expertise to undertake and are usually time consuming to establish. However, they are very good at integrating across different impacts including adaptation, something often not undertaken using other methods. Often not mentioned in adaptation frameworks is the idea that strategies should assess and build resilience, both social (Marshall *et al.*, 2009) and ecological (Maynard *et al.*, 2010).

Summary

A good framework should:

- Identify both active and passive adaptive strategies,
- Be tiered from data rich to data poor methods – starting with the latter,
- Consider the policy and governance framework,
- Include consideration of what level (policy, social etc.), and scale (local, regional or all) at which the strategies should work, and
- Identify the target audience to whom the framework aims.

2.3 Relationship between Governance and Adaptation Strategies

Estuarine and coastal systems are likely to be directly impacted by both climate and sea level changes and indirectly by human land use responses to change. Existing institutions (systems of rules that guide interactions of institutional actors (e.g., individuals, organisations)) have been acknowledged as one of the barriers for Climate Change adaptation at all governance levels (e.g., the Millenium Ecosystem Assessment (MA), 2005; Peel, 2008; Measham *et al.*, 2011). The most recent Commonwealth Inquiry into the Coastal Zone (House of Representatives, 2009) highlighted the need for leadership working in a collaborative framework with all levels of government in a diverse range of jurisdictions. Developing a collaborative framework involves integrating strategies into an institutional framework to allow the flow of relevant information, connecting management and science.

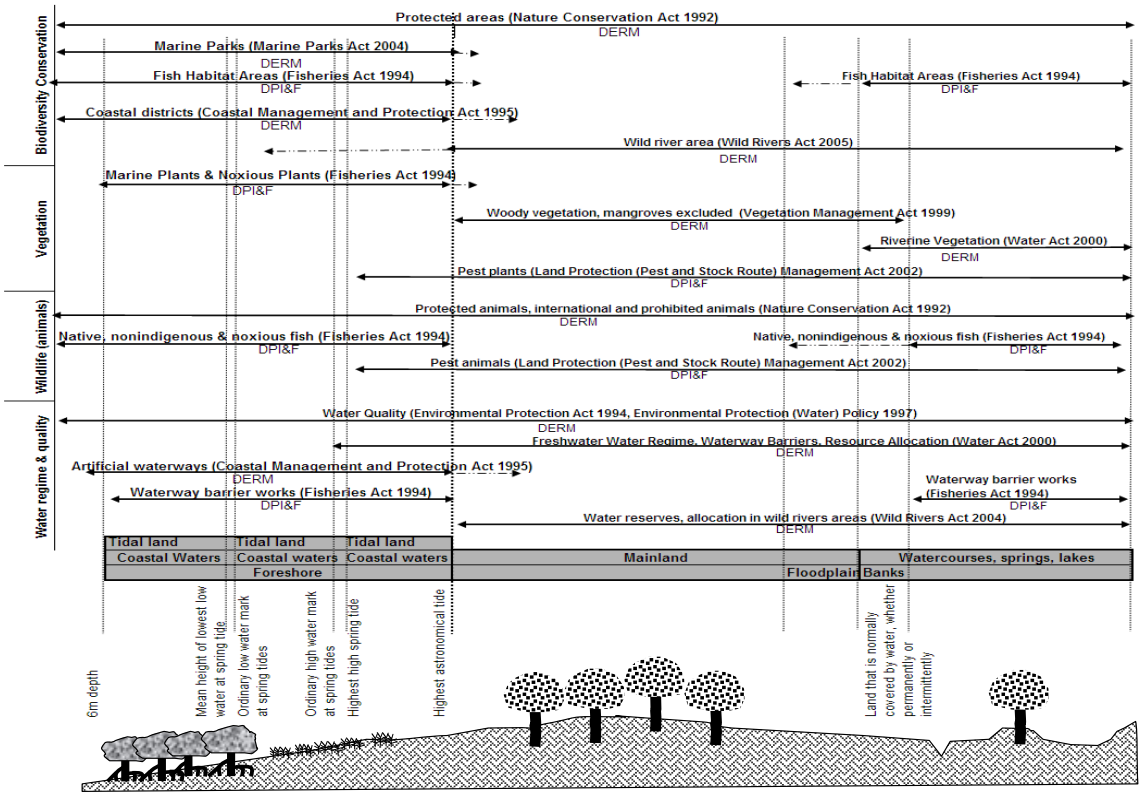


Figure 6: Jurisdictional fragmentation on the Queensland coastal area (adapted from Dale *et al.,* 2010).

Estuaries and coastal zones are valuable habitats for a diverse range of species, as well as being attractive locations for human settlements and industrial use. In Australia, the management of coastal zones and estuaries, as well as activities impacting those areas is carried out by a large number of institutional actors. They operate at all governance levels and are guided by 'a mosaic of different policies and pieces of legislation which, while not directly contradictory, generally evince no common approach' (Peel, 2008: p.943). For example, Figure 6 illustrates the diversity of institutional arrangements and their spatial mandates at the state level in the coastal zone of Queensland. Ecosystem properties such as biodiversity, vegetation, water and wildlife, are governed under different statutes and

managed by various policy instruments. As a result, stakeholders benefiting from different uses (services) of coastal ecosystems cut across a range of institutional boundaries (both horizontal and vertical).

The effectiveness of environmental programs and strategies can be expressed as the extent to which they achieve stated goals. Design of adaptive strategies for managing estuarine and coastal systems in the context of climate and sea level changes needs to account for cumulative pressures from various resource users. Therefore, strategies need to be placed in the context of the overall governance framework providing for the management of both direct (e.g. land use, water quality and regimes) and indirect (e.g. economic incentives, management capacity) drivers of change in particular location.

The analysis of the governance framework is required to:

- scope involved decision-makers and developed policy instruments and decision-making support systems for the management of particular coastal zones and estuaries vulnerable to Climate Change;
- identify existing and potential land and resource uses that either benefit from (use synergies) or adversely affect (conflicting use) ecosystem functions;
- establish the required information flow (both horizontal and vertical) to connect the decision-making at various governance levels;
- develop integrated CAS for the maintenance of ecosystem services in estuaries and coastal zones for multiple uses;
- facilitate institutional change to enable Climate Change adaptation.

Figure 7 outlines some major steps required to establish the overall institutional framework for the integration of CAS for the coastal zones and estuaries. The first step covers identifying ecosystem properties and the scope of ecosystem services provided. The second step involves identifying the cumulative scope of human impacts, including the use of services, affecting ecosystem functions both existing and potential under Climate Change scenarios (win-wins and trade-offs). The third step covers identification of all institutions across several governance levels providing for the management of identified impacts in the area (i.e., coastal zone, estuary and ecologically connected areas). Finally, the fourth step involves scoping and analysing various policies and management instruments developed under different institutions to establish the necessary linkages for the implementation of the adaptation strategies.

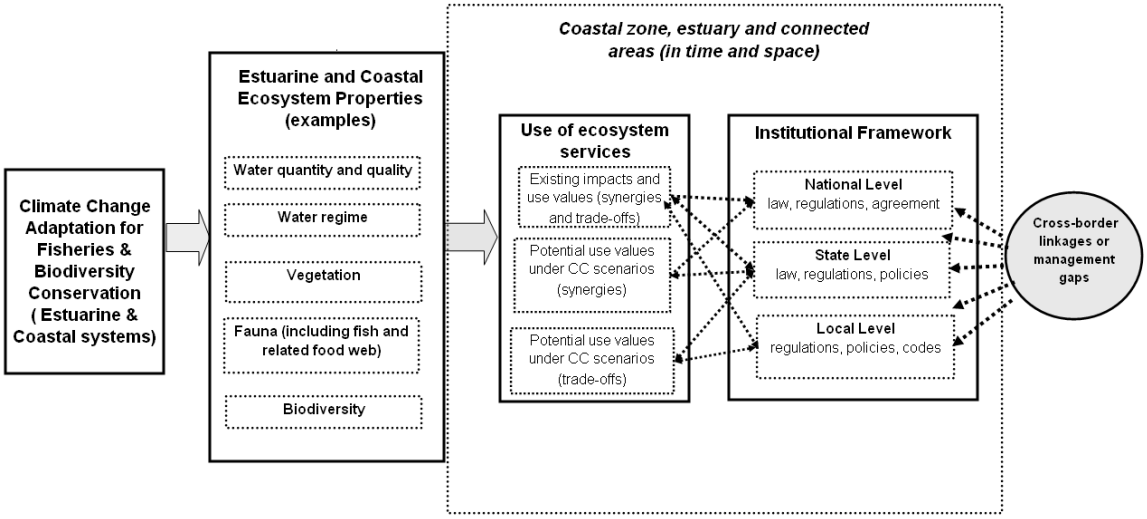


Figure 7: Framework for establishing institutional linkages (connectivity) for the integration of Climate Change Adaptation Strategies in coastal zones, estuaries and ecologically connected areas.

In summary, successful implementation of strategies for Climate Change adaptation requires integration of the strategy within a broader governance context, which allows for evaluation of potential cumulative effects, identifies required linkages to establish 'institutional connectivity', as well as negotiating potential actions that meet the requirements of a broader stakeholder range.

Objective 3

Objective 3: Develop tools and guidelines, at a National level, for developing adaptation strategies for the estuarine environment that take account of bioregional and typological differences among estuaries.

3.1: Step-Wise Development of the Guideline Toolbox Framework

Step 1: Qualitative Modelling

An initial case study was selected as a "stalking horse" for thinking about and estuarine-specific model framework structure and testing and comparing alternatives. The initial case study selected was a generic Burdekin Delta estuary. The important components of the Burdekin Delta estuary ecosystem-impact-adaptation system were modelled using a signed digraph qualitative modelling approach, focussing on one management focus; bund walls. The signed digraph (Fig. 8) was developed in a one-day workshop conducted by Dr Jeff Dambacher [CSIRO Mathematics, Informatics and Statistics]. The model assumptions for the case study system were: key environmental asset - nursery provision; target of management - bund walls as the thing to be managed; primary Climate Change factors - sea level rise and alteration in extended dry cycle (≅ El Niño) [in this context, extreme events were seen as largely extensions of wet season flooding which probably has a threshold level with respect to the bund wall/nursery relationship].

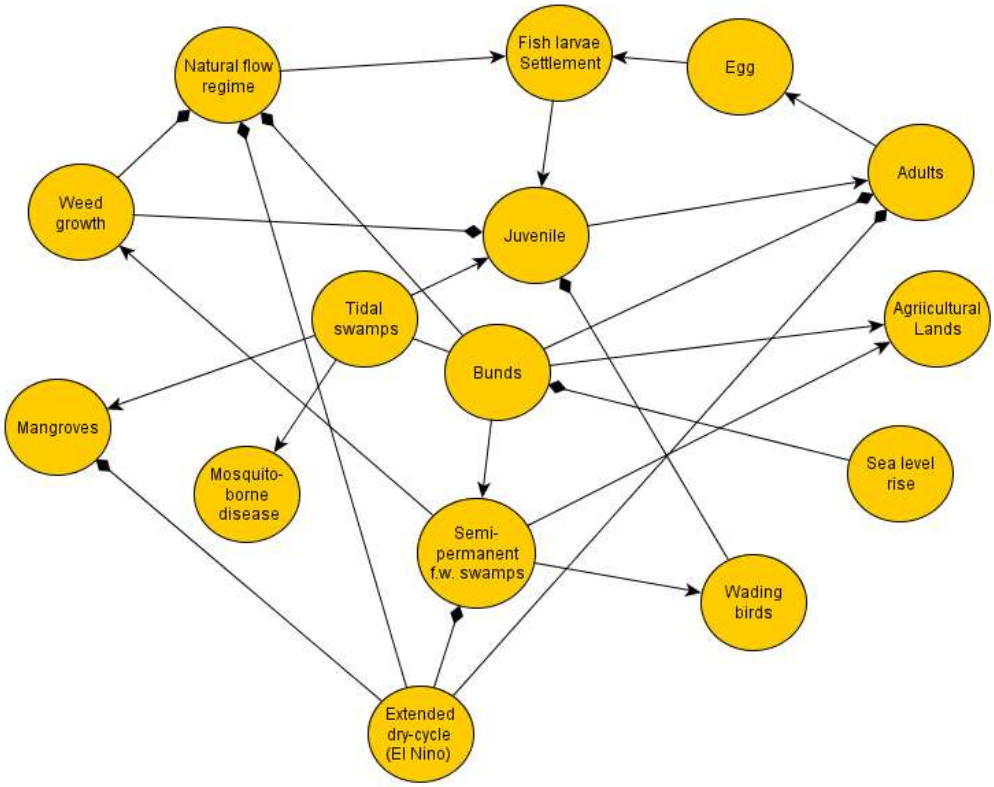


Figure 8: Signed digraph of the preliminary cases study [generic Burdekin Delta estuary]. Pointed vectors = positive effects; blunt-ended vectors = negative effects.

It seems likely that this might be a reasonable base model of a "connectivity barrier" scenario that might be modifiable to deal with other situations around Australia.

The modelling process emphasised:

- the key role of specific vulnerability assessment,
- usefulness of a system modelling phase as a component of the framework,
- the key point of adaptation strategies; that the adaptation is about managing human responses to Climate Change
- a framework needs to be multi-entry to make it applicable to a wide range of users: there needs to be a model step that allows the option of working holistically while recognising that some will enter the model at the issue level. In that case the process should accommodate the need to ensure that both lines of entry feed into a "consequences" step.

Step 2: Framework Conceptualisation

To prevent model development from being constrained by a particular structure, a conceptual model of framework components (Fig. 9) was developed based solely on logical linkages informed by group knowledge and the qualitative modelling in step 1. This model ensured

that there was a clear group vision of the components that needed to be included in the final framework before a framework was developed.

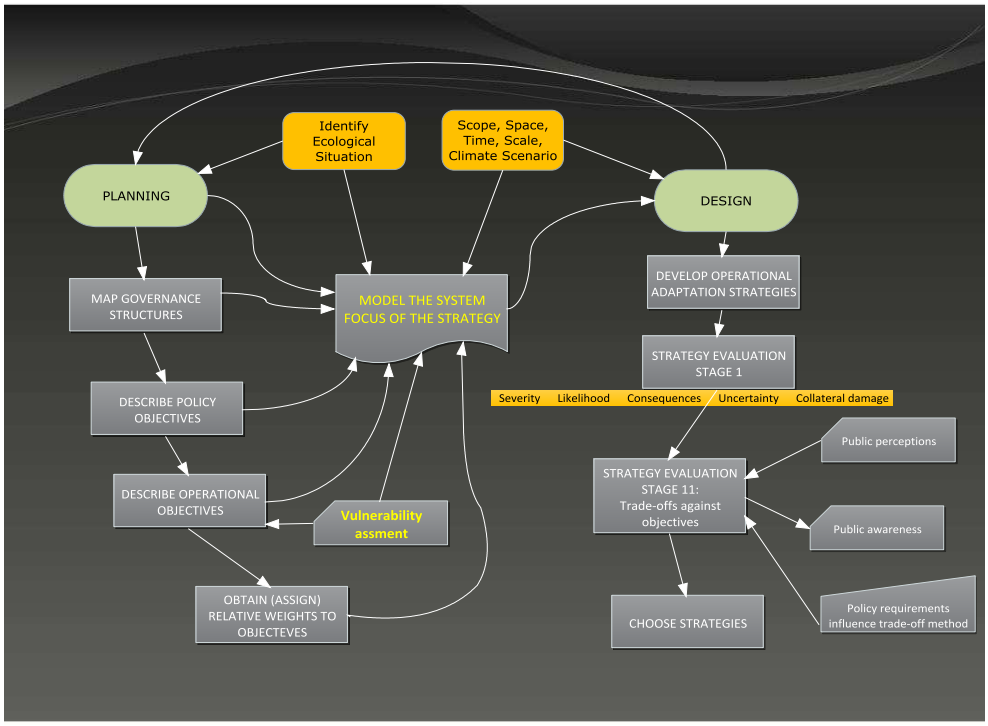


Figure 9: Conceptualisation of framework components (N.B. this is an interim model to allow conceptualisation of components and linkages but with no implied sequence).

Step 3: Contextual Development

To ensure a deep understanding of the model components and their implications for framework development, the components of the conceptualisation framework (Fig. 9) were investigated in the context of the generic Burdekin Delta estuary case study, and published adaptation frameworks. This investigation identified a range of key components (informing steps) that are critical to the process of developing the strategy, but sit outside many published frameworks, and that provide critical inputs to multiple steps in the framework. These include:

- vulnerability assessment,
- identification of details of the ecological situation: needs to be at a more extensive level than initial ideas of the problem would suggest because it needs to capture a variety of aspects that inform other stages and components of the framework, and to account for a propensity for unexpected issues to occur, and
- model the system focus of the strategy.

Step 4: Base Framework Selection

Based on previous components of the project (Milestone 2), qualitative modelling (Step 1), framework conceptualisation (Step 2), and contextual development (Step 3), the Klein *et al.*, (1999) adaptation model (Fig. 4) was selected as a "standard" base adaptation model for framework development. In particular, its iterative components of (i) information awareness, (ii) planning design, (iii) implementation, and (iv) monitoring/evaluation are core elements of an effective adaptation strategy.

Step 5: Development of a Functional Framework

The "standard" Klein *et al.*, (1999) model framework was developed into a functional framework. This involved specifying and elaborating the components of the framework to make them explicit and therefore able to inform actions specific to the needs and circumstances of Australia's estuaries and coastal ecosystems. This functional framework development culminated in an adaptive model that goes beyond the basic Klein *et al.*, (1999) framework by defining a specific sequence of steps within the core information/planning/implementation/monitoring module of the Klein *et al.*, (1999) framework (Fig. 4).

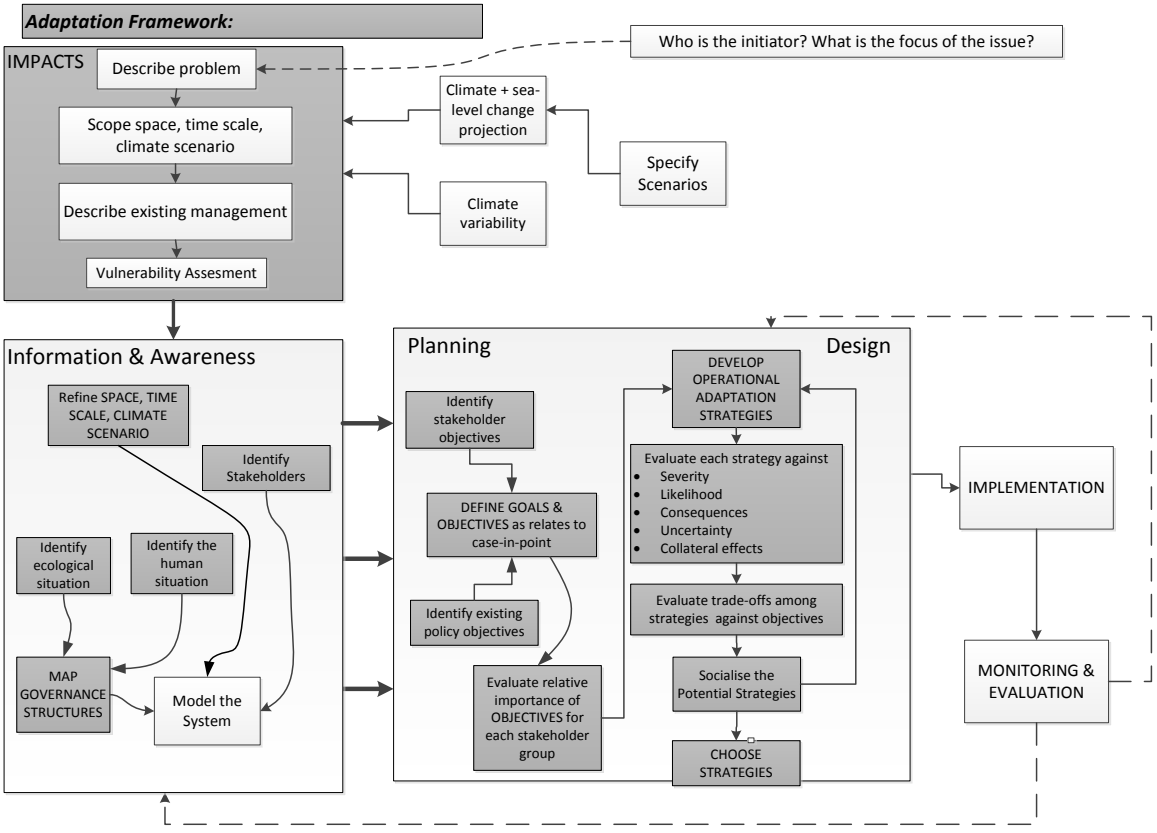


Figure 10: The Guideline Toolbox Framework: a Functional Adaptation Framework model based on the "standard" Klein *et al.,* (1999) model framework; an adaptive model with a sequence of steps specific to the situation in Australia's estuaries and coastal ecosystems.

Step 6: Initial Model Evaluation

As a final step in developing the Guideline Toolbox Framework the completed framework was evaluation using a step-by-step empirical test "case study" situation, asking the questions "what would actually happen in each step and how would they relate to each other?" This was based on a "Fisheries in Clarence River" case study, a situation familiar to most of the project team. The outcome of this procedure was further refinement of the framework structure and its linkages to produce the final framework (Fig. 10). Detailed descriptions of the logic behind the structure of the modules and notes on their further development can be found in: Impacts, Annex A; Information and Awareness, Annex B; Planning and Design Annex C.

Step 7: Model Performance Testing

Step 6 culminated in a 'final' model (Fig. 10), but this model could only be valuable in a general sense if it performed successfully for typologically different situations. Consequently, the model was applied to a series of case studies with different characteristics. It became clear after the first two Performance Testing scenarios (Kakadu and Barratta case studies) that developing a one-stop model for adaptation in the context of Australia's estuaries was unrealistic. This was because different aspects of the model were important in different contexts; (i) in each situation particular model components were emphasised while others appeared unimportant, (ii) some components needed to be repeated in different modules, (iii) the order in which some components needed to be addressed, and even their logical position in the model, changed from situation to situation. Consequently, this 'one-stop-shop' approach was of doubtful value; probably why proponents have repeatedly seen the need to develop new frameworks. These issues are detailed for the Kakadu Performance Testing case study in Annex D.

Conclusion

The original concept was to produce a final Adaptation Guideline Toolbox Framework (Fig. 10) for Australia's estuaries, then develop a suite of tools to support decisions implicit in the Guideline Toolbox Framework - in a conceptual sense that would involve developing tools to support each decision point (e.g. Fig. 11).

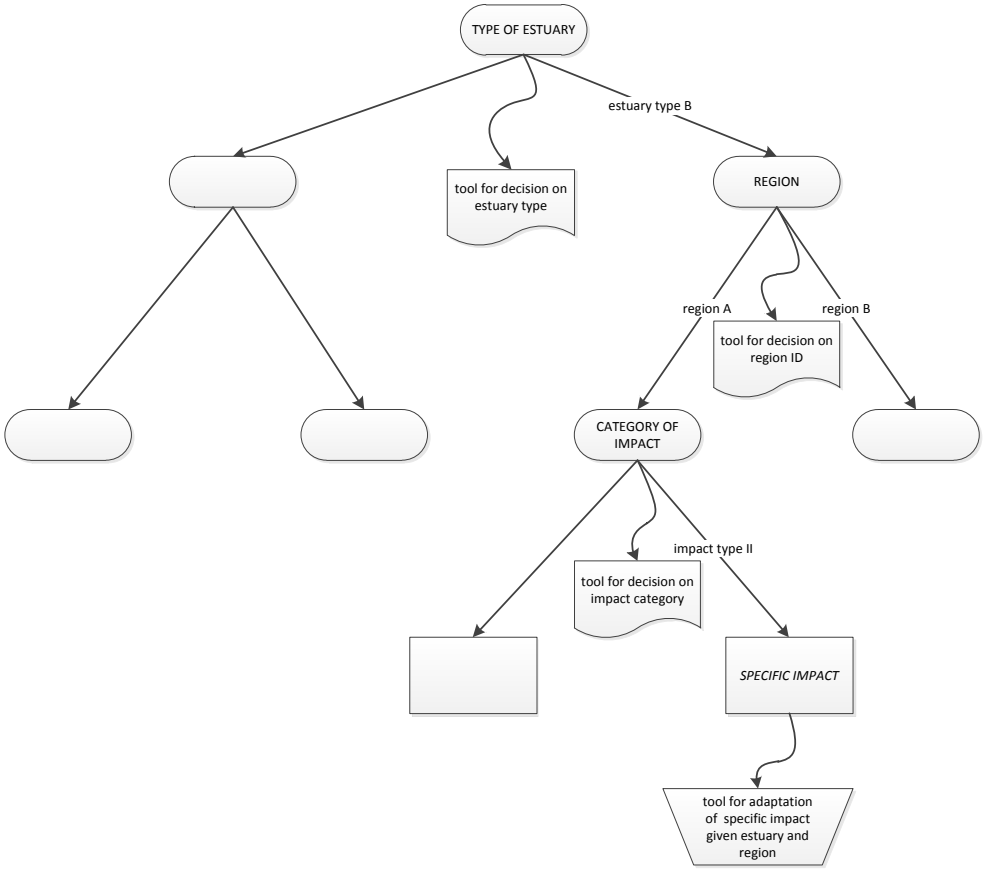


Figure 11: Concept diagram for future development of the Guideline Toolbox Framework. If the framework is considered as a series of decision nodes (rounded boxes in the concept diagram) decision support tools will be developed to support those decisions (curved-base boxes) and to support final decision (tapered box).

Testing the performance of this framework led to the conclusion that the Framework is a rather prescriptive tool, and while it is good for summarising the steps in the process, it is too general to provide useful advice on strategies across Australia's estuaries and coasts; a generalised, one-stop-shop guideline framework is really not what is needed to support Adaptation Strategies; its rigid framework is too restrictive, too inflexible, and a one-stop-shop approach is too prescriptive, to provide an overall focus for Australia's estuarine and coastal Adaptation Strategy needs. Every situation will be qualitatively and quantitatively different; each problem unique; the focus of adaptation different (e.g. conserving the values of Kakadu National Park versus reaching a compromise between protecting agricultural land in the Burdekin Delta and maintaining the fisheries values of the Delta's coastal wetlands); the stage of development of plans and actions different; the purposes varied (e.g. some aimed at determining vulnerabilities, others aimed at determine future options, others aimed at specific actions); and each system typologically different and of different spatial extent.

Overall, the process of assessing and appraising the 'framework' approach to Adaptation Strategy support indicates that, to be useful, advice needs to have a higher level and conceptually different focus if it is to provide support that is valid and applicable across Australia. In addition, from the point of view of a tool; although the Framework approach is applicable in an overall sense:

(i) its usefulness depends on the proponents vision of what an 'adaptation strategy' is;

(ii) it is difficult to see exactly how the Framework would really help to produce specific results without including much greater complexity - this would defeat the purpose of having a simple model, and,

(iii) it is difficult to see that all components would be applicable to all cases, or that their emphases would need to be the same – in that case (and in case (i)) it would be more valuable to a proponent to have the potential of the tools that are already available assessed and their application to particular purposes identified.

So, although the Framework may provide more direction than a standard approach like Klein *et al.*, (1999), and is generally a good summary of the steps that could be followed, its practical utility and general applicability is limited. As a result, effort around modelling was redirected to a comprehensive evaluation of the tools and methods that are available for Adaptation Strategy development and assessment of their value for particular purposes. The results of this are reported in detail in Appendix 5, which comprises a comprehensive evaluation of the tools and methods available for Adaptation Strategy development and assessment.

In recognition that traditional frameworks are too rigid for use across Australia's diverse estuary and coastal marine systems and that no one approach would be suitable given the range of plant and animal assemblages, climates, and region-specific threats and matters of contention, the overall project was directed towards developing a set of general principles to help direct adaptation strategies whatever the particular situation – see Phase 2: *Developing Principles of Operational Adaptation Strategies* (below).

3.2: Phase 2: Developing Principles of Operational Adaptation Strategies

This final phase of the project develops a set of general principles to help direct adaptation strategies whatever the particular situation – general principles that help guide, but not constrain, development of informed adaptation policies, plans and actions, whatever the particular situation and purpose.

3.2.1 Environmental Governance

Adaptation strategies cannot be designed in isolation and need to take into account existing governance frameworks. Two areas of information are important because they constrain what is possible in the adaptation space: (a) distribution of decision-making roles and responsibilities in relation to natural resource management, and (b) regulatory and administrative frameworks.

(a) The distribution of decision-making roles and responsibilities: Australian environmental governance is complex. The management of various environmental assets is shared between the Commonwealth, State and Territory, and local governments, co-management arrangements, regional natural resource management bodies, Indigenous communities, community-based organisations, as well as private land owners and holders. A lack of clear delineation of responsibility boundaries, coordination and cooperation are common and ongoing governance challenges. These challenges raise the question of leadership, namely: which governance actor should take a lead role in looking after ecological assets of coastal fisheries. At the current stage, this role (to differing degrees) is performed by the State government departments holding responsibility for the implementation of fisheries legislation. To this end, NSW Department of Primary Industries can be regarded as a good example of the lead authority establishing cross-jurisdictional linkages, providing financial resources, coordinating habitat restoration activities and mobilising public support. At the same time, the organisational structure of the State governments is highly dynamic and subject to frequent reorganisations and shifts in political directions.

(b) Regulatory and administrative frameworks: Strategic planning of ecological assets involves long timeframes and requires long-term political commitment. However, slow progress in the comprehensive assessment of the state of the assets and protection of freshwater systems in all jurisdictions suggest that existing governance structures face a range of problems that extend into the estuarine/coastal space.

There is a need for more detailed examination of current governance systems to identify their potential to protect and enhance these large-scale public assets over long term. While strategies need to incorporate large scale, long term goals, implementation actions need to be planned at a relatively local level. Each jurisdiction has a different mix of governmental and non-governmental management bodies which are or can be potentially involved in the protection and maintenance of fish habitat assets. In practice, generalized assumptions cannot be made. For example, many reported studies indicate the willingness and capacity of local governments and community organisations to participate in the restoration of the coastal zone and riverine and riparian systems. At the same time, most of Australia is scarcely populated and a significant proportion of coastal or near coast local governments is struggling with financial and human resources (see e.g., Productivity Commission 2008).

The complexity of Australian environmental governance 'landscape' suggests that application of a 'one size fits all' subsidiarity model to implementation will not be possible. Adaptation strategies will need to consider the variety of jurisdictional, geographic, social, economic and cultural contexts defining capacities and interests of particular actors.

In all Australian jurisdictions, management of environmental assets follows some sort of 'sectoral' pattern. At the state level, there are a large number of statutes and subordinate legislation providing for the regulation of environmental assets and threatening processes. Government departments or their sub-units administer specific legislation portfolios. Fragmentation of regulation cutting across separate properties of ecosystems is almost unavoidable feature of the current regulatory system. As a result, the regulators may ignore or overlook the interests of other management sectors when they try to address particular resource problem.

Fish habitat protection does not fall neatly within conventional sectoral boundaries; many of the regulators responsible for the implementations of fisheries legislation are deficient in authority to achieve stated habitat protection outcomes (e.g., have no control over the impacts on riparian or coastal vegetation, or development on private land). Long-term protection of fisheries assets, therefore, is dependent upon the level of incorporation of protective measures into other legislative frameworks providing for activities affecting these assets. A range of governance techniques is available to achieve this goal.

Design of an adequate legislation and policy framework enabling protection and enhancement of fisheries assets depends on two other factors. The first factor is the interests and priorities of other sectors. Australia's economy strongly depends on other primary industries such as mining and agriculture and related developments producing different pressures on coastal and freshwater ecosystems. Similarly, urban and industrial development is an important part of the economy and revenue stream of national, state and local governments. Incorporated interest 'balance' in legislative frameworks often reflects economic importance of each sector and the ability of industries to promote their interests and gain political and public support.

The second factor is the ability of responsible agencies holding 'fisheries portfolio' to form strategic partnerships and negotiate with regulators of other sectors. For example, both NSW and Queensland Departments of Primary Industries have gained considerable level of control over the assessment of development impacts on fisheries habitats (Scandol et al., 2005). Established linkages also enable the departments to provide best practice guidelines for development activities requiring construction of fish passages.

Clearly, adaptation strategies need to consider cross-sectoral interests. Each sector will respond differently to external economic and environmental drivers, including Climate Change. Therefore, an ongoing engagement and communication with other industries, their regulators and the public is the key to ensure that the threats to fisheries assets are understood and considered. To this end, sound knowledge of fisheries assets, their locations and economic values to the society can become an important determinant of negotiating capacity of coastal fisheries.

In the face of different pressures, there is a need to improve and, possibly, expand ecosystem assets of coastal fisheries, although budgetary constraint is a common argument for limited implementation of environmental protection measures (see e.g., National ESD Strategy).

Distribution and funding sources are important determinants of adaptive responses. However, they also need to be considered in other contexts where higher priority issues may lie.

In most cases the income from allocation of fisheries resources is collected and distributed by State governments. Fish and other aquatic species are common-pool goods providing benefits for the whole society. From the policy side, a strategic question that remains is: which facet of and to what extent governments could be expected or required to commit resources both in kind and financial to sustain assets required for the provision of these goods? For example, Australian local governments neither distribute extractive resources nor are entitled to collect fees or royalties. Therefore, decisions directed to meet community needs or increase income base may not be in line with large-scale public benefit goals. Similarly, private land holders will not be willing to sacrifice their land resources and bear the losses (e.g., decrease in productive capacity or market value) to provide additional coastal habitat (Boer 2010). In practice, private land tenure is one of the core obstacles for the development of freshwater habitat networks and expansion declared of tidal habitat areas (R.Quinn, pers. communication).

Currently, most of the legislative frameworks include provisions for collection and allocation of funds to support monitoring and research of an allocated resource. Application of environmental offset policies in several jurisdictions (e.g., NSW, Queensland) enabled regulators to gain additional funds from the development industries. This report has not examined in detail funding distribution arrangements. However, as applied regulatory mechanisms suggest, there is a limited use of funding to support conservation agreements and covenants which would engage private landowners in the long-term protection and management of fisheries assets.

Planning and implementation of adaptation responses (e.g., increase in protected areas, rehabilitation of degraded habitats) requires consideration of broader economic context and established incentive systems shaping interests and priorities of other governance actors. State governments should be prepared to share collected income to support local management initiatives, particularly when management functions place additional financial burden on local governments. Extension of the scope of applied incentive-based instruments may also be required to align priorities.

Conclusions: Based on this assessment, there are several potential challenges to effective governance responses to Climate Change adaptation of coastal fisheries common across all jurisdictions. In particular, Australian environmental governance is complex and many factors need to be considered in the planning and implementation of adaptation responses; three tiers of government and numerous non-governmental bodies have created a range of administrative, political, regulatory and strategic frameworks to enable management and sharing of land and environmental resources. These arrangements form a complex and dynamic governance system with many decision-making bodies performing complementary, overlapping and sometimes conflicting regulatory and management roles. Understanding and unpacking this complexity allows accounting for multiple factors that can operate as enabling or constraining conditions in particular jurisdictions. Consequently, while it is important to continue focusing on responses within particular resource sectors, narrow sectoral view on governance problems will not provide sufficient basis for the design of effective governance responses in such contested and multi-actor space as Australian coastal zones and estuaries.

Five major factors need to be considered to support the long-term protection of ecological assets to sustain the provision of fisheries resources.

1. shared strategic goals and frameworks supporting identification, planning and management of coastal, estuarine and connected freshwater habitats;

2. clear distribution of roles and responsibilities and allocation of the lead role (mandate) with regard to the management and protection of ecological assets ;

3. recognition of sectoral interdependencies or 'connectivity' of environmental governance structures and regulatory frameworks;

4. collection and distribution of revenues to support involvement of relevant governance actors taking into account their roles, interests and capacities;

5. development and application of incentive mechanisms to promote restoration and conservation of fisheries habitats, including on private land.

Supporting Documents

Section 3.2.1 is supported by a full report on Environmental Governance presented in Appendix 1: *Environmental Governance: barriers and bridges to the long term protection of coastal fisheries*.

3.2.2 Using Expert Opinions to Elicit Enablers and Limitations for the Adaptive Management of Estuaries and Waterways under Climate Change

Much of the knowledge and experiences of past, recent and ongoing adaptation research for environmental management resides in the collective experience of key individuals, frequently managers, scientists and stakeholders in general. This expert knowledge has been used and is currently applied to a wide range of cases, localities of many estuarine and coastal ecosystems of Australia, representing also a range of different contexts, complexities and dynamics. In this work we use the expert opinions, knowledge and experiences of a range of experts as a proxy data source to acquire, assess and gain understanding of current practices, drivers, enablers and constrains of the adaptive management of aquatic ecosystem under climate change and variability in Australia. We interviewed 18 senior managers, scientist, and planners, from a cross-section of various governance structures of Australia's estuarine and coastal ecosystems. These interviewees represented a total of 26 case studies that include specific aquatic systems, research projects and programs, management instruments, local governments actions and planning and management of commercial sectors. Our aim was to gather the interviewees' opinions and experiences on five target themes: (1) motivational drivers, (2) enablers and constrains to success, (3) experiences in specific case-studies, (4) incorporation of climate change, which included enablers and constrains, and (5) the role of governance.

We found that there is a wide range of motivational drivers (n=20), where the more frequent was the public pressure, problems and conflicts (both from the bottom-up), and the operational management needs (from the top-down). Other intuitive drivers like political will and information provision were surprisingly low in their occurrence in the interviews, contradicting mainstream literature on the topic. The enablers of success were also many

(n=17), and largely dominated by focused and coordinated collaboration, strong leaders and champions, as well as good information basis and overall clarity (mandate, goals, challenges, objectives). The limitations and constrains were less (n=13), and also a more or less reverse mirror of those of success –i.e. the lack of clarity, poor information basis, and poor communications, engagement and understanding were the most frequent constrains. However, only the lack of clarity had a frequency of occurrence higher than 50 percent among respondents. Interview data suggests that there is also a wide range of ways to include climate change into the adaptive management (n=19). Here, the clarity of aims and goals for management problems as well as the need for mainstreaming climate change into the governance showed the highest frequency of occurrence. Lastly, a much less number of functions and roles of the governance we elicited through the interviews (n=11). The need for a system view (to reduce fragmentation), a focus on cross-cutting and holistic approach to management (whole-of-government system), as well as emphasis in planning and managing for extreme events were the highest roles identified for the governance of estuaries an coastal ecosystems.

None of these finding are novel, unknown or surprising, but the frequency in which they occur demonstrate some differences from findings from elsewhere and underlines a key point - it is critical for adaptive management initiatives to be context-dependent. In addition, this work developed a unique knowledge-basis system that could be used to (i) expand and create a broader information basis via monitoring and evaluation, (ii) opens up a field of socioecological research that will complements environmental management and (iii) inform and guide administrators in the future development of adaptive management strategies for estuaries, wetlands, and coastal ecosystems of Australia.

Supporting Documents

Section 3.2.2 is supported by a full report presented in Appendix 2: *Using Expert Opinions to Elicit Enablers and Limitations for the Adaptive Management of Estuaries and Waterways under Climate Change*.

3.2.3 Current Status of Adaptation Planning

Coastal communities are vulnerable to a diversity of marine Climate Change impacts, ranging from the effects of sea level rise on coastlines and infrastructure, to biological and physical changes in marine ecosystems and the flow on effects for marine resource users. The way that marine Climate Change manifests in coastal communities will be dependent on local conditions and systems, and adaptation responses will need to be tailored to suit individual communities. The responsibility of adaptation planning is therefore largely placed on municipal councils, as they are situated to organise action at the local level (but Australia's complex governance arrangements often lead to conflicts in regulatory and management roles (see Section 3.2.1)).

Initial assessment of the literature showed little primary literature on the status of adaptation planning in Australia. In contrast, our assessment of local government documentation provided a rich source of information on progress in adaptation to marine Climate Change in Australia's coastal communities. Clearly, much goes unreported in the peer-reviewed literature.

Adaptation Progress: In general, progress in Climate Change adaptation in Australia is in the early stages; most local governments have not yet implemented any form of adaptation, and were still either gathering information in order to understand the local impact of Climate Change in the marine environment, or were still planning the kind of action they would undertake in the future. Of the 67 councils investigated in this study, 42% did not have any official marine adaptation plans or the plans were in preparation and existed in draft form only (25 and 3 councils respectively). The presence of plans seems to be related to the magnitude of council income (Fig. 12). In our sample of councils the average rates base was around $66 million in 2013, with the smallest council at $1.2 million (Nannup in WA) and the largest at $871 million (Brisbane in QLD). As would be expected this same relationship applies to population size and total spending, as the correlation of these two variables with income from rates is 0.973 and 0.958 respectively.

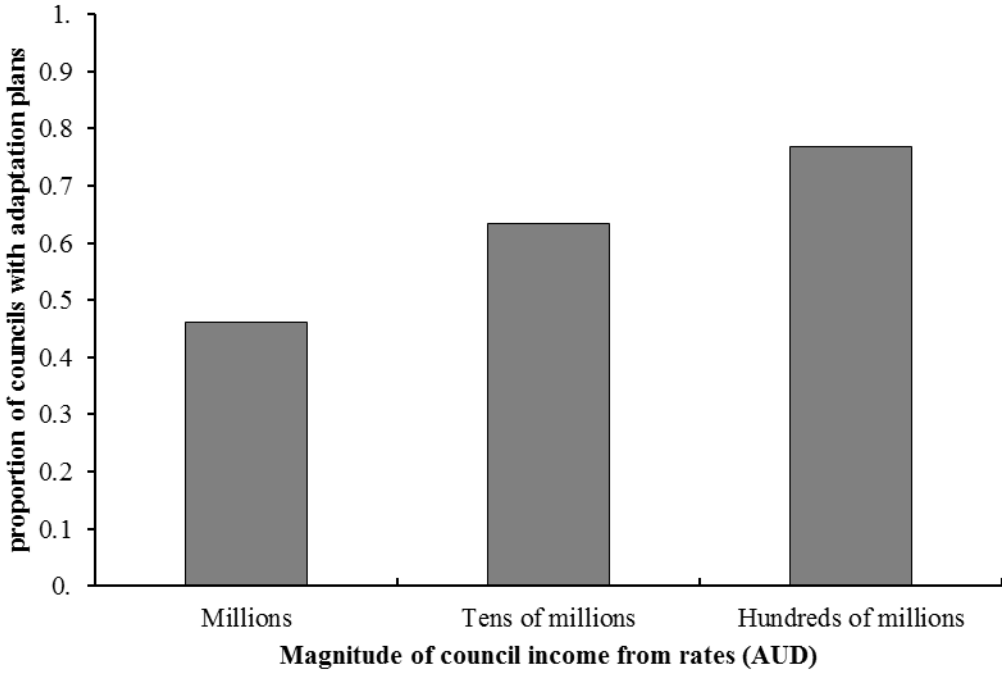


Figure 12: The proportion of councils with marine Climate Change adaptation plans grouped according to magnitude of income from municipal rates paid by home owners. Millions (1-9 million) Tens of millions (10-99 million) and Hundreds of millions (100 million and over) (information from individual council papers).

Participation in regional or international adaptation networks appeared to have a positive influence on the development of marine adaptation plans (Fig. 13). In total 35 councils were members of organisations that had the facilitation of local adaptation to Climate Change as a stated aim (this did not include membership of state council associations, to which all councils belong). In fact, councils that were voluntary members of regional or international networks mostly had marine adaptation plans.

MDS analysis indicated that councils fell into four distinct groups that relate strongly to certain characteristics (Fig. 14). These groups are distinguished from each other by three important factors – councils 'size' (the highly correlated variables of population, total spending and income from rates), the degree to which their adaptation plans were developed

(the strength of their adaptation statements, their progress in terms of stage reached in the adaptation process), and whether drought was the dominant driver addressed in their adaptation plans. The group found within the positive area of both dimension one and two are large councils with well-developed adaptation plans. However, many other large councils also had poorly developed adaptation plans, and these form a separate group. In addition, not all councils that had well-developed plans were large, with smaller councils mainly from WA forming a separate group, distinguished also by the dominance of drought in their adaptation plans if these were present. Finally, small councils that had poorly developed plans formed a separate group. These four groupings demonstrate that the degree to which adaptation plans are developed is decoupled from council size and access to resources in an important way. Taken together with the results presented above (Fig. 12) this suggests that while income seems to have an impact on whether a council develop plans in the first place, it does not seem to have an impact on how well developed those plans are.

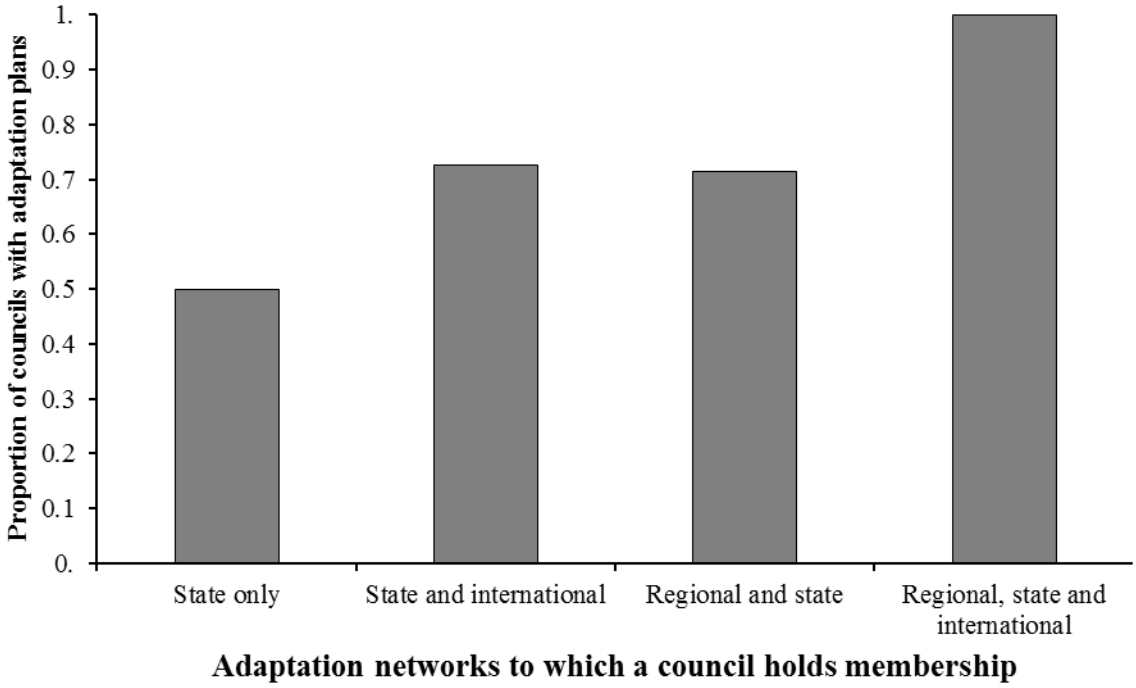


Figure 13: Proportion of councils with adaptation plans according to their membership to regional, state and international adaptation networks.

Of those councils that had plans, only half had progressed beyond the understanding phase. Of the 42 councils that had official adaptation plans 18 were in the initial phase aimed at 'understanding the problem'. These councils were still in the process of identifying and understanding marine Climate Change impacts, and actual adaptation planning had not yet commenced. Their activities were aimed at understanding the local impacts of marine Climate Change included modelling and forecasting, as well as assessments of how these projections relate to existing infrastructure or land use. A total of twenty councils had undertaken initial research assessments and were now in the so-called 'planning adaptation options' phase. The plans of the councils in this phase detail the ways in which they will incorporate understanding of the impacts of marine Climate Change, and thus identifying the circumstances where adaptation will take place. This indicates that these councils have

engaged with the critical step of developing robust criteria for action. Ten of these councils had detailed plans that addressed specific impacts or identified particular impacted areas. For example Break O'Day council, TAS, had detailed plans to address the inundation of sewage treatment ponds due to sea level rise and increased storm tide heights, which shut down aquaculture in the bay for a month after each event.

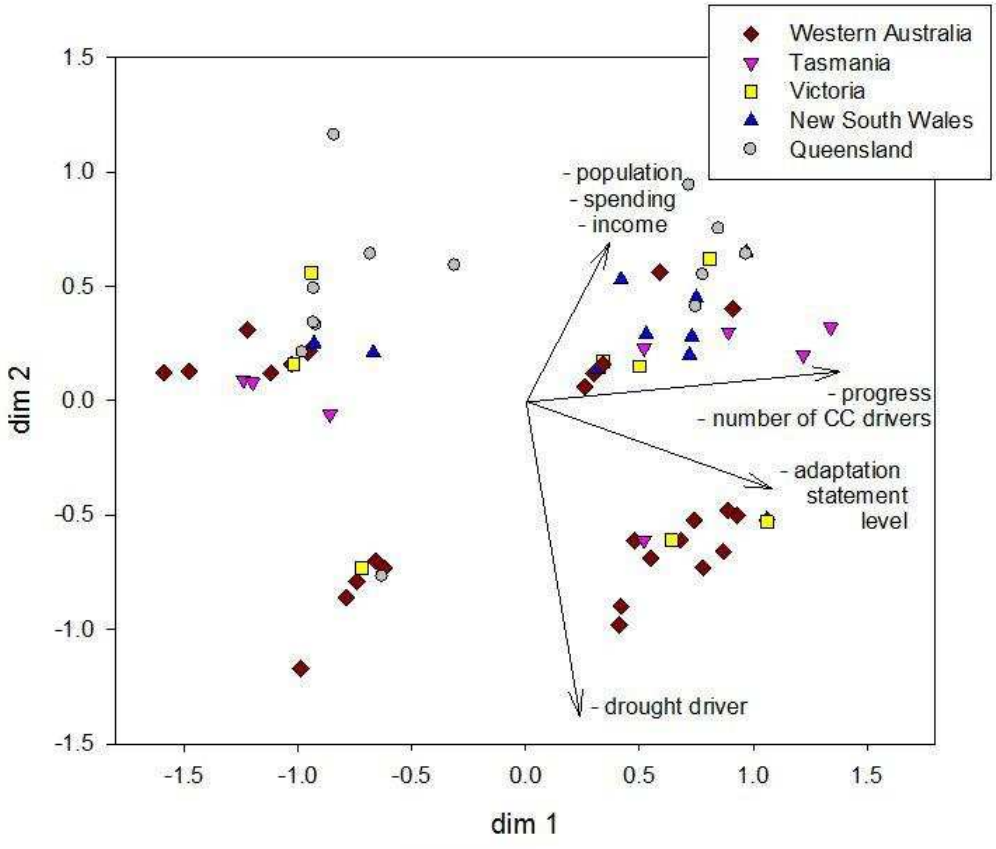


Figure 14: MDS ordination plot of all 67 councils according to all attributes gathered in this study. Samples are coded according to state. Vectors indicate the direction in which council attributes correlate most substantially with the ordination space. Stress =0.08.

It is clear that some councils within this phase appear further developed than others due to the presence of specific plans as opposed to less specific decision criteria. However, for reasons detailed in our methods section, in some situations councils may have prudently adopted an 'abandon' approach or a 'wait and see' approach, both of which are unlikely to be included as part of official adaptation action plans. Drawing a distinction between groups with detailed decision criteria but no specific plans, and those with specific plans would be premature without a more detailed assessment of their internal decision making process – a task beyond the scope of this study.

Adaptation Focus: The focus of marine adaptation planning is largely restricted to one driver – sea level rise. Of the 42 councils with marine adaptation plans, 36 restrict their attention to sea level rise. Of the councils that focus on sea level rise 18 specifically address the breadth of associated impacts such as increases in storm surge frequency and height, coastal erosion, and salt-water intrusion. In general, the way councils plan for sea level rise is to acknowledge the potential impact and outline how future conditions may be incorporated into current

management practices or how current management practices may need to be adjusted. The use of current town planning and land zoning practices proved to be a common method of dealing with predicted inundation, for instance Bega Valley, NSW, states that "in urban areas… council may have to look at the delineation of a coastal hazard line or zone and either prohibit/restrict development in these areas" (Natural Resource Planning, pg 6).

Changing sea surface temperatures and ocean acidification were largely ignored, despite predicted impacts on coastal ecosystems and the communities that depend on them. Only 4 councils addressed sea surface temperature (SST) increase in their adaptation plans, and none addressed ocean acidification. For those councils in the implementation stage this may simply reflect the results of prior vulnerability and risk assessments, however the absence of the investigation of these drivers among councils in the understanding phase suggests a pervasive lack of focus on these other aspects of marine Climate Change.

Where SST was included its impacts were mainly discussed in terms of the potential impact on marine industries and resource users. For instance, the Sunshine Coast council, QLD, focused on the acute impact of SST increase on the "emergent health risks" from the southward spread of Irukandji stingers (pg 32). The South Perth council, WA, was taking a holistic approach to improve their "understanding of how fishes and their supporting ecosystems respond to changes and how these changes impact biodiversity, recreational and commercial values" (Climate Change Strategy 2010 – 2015, pg 16). While the South Perth council actively aims to support the resilience of the fisheries resource, the Tasmanian Break O'Day council's adaptation actions is of a more 'responsive' type, and has final adaptation plans for increased SST. The stated aim of the Break O'Day plan was to facilitate fisheries and aquaculture industries to adapt to the changes in species of fish available/suitable under future conditions. The adaptation plan indicates that the potential barriers to change are "government regulations such as species-specific licenses and catch limits" (pg 2). Even though an adaptive management approach and institutional change may be one adaptation measure to marine ecosystem change, the Council plans did not discuss this adaptation option.

Council adaptation plans were generally focused on council assets and town infrastructure (33 and 38 councils respectively), with little attention paid to the impact of Climate Change on local economies via its impacts on marine ecosystems, marine resources or tourism. Only five councils discussed the predicted effect of future marine Climate Change on local businesses and the potential economic and social flow-on effects. The way in which these five councils planned to assist local businesses adapt was by means of treating the symptoms including, for instance, "programs that encourage and assist" the development of relevant skills (Bayswater, WA, Regional Climate Change Adaptation Action Plan, pg 31) or by ensuring "appropriate planning and policy mechanisms are able to support business" through the "identification of new industries & businesses, urban design & investment in infrastructure" (Belmont, WA, Local Climate Change Adaptation Action Plan, pg 24).

Conclusions: Most Australian coastal communities are in the early stages of progress in marine Climate Change adaptation planning. Despite local governments being positioned 'on the front line' of responding to Climate Change, not all councils had considered marine drivers. Of those coastal councils who had considered it, few had progressed beyond the understanding and planning phases. This is mirrored in developed countries world-wide; actual intervention is rare, and where it is occurring, it is typically in the early stages (Moser & Ekstrom 2010). Importantly, the presumed high adaptive capacity of developed nations

such as Australia may not necessarily translate into adaptation action (Ford *et al.,* 2011). The various barriers that constrain the local adaptation process and result in this global pattern of inaction are the subject of continued scholarship (Moser & Ekstrom 2010).

Our study provides evidence of two widely reported barriers; a lack of resources and a lack of connections to relevant organisations that provide information and assist in communication. These two factors may be contributing to the slow progress of adaptation planning, and translating planning into action, in Australia's coastal communities. In particular, a lack of resources, whether absolute or perceived, may limit actions that would otherwise progress adaptation (Tribbia & Moser 2008). However, resources are only important up to a point. Once councils have enough resources to begin developing plans, other factors not examined in this study may become more significant. For instance, attributes of council staff such as level of education and specific Climate Change adaptation training, as well as institutional culture have emerged as important enablers of action in other developed countries (Burch 2010), as is the presence of a champion in the council or nearby in the social and political landscape (Roberts 2008).

Effective communication, particularly between and across different levels of government in the coordination of adaptation efforts, has been identified as a major barrier to action within European countries (Biesbroek *et al.,* 2010). An aid to overcome this may be participation in adaptation-focused networks, which emerged as being closely linked with marine adaptation plans in our study. Participation in adaptation-focused networks seems especially pertinent in regional initiatives that link several local governments in a geographical area. Regional organisations of councils are voluntary partnerships between several (usually neighbouring) councils in a region, dedicated to cooperatively perusing certain agendas by sharing resources, information and responsibilities across jurisdictional boundaries. Many have developed into sophisticated regional governing networks (Marshall *et al.,* 2003). Some have taken up the challenge of regional adaptation, and serve as the hub for the development of member council adaptation plans. This may be particularly important in advancing adaptation if the social-ecological system of concern functions at a larger spatial scale than local government areas (Moser & Ekstrom 2010). In that circumstance functional relationships between councils would be crucial to avoid serious barriers (Cash *et al.,* 2006).

In the context of climate driven change in the marine environment, it seems most councils focus solely on sea level rise with an obvious lack in accounting for the multiple drivers involved. Given the wide range of impacts for coastal communities associated with the effect of increased sea surface temperatures and ocean acidification on marine ecosystems, this appears to be a major gap in Australia's overall preparedness for predicted Climate Change. As many of the economic impacts of marine Climate Change are linked to these other drivers, it is somewhat surprising that few councils have plans to adapt to the economic aspects of marine Climate Change. This is a trend throughout the developed world – adaptation is overwhelmingly focussed on transportation, infrastructure, and utilities sectors – areas where investments have a long lifespan (Ford *et al.,* 2011).

Sea level rise impact assessments are relatively simple to translate into council policy, and are fairly straightforward to respond to with the management tools commonly used by councils, such as rezoning areas of development and residence, and as evidenced in this study, this is how councils are proceeding. However, this is not the case for most other Climate Change impacts that show pervasive uncertainty (Harris and Heathwait 2012). Response to these requires robust strategies (Lempert *et al.,* 2010).Where dynamic social-ecological systems

like fisheries are involved important options are approaches such as building adaptive capacity (Madin *et al.*, 2012), developing institutions and instruments for reflexive and adaptive management (Brander 2010) and building and diversifying the livelihood asset base of the community (Badjeck *et al.*, 2010). These often explicitly require the use and sometimes the development of new management tools. Information on ways to operationalise resilience (Davidson *et al.,* 2013) is available, yet it seems these types of approaches have not yet been widely adopted by councils.

While councils have been positioned on the 'front line' of implementing local change, there seems to be a duality to their involvement in adaptation activities. On one hand there is the well-established legal and institutional impetus to properly manage their own assets and responsibilities in the face of change, and on the other is the relatively recent high-level directive of their role in providing leadership in adaptation. The former may be a more immediate incentive for councils. Legal responsibility in the face of Climate Change impacts was a stated concern of councils (Pillora 2011), and a report by the legal firm Baker & McKenzie (2011) regarding this was commissioned by the Australian Local Government Association. Councils face legal liability if they 'unreasonably' fail to take into account the effects of Climate Change in their service, planning and development activities. Effectively, this leaves them open to liability from tangible impacts, but not from less tangible and predictable impacts such as those reported for ecosystem change. Responsibility may play a key role in decision making for councils, especially in the prioritisation of actions. For example, the Climate Change risk report (Travers *et al.,* 2009) commissioned by Mandurah, WA, to determine their adaptation response categorised the council's level of responsibility for implementation for each adaptation option. Aspects of marine Climate Change adaptation that are clearly the responsibility of councils (legally or otherwise) may be receiving the bulk of what resources are available, while other aspects of adaptation where responsibility remains ambiguous may be falling by the wayside.

From the perusal of council documents it is clear that every situation will be qualitatively and quantitatively different; each problem unique; the focus of adaptation, the stage of development of plans and actions different; the purposes varied (e.g. some aimed at determining vulnerabilities, others aimed at determine future options, others aimed at specific actions); and each system typologically different and of different spatial extent. Councils are not equivalent, and given that the process of adaptation must be unique, each council will necessarily progress through this at different rates. More important is the quality of the process, which rests heavily on the reasoning used in decision making. The basis on which these decisions are made is the locus of adaptive success. Having robust criteria that take into account both the dynamic nature of the social ecological system in question, and the seemingly obvious but often unacknowledged requirement that adaptation plans must necessarily be 'adaptive', can help ensure that action taken is appropriate in the long term. Key aspects of this process take place during closed meetings and communication, and are part of the social and political context in which all council processes are embedded. So, while difficult to assess and well beyond the scope of this study, these are probably the areas where the most fertile improvements can be made.

Supporting Documents

Section 3.2.3 is supported by a full report presented in Appendix 3: *Assessment of local government progress in marine climate change adaptation in Australia*.

3.2.4 Principles of Operational Adaptation Strategies

Rather than the prescriptive model of a series of steps e.g. that modified from the IPCC (Fig. 10), adaptation can be conceptualised in a more fundamental way (Fig. 15); simply as a model of the various factors that bear on the development of an adaptation strategy. Such a model does not prescribe a sequence of tasks but indicates a range of factors that need to be considered – any combination might be important for a particular situation and purpose; the tasks will need to be expanded and developed in particular ways depending on the situation in question.

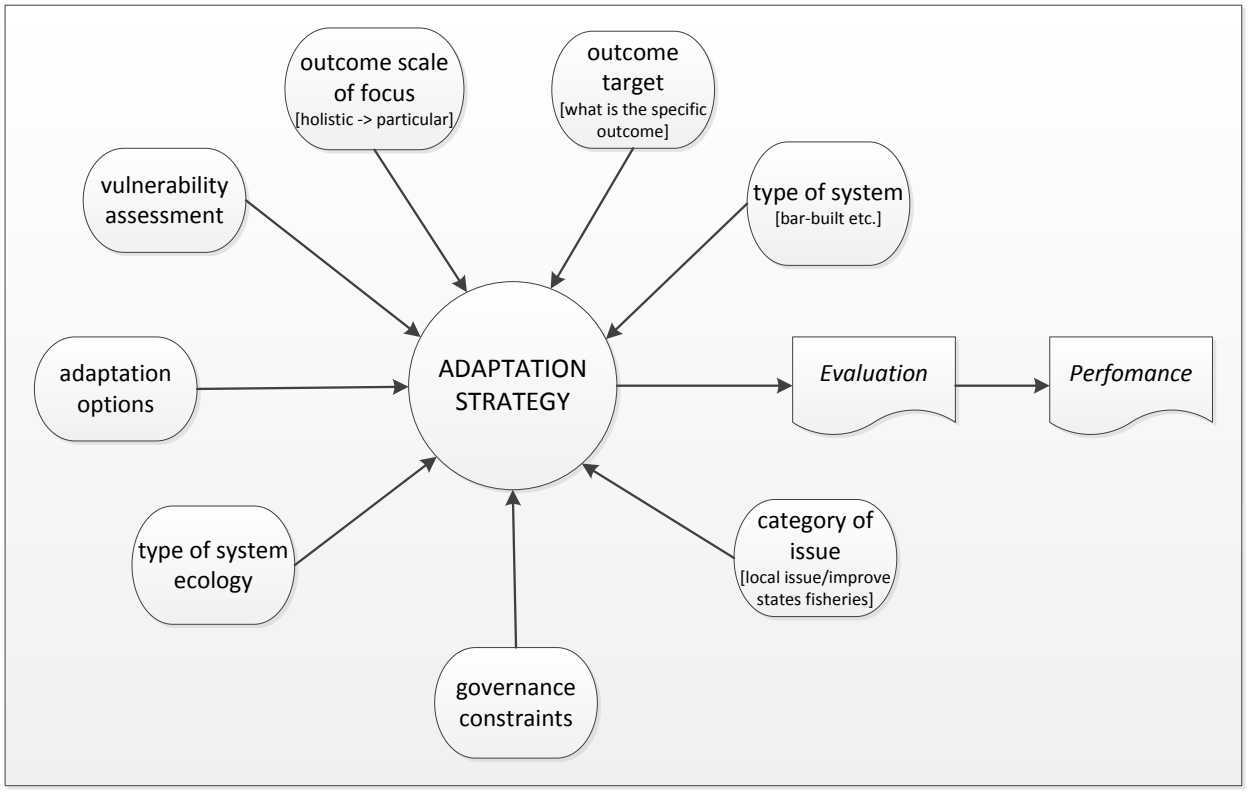


Figure 15: A generic model of an adaptation strategy: simply a depiction of the various factors that bear on the development of an adaptation strategy.

This suggests that what are needed are general principles to help direct adaptation strategies, with common attributes and approaches to help guide, but not constrain, the development of informed adaptation policies, plans and actions. These principles outline the key attributes of an Adaptation Strategy suitable for Australia's ECMEs, detailed in the report Appendix 4: "*Adaptation strategies for optimised public benefits from Australia's estuarine and coastal marine ecosystems: 9 principles*", fall into 4 categories:

- Strategy Landscape
- Strategy Development
- Governance
- Tools

Strategy Landscape

The Strategy Landscape refers to the broad context in which strategy objectives need to be developed to provide meaningful outcomes harmonised across all stakeholders and over multiple relevant timescales.

What 'types of strategies' will give the optimal resource sustainability outcomes over different time horizons? This needs to account for such things as regional and typological differences and interactions with impacts on and from other sectors. The problem here is that most actions focus on local problems resulting in problem-specific actions. This approach tends to produce fragmented outcomes as different groups focus on their own priorities. Most importantly, such actions are unlikely to lead to '*strategic*' outcomes; outcomes that support major resources for the overall public good. Rather robustness and resilience of large-scale resources are conferred at large scales, such as whole-of-ecosystem, whole-of-catchment or whole-of-fishery scales (Christensen *et al.,* 1996; Richards *et al.,* 1996) that include whole ecosystem complexes and the connectivities among them. To achieve this requires actions that integrate over local areas to focus on whole regions to produce outcomes at the scale of whole of resources.

There are two important aspects to the '***Strategy Landscape***', (i) the need to develop adaptation strategies in a broad, holistic context, and (ii) the need to focus on whole-of-system, long-term outcomes for socio-ecological systems.

Principle 1: ***Successful adaptation strategies need a to be developed in a broad, holistic context***

Climate Change is only one of a broad suite of factors that impact coastal systems (e.g. port developments (Grech *et al.,* 2013), increasing urbanisation (Lee *et al.,* 2006), and natural disasters (Loneragan *et al.,* 2013)). Climate Change should be seen in the context of the Driver-Pressure-State-Impact- Response (DPSIR) framework ((OECD 2003) which is an extension of (OECD 1993)) which describes the causal links between Drivers (D – natural and human-induced activities and processes that cause pressures) and the resulting social, cultural, economic and environmental Pressures (P – direct stresses on the SES), their consequences on the State (S – abiotic, biotic, social, economic, cultural conditions of the SES), the Impacts (I – effects on human and ecological systems due to changes in state) and Responses (R – actions to solve the impacts), such as management and adaptation measures resulting from the changes in the SES. In fact many of the impacts (e.g. extreme events) only represent changes in the frequency of pressures that have been active for millennia (Proske & Haberle 2012). Similarly, strategies that lead to impacts need to be developed in a SES landscape where there are many competing interests to be considered; for example, actions that might be good for shoreline protection might negatively impact industry, livelihoods, fisheries, tourism or the environment. The embedding of Climate Change DPSIR framework as well as the need to consider the multiple ways in which any action can impact other facets of the SES and the need to consider short- and long-term goals and effects, means strategies need to be developed in a broad, holistic context (Hughes *et al.,* 2013).

Undertaking adaptation strategies in an expansive, holistic context is a broad contextual principle; in essence, an overarching principle within which the succeeding principles are embedded.

Principle 2: ***Focus on whole-of-system, long-term outcomes for socio-ecological systems***

Each of the reviews and the interviews (Appendix 2) indicated that the relative values of alternative actions and alternative strategies to different sectors (public, commercial, individual) differed depending on the time horizon considered. However, in each case short term, local actions focused on relatively small-scale local problems and were unlikely to lead to positive outcomes for large-scale public resources (such as ensuring fisheries sustainability or ecosystem health); either because they didn't focuses on large-scale issues, or if they did they only addressed them at the local level. This means they neither explicitly addressed large-scale questions nor were likely to align with actions taken in other jurisdictions to produce coordinated large-scale outcomes (Kates *et al.,* 2012). Thus these seem like suboptimal approaches if the aim is to ensure the sustainability and resilience of our estuarine and coastal resources into the long term.

In fact, there is ample evidence that, from a broad range of perspectives, maximum public benefit accrues from maintaining and restoring resilient ecosystems (Christensen *et al.,* 1996; Pikitch *et al.,* 2004) that provide healthy human living environments (Corvalan *et al.,* 2005), support optimal biodiversity (Folke *et al.,* 2004), and underpin robust and productive fisheries (Dickey-Collas *et al.,* 2014). This is best achieved by focussing on long-term transformative outcomes that provide on-going benefits by enhancing resilience and reducing vulnerability in the long term (Lim *et al.,* 2004). In estuaries, one key aspect of resilience is concentrating on maintaining system continuity. In the past adaptation has usually taken the form of incremental change intended to avoid disruptions to systems at a local scale (Kates *et al.,* 2012), however, these continued marginal adjustments are ineffective at reducing long term vulnerability and preventing eventual resource degradation (Rickards & Howden 2012). This is particularly concerning in the face of the rapid environmental alterations engendered by Climate Change (Stafford Smith *et al.,* 2011) that can lead to regime shifts – sudden catastrophic transitions to contrasting states (Scheffer *et al.,* 2001). In contrast, focussing on maintaining and enhancing ecosystem resilience (Holling 1996) provides long term durability and availability of resources because it supports continued ecosystem functioning in the face of substantial change; in essence future-proofing the system (Lawler 2009). Supporting ecosystem resilience is particularly important in the case of Climate Change, where rapid, large scale change can lead to regime shifts necessitating ecosystem processes to be robust and able to adjust to altered states (Scheffer *et al.,* 2001), reducing the long term vulnerability of the resources the ecosystems support.

Because ecological systems are intimately influences by the social systems that rely on them (Fig. 13), ensuring resource resilience needs to focus on the SES as a whole (Folke *et al.,* 2010). Accounting for the interconnectivity and interdependencies of SES's components will involve considering both the components themselves and their connectivities. This means that effective CAS will necessitate trade-offs; requiring flexible policy able to cope with change and sensitive to the balance between ecosystem outcomes and local socio-economic needs.

What sort of strategies and goals might support long-term resilience? Strategies and actions will need to match with the scale of the resource and resource supporting processes (e.g. the whole land- and sea-scape that provides nutrient and nursery ground support for a whole fisheries population (Fig. 16)); that will require whole-of-system thinking. Smaller-scale actions are likely to only act on one part of a resource, and may even increase vulnerability if interrelationships between different components of the resource are not recognised (Harris &

Heathwaite 2012). This is likely to be the case where actions relating to one part of the SES fail to account for outcomes in another part (Lempert *et al.*, 2010). To ensure that actions have real broad-scale benefits, goals need to match with the scale of resources and resource supporting process (e.g. aiming for no net fisheries loss, no net loss in productivity or no net loss in nursery ground value at a landscape scale).

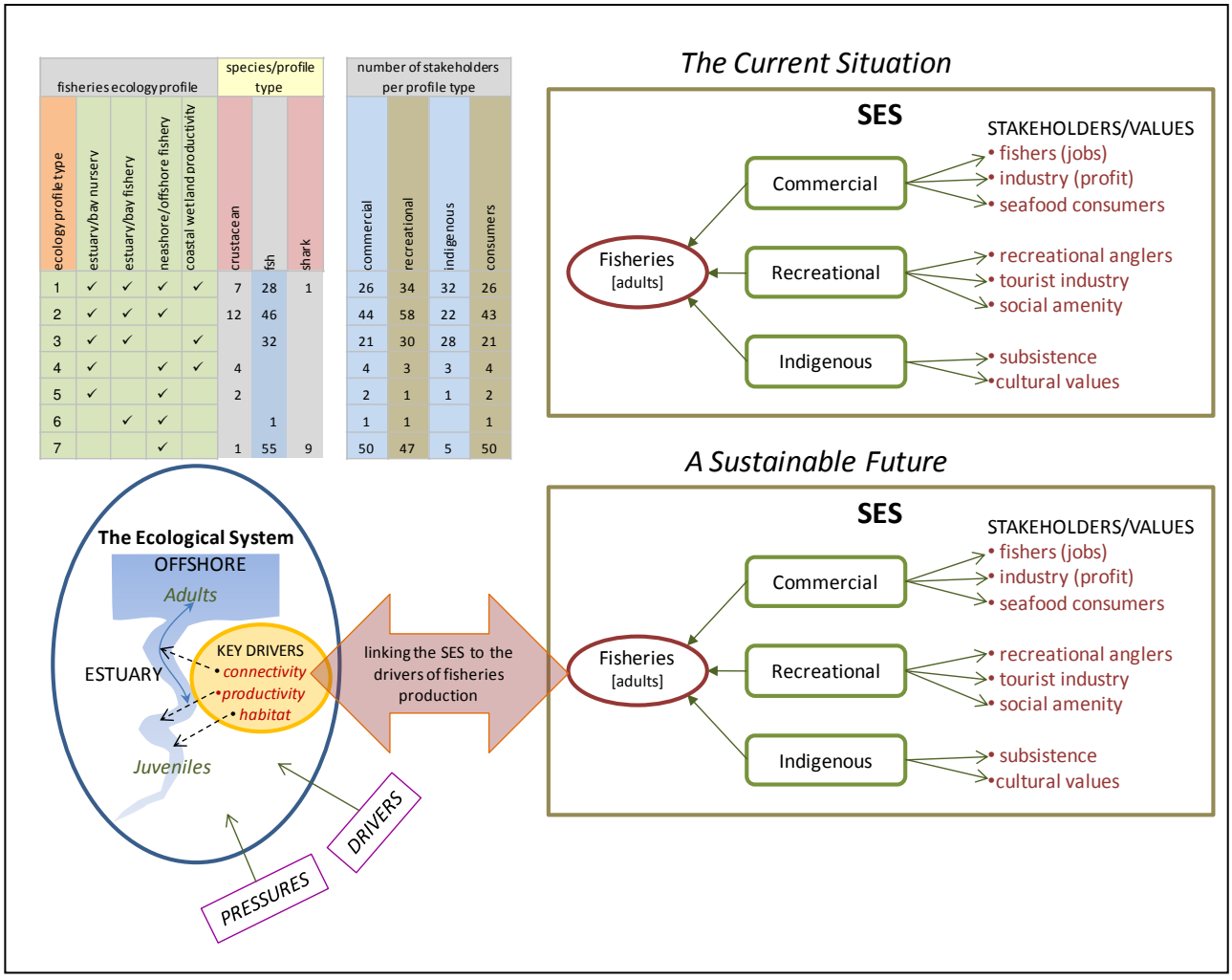


Figure 16: The pathway to a sustainable future for coastal ecosystems and their Socio-Ecological systems.

The upper right hand panel summaries the current situation, where conceptualisation of the dependencies between ecosystems and stakeholders in socio-ecological systems largely ignores key connectivities between coastal and estuarine habitats and fisheries stocks (ecological profile types 1-6 in the upper left hand table). The lower half of the figure indicates what is needed for a sustainable future; explicitly linking estuarine and coastal ecosystems into conceptualisations of socio-ecological systems.

Table codes:- ***estuary/bay nursery:*** *estuaries, bays and their component habitats (e.g. seagrass, mangrove, sandy beaches) are recognised primary nursery habitats;* ***estuary/bay fishery:*** *a component of the fishery occurs in estuaries, bays and their component habitats;* ***neashore/offshore fishery:*** *a component of the fishery occurs in neashore and/or offshore waters;* ***coastal wetland productivity dependent:*** *species are thought to depend on the productivity of coastal wetlands; this includes most species using estuaries;*

Resilience needs to be measured and communicated. Moving towards ecosystem resilience requires a detailed and specific knowledge base about what constitutes a 'healthy' ecosystem, how to maintain it, and how to value it in ways that can be understood and appreciated by all recipients of ecosystem services (Dickey-Collas *et al.,* 2014). Valuing ecosystem services in a currency that allows direct comparison against the values of competing needs is particularly important. In most cases this requires monetary evaluation. Such valuations are rare but their development is fundamental to ensuring effective management.

What sorts of actions are available to support broad-scale goals? In most cases specific practical CAS options will be limited (Lawler 2009). So where there are few real long-term fixes, meaningful adaptation will be more about non-Climate Change actions that will support the large focus outcomes as Climate Change proceeds (e.g. ensuring fisheries resilience by repairing and remediating habitats that have been damaged or lost through past human actions (Hughes *et al.,* 2013)).

Strategy Development

It is vital to ensure that adaptation strategies are developed in the context of outcomes and large-scale goals, and in particular to ensure that actions taken lead to optimal outcomes given uncertain knowledge and the potentially conflicting objectives of stakeholders.

There are three aspects of '***Strategy Development'*** that need to be considered; i) Employ robust and adaptable strategies that minimise harm across human and natural systems; ii) Acknowledge a multi-scale vision and incorporate a multi-scale approach and iii) Ensure fair, representative and equitable stakeholder engagement.

Principle 3: ***Employ robust and adaptable strategies that minimise harm across human and natural systems***

There has been considerable theoretical (Lempert & Collins 2007; Harris & Heathwaite 2012) and practical (Harris 2009) development of the idea of *Robust Decision Making* (RDM). RDM is based on the idea that where outcomes are uncertain it is best to use robustness rather than optimality as a decision criterion, to characterise uncertainty with multiple representations of the future, and to select strategies that perform acceptably across the range of plausible outcomes (Lempert *et al.,* 2010).

RDM contrasts with the traditional decision making approach that is based *Optimum Expected Utility (OEU),* which assumes the likelihood of a particular outcome can be described by a single probability distribution, leading to a predictable link between action and effect. Investing in actions to promote change means making appropriate decisions in the face underlying risk. As a result, the level of uncertainty determines the type of decision

making that is likely to be effective. When uncertainty and cause-effect relationships are well understood, OEU will provide the optimal decision (Lempert & Collins 2007). However, ***this will rarely be the case with ecological questions*** where complexity limits what can be deduced (Harris & Heathwaite 2012), so there is pervasive uncertainty about the outcome of actions (Lo & Mueller 2010). As a result, approaches that allow robust decision making in the face of uncertainty are required. Almost at the opposite extreme to assuming a defined optimal outcome based on OEU is the *Precautionary Approach* (PA), where decision makers aim to prevent future harm when the causal link between action and outcome is unclear. The avoidance of harm makes the PA an appealing fall-back position; however RDM can often provide enhanced outcomes because it provides a basis for reconciling competing goals (Lempert & Collins 2007). RDM provides a way forward when substantial uncertainty limits predictability of outcomes and so prevents the determination of optimal outcomes (Lempert *et al.*, 2010).

In effect a *Robust Strategy* (RS) is insensitive to uncertainty about specific outcomes (Lempert & Schlesinger 2000). An RDM might involve trading optimal performance for reduced sensitivity to violations of assumptions, adopting a strategy that performs well across a wide range of alternative responses, or selecting an approach, such as a no-regrets strategy, that keeps options open (Lempert & Collins 2007). RDM strategies should be adaptive in the sense that they should be designed to shape and maximise the options available to future decision makers (Lempert *et al.*, 2010). An RDM approach challenges decision makers to explore a wide range of plausible outcomes, so can help reduce problems of overconfidence in outcomes that hamper the success of traditional decision-analytic methods when uncertainty is substantial (Lempert *et al.*, 2006).

The inherent uncertainty of responses in estuarine ecosystems suggests that RDMs will usually be most appropriate. RDMs are based on the idea of minimising the potential of unacceptable outcomes rather than necessarily obtaining an "optimal" but risky solution. Different types of RDMs use different approaches and criteria for making RDM decisions (Table 10). Development of option sets usually proceeds via quantitative assessment of competing models of system behaviour (Lempert *et al.*, 2010), but because the methods are based on simple logic they lend themselves to qualitative displays of options that allow stakeholders to make informed decisions (Lempert & Collins 2007) as long as they understand the approach, the goal of the exercise and the nature of uncertainty. RDM methods are aimed at the development of strategies that satisfy with particular robust goals (Table 11). The characteristics of strategy developed may be influenced to some extent by the approach chosen but the strategy chosen will often satisfy more than one of the robust criteria (Hallegatte 2009). The unpredictable nature of the action-outcome link will mean there will almost invariably be incomplete certainty about the attainment of the goal. For instance, in reality no-regrets strategies will usually be low-regrets or low-probability-of-regret strategies.

Table 10: Three different approaches for making Robust Decisions (based on (Lempert & Collins (2007)).

RDM Approach	Details
Trading Some Optimal Performance for Less Sensitivity to Assumptions	The aim is to find strategies that reduce the major risks due to uncertainty at the expense of not aiming for the overall best possible outcome. The decision on the best strategy is then determined by the trade-off between acceptable risk and an acceptable outcome.
Keeping Options	The aim is to produce an interim outcome that moves towards a definable

Open	goal but is conservative in the sense that its results don't constrain future decisions aimed at achieving the goal. It is important when uncertainty is large because it allows for progress to be made followed by re-evaluation of the interim outcomes.
Satisficing Over a Wide Range of Futures	The aim is to find a robust strategy that performs reasonably across a wide range of plausible futures. Tends to produce many strategies that are acceptable choices.

Table 11: Some common robust strategy goals, their attributes and examples.

Goal	Attributes	Example
No-regrets	Actions that will produce no known detrimental impacts on the target situation regardless of uncertainty of outcomes and that have no known adverse collateral impacts	Replanting mangroves to replace forest lost after a cyclone Improve the habitat value of a seawall
Minimising collateral damage	Choices that minimise detrimental impacts to other sectors of actions that address imperative needs	Make choices that have the lowest impact on surrounding values (e.g. agriculture) where immediate action is required (e.g. due to legislation) to prevent severe degradation of protected areas
Reversibility	Actions that minimise future damage and costs of retrofitting if initial outcomes are inappropriate	Constructing a culvert under a road to reconnect an isolated area of coastal wetland
Bet hedging	Solutions that incorporate 'safety' features; important where desirable actions may have undesirable outcomes under some circumstances	Reconnect wetlands with culverts but include flood gates to allow exclusion of excessive tidal water to maintain hypersaline conditions
Safety margin	Build in extra capacity to facilitate future change that extends the effectiveness time-frame of actions; increases longevity of beneficial outcomes; usually an addition to other strategies	Assume sea-level rise will be faster than predicted and increase minimum elevation criteria for resettlement when moving dwellings landward away from foreshores
Increasing time horizon for additional action	Actions that allow time for other options to be developed and implemented	Move houses back from foreshores to facilitate habitat migration allowing time for development of alternative responses to habitat loss
Maximising complimentary benefits	Actions that result in the maximum network of advantages across all affected sectors	Legislation aimed to provide benefit across impacted sectors
Balancing risk and reward	Choose less attractive action with more assured benefit where value of the attractive action with greater potential value is uncertain	Restock fish if value of removing a barrier is uncertain in the long term (e.g. because of uncertainty about future river flow patterns)
Soft options	Approaches that do not involve remedial actions; these are reversible solutions that keep options open	Detailed monitoring to give early warning of the need for specific action if it is ever required, coupled with pre-planning of potential responses

Action criteria based on understanding of the nature and extent of uncertainty provide the basis for identifying achievable outcomes and sensible approaches to measuring their success. However, it is critical that all parties involved in the process have a full appreciation of uncertainty and its implications (Harris & Heathwaite 2012). Communicating this effectively and ensuring that this understanding is explicit in all levels of decision making is a major challenge, but is critical to success; it is necessary both to ensuring that uncertainty is fully

included in decision making and to enabling end-users (e.g. politicians, the public sector) to understand the value of outcomes free from unrealistic expectations.

Principle 4: ***Acknowledge a multi-scale vision and incorporate a multi-scale approach***

The coastal space is by nature complex; it has a large range of stakeholders with very different and, potentially, conflicting objectives (Grech *et al.,* 2013). Furthermore, governance systems are fractioned into different tiers of government and local bodies, making a co-ordinated approach to management difficult (Dale *et al.,* 2010). This means that there can be a disconnect between local knowledge and regional decision makers – both temporally and spatially. For example, locals often see a local scale issue well before regional or national bodies. Yet, a long-term strategic overview of a region may be more visible to a regional body than a local resident. This means that there is the potential for a real divide to occur between small-scale, localised management actions and large-scale catchment level management responses (O'Loughlin & Nambiar 2001). Furthermore, the adaptive management loop may indicate the benefit (or not) of an action at totally different time and spatial scales than was originally intended. Due to the long-term nature of some climate adaptations, the system response to an action may be well beyond the life cycle of a management body.

Consequently, comprehensive adaptation strategies need a vision that embraces these multiple scales and leads to decisions and actions that embrace multi-scale understanding (Raven *et al.,* 2012). All proponents need to understand this multi-scale vision and recognise that incorporating it will often require different approaches by different players. It must be clearly understood that scale (both temporal and spatial) matters – it is likely that actions will occur on a much smaller time and temporal scale than the strategy. For example, whereas the strategy needs to have an over-arching broad scale view linking relevant policies together, actions may need to be an accumulation of several small to medium actions delivered by several agents (Raven *et al.,* 2012). The systems under which this can operate will need to be informed by, and inform, actions at all scales; communications between locals and management bodies need to be strong and two-way.

However, in taking a multi-scale approach it is important to acknowledge the reality that objectives need to be relevant to specific impacts and vulnerabilities; they should produce effective outcomes for the target issue at the target scale of effect. A multi-scale perspective requires that gains at the target scale should be consistent with, and value-add to, goals at larger conceptual scales of the adaptation strategy landscape, and should be operable and appropriate in the light of other coastal and Climate Change issues (Klein *et al.,* 1999: p. 241). The final strategy employed should not hamper but if possible value-add to larger strategy goals – if not it will produce overall negative outcomes.

Principle 5: ***Ensure Fair, Representative and Equitable Stakeholder Engagement***

Comprehensive stakeholder engagement is important to achieve natural resource outcomes in the context of adaptation to Climate Change. Engagement of all stakeholders in strategy development in a participatory approach combining top-down and bottom-up perspectives provides both a richer suite of perspectives and legitimacy through participation and consideration of stakeholder aspirations. Stakeholder involvement needs to occur from the beginning to the end of the process, to ensure translation of large scale objectives to local

solutions. Keeping stakeholders engaged requires facilitation of on-going stakeholder interest and involvement through mentoring and championing, and ensuring they are intimately involved in decision-making.

There are several types of stakeholder engagement largely defined by the tasks to be undertaken and the political and social norms, as well as the capabilities and aspirations of the stakeholders (Sen & Hasan 2001). Instructive involvement is a mechanism for information exchange. Consultative involvement is where stakeholders have a degree of influence over the process and outcomes. Cooperative involvement is where primary stakeholders act as partners in the decision-making processes (Sen & Hasan 2001). None of these types of involvement is more desirable than another, or mutually exclusive.

In situations where community opportunities to participate in and influence decision-making processes are not widely available, adaptation policy and options may not match the community's views, in which case there is a high risk they may fail to achieve the intended outcomes (Productivity Commission 2012). Through community engagement the public is involved in solving problems or making decisions, and public input can be used to make decisions (International Association for Public Participation, http://www.iap2.org.au/).

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. Fernández-Bilbao *et al.*, 2009; Booth 2012). 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. Fernández-Bilbao *et al.*, (2009) bases 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.

An advantage of deliberative methods that involve active stakeholder participation is that they encourages social learning as part of this process. This approach is particularly useful when the problem is complex and uncertainty is high (Walters & Holling 1990). 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.*, 2009; Ison 2010). Social learning frameworks have been used in a climate adaptation context mainly in case study applications; for instance, water resources, wildlife management and agriculture (Martin *et al.*, 2009). Social learning is increasingly gaining interest over more traditional methods of information dispersal and expert-based teaching (e.g. Blackmore *et al.*, 2007; Muro & Jeffrey 2008; Pahl-Wostl 2009).

The sharing of experiences in group discussions provides rich outcomes in terms of, for instance, the ability to process uncertainty information (Albert *et al.*, 2012). The process of undertaking the adaptation assessment plays an important role in catalysing social learning and collective action (Eakin & Patt 2011). Empirical evidence suggests that the ability of societies to adapt is determined, in part, by the ability to act collectively (Adger 2000).

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). Nevertheless, after finishing a set of engagement activities, continued communication with stakeholders should be part of a long-term strategy.

Governance

There are two aspects of '***Governance'*** that need to be considered; i) Harmonise legislation, policy and actions to achieve large-scale, long-term public benefits; and ii) Effective governance that is clear, consistent and complementary.

Principle 6: ***Harmonise legislation, policy and actions to achieve large-scale, long-term public benefits***

Harmonising actions and public benefit involves increasing the concordance between the scales at which ecological and biophysical processes occur, the scales at which legislation and policy are made (central government), and the scales where actions are taken (local governments/regional bodies).

Harmonising policy with ecosystem: Harmonising policy with ecosystem outcomes requires determination and incorporation of the large-scale long-term ecological and biophysical processes that need to be supported to ensure healthy, resilient ecological assets (Fig. 16). These include the key drivers of ecosystem wellbeing and resilience [appropriate productivity, connectivity and habitat] and the processes that support them (Lake *et al.,* 2007; Carroll *et al.,* 2010). Once these factors are recognised they need to be used to inform policy (Gaydos *et al.,* 2008). This means the development of an extensive two-way dialogue between scientists and policy makers. Getting this right will go a long way to ensuring all levels of decisions are made in a holistic context that focuses on whole-of-system, long-term outcomes.

Harmonising actions with policy: Ensuring continuing ecosystem resilience requires adaptation strategies aimed at protecting and/or enhancing these large-scale public assets over the long term (Creighton 2013). However, many "adaptation strategies" are developed and implemented at a relatively local level and more closely represent tactics for achieving specific outcomes rather than truly being strategies aimed at optimising outcomes in the face of changing climate and sea level rise (Hallegatte 2009; Drake *et al.,* 2013). True adaptation strategies need to take a broader view because they need to focus holistically on achieving optimal outcomes for all sectors and participants into the future. Consequently, they need to incorporate a large scale, long term view that focusses on optimising cross-sectoral benefits. Exactly what the large scale, long term goal(s) should be is a key question that needs to be developed in a public consultative process aimed at reconciling different perspectives and values (Harris & Heathwaite 2012).

Although strategies aimed at public benefit need to address large scale, long term goals, actions to implement strategies generally occur at a relatively local level (Drake *et al.,* 2013). Consequently, there is a need to reconcile and align policies (that have large scale goals) and local level actions to achieve public benefit outcomes. Many local level actions will rarely align with large scale pubic benefit goals, and may even be contrary to those goals (e. g

draining wetlands to reduce local flooding [private benefit] is likely to produce a very negative public good outcome [i.e. loss of carbon sequestration potential] (Drake *et al.*, 2013)), so there is a clear need to include evaluation of the extent to which any particular local level action aligns with large scale goals when developing local level action plans. To date such evaluations seem to be rare occurrences in Australia (Appendix 3 *Assessment of Local Government Progress in Marine Climate Change Adaptation in Australia*) but are critically important if Climate Change actions are to lead to large-scale public benefits.

From the policy side, there is a need to ensure that governance structures are sensitive to the complexity of the Climate Change adaptation problem and that translate into local level actions that support public benefit goals (Roberts 2008). Ensuring that policy goals produce actions focused on public benefits will mean increasing the integration and coherence of legislation and action between different catchment components (e.g. freshwater vs. estuary vs. coasts/ocean) and government level (Local, State, National), as well as communicating the need for actions to lead to overall public benefit as an overall goal of adaptation actions and action plans. This will require adjusting policies and particularly the communication of the goals of policy to ensure they are sensitive to social, economic, and environmental dimensions (Fidelman *et al.*, 2012; Fidelman *et al.*, 2013).

Principle 7: ***Effective governance that is clear, consistent and complementary***

The complexity of governance relating to Climate Change, and responses to it, means there is a need for clarity, consistency and complementarity in defining responsibilities and policy implementation of different management/governance authorities. Consequently, substantial success requires integration of top-down (State, Commonwealth) policies and legislation, and bottom-up (local, community) level actions, together with a clear definition of roles and responsibilities.

The concept of ‘governance’ describes ‘who’ makes decisions, has powers and responsibilities, and ‘how’ they are exercised (Borrini-Feyerabend *et al.*, 2006: p.116). Governance has long been identified as both the source and solution to environmental problems. Effective governance can support and encourage adaptive capacity to maintain or improve the conditions of SES.

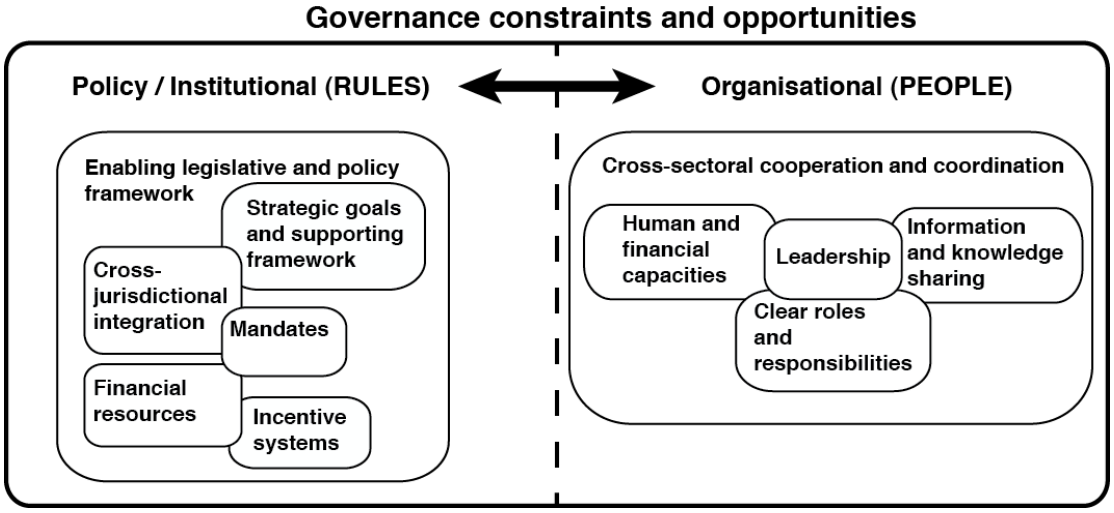


Figure 17: Opportunities and constraints from the interaction of the two components of governance systems: institutions (rules) and organisations (people).

Governance comprises two interacting components: institutional (rules) and organisational (people) (Fig. 17). Institutions are the laws, policies, regulations, norms, customs, cultural processes and other rules that shape human action. Organisations are the actors, which can be broadly defined as an organised body of people with a particular purpose, where its members develop rules for collective decision delegation and membership (Argyris & Schon 1978). While institutions define opportunities and constraints within which governance actors work, governance actors may shape and alter institutions (Hodgson 2006).

In the governance context fisheries SES can be seen as "nested sub-systems within wider systems that, at any particular scale, are influenced by and in turn influence, outcomes at other scales" (Dale *et al.,* 2013:2). Adaptation strategies cannot be designed in isolation. It is important to ensure that adaptation strategies are 'fitted in' the broader governance context.

Australian environmental governance is a highly complex, dynamic and multi-level system with numerous governmental and non-governmental actors interacting within and across levels and authority domains (Appendix 1). Due to the complexity of interactions it is difficult to predict how governance arrangements will evolve to deal with Climate Change issues over long term. To this end, this report does not aim to provide principles of governance design or advice on how to regulate coastal zone or fisheries resources. It rather identifies several governance factors from both institutional and organizational perspectives that may operate as enabling or constraining factors to adaptation responses of Australian coastal fisheries.

There are two governance aspects that need to be considered in the design and implementation of adaptation responses: i) identifying enabling and constraining factors of existing legislative and policy frameworks and aligning strategic responses while maintaining the focus on large-scale, long-term environmental benefits; ii) acknowledging diversity and complexity of governance structures and developing organisational arrangements that facilitate cross-sectoral cooperation and coordination, capacity building, knowledge generation and exchange.

i) Identifying enabling and constraining factors of existing legislative and policy frameworks and aligning strategic responses while maintaining the focus on large-scale, long-term environmental outcomes

Enabling legislative framework is one of the core determinants of the abilities of governance actors to bring policy into action. Australia's institutional system is dynamic. Statutes, regulations, policies, strategies and other instruments are frequently amended, revoked and reinvented, which brings new opportunities and challenges. To move towards established long-term outcomes planned strategic responses need to maintain flexibility to adapt to changes in the political environment.

Australian coastal zone and estuaries are under the jurisdiction of States and the Northern Territory. Consequently, there are seven different regulatory and administrative frameworks which reflect differing histories of political development, resource uses, as well as social, economic and political conditions. There are nonetheless several common institutional dimensions that require consideration to pursue long-term protection of ecological assets of Australian coastal fisheries. These include: (1) strategic goals and supporting framework; (2) mandate boundaries; (3) cross-jurisdictional integration; (4) distribution of financial resources and (5) incentive systems.

Strategic goals and supporting framework: To pursue Climate Change adaptation, there is a need to identify large-scale ecological and biophysical processes which are to be maintained to sustain ecological assets. A lack of shared long-term vision, goals and strategic framework developed for ecologically relevant scales can become a significant impediment for adaptation planning and targeted investment. As observed, many governance responses to various pressures affecting coastal habitats are still developed in ad hoc fashion and implemented at a relatively local level aimed to achieve specific operational outcomes.

Mandate boundaries: In all Australian jurisdictions, management of environmental assets follows a 'sectoral' pattern with different legislative and administrative frameworks established for the management of separate resources. Protection of fisheries ecosystem assets does not fall neatly within conventional sectoral boundaries. Many regulators responsible for the implementation of fisheries legislation are deficient in authority to achieve stated habitat protection outcomes (e.g., have no control over the impacts on riparian or coastal vegetation, development on private land, which often have negative effects on fish habitats). Limited mandate can also affect strategic planning with responsible authorities focusing on those actions within the scope of their mandate.

Cross-jurisdictional integration: Australian coastal zone is a contested space. While insufficient mandate and jurisdictional fragmentation is a common complaint, these problems will never be resolved to satisfy the needs of all sectors. Long-term protection of fisheries assets, therefore, is dependent upon the level of incorporation of protective measures into other legislative frameworks providing for activities affecting these assets. If these frameworks lack sufficient power to prevent adverse effects, the loss of habitats will continue. To this end, strategic planning of fisheries assets cannot occur in isolation and should be sensitive to potential interests and actions of other sectors.

Financial resources: Each jurisdiction has a different mix of government and non-government management bodies which are or can be potentially involved in the protection and maintenance of fish habitat assets. Fish and other aquatic resources (with some

exceptions) are common goods. From the policy side, the question remains who and to what extent could they be expected or required to allocate financial and human resources to sustain assets required for the provision of these goods on a regular basis. Allocation of fisheries resources and collection of fees and charges is controlled by the Commonwealth, State and Northern Territory governments. Strategy documents frequently identify local governments and communities as potential partners in the management and maintenance of coastal habitats. To achieve implementation, however, strategies need to be sensitive to the capacities and funding sources of other governance actors. Redistribution of financial resources may need to be considered to support ongoing local management initiatives and align priorities.

Incentive systems: Planning and implementation of adaptation responses (e.g. increase in protected areas, rehabilitation of degraded habitats) requires consideration of broader economic context and established incentive systems shaping interests and priorities of other governance actors. Australian land is an important economic asset. Private land holders are generally unwilling to sacrifice their land resources and bear the losses (e.g., decrease in productive capacity or market value) to provide additional coastal habitat (Boer 2010). Currently, private land tenure is one of the core obstacles for the development of freshwater habitat networks and expansion of tidal habitats (R. Quinn, pers. communication). These problems suggest that an extension of the scope of applied incentive-based instruments may be required to align priorities and involve private land-holders in the management and maintenance of fisheries assets.

ii) Acknowledging diversity and complexity of governance structures and developing organisational arrangements that facilitate cross-sectoral cooperation and coordination, capacity building, knowledge generation and exchange

Over history, Australian jurisdictions have experimented with a large variety of organisational arrangements. In practice, there is no single recipe to the design of environmental governance structures. However, there are several attributes related to organizational issues that require consideration to build and strengthen adaptive capacity of Australian coastal fisheries. These include: (a) cross-sectoral cooperation and coordination; (b) clear roles and responsibilities; (c) leadership; (d) information and knowledge, and (e) human and financial capacities.

Cross-sectoral cooperation and coordination: No single agency manages the coastal zone. There are multi-level governance arrangements, where different departments are in charge of parts of the coastal zone, often with overlapping mandates. Therefore, ongoing engagement and communication with other industries, their regulators and the public is the key to ensure that the threats to fisheries assets are understood and considered. Actors must negotiate different goals in an attempt to manage simultaneously for multiple uses (e.g. fisheries, water quality, tourism, biodiversity) (Fidelman *et al.*, 2012; Fidelman *et al.*, 2013).

There are different ways in which cross-sectoral interactions can be organised. One approach is the use of bridging organisations. They provide forums for stakeholder interactions and contribute to reciprocity and trust, co-production and exchange of knowledge, learning and conflict resolution (Cash *et al.*, 2002; Cash *et al.*, 2006; Berkes 2009; Brondizio *et al.*, 2009). In Australia bridging organisations are known to have effectively crossed management and ecological boundaries and to have successfully facilitated the flow and exchange of information and knowledge within and across SES (Myers *et al.*, 2012; Shaw *et al.*, 2013).

Clear roles and responsibilities: Cross-sectoral cooperation and coordination is facilitated by clear definitions of roles and responsibilities. When government, communities and industry clearly understand their roles and responsibilities leaders are in a better position to act and/or coordinate activities with other actors (Clarke *et al.,* 2013). This also builds adaptive capacity by helping identify mismatches between management and ecological boundaries.

Information and knowledge: Actors involved in NRM recognise the importance of producing and exchanging knowledge and information to improve the process of making decisions (Dutra *et al.,* 2011; Day & Dobbs 2013). However, knowledge (scientific and/or local and traditional) is often ignored in decision-making processes where decisions depend more on the ability of individuals and groups to communicate their concerns or to lobby effectively (Palmer 2004; Dutra *et al.,* 2011). There is an urgent need for fisheries management and policies to move towards more effective knowledge and practice integration and dissemination (Kothari 2008; Clarke *et al.,* 2013). To this end, sound knowledge of fisheries assets, their locations and economic values to the society can become an important determinant of negotiating capacity.

Leadership: The role of leaders is a widely recognised success factor in any management sector, including environmental. Leaders are known to perform such functions as developing and communicating visions, building trust, coordinating the exchange of knowledge and information, managing conflicts, initiating partnerships, lobbying, and mobilising broad support for change (Folke *et al.,* 2005). Lack of leadership can also lead to inertia in decision-making processes (Arvai *et al.,* 2006; Bohensky *et al.,* 2011; Cinner *et al.,* 2013; Davidson *et al.,* 2013). In Australia, the ability of responsible State agencies to actively promote fisheries interests, disseminate information and form strategic partnerships is one of the core determinants of incorporation of protective measures in other regulatory portfolios.

Human and financial capacity: All levels of governments have policies, laws and programmes to facilitate fisheries governance, but do not necessarily have adequate capacity to implement them. This lack of capacity may apply to one or more of the partners, and may be of a financial, technical or human nature (Kothari 2006:544). For example, local governments often do not have the revenue necessary to adequately deal with water quality and quantity issues, which could potentially impact fisheries. This problem may be aggravated by so called ‘cost-shifting’ strategies when local governments are “left ‘holding the program’ after State and Commonwealth governments decide they can no longer fund a program they initiated” (Stocker *et al.,* 2012:30).

Implementation

A key component of a successful outcome to a climate adaptation strategy is in the implementation of both the process of development of climate adaptation strategies, and subsequent management actions and monitoring.

Successful ***implementation*** requires the proponent to i) focus on achievable and realistic delivery of CAS outcomes and outcome-support tools, and ii) optimise outcomes by employing adaptive feedback cycles appropriately.

Principle 8: ***Focus on achievable and realistic delivery of CAS outcomes and outcome-support tools***

Many CAS concentrate on developing CAS frameworks, yet few have moved to direct management action (Appendices 3 & 5). A review of different climate adaptation strategies (Appendix 5) has highlighted that several frameworks are available and several may be applicable to a specific case. This means that CAS outcomes should concentrate more on developing achievable and realistic delivery rather than on what framework to use. However, if it is preferred to develop CAS under a specific outcome, two frameworks stand out (Fig. 4 and Fig. 10). The first (Fig. 4) is a modified form of that from the IPCC (Klein *et al.,* 1999) and articulates the steps needed to develop a CAS – some more detail has been provided under the original headings. The other framework (Fig. 10) was constructed following detailed review of the literature, and is a generic construction that simply highlights the different products that would help to develop robust CAS. Regardless of which framework works best for a specific system, or whether the choice is to proceed free from the constraints of any framework, the following *Adaptation Checklist* (rather than a framework) for the *process* of developing an effective adaptation strategy is a useful guide to developing an achievable and realistic product (

Table 12). The ***Adaptation Checklist*** is intended as a guide rather than a prescription. Consequently, some components may not be necessary in a particular situation, others may be missing, and the order of steps may well change from case to case.

Table 12: A checklist for developing an effective adaptation strategy.

A. Conduct comprehensive forecasting
B. Conduct ecosystem triage
C. Specify an adaptation focus
D. Define specific objectives
E. Identify end-users comprehensively
F. Identify appropriate Climate Change scenarios
G. Assemble all relevant information
H. Assess the quality of available information and identify key gaps
I. Assess and communicate uncertainties
J. Evaluate constraints
K. Assess the range of actions possible in the situation
L. Develop the adaptation strategy
M. Evaluate adaptation outcomes and monitor success
N. Reassess uncertainties
O. Collect additional information as necessary

Each component of the list is explained below, where appropriate with a series of tools that can be used to progress that part of the checklist. The first 12 components of the checklist relate directly to *Principle 8* but the final 3 relate specifically to *Principle 9*.

A: Conduct comprehensive forecasting

Effective decision-making depends on the accuracy of predictions of the full spectrum of effects of Climate Changes. These need to include forecast of the evolution of ecosystems and social, technological, and economic systems as well as the behaviour of the climate system itself (Lempert and Schlesinger 2000). It is important to understand the limits of the ability to predict trajectories of change because there are many parameters to be estimated (e.g. Climate Change, the behaviour of economic systems, the response of ecosystems), meaning even small errors can magnify uncertainty.

B: Conduct ecosystem triage

Ecosystem triage relates to the process of prioritizing which ecosystems or ecosystem components are the most profitable targets for the expenditure of scarce resources (Lawler 2009). Many approaches and criteria are possible (see Lawler 2009) but these will depend on the exact focus of adaptation and the specific situation, needs and resources. For instance, triage prioritization could be based on evaluation of the value of an ecosystem service relative to the projected severity of impact (Fig. 18).

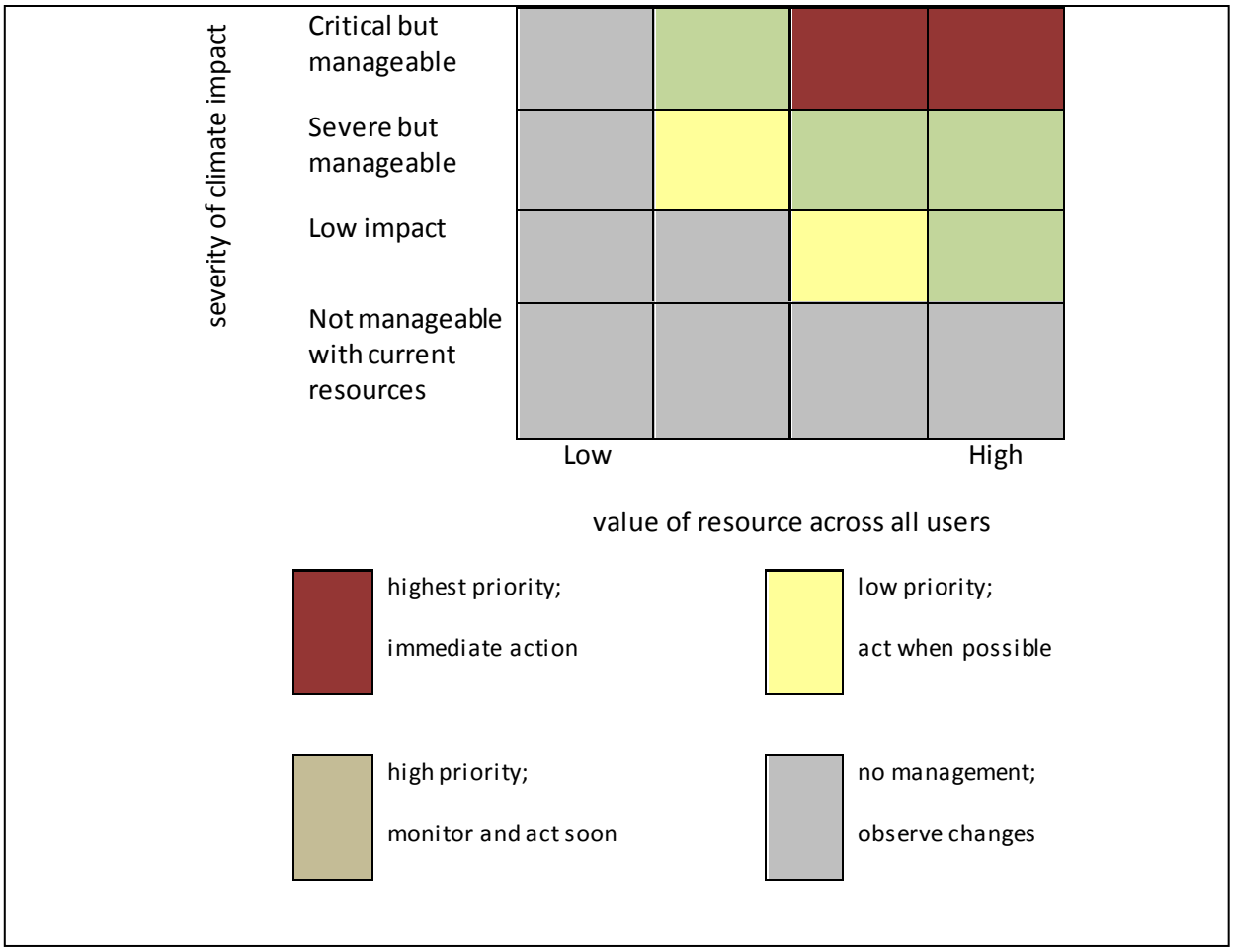


Figure 18: Example of an ecosystem triage classification. Modified after Lawler (2009).

Triage cannot be undertaken lightly because it relies on the complex interplay of a number of factors (Fig. 19).

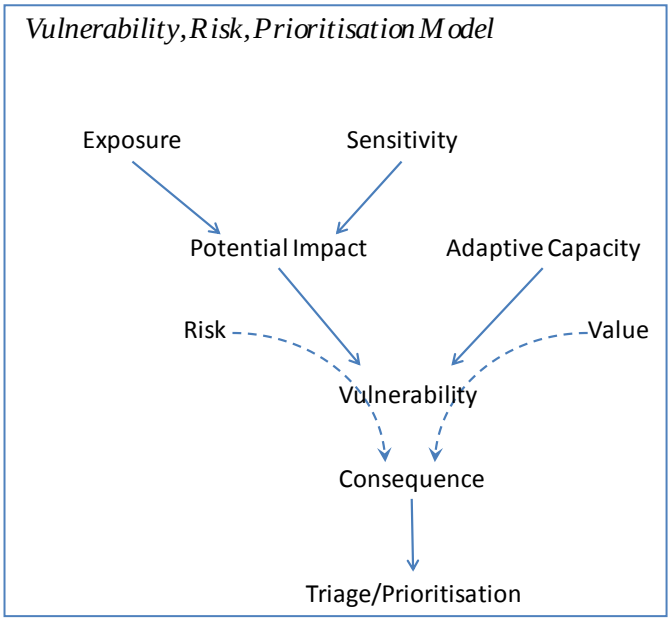


Figure 19: A conceptual model of the factors influencing ecosystem triage decisions.

Definitions: *Adaptive capacity:* the potential or capability of a system to adapt to climatic stimuli; **Exposure:** the extent to which specific events are likely to affect the system; **Resilience:** the ability of a system to rebound or recover from a stimulus; **Responsiveness:** degree to which a system reacts to stimulus; **Risk:** likelihood of negative outcomes relative to consequence of the outcome; **Sensitivity:** degree to which a system is affected by, or responsive to, stimuli; **Vulnerability:** degree to which a system is susceptible to damage or harm: a function of the character, magnitude and rate of exposure; sensitivity; adaptive capacity. (based on Holling 1973, Olmos 2002, IPCC 2001, Hills & Bennett 2010, Marshall *et al.*, 2010)

C: Specify an adaptation focus

The success of adaptation is greatly influenced by the focus of the adaptation strategy, so a clearly specified adaptation focus is a key underpinning of success. Two components of the adaptation focus are important:

1. Where the focus is directed along the ***continuum from transformative to targeted change***. Transformative change includes building resilience, reducing vulnerability etc., and is aimed at long-term, sustainable outcomes. Targeted change often represents expedient/band-aid solutions, which usually offer only local gains specific to the target, and so often only lead to short-term solutions or solutions that are not necessarily in tune with large scale goals (Lim *et al.*, 2004; Folke *et al.*, 2010).

2. Whether the focus is ***impact- or vulnerability-driven***. Focussing on reducing impacts can produce substantially different outcomes to a focus on reducing vulnerability. Focussing on impacts will often match with targeted solutions, while focussing on vulnerability will usually match with transformative change (Lim *et al.,* 2004; Lawler 2009).

D: Define specific objectives

Along with the need for a specific adaptation focus goes the need to specify goals clearly (Christensen *et al.,* 1996; Folke *et al.,* 2010). Defining objectives requires a number of components:

- Objectives/Goals need to be explicit e.g. more resilient fisheries at a specified spatio-conceptual scale;
- Objectives need to be relevant to specific impacts and vulnerabilities;
- Identify the assets that require adaptation action;
- Governance objectives need to be defined;
- The spatial limits of the area the strategy is intended to apply to need to be defined;
- All end-users need to be identified;
- The end-user objectives of the strategy need to be identified;
- Any additional constraints for strategy development should be defined; e.g. governance structures or boundaries that are beyond the limits of influence of the strategy.

E: Identify end-users comprehensively

There will usually be a diverse suite of end-users and stakeholders. Comprehensive identification is important because the success of adaptation strategies often relies on the extent of stakeholder engagement (Sen & Hasan 2001), particularly useful when the problem is complex and uncertainty is high (Walters & Holling 1990).

F: Identify appropriate Climate Change scenarios

This step involves defining the exposure to be planned for. The scenario needs to be defined taking into account the key Climate Change threats which will help define the logic of the assumed time horizon.

G: Assemble all relevant information

A key step that includes collection of information on:

- Available GIS;
- Risk assessments;
- User groups (farmers, miners etc.);
- Climate projections;
- Local views on needs;
- Capacity (people, money, infrastructure);
- Governance and Legal situations and constraints;

- The local political context.

H: Assess the quality of available information and identify key gaps

The quality of information available is a critical determinant of the rigour and quality of the adaptation strategy development, and so is an important contributor to outcome uncertainty. If possible any major gaps identified should trigger the collection of additional information and the operation of an adaptive loop.

I: Assess and communicate uncertainties

A clear understanding of the level of uncertainty will help to determine the limits on predictability of the action-outcome link, and (usually) emphasise the extent to which robust strategies are necessary (Harris & Heathwaite 2012). Communicating the nature and extent of uncertainty, and its consequences for the predictability of outcomes is critical in enabling proponents to make effective decisions in the face of the business as usual approach of assuming a particular action will produce a predictable outcome, something that is rarely the case in systems with high levels of uncertainty from multiple sources (Lempert & Collins 2007; Harris & Heathwaite 2012).

J: Evaluate constraints

Constraints of all types should be evaluated because they determine the range of adaptation actions that are possible and consequently the eventual adaptation strategy. Early identification of constraints is valuable because it can provide time to work with stakeholders to overcome some of the issues, freeing up adaptation options. Constraints come in many forms both at the local level (e.g. geography, local climate, local tides, socio-economic, local political imperatives etc.) and at large scales (e.g. legislative requirements, national attitudes to development).

K: Assess the range of actions possible given the situation

This step involves the development of a prospectus of the range of actions available in the context of large scale constraints, local situational constraints, the nature of the threats, and the assets requiring adaptation action.

L: Develop the adaptation strategy

Develop the strategy in the light of available information, constraints, levels of uncertainty and possible actions. This involves consideration of the outcomes of different actions, employing decisions-support tools, considering available recommendations and advice, and prioritisation of actions.

M: Evaluate adaptation outcomes and monitor success

Without detailed evaluation and monitoring there is no way to determine the extent to which any strategy or action has been successful, no way to justify the expenditure of resources, and no way to determine what follow-up actions might be necessary. Evaluation relies on having extensive, well defined baselines in place before any action is taken. Many aspects need to be included in evaluation, for example:

- Outcomes:

    - how outcomes relate to different end-user needs and aspirations;
    - cost-benefit of adaptation solutions of different complexity (e.g. framework vs. simple determinants model);
- Scales of outcomes:
    - conceptual scale of outcome: transformative, incremental, targeted, expedient (band-aid);
    - spatial (whole-of-system vs. individual objectives);
    - areal (local vs. multi system);
    - temporal scale of outcome: short term needs of end-users vs. long term benefits;
    - conceptual (proximal vs. ultimate outcomes);
- Context/Implications:
    - outcomes for non-target end-users, interest groups or systems;
    - collateral damage/complimentary benefits;
    - feasibility.

N: Reassess uncertainties

This is a key step that combines information on uncertainties that have come to light during the process of developing an adaptation strategy. Judgement of the functional magnitude of the accumulated uncertainties will determine if it is suitable to employ the adaptation strategy at this stage or if it is necessary to continue on in an adaptive loop to enable collection of the information needed to reduce uncertainty to an acceptable level.

O: Collect additional information as necessary

Collect any additional information or develop any additional understanding as identified during the assessment of information quality or during the strategy development and evaluation process.

Principle 9: ***Optimise outcomes by employing adaptive feedback cycles appropriately***

Principle 9 focusses specifically on the last 3 components of the ***Adaptation Checklist***. Inflexible strategies are rarely effective so it is vital to employ adaptive feedback cycles, and to employ them appropriately. Adaptation options as cycles (adaptive management) should be seen as the "normal" way to do business: flexible adaptive management that allow whole of system approach (e.g. catchment – estuarine – marine) across different management levels. An adaptive process should be adopted because, although complex relationships between cause and effect (a “wicked problem”) usually mean that optimal solutions are impossible, adaptive loops allow movement towards a defined goal. The adaptive management loop involves iterative decision making, evaluating the outcomes from the previous decisions and adjusting subsequent actions on the basis of this evaluation. The uncertainty of outcomes means that robust strategies should be the favoured actions in the adaptive framework because they provide for re-evaluation and adaptive responses. An adaptive process also affords the important benefit of making it possible to take advantage of opportunities as they arise.

Conclusion

Ecological systems are intimately influenced by the social systems that rely on them. This is particularly true of Australia's ECMEs, with their broad diversity of structure, the wide range of climatic and geomorphic conditions they occur under, and the diverse interactions they have with humans, human infrastructure and human utilisation. Consequently, to be effective in supporting the long-term productivity and resilience of Australia's ECMEs, Climate Change Adaptation Strategies need to be broadly and holistically focussed on sustaining the whole SES. A holistic focus is also crucial because, not only are there many competing interests to be considered, but Climate Change is only one of a suite of factors that impact ECMEs. Adaptation Strategies also need to have a whole-of-system vision that focuses on long-term transformative outcomes aimed to maintain and restore resilient ecosystems; resilient ecosystems provide healthy human living environments, support optimal biodiversity and underpin robust and productive fisheries. Maintaining and enhancing ecosystem resilience provides long-term durability and availability of resources future-proofing SESs by supports ecosystem functioning in the face of change.

ECMEs are characterised by substantial and pervasive variability, incomplete knowledge bases, and complex interdependencies. These characteristics mean that problems in these systems are resistant to resolution because of tortuous relationships between cause and effect. Such complex problems require robust solutions that give the greatest security of long-term positive outcomes in the face of uncertainty in both the trajectory of change and the outcomes of remedial actions. Pervasive uncertainty also means that there is continual need for more and better knowledge to support adaptation actions – but it also means that all involved need to be clear that there will never be 'enough' knowledge to provide certainty of outcomes. This uncertainty and complexity extends to governance systems further complicating pathways to successful outcomes, particularly because systems outcomes may occur well beyond the life of the current management regime. Not only is there a need to harmonise policy and actions, to have consistent governance, and to focus on long-term outcomes, but it is critical that all stakeholders are well informed, have a full appreciation of uncertainty and its implications, and are deeply engaged with adaptation planning and actions; something that requires extensive resourcing and continual attention. Perhaps most importantly, it is vital to focus on outcomes that are realistic and achievable; again an argument for robust solutions that are not tightly constrained by the expectation of specific outcomes but produce acceptable outcomes across a spectrum of possible trajectories of response.

The diversity in structure and conditions of Australia's ECMEs, the diversity of challenges they face, combined with pervasive uncertainty has implications for the tools that support strategy development. No single frameworks will be applicable across Australia's ECMEs; if they are general enough to have broad utility they will be too non-specific to be operationally useful, if they are tightly constrained they will usually be too restrictive and inflexible for general applicability. Each situation is qualitatively and quantitatively different and each problem will have unique features. Rather, what are needed are tools that provide advice to support strategy development and general principles that help guide, but not constrain, development of informed adaptation policies, plans and actions, whatever the particular situation and purpose.

Adaptation Strategy Development is a very uncertain ‘science’. It involves making decisions now on (uncertain) actions to respond to (uncertain) predicted outcomes of (uncertain) predicted change! The uncertainty is complex and interactive and is perhaps the one ‘constant’ in the whole Adaptation equation! Dealing with this will require clear and flexible thinking on the part of the whole Australian population; everyone is a stakeholder because every member of the community has a stake in the longevity and resilience of ECMEs and all the services they provide to humanity and the natural world. Consequently, the single most important factor in successful adaptation to Climate Change is extensive and intimate common sense engagement by the whole community.

Implications

Successful Climate Change Adaptation requires engagement by all sectors of the population – stakeholders from every walk of life. All need to be included, so those charged with facilitating change (managers in the broad sense) need to focus on engagement and education. In particular it is critical that all players understand the levels of uncertainty involved and the consequences of that pervasive uncertainty. Prescriptions will not solve the diverse problems presented by climate change – flexibility and open minded approaches to achieving big picture goals to support the public good, and extensive and intimate common sense engagement by the whole community provide the pathway that will need to be followed to achieve effective Climate Change adaptation in the ECME.

Recommendations

1: Successful adaptation strategies need a to be developed in a broad, holistic context

Climate Change is only one of a broad suite of factors that impact coastal systems with many of the impacts of Climate Change only representing changes in the frequency of stressors that have been active for millennia. Strategies need to be developed in a SES landscape where there are many competing interests to be considered; for example, actions that might be good for shoreline protection might negatively impact industry, livelihoods, fisheries, tourism or the environment. The embedding of Climate Change in an array of stressors and the need to consider the multiple ways in which any action can impact other facets of the SES, together with the need to consider short- and long-term goals and effects, means strategies need to be developed in a broad, holistic context.

2: Focus on whole-of-system, long-term transformative outcomes for socio-ecological systems

From a broad range of perspectives, maximum public benefit accrues from maintaining and restoring resilient ecosystems that provide healthy human living environments, support optimal biodiversity and underpin robust and productive fisheries. This is best achieved by focussing on long-term transformative outcomes at a whole-of-system scale that provide on-going benefits by enhancing resilience and reducing vulnerability into the future. Focussing at a whole-of-system scale reduces the chance of local level actions producing contradictory outcomes. Focussing on maintaining and enhancing ecosystem resilience provides long term durability and availability of resources because it supports continued ecosystem functioning in the face of substantial change; in essence future-proofing the system. In addition, because ecological systems are intimately influenced by the social systems that rely on them ensuring resource resilience needs to focus on the socio-ecological system as a whole.

3: Employ robust strategies that minimise harm across human and natural systems

Strategies need to be considered with respect to the life-time of their consequences; decisions with short term consequences are usually only taken in the context of the current climate or with a short-term change horizon. In contrast, adaptation decisions aimed at long term outcomes need to accommodate future predicted change. In the absence of the ability to look into the future and choose desirable rather than maladaptive pathways, decision makers need to adopt strategies that limit the risks of unforeseen consequences. This requires the development of robust strategies that recognise the intrinsic uncertainty of our knowledge of the future and the consequent limitations on our ability to predict future events and the consequences of actions. These strategies should be robust across the range of future possibilities, and not rely on tightly predicted outcomes but are robust in the sense that they do no harm if an unexpected course of events occurs, and do not close off the possibility of future actions.

4: Acknowledge a multi-scale vision and incorporate a multi-scale approach

The coastal space is by nature complex; it has a large range of stakeholders with very different and, potentially, conflicting objectives. Furthermore, governance systems are fractionated into different tiers of government and local bodies, making a co-ordinated approach to management difficult. Furthermore, the adaptive management loop may show up the benefit of an action at totally different time and spatial scales than was originally intended. In fact, due to the long-term nature of some climate adaptations, the system response to an action may be well beyond the life cycle of a management body. Consequently, comprehensive adaptation strategies need a vision that embraces multiple scales and leads to decisions and actions that embrace multi-scale understanding.

5: Ensure Fair, Representative and Equitable Stakeholder Engagement

Comprehensive stakeholder engagement is important to achieve natural resource outcomes in the context of adaptation to Climate Change. Engagement of all stake-holders in strategy development in a participatory approach combining top-down and bottom-up perspectives provides both a richer suite of perspectives and legitimacy through participation and consideration of stakeholder aspirations. Stakeholder involvement needs to occur from beginning to end to ensure translation of large scale objectives to local solutions. Keeping stakeholders engaged requires facilitation of on-going stakeholder interest and involvement through mentoring and championing, and ensuring they are intimately involved in decision-making.

6: Harmonise legislation, policy and actions to achieve large-scale, long-term public benefits

Harmonising actions and public benefit will involve increasing the concordance between the scales at which ecological and biophysical processes occur, the scales at which legislation and policy are made (central government), and the scales where actions are taken (local governments/regional bodies).

7: Effective Governance that is clear, consistency and complementary

The complexity of governance relating to Climate Change, and responses to it, means there is a need for clarity, consistency and complementary in defining responsibilities and policy implementation of different management/governance authorities. Consequently, substantial success requires integration of top-down (State, Commonwealth) policies and legislation, and bottom-up (local, community) level actions; together with a clear definition of roles and responsibilities.

8: Focus on achievable and realistic delivery of adaptation strategy outcomes and outcome-support tools

Do no fixate on different frameworks; this is a side-track and the strict structure of a framework can lead to unrealistic outcomes. Rather, concentrate on what is needed for the task at hand and only choose a framework if it helps achieve a specific, realistic and achievable outcome.

9: Optimise outcomes by employing adaptive feed-back cycles appropriately

Adaptation options that include adaptive management cycles should be seen as the "normal" way to do business: flexible adaptive management that allows whole of system approach across different management levels. An adaptive framework should be adopted because, although complex relationships between cause and effect (a “wicked problem”) usually mean that optimal solutions are impossible, adaptive frameworks allow movement towards a defined goal.

Extension and Adoption

During the project communication and extension was via one-on-one meetings with key stakeholders from across the management spectrum. In addition, project components were cycled through proponents from management and science for comment and feedback. Additional face to face communication occurred during the interview process with key climate change protagonists.

Communication to the scientific community is primarily through papers that are submitted or in preparation for submission to peer reviewed international journals. The project report will be distributed to management agencies and fishing industry peak bodies, and the report and appendices will be publically available on the maintained web sites: coastalclimateblueprint.org.au and http://research.jcu.edu.au/research/tropwater/resources/tropical-ecosystem-research, which will provide the primary source of on-going extension and communication.

Glossary

Adaptation strategy	the large-scale conceptual vision of alternative adaption pathways.
Adaptive capacity	the potential or capability of a system to adapt to climatic stimuli.
Common Goods	resources that are non-excludable but are rivalrous (one person's use subtracts from another's use) (Ostrom 1990).
Estuarine and Coastal Marine Ecosystems (ECMEs)	estuaries, nearshore marine waters, tidal wetlands and coastal freshwater wetlands.
Exposure	the extent to which specific events are likely to affect the system.
Optimum Expected Utility (OEU)	assumes the likelihood of a particular outcome can be described by a single probability distribution, leading to a predictable link between action and effect (Lempert & Collins 2007).
Precautionary Approach (PA)	where decision makers aim to prevent future harm when the causal link between action and outcome is unclear (Lempert & Collins 2007).
Private Goods	resources that are rivalrous (consumption by one individual prevents consumption by another) and excludable (access is limited to particular individuals) (Drake *et al.*, 2013).
Public Benefits	benefits stemming from resources that are available to all (Public Goods and Common Goods), as opposed to Private

	Benefits that accrue from the possession of resources where access is limited to particular individuals (Private Goods) (Drake *et al.,* 2013).
Public Goods	goods that are non-excludable (available to all) and non-rivalrous (benefits all equally) e.g. level of environmental quality (Drake *et al.,* 2013).
Resilience	the capacity of a system to absorb disturbance and reorganise while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks
Resilience	the capacity of a system to rebound or recover from a stimulus: to retain identity and function in the face of disturbance & change (Folke *et al.,* 2010)
Responsiveness	the degree to which a system reacts to stimulus
Risk	the likelihood of negative outcomes relative to consequence of the outcome
Robust Decision Making (RDM)	based on the idea that where outcomes are uncertain it is best to use robustness rather than optimality as a decision criterion, to characterise uncertainty with multiple representations of the future, and to select strategies that perform acceptably across the range of plausible outcomes (Lempert *et al.,* 2010).
Robust Strategy (RS)	a strategy that is insensitive to uncertainty about specific outcomes (Lempert & Schlesinger 2000).
Robustness	the maintenance of system characteristics despite fluctuations in the behaviour of its component parts or its environment (Anderies *et al.,* 2004)
Sensitivity	degree to which a system is affected by, or responsive to, stimuli
Socio-Ecological Systems (SESs)	the interaction of biophysical and social factors in a resilient and sustainable manner (Redman *et al.,* 2004).
Vulnerability	degree to which a system is susceptible to damage or harm: a function of the character, magnitude and rate of exposure; sensitivity; adaptive capacity
Wicked problem	a problem that is resistant to resolution because complex relationships between cause and effect. Wicked problems usually feature incomplete or contradictory knowledge and/or have complex interdependencies meaning attempts to solve one aspect of the problem can expose or create other problems (Hulme 2009).

Project materials developed

Peer-reviewed papers

Submitted

Bradley, M, L. Dutra, I. van Putten, I. Sporne, P. Dale, C. Dichmont, R. Bustamante, M. Sheaves. Marine Climate Change adaptation planning in Australia's coastal councils: An assessment of progress. *Marine Policy*

Dichmont, C.M., Deng, R.A., Sheaves, M., Bustamante, R., van Puten, I. Dutra, L., McLean, N., Dale, P., Sporne, I., Savina-Rolland, M. Which estuarine climate adaptation tool suits your needs? A review and assessment of tools to support climate adaptation for estuaries. *Regional Environmental Change*

In preparation

Dutra, L.X.C. E. Ligtermoet, I. van Putten, I. Sporne, P. Dale, C. Dichmont, R. Bustamante, M. Sheaves. Attributes of governance that strengthen adaptive capacity in the coastal zone

Dutra, L.X.C. E. Ligtermoet, I. van Putten, I. Sporne, P. Dale. Attributes of social-ecological systems that support effective co-management arrangements: a case study from Northern Australia

Sheaves, M, R. Bustamante. C. Dichmont, L. Dutra, M Savina-Rolland, M., I. van Putten, I. Sporne, P. Dale Estuaries dynamics and cross-systems linkages under Climate Change.

Sheaves, M, R. Bustamante. C. Dichmont, M. Brians. Projected impacts on Australia's estuarine nekton assemblages, ecosystem linkages and productivity in the face of Climate Change.

Reports (available on coastalclimateblueprint.org.au)

A Synthesis of Current Knowledge of Climate Change Impacts on Australia's Estuaries

Developing and Testing a Purpose-Designed Mechanistic Climate Change Adaptation Framework

Environmental Governance: Barriers and Bridges to the Long Term Protection of Coastal Fisheries

Using Expert Opinions to Elicit Enablers and Limitations for the Adaptive Management of Estuaries and Waterways under Climate Change.Assessment of Local Government Progress in Marine Climate Change Adaptation in Australia

Adaptation Strategies for Optimised Public Benefits from Australia's Estuarine and Coastal Marine Ecosystems: 9 Principles

Review and Assessment of Tools to Support Climate Adaptation for Estuaries

A Checklist for Developing Effective Adaptation Strategies for Australia's Estuary Ecosystems

Appendices

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Supporting documents

Appendix 1: Environmental Governance: Barriers and Bridges to the Long Term Protection of Coastal Fisheries

Appendix 2: Using Expert Opinions to Elicit Enablers and Limitations for the Adaptive Management of Estuaries and Waterways under Climate Change

Appendix 3: Assessment of Local Government Progress in Marine Climate Change Adaptation in Australia

Appendix 4: Adaptation Strategies for Optimised Public Benefits from Australia's Estuarine and Coastal Marine Ecosystems: 9 Principles

Appendix 5: Review and Assessment of Tools to Support Climate Adaptation for Estuaries

Appendix 6: A Checklist for Developing Effective Adaptation Strategies for Australia's Estuary Ecosystems

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Appendix 1: Environmental governance: barriers and bridges to the long term protection of coastal fisheries

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FRDC Project No **2011/040**

Executive Summary:

This report examined governance issues influencing adaptation of Australian coastal fisheries to climate change and environmental pressures experienced in the estuarine and coastal zone, in particular in the context of loss and degradation of coastal habitat.

In Australia, three tiers of government and numerous non-governmental bodies have created a range of administrative, political, regulatory and strategic frameworks to enable management and sharing of land and environmental resources. These arrangements form a complex and dynamic governance system with many decision-making bodies performing complementary, overlapping and also conflicting regulatory and management roles.

Adaptation strategies cannot be designed in isolation and need to take into account existing governance frameworks. To this end this report had two major objectives:

(1) to provide information on the current distribution of roles and responsibilities among the key groups of actors in the management of Australia's environment and underpinning policy and regulatory frameworks;
(2) To identify opportunities and challenges the current governance system presents for the design and implementation of climate change adaptation strategies of coastal fisheries.

The report was based on a desktop study. It drew on a range of formal primary sources, in particular legislation, agreements, and policy and strategy documents. It also examined various secondary sources such as government reports, commissioned research studies, government websites and, to a lesser degree, academic publications.

The first part of the report focused on the review of established governance arrangements at the national, state, regional, local and individual levels. It examined distribution of decision-

making roles and responsibilities in relation to natural resource management. The second part examined regulatory and administrative frameworks structuring management and conservation of fisheries resources in five Australian States and Northern Territory.

By placing established administrative and regulatory frameworks of Australian coastal fisheries in the broader governance context this report distinguished five major factors that require consideration to pursue long term protection of ecological assets to sustain provision of fisheries resources. These include:

(1) shared strategic goals and frameworks supporting identification, planning and management of coastal, estuarine and connected freshwater habitats;
(2) clear distribution of roles and responsibilities and allocation of the lead role (mandate) with regard to the management and protection of ecological assets ;
(3) recognition of sectoral interdependencies or 'connectivity' of environmental governance structures and regulatory frameworks;
(4) collection and distribution of revenues to support involvement of relevant governance actors taking into account their roles, interests and capacities;
(5) Development and application of incentive mechanisms to promote restoration and conservation of fisheries habitats, including on private land.

Contents

1. Introduction

1.1. Background

Intense use of land and extractive natural resources to support primary industries, growing population, urban and industrial development and extreme weather events are well known pressures to Australian ecosystems (SOEC 2011). These cumulative effects combined with changing climatic conditions are affecting and will continue to affect coastal fisheries. Key strategies to offset these pressures involve increased protection and rehabilitation of existing habitats, and construction of new fish habitat areas (Sheaves et al. 2014).

Protection of fisheries habitats in the coastal zone and estuaries encounters a wide range of challenges. Primary industries and urban and industrial development compete for valuable land resources (SOEC 2011). Resulting effects such as dredging, chemical and nutrient pollution, damages to marine, riverine and riparian vegetation, water extraction, diversion of water streams, and construction of artificial barriers substantially alter ecological processes with flow on effects on coastal fish stocks (Sheaves et al. 2014). Accumulating pressures require the design and implementation of effective governance responses.

Climate change adaptation strategies cannot be designed in isolation. They need to be embedded in administrative and regulatory frameworks of the current governance system and build on accumulated capacities. Australian governance is a complex multi-level system involving a large diversity of actors with different roles and responsibilities. While it tends to be criticised as ineffective, fragmented, complex, and convoluted, few attempts have been made to unpack the complexity (see e.g., Dovers and Wild River 2003) and provide insight into different opportunities and challenges it presents for particular resource management problem.

1.2 Objectives

This report is prepared for the project Estuaries and Coasts: adaptation options for a changing climate (FRDC 2011/040) to support formulation of the core principles and assist development of adaptation strategies to various pressures experienced in the estuarine and coastal zone, in particular in the context of loss and degradation of coastal habitat. The core objectives of the report are to:

(1) provide information on the current distribution of roles and responsibilities among the key groups of actors in the management of Australia's environment and underpinning policy and regulatory frameworks;
(2) Identify opportunities and challenges the current governance system presents for the design and implementation of climate change adaptation strategies of coastal fisheries.

1.3 Approach and limitations

This report is a desktop study. Discussed problems are primarily derived from the analysis of documentary sources, in particular, legislation, agreements, policy and strategy documents and government reports. Data derived from interviews, conducted within the scope of the project and personal communication have been used to assist with the analysis of documentary sources.

This report is presented with two major limitations. First, Australian environmental governance is a highly complex and dynamic system. It comprises three tiers of government having different regulatory powers and a large number of management bodies both governmental and private performing different environmental planning and management functions. This report cannot cover in detail each jurisdiction and different socio-political, economic and environmental factors which have contributed to the present governance arrangements. Instead, it presents a series of examples illustrating how respective management problem(s) have been approached in one or several jurisdictions. Consequently, additional studies may be required to examine the extent of identified problems in particular jurisdictions and their effects on adaptation potential of coastal fisheries.

Second limitation relates to the scope of addressed pressures and related governance responses. There is a wide range of pressures affecting coastal fisheries. This report, however, focuses on governance problems related to the protection of marine, tidal and riverine habitats and maintenance of catchment-to-coast habitat connectivity. Other problems requiring governance responses such as overfishing, pest eradication, point and non-point source chemical and nutrient pollution are not addressed in this report. These issues have been already covered in state of environment and other government reports (GBRMPA 2001, SEQHWP 2007, SOEC 2011).

1.4 Structure

The report is divided into four major sections:

- Section 2 outlines the overall context of the power distribution among the three tiers of government in Australia and their revenue raising capacities and sources;
- Section 3 examines roles and responsibilities of different governmental and non-governmental actors involved in the regulation, distribution and management of land and environmental resources and underpinning institutional frameworks;
- Section 4 explores regulatory and administrative frameworks structuring management and conservation of fisheries resources and habitats in five Australian States and Northern Territory;
- Section 5 identifies five governance factors that require consideration in the achievement of long term protection of ecological assets of coastal fisheries.

2. Setting the context: federation structure

2.1 Foundations of power distribution

The Commonwealth of Australia was formed in 1901 as a result of the agreement between six British colonies New South Wales (NSW), Queensland, South Australia (SA), Tasmania, Victoria and Western Australia (WA) which subsequently became separate states. Commonwealth of Australia Constitution Act 1900 (Australian Constitution) came into force on 1 January 1901. Northern Territory (NT) and Australian Capital Territory (ACT) were ceded to the Commonwealth in 1911 and received self-government rights in 1978 (NT) and 1988 (ACT). The legislatures in the two Territories exercise powers delegated by the Commonwealth and the Commonwealth Parliament retains the power to override the legislation (Australian Constitution, s122).

The distribution of legislative powers between the Commonwealth and the States is determined by the Australian Constitution. The legislative power of the Commonwealth Parliament is limited to the 'heads of power' listed in section 51. This section contains[1] 40 subsections each describing a 'head of power' under which the Commonwealth Parliament is authorised to make laws. Among the core legislative powers of the Commonwealth are trade and commerce, corporations, taxation, postal and communication services, quarantine, defence, external affairs, monetary system and immigration. Powers not listed in section 51 remain the legislative domain of the States unless they decide to refer particular matter to the Commonwealth (Australian Constitution, s51 (xxxvii)). This domain includes enactment of legislation providing for natural resource management, environmental conservation and land use planning and development assessment. The States can legislate on the matters listed in section 51. However, in case of inconsistency the Commonwealth law prevails (Australian Constitution, s109).

Local government is the lowest tier of government in Australia. It was created in the 1840's to enable colonial governments to deliver local services (DIRD 2013a). Local government is not recognized in the Australian Constitution. As a result, territorial boundaries, authority, as well as revenue raising capacity of local government are determined by the regulatory framework of the respective State or Northern Territory[2]. Each jurisdiction has separate local government acts that provide the framework for the operation of this tier of government. Legislative functions of most local governments are undertaken by councillors elected by eligible voters. Distinct group in terms of roles and responsibilities are Indigenous local governments, which may operate under different legislation (DIRD 2013a). Currently, there are 565 local governing bodies in Australia (DIRD 2013b).

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[1] Note: this includes section xxiiiA

[2] Note: ACT has only Legislative Assembly which also performs local government functions.

There are no direct power relations between the Commonwealth (Australian) and local governments. While several attempts have been made by the Australian government to gain constitutional recognition of local governments, proposed amendments to the Australian Constitution were not accepted in public referenda (held in 1977 and 1988). Despite the lack of formal recognition, local governments participate in policy-making processes. At the national level, they are represented by the Australian Local Government Association (ALGA) which is a federation of the state and Northern Territory local government associations. This organisation represents interests of local governments on national bodies and ministerial councils and provides forum for local governments to guide national policies (ALGA 2014).

2.2 Revenue sources

One of the core determinants of power relations between the Australian and State/Territory governments has been the taxation system. The major amount of national taxation income under 'taxation' power is collected by the Australian government. For example, in 2010 the Australian government raised 80.3 per cent of Australia's total tax revenue (The Treasury 2013). The major part of revenue came from direct taxation with income tax being the core source. According to The Treasury (2013), in 2012-13 income tax represented around 74.4 per cent of total taxation receipts. The remaining part has been derived from indirect taxation which includes the goods and services tax, petroleum and other excise, customs duty and property taxes (see Figure 1 below).

The States and Territories have retained some rights to collect taxes. While developed taxation systems differ, core sources of their tax revenue are payroll taxes and stamp duties or taxes on property transfers. Among other sources are taxes on insurance, gambling and motor vehicle registration (ABS 2013). In addition, all States and Northern Territory collect royalty revenue from mining. In 2011-12 this source represented 8.9 per cent of own revenue (CGC 2013). The income collected by the States and Territories is insufficient to finance expenditures. As a result, the Commonwealth grants form about 45 per cent of total state government revenue (The Treasury 2013).

Section 96 of the Australian Constitution allocates the right to the Commonwealth to provide financial assistance to the States. Over the years, both taxation and financial assistance powers have given the Australian government a good position to shape the policies of the States in exchange for funding (Williams 2005). These powers have been also applied to implement the Commonwealth and national policies and strategies in the resource management sector (see section 3).

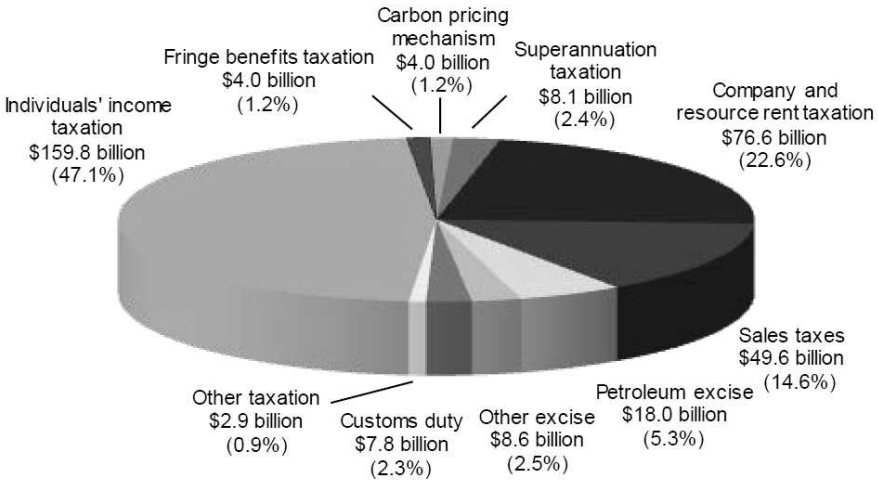

Figure 20: Figure 1: Australian Government Tax Mix, 2012-13: Source: The Treasury (2013:6)

The current fiscal relations between the Commonwealth and the States and Territories are based on two major reforms. In 2000, the Commonwealth government introduced Goods and Service Tax (GST) which is a value added tax of 10 per cent on most transactions with goods and services. While centrally collected, all of the GST revenues are distributed by the Commonwealth Grants Commission (CGC) to the States and Territories as unconditional (untied) grants.

In 2008, the Commonwealth, State and Territory governments signed the Intergovernmental Agreement on Federal Financial Relations (IAFFR). According to the Agreement (clause 19) the Commonwealth government commits to provide ongoing financial support for the States' and Territories' service delivery through:

> '(a) general revenue assistance, including the on-going provision of GST payments, to be used by the States and Territories for any purpose;
>
> (b) National Specific Purpose Payments (SPPs) to be spent in the key service delivery sectors;
>
> (c) National Health Reform (NHR) Funding; and
>
> (d) National Partnership payments to support the delivery of specified outputs or projects, to facilitate reforms or to reward those jurisdictions that deliver on nationally significant reforms.'

The IAFFR includes separate agreements appended as schedules which specify particular financial arrangements.

Local governments have their own source of revenue. Most part of the revenue comes from property rates and the fees and charges for provided goods and services (DIRD 2013a). Rates are the only tax instrument available to local governments. They are applied to fund provision of public goods and services required by local communities (e.g., local roads and bridges, drainage, street lighting). Local governments impose other property related charges for provided services such as water, sewerage and waste

collection. Other sources of revenue are administration fees (e.g., development assessment), fees for land clearing, parking, camping and use of community facilities. Local governments can also apply special levies to cover the costs of particular works or services (e.g., public parks, roads) (Productivity Commission 2008). The allowable sources of income, calculation methods, exemptions and concessions are determined by the legislation of the States and Territories.

In 2010-2011, local government's revenue accounted for about 2.7 per cent of Australia's gross domestic product. Taxation revenue amounted to 3.5 per cent of all taxes raised across all levels of government. Aggregated at the national level, local governments raised around 90 per cent of their own revenue with grants and subsidies making only 10 per cent of income (DIRD 2013a).

At the individual level, local governments vary considerably in their revenue raising capacity. According to Productivity Commission (2008) urban councils were predominately funded from their own sources whereas in most rural and remote councils State/Territory and Commonwealth grants formed substantial part of the revenue (44 per cent and more). Over the last two decades the State and Northern Territory governments have implemented several amalgamation reforms aimed to reduce local government numbers to increase their economic efficiency (DIRD 2013a).

The problem of financial sustainability of local governments has been raised at the national level. In 2003, the report by the House of Representatives Standing Committee on Economics, Finance and Public Administration (SCEFPA) pointed to insufficiency of local government resources to cover the costs of services required by the communities and those mandated (devolved) by the State and Territory governments. Among the main reasons for increases in local government expenditure the report identified a range of 'cost-shifting' strategies employed by the State governments resulting in devolution of their responsibilities without adequate financial support (SCEFPA 2003). In 2006, the ALGA, the Commonwealth and State/Territory governments signed the Intergovernmental Agreement on Establishing Principles Guiding Inter-Governmental Relations on Local Government Matters. The Agreement provides the framework for the delivery and funding of services provided by the local government on behalf of other levels of government.

The Australian Constitution does not provide the Commonwealth with power to directly fund local governments. Notwithstanding that, since the 1970's the Commonwealth government provides regular financial assistance directed to support local governments in form of general purpose and special purpose (local roads) grants. Currently, this assistance is regulated under the Local Government (Financial Assistance) Act 1995. Grants are paid to the State governments which pass them to the local governments based on the recommendations of local government grants commissions (DIRD 2013a). Commonwealth government periodically provides for other funding directed to support particular local government initiatives (DIRD 2013b). Local governments also participate in the implementation of national policies and programs supported by federal funding.

3. Environmental governance: roles, responsibilities and institutional framework

3.1 The Commonwealth

3.1.1 Power Distribution

Environmental problems were not of particular concern in the federation-building period. As a result, the Commonwealth (Australian) government has limited direct powers in relation to the distribution and management of environmental resources. The Australian Constitution allocates only one head of power to the Commonwealth Parliament which is ‘offshore fisheries’ described as ‘fisheries in Australian waters beyond territorial limits’ (s51(x)). At the same time, several indirect heads of power have given the Commonwealth considerable influence in environmental matters. Over the history, these matters have been subject to various jurisdictional disputes with the Commonwealth applying ‘the interstate trade and commerce’ (s51(i)), ‘the corporations’ (s51(xx)) and ‘the external affairs’ (s51(xxix)) powers to override the State regulation.

Of particular importance in power distribution has been ‘external affairs’ power which enables the Commonwealth Parliament to pass the legislation to implement obligations under international agreements. Australia is a contracting party of many international agreements addressing environmental problems. They include: Convention on Biological Diversity 1992, United Nations Framework Convention on Climate Change 1992, Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973, Convention on Wetlands of International Importance especially as Waterfowl Habitat 1971 (Ramsar Convention), Convention concerning the Protection of the World Cultural and Natural Heritage 1972, International Convention for the Regulation of Whaling 1946, Vienna Convention on the Protection of the Ozone Layer 1985 and United Nations Convention on the Law of the Sea (UNCLOS). Growing global environmental concerns and subsequent expansion of the scope of international agreements have significantly expanded the power and responsibilities of the Commonwealth government in these matters.

In the 1970’s several jurisdictional disputes emerged regarding the exploitation of marine resources. In line with UNCLOS, in 1973 the Commonwealth Parliament passed the Seas and Submerged Lands Act 1973 which established the Commonwealth jurisdiction over all territorial waters, sea bed and air space. The act and subsequent High Court decision in 1975 triggered negotiations between the Australian government and the States on a range of policy matters including seabed minerals, shipping, marine pollution and fishing. In 1979, the Commonwealth and the States arrived at so called 'Offshore Constitutional Settlement' (OCS) determining the jurisdiction over marine resources. In 1980 the Commonwealth passed the Coastal Waters (State Powers) Act 1980 extending the legislative powers of the States in relation to coastal waters.

Under the OCS, the Commonwealth controls the Exclusive Economic Zone (EEZ) extending from 3 to 200 nautical miles. The States generally have jurisdiction over marine areas from the low water mark to three nautical miles offshore. The exception is the matters relating to the Commonwealth international obligations. Consequently, the States and the Northern Territory have responsibility for the management of extractive resources in coastal waters, which includes coastal recreational and commercial fishing and aquaculture. The Commonwealth controls and manages fisheries in the EEZ. This power distribution has led to a range of intergovernmental agreements where the management of some of the fisheries or fish stocks has been transferred to a single jurisdiction or has been conducted under a joint authority agreement (e.g. northern prawn fisheries, Dichmont et al. 2013).

Since the 1990's the Commonwealth and the States have adopted a more cooperative approach in resolving jurisdictional disputes (Bates 2003). Significant change in the intergovernmental relations occurred with the establishment of the Council of Australian Governments (COAG). The COAG was established in 1992 following the agreement between the Australian Prime Minister and Premiers and Chief Ministers of the States and Territories. Over the years, the COAG has become a core governmental forum for coordination of powers and responsibilities between the Commonwealth and State and Territory governments on issues of national or cross-jurisdictional importance, including environmental matters.

In 1992, two major agreements have been reached by the COAG setting the foundation for the current environmental governance. The first was the Intergovernmental Agreement on the Environment (IGAE) concluded between the Commonwealth and all State/Territory governments and the ALGA aiming to define 'the roles, responsibilities and interests of all levels of the Government in relation to the environment' (clause 2.1.1). The second was the National Strategy for Ecologically Sustainable Development (the National ESD Strategy) endorsed by the COAG in December 1992. The National ESD Strategy defined the concept of 'ecologically sustainable development' (ESD), formulated core principles and provided a broad framework for the development and implementation of environmental policies across different sectors.

The IGAE is key intergovernmental agreement specifying roles, responsibilities and interests of all tiers of government in environmental matters. According to the agreement the Commonwealth Parliament retains the responsibility for the management of environmental resources on Commonwealth land and for 'national environmental matters' which according to clause 2.2.1 include:

> '1. Matters of foreign policy relating to the environment and, in particular, negotiating and entering into international agreements relating to the environment and ensuring that international obligations relating to the environment are met by Australia;
>
> 2. ensuring that the policies or practices of a State do not result in significant adverse external effects in relation to the environment of another State or the lands or territories of the Commonwealth or maritime areas within Australia's jurisdiction (subject to any existing Commonwealth legislative arrangements in relation to maritime areas);

3. Facilitating the co-operative development of national environmental standards and guidelines as agreed in Schedules to this Agreement.'

The States and Territories retain full responsibility 'for the development and implementation of policy in relation to environmental matters which have no significant effects on matters which are the responsibility of the Commonwealth or any other State' (clause 2.3.1).

3.1.2 Legislative and policy framework

Based on established power distribution, in 1999 the Commonwealth Parliament enacted the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). The Act declares the matters of Commonwealth concern including matters of national environmental significance. The EPBC Act regulates identification of threatening processes, environmental impact assessment and approvals of projects having a significant impact on national environmental matters. As of 2013, there are nine matters of national environmental significance, namely:

- world heritage properties,
- national heritage places,
- wetlands of international importance (i.e., 'Ramsar wetlands'),
- nationally threatened species and ecological communities,
- migratory species,
- Commonwealth marine areas,
- the Great Barrier Reef Marine Park,
- nuclear actions (including uranium mining),
- water resources in relation to coal seam gas and large coal mining development.

Important part of national environmental policy is state of environment (SoE) reporting. Introduced by the National ESD Strategy, provisions for the state of environment (SoE) report have been incorporated in the EPBC Act. The Act requires the Minister to prepare and table before the Parliament 'a report on the environment in the Australian jurisdiction' every 5 years (section 516B). The report is prepared by an independent committee and its scope is determined by the responsible Commonwealth department (DOE 2014a). In general, reports follow 'drivers-pressures-states-impacts-responses' framework (OECD 1993) identifying current condition of the environment and its resources, the pressures determining the condition, implemented management responses and their impacts (DOE 2014a). The Sate and Territory governments prepare their own state of environment reports.

Apart from the EPBC Act there is a range of other Commonwealth statutes regulating environmental matters. Several statutes regulate the marine environment and its resources. In 1975, the Commonwealth enacted Great Barrier Reef Marine Park Act 1975 which provides for direct Commonwealth responsibilities in managing the Great Barrier Reef. The Fisheries Management Act 1991 is the overarching statute providing for the management of Commonwealth fisheries resources. Other statutes addressing marine areas are the Antarctic Treaty (Environment Protection) Act 1980, Antarctic Marine Living Resources Conservation Act 1981, Environment Protection (Sea Dumping) Act 1981 and Sea Installations Act 1987.

Both the IGAE and the National ESD Strategy set foundation for a range of other national environmental policies. Over the last two decades, the Commonwealth government and the COAG have introduced a range of policies, strategies and frameworks aiming to develop uniform approaches to national environmental problems. While not formally enforceable, they have triggered changes in the legislation and environmental policies of the States and Territories. Implementation of national policies and agreements often has been supported by various programs and Commonwealth funding. Box 1 provides a brief description of several national initiatives relevant to the coastal zone and management and conservation of fisheries resources and habitats.

Box 1 - National environmental policies and agreements

Agreement on Water Resource Policy (AWRP) 1994, National Water Initiative (NWI) 2004

In response to increasing environmental degradation and competition for scarce water resources the AWRP provided the framework for a comprehensive reform in water resource management. Major elements of the reform were the establishment of water markets and water rights, recognition of the environment as legitimate water user and separation of service delivery and resource management functions. The implementation of the AWRP became the part of the *National Competition Policy* (NCP) endorsed by the COAG in 1995.

The NWI continues the reform. Established through the *Intergovernmental Agreement on a National Water Initiative*, the NWI aims to introduce a nationally compatible and adaptive water planning and market system. The NWI sets out a number of objectives which among others include: integrated ground and surface water planning, nationally compatible water access entitlements, open water markets, resolution of water over allocation and overuse and improved environmental outcomes. The reform is implemented under the supervision of the National Water Commission established under the *National Water Commission Act 2004* (NWC 2014).

Commonwealth Coastal Policy (CCP) 1995

The policy was the Commonwealth response to the report of the Resource Assessment Commission *Coastal Zone Inquiry* identifying ongoing degradation of Australian coastal zone. The policy aimed to promote the ecologically sustainable use of Australia's coastal zone and identified specific objectives: sustainable resource use, resource conservation, public participation and knowledge and understanding. The policy set out an action program (National Coastal Action Plan) to achieve practical improvements in coastal management covering four broad areas: community involvement in coastal management; coastal development and pollution; awareness, education and knowledge improvement and promotion of coastal management expertise (Commonwealth of Australia 1995). Implementation of the policy was supported by several programs, including Coastcare and Coasts and Clean Seas program, and Commonwealth funding. As CCP was Commonwealth policy, it did not oblige the States and Territories to support its implementation. The policy was implemented through memoranda of understanding negotiated between the Commonwealth and respective State governments. The MOUs and programs were abolished in 2002 (SCCCWEA 2009).

National strategy for the conservation of Australia's biological diversity (National Biodiversity Strategy) 1996, Australia's Biodiversity Conservation Strategy 2010–2030

Endorsed in 1996 by the COAG the National Biodiversity Strategy aimed to fulfil Australia's obligations under the Biodiversity Convention. Pursuing the aim 'to protect biological diversity and maintain ecological processes and systems' the Strategy identified six key target areas: conservation of biodiversity across Australia, integration of biodiversity conservation and natural resource management, management of threatening processes, knowledge improvement, community involvement, and implementation of Australia's international role (ANZECC 1996:11).

In 2010, this strategy was replaced by the *Australia's Biodiversity Conservation Strategy 2010–2030.* The new Strategy contains three priorities for actions: (1) engaging all Australians in biodiversity conservation; (2) building ecosystem resilience in a changing climate; and (3) getting measurable results. It is supported by 10 interim national targets for 2015 (NRMCC 2010).

National Oceans Policy (NOP) 1998

The NOP was launched in December 1998. The policy established a framework for the application of sustainable development principles to the management of Australia's oceans and outlined a new national approach for ecosystem-based management. The policy provided for the development of regional marine plans to integrate industry interests with conservation requirements and achieve ecosystem-based allocation of resources. The development of a National Representative System of Marine Protected Areas (NRSMPAs) was part of the regional marine planning process. NRSMPA framework set foundation for marine bioregional planning through which the governments identify areas for inclusion within a National Representative System of MPAs. Funding has been provided to support rapid assessment of the biological resources of the ocean and human pressures (DOE 2014b).

Framework for a National Cooperative Approach to Integrated Coastal Zone Management (NCAICZM) 2006

The NCAICZM was endorsed in 2006 by the Natural Resource Management Ministerial Council (NRMMC). The framework places emphasis on integrated management of Australian coastal zone. It provides a national policy framework and action plan aiming to protect coastal and estuarine water quality, coastal biodiversity and the economic based of coastal areas. Implementation plan sets out strategic priority areas, implementation objectives and actions required to address coastal management issues (NRMMC 2006).

While the overall coordination is achieved through the COAG, a range of administrative bodies have been created to oversee the development and implementation of national strategies and policies. Among the management bodies coordinating national environmental policies are the National Environment Protection Council (NEPC), Natural Resource Management Ministerial Council (NRMCC), Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and related working groups and committees. These councils also cooperate with non-governmental organizations and community groups (Australian Government 2009).

3.1.3 Funding

There is a variety of funding arrangements supporting the implementation of national policies. In the last two decades the most extensive funding commitment of the Australian government has been Natural Heritage Trust (NHT). In 1997 the Commonwealth Parliament enacted the Natural Heritage Trust of Australia Act 1997 (NHTA Act) with the main objective to establish the account 'to conserve, repair and replenish Australia's natural capital infrastructure' (s3).

The Natural Heritage Trust (NHT), a large funding program, was created under the NHTA Act. In the period from 1997 to 2008, the NHT provided funding of $3.1 billion for projects to restore and conserve Australia's environment and natural resources. The NHT operated as an umbrella for a range of programs such as National Landcare Program, Farm Forestry Program, National Rivercare Initiative, Murray-Darling 2001 Initiative, Endangered Species Program, National Reserve System Program. In 2008, NHT was consolidated into funding program Caring for Our Country with a budget of $2.25 billion over five year period (2008–2013) (SOEC 2011). The NHT and subsequent arrangements have been implemented in partnership with State and Territory governments.

The Commonwealth government is also the initiator and funder of research. The fields include primary industries, natural resources, population trends and climate. National data services are funded through the Bureau of Meteorology. The government

supports several research organisations including the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Australian Institute of Marine Science (AIMS), Geoscience Australia, and the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES).

3.2 States and Territories

The States and Territories (further referred to as 'the States') play the central role in Australian environmental governance. They have constitutional responsibility for the regulation of environmental resources under their jurisdiction. As a result, the States control distribution and use of most of the land and extractive environmental resources in Australia.

Each jurisdiction has developed different legislative and administrative frameworks. The overall system is extensive and cannot be covered within the scope of this report. Therefore, this section addresses common arrangements underpinning resource allocation and use. While there is no formal classification, for the ease of the review all regulatory frameworks are divided into three major groups: (1) frameworks establishing the system of resource use rights; (2) frameworks providing for resource distribution and planning; (3) frameworks providing for regulation of multiple/conflicting uses of environmental resources.

3.2.1 Resource rights

British Colonies in Australia adopted common law and statutory legislation of the United Kingdom. At the time of settlement, the doctrine of 'terra nullius' (i.e., 'land belonging to no one') was applied with regard to Australian land. The land ownership was vested in the Crown. Over the years, the Crown (i.e., the governments representing the Crown) granted interest in land to the settlers. As a result, two major types of land tenures have evolved: freehold land and Crown leasehold land. Until the 1970's Indigenous Australians were not acknowledged as rightful land owners and did not have land right (see section 3.4 for land ownership).

While common law provides for general principles of land ownership, all States have statutory systems providing for land rights. These systems define the scope of interest in land, associated restrictions, registration, as well as transfer of rights. For example, Queensland has two separate acts regulating land rights. The Land Title Act 1994 (Qld) provides for registration of freehold title. Administration, management and transfer of non-freehold land are regulated under the Land Act 1994 (Qld). This Act provides for several types of tenures of non-freehold land and contains provisions regarding land allocation, administration, use, terms of holding and transfer of rights. Similar regulatory frameworks exist in other jurisdictions (e.g., Crown Land Act 1989 (NSW), Land Administration Act 1997 (WA), Land Act 1958 (Vic) and Crown land (Reserves) Act 1978 (Vic), Crown Land Management Act 2009 (SA)).

In Australia, significant portion of terrestrial land resources is under the management of State governments (see Table 1). Part of the land is reserved for public purposes as a Crown (public) land and is managed by the State and, to a lesser extent, the Commonwealth and local governments in public interest. Public land includes the

land reserved for such uses as nature conservation, Aboriginal land, forestry, marine conservation, water resources, mining and defence. Public land is also a vacant Crown land which is available for distribution to potential users (Geoscience Australia 2011). Other Crown land which generally cannot be granted in private ownership is the land under watercourses and the land below high water mark (see e.g., Land Act 1994 (Qld)).

Table 13: Land Tenure in Australia 1993.

TOTAL LANDS CATEGORY (1993 data)	**(thousand square kilometres)**									
	QLD	**NSW**	**VIC**	**SA**	**WA**	**NT**	**TAS**	**ACT**	**TOTAL**	**% of Australia**
Public	118.0	85.7	72.3	217.6	1095.0	137.2	40.6	1.5	1767.9	23.0%
Private	1567.0	714.4	155.3	576.8	1105.0	673.0	27.2	0.9	4819.6	62.75%
Freehold	627.2	405.5	155.2	158.4	205.1	6.4	27.2	-	1585.0	(20.6%)
Crown leasehold	939.8	308.9	0.1	418.4	899.9	666.6	-	0.9	3234.6	(42.1%)
Aboriginal & TSI*	42.2	1.5	-	189.6	325.5	536.0	-	-	1094.8	14.25%
Freehold	20.5	0.4	-	189.0	-	516.8	-	-	726.7	(9.5%)
Crown leasehold	18.9	1.1	-	0.6	126.1	19.2	-	-	165.9	(2.1%)
Reserve	2.8	-	-	-	199.4	-	-	-	202.2	(2.6%)
TOTAL	**1727.2**	**801.6**	**227.6**	**984.0**	**2525.5**	**1346.2**	**67.8**	**2.4**	**7682.3**	**100**

*TSI – Torres Strait Islanders
Source: Adapted from Geoscience Australia (2011)

Granted interest in land is not absolute. In all States the Crown retains the interest in minerals and other mining resources that lie on and under the land surface. The State governments on behalf of the Crown can grant this interest irrespective of established private interest (freehold or leasehold) in land (see e.g., Mineral Resources Act 1989 (Qld), s8). Each State has its own regulatory framework providing for allocation of mining exploration permits and leases. In practice, apart from specifically restricted areas such as national and conservation parks, places of culture heritage, water supply catchments or urban settlements, little restrictions exist for allocation of mining rights (see e.g., Mining Act 1992 (NSW) s252).

Over the settlement history, the States have progressively vested ownership of other natural resources in the Crown. Water, fish and other wildlife are owned by the Crown. In addition, the Crown reserves certain rights associated with the leasehold land. In pastoral leases this typically includes ownership of timber and soil

(Productivity Commission 2002). As a result, around 74 per cent of the forest in Australia is administered by the States (ABARES 2011). The State governments, on behalf of the Crown, plan and allocate these resources to the members of the public based on different licencing agreements (Bates 2003).

Resource ownership system became more complex in 1992 with the High Court decision in case Mabo v Queensland (No 2) 1992 175 CLR 1 which rejected the 'terra nullius' doctrine. The High Court recognised a form of 'native title' which had survived the property law in Australia and must be treated equally with other titles. In response, the Commonwealth enacted the Native Title Act 1993 (NTA) to provide for the recognition and protection of native title. 'Native title' acknowledges that Indigenous people have rights and interests in the land and resources originating from their traditional laws and customs. Recognition of 'native title' cannot be granted by the Crown as such right originates in traditional law and custom (Langton 1998).

The recognition of 'native title' had significant implications for established system of resource use rights. The Native Title Act 1993 (NCA) makes extensive provisions for the use of land and other environmental resources where native title is determined to exist. It sets out provisions for acts that affect native title and establishes 'the right to negotiate' with regard to exploration and mining activities on the land subject to native title. According to the NCA, freehold land extinguishes native title. Crown leasehold land, however, can be subject to native title. The NCA specifies detailed requirements for the payment of compensation, if certain acts extinguish or impair native title rights. Each State and Territory has adopted own legislation providing for the regulation of the scope of rights in relation to native title.

3.2.2 Resource allocation and planning

The statutes providing for the allocation of extractive environmental resources differ in their regulatory scope. However, as Bates (2003) summarises, they contain some common features. These include:

- allocation of regulatory authority and associated rights and responsibilities (e.g., responsible Minister),
- creation of new authorities responsible for particular functions (e.g., planning committees, advisory committees, panels, tribunals);
- resource planning, which may include provisions specifying type and content of the management plan, planning and approval process, rights and responsibilities of involved actors;
- resource distribution system, which includes provisions for resource access authorities (e.g., licences, permits) and their application conditions (e.g., resource extraction limit, timing, area, amount, use of technology), rights associated with the resource authority (e.g., transfer of quotas, compensation) and related charges;
- prohibited (e.g., mining in conservation areas) and restricted activities, which adversely affect the resource and require permit from the regulator (e.g., damaging forest resources or marine plants, dredging);
- management of other processes that adversely affect the resource (e.g., management of weed and pest species, land erosion);
- provisions for offences, criminal and civil sanctions and enforcement proceedings;
- conflict resolution mechanisms and processes.

In most jurisdictions, the regulation of resource allocation and planning tends to be 'sectoral'. Almost all groups of resources are managed under separate legislative frameworks. For example, in Queensland, water planning and allocation system is established under the Water Act 2000 (Qld), fisheries are regulated under the Fisheries Act 1994 (Qld), wildlife under the Nature Conservation Act 1992 (Qld) and forest resources (including wildlife in state forests) under the Forestry Act 1959 (Qld). Vegetation clearing on freehold land is restricted under the Vegetation Management Act 1999 (Qld). Allocation and extraction of mineral resources is provided under the Mineral Resources Act 1989 (Qld) and petroleum products - under the Petroleum and Gas (Production and Safety) Act 2004 (Qld). Similar regulatory structures exist in other jurisdictions (see section 4 for the review of fisheries).

In general, the States cover the costs associated with the management of public lands, including management and maintenance of conservation reserves (Australian Government 2009). The States also cover part of the management, monitoring and research costs associated with resource planning and allocation. The revenues come from several sources. As indicated before, mining royalties form significant part of the State and Northern Territory revenues with highest proportion collected by Western Australia and Queensland (CGC 2013). Allocation of other extractive resources such as water, wildlife, forest resources generates revenue in form of different payments (charges, fees, royalties) made for resource access authorities. Revenue associated with land holdings comes from land tax levied on freehold land (not applicable in Northern Territory) and rent payments collected from Crown lease landholders. The States also levy stamp duties on land transactions.

3.2.3 Regulation of multiple uses

Regulatory frameworks providing for multiple uses of resources are established for separate areas. On the one end of the spectrum are regulatory frameworks established for the management of reserve areas with a dominant purpose to protect environmental values or particular resource (e.g., national parks, marine parks, forest reserves). Each State has a legislation portfolio determining declaration, administration, planning and permissible uses of protected areas and other public reserves (e.g., National Parks and Wildlife Act 1972 (SA), Nature Protection Act 1992 (Qld), Marine Parks Act 2004 (Qld), National Parks Act 1975 (Vic)). These frameworks mostly regulate the use of the state reserve land and do not cover water allocation (however, see section 3.4 for private protected areas).

In some jurisdictions, specific regulation aiming to accommodate multiple uses of environmental resources has been established for areas with different tenures. For example, Heritage River Act 1992 (Vic) and Wild River Act 2005 (Qld) provide for the identification and protection of river areas with heritage, scenic and environmental conservation values. The Acts and subordinate legislation prohibit or place restrictions on some land-, water- and vegetation- related management activities that could significantly affect protected attributes. Another example is River Murray Act 2003 (SA) which aims to protect, restore and enhance the River Murray (s6). The Act provides for integrated management of activities that can impact on the river and establishes a referral system allocating to the responsible Minister the power to make decisions on certain resource use or land development activities.

On the other end of the spectrum are planning systems providing for the regulation of areas where the dominant land use adversely affects ecosystems. Commonly, detailed regulation is provided for multiple use areas which involve urban settlements, infrastructure and industrial development. These regulatory frameworks integrate or accommodate environmental interests via development restrictions in particular zones or incorporation of environmental conditions particular types of development must observe. Developments can be also subject to environmental impact assessments. Each State and Territory has own framework providing for the regulation of environmentally relevant activities and environmental impacts (e.g., Environmental Protection Act 1994 (Qld), Protection of the Environment Operations Act 1997 (NSW), Environment Protection Act 1993 (SA)). Activities having impact on the matters of national environmental significance or resources under Commonwealth jurisdiction may trigger application of the EPBC Act.

Broadly, multiple use planning systems can be described as multi-layered systems with different regulatory authorities contributing to the planning outcomes. In the marine context, significant emphasis has been placed on the planning and restoration of the coastal zone (see Box 1). For example, in some jurisdictions (e.g., NSW, Queensland, South Australia) coastal zone management is carried out under separate regulatory framework (see SCCCWA 2009 for detailed review). At the same time planning provisions are embedded in broader land use planning framework creating another overlay in the overall system (Box 2). Different regulatory mechanisms can be applied in integrating different planning layers and development assessment requirements (see e.g., Integrated Development Assessment System under the Sustainable Planning Act 2009 (Qld))

Box 2 – Coastal land use planning in NSW

Coastal development is controlled by provisions of the *Environmental Planning and Assessment Act 1979* (NSW). Planning instruments under the Act include:
- State Environmental Planning Policies (SEPPs),
- Local Environmental Plans (LEPs)

SEPPs and REPs are initiated by State Government. These instruments provide a framework for local councils to prepare their plans that are consistent with the state policies. The planning instrument applicable to the coastal zone is State Environmental Planning Policy No 71—Coastal Protection.

A local environmental plan (LEP) is made by a Local Council, covering a part or whole of a local government area. The LEP outlines the zoning boundaries for different types of land use. A LEP must be approved by the Minister for Planning.

Source: Department of Planning and Infrastructure, NSW

It should be noted that not all development activities are managed as part of integrated planning systems and incorporated in the local government planning schemes. For example, in Queensland mining and port developments are fully controlled by the State government and regulated under separate frameworks. Similarly, planning of the State and national infrastructure is carried out outside the local planning system.

3.3 Regional management bodies

The last three decades in Australia have been characterised by more strategic and 'regional' approach to natural resource management and planning. Centralised, state government led resource planning systems have been supplemented by different regional natural resource management bodies. A characteristic of this trend is broad involvement of community members.

In the end of 1980's beginning 1990's the need for more strategic approach to the land management and planning initiated another set of policy responses under the umbrella of Integrated Catchment Management (see Bellamy et al. 2002 for a review). This shift was marked by an increasing emphasis on the community and government cooperating to solve land degradation problems at the watershed scale. Different catchment management bodies were established in the States having various membership requirements and authority levels (Ewing 2003).

Regional approach to natural resource management was also introduced nationally under two national programs Nature Heritage Trust (see section 3.1.3) and the National Action Plan for Salinity and Water Quality. In the period from 2002-2004 Australian, State and Territory governments agreed on boundaries of 56 natural resource management (NRM) regions. Their operation and legal status was determined through bilateral agreements concluded between the Commonwealth government and respective State and Territory government. Under the NHT the regional community-based management committees received significant responsibilities to deliver NRM outcomes through regional planning (HC Coombs Policy Forum 2011).

NRM management 'landscape' is dynamic and established bodies differ significantly across jurisdictions. In some jurisdictions they have a formal authority. For example, in NSW introduction of the NRM framework was supported by a legislative reform. The Catchment Management Authorities Act 2003 (NSW) established 13 Catchment Management Authorities (CMAs) charged with coordination and catchment management planning functions. CMA's prepared and reviewed Catchment Action Plans (DEAH 2013)[3]. Similarly, formal NRM boards (Catchment Management Authorities) operate in Victoria under the Catchment and Land Protection Act 1994 (Vic). They have primary function to address water quality and land degradation issues in allocated regions. In South Australia vegetation management and water planning functions are undertaken by regional councils established under the Natural Resource Management Act 2004 (SA). In contrast, NRM bodies in Queensland and Western Australia do not have formal authority.

Taking into account diversity of these governance actors in each jurisdiction this report cannot provide a detailed review of their structure and role in Australian environmental governance. One common feature of these bodies is significant dependence on external funding sources. Unlike general purpose governments, regional management bodies do not have separate revenue raising powers to support implementation of their plans. Their operation is dependent on the funding from the

[3] Note: currently CMA's are undergoing major reform.

Commonwealth, State and Territory governments and other contributing sources. To this end, their operation has been volatile with several shifts in direction dictated by the funding body (see HC Coombs Policy Forum 2011).

3.4 Local governments

At the national level, there is no common agreement regarding what environmental matters should be devolved to the local government level. The clause 2.4.1 of the IGAE established the responsibility of local governments for 'the development and implementation of locally relevant and applicable environmental policies within its jurisdiction in co-operation with other levels of Government and the local community'. The agreement also acknowledged that local governments 'have an interest in the environment of their localities and in the environments to which they are linked' (clause 2.4.2). Supporting schedules, however, did not provide for detailed description of rights and responsibilities of this tier of the government.

Australian local governments perform a variety of functions. Their scope is determined by a range of factors such as the State/Territory legislation, revenues, aspirations of local communities, as well as physical, economic and social environments (DIRD 2013a). Among common functions are planning and development approval, construction and maintenance of local infrastructure, management of the recreation areas (e.g., parks and gardens, sports facilities, camping grounds), administration of local government facilities (e.g., libraries, parking stations), public transport, public health (e.g., water or food sampling, noise control) and community services (e.g., aged care, child care) (Productivity Commission 2008).

In the environmental context, the most important regulatory function performed by local governments is land use planning and development assessment. This function is allocated to local governments under respective statutory frameworks providing for land use planning systems (e.g., Environmental Planning Act 1979 (NSW), Sustainable Development Act (Qld)). Consequently, the scope of functions, as well as unilateral rights to decide on appropriate uses of land or development needs to be examined within the context of respective regulatory framework. As outlined previously (see section 3.2.2), planning systems include several levels of planning, which provide for incorporation of the 'matters of state significance'. Notwithstanding that a large number of development decisions in settlement areas will fall within the regulatory scope of local governments.

Coastal local governments play a significant role in environmental protection and management of the coastal areas. Their primary function is provision of infrastructure such as water, sewerage and waste collection systems which impact upon water quality. Some coastal councils also perform water quality monitoring functions in estuaries and are actively involved in habitat restoration activities (Box 3). Local governments are also involved in the management of coastal public land, in particular beaches, which may or may not be formally under their control.

Box 3 - Case Study - the Brunswick Estuary, Byron Shire Council

The Brunswick estuary has a unique ecological value as it supports a high biological diversity including several floral and faunal species identified as threatened or endangered. The estuary and surrounding catchments also supports several significant and important vegetation community assemblages such as wetlands, littoral rainforest, Coastal Saltmarsh and others.

The main pressures affecting the Brunswick Estuary are:

- Poor ecological health and water quality due to:
    1. Stormwater run-off
    2. Sedimentation
    3. Waste water discharge
    4. Impacts of agriculture and forestry (land clearing and associated impacts)
    5. Impacts associated with dredging and waterway structures
- Riverbank Erosion
- Loss of Riparian vegetation
- Depleted fish stocks
- High levels of human use

In order to sustainably manage the Brunswick Estuary and its associated ecosystems into the future, Byron Shire Council completed the Brunswick Estuary Management Study and Plan in 2008.

Achievements on the Brunswick Estuary Management Plan include:

- over 60,000 trees planted
- over five kilometres of cattle exclusion fencing
- stabilisation of 500 metres of slumping river bank
- over 1500 man hours in volunteer and paid riparian bush regeneration including endangered ecological communities such as salt marsh, floodplain rainforests and wetlands
- improvement of eight barriers to fish passage opening up 30 kilometres of the river and tributaries
- reintroducing snags for fish habitat
- expansion of the Main Arm effluent reuse scheme
- introduction of "Land for Wildlife" program
- ongoing water and catchment education in local schools

Source: Byron Shire Council (http://www.byron.nsw.gov.au/brunswick-estuary-management)

While not prescribed by regulation, many councils across Australia can acquire land for conservation purposes. According to the Productivity Commission (2008) all local governments except for Northern Territory can collect environmental levies to acquire land. This source is used to acquire environmentally sensitive areas, including wetlands and manage them for public purposes (Box 4). Performance of these functions, however, significantly depends on revenue raising capacities of local governments and interests of their communities.

On the other hand, caution needs to be taken in promoting local governments as the lead management body in environmental protection and conservation (see e.g., Wild River 2006 for detailed discussion). Local governments across Australia differ significantly in area, population size and distribution. For example, in Queensland Cook Shire Council serves an area of 117,084 square kilometres while Wujal Wujal Aboriginal Shire Council is managing an area of just 11 square kilometres. Due to uneven distribution of population 24 non-indigenous (out of 59) and most Indigenous local governments in Queensland have a population of less than 5000 residents (DIRD 2013a, DLGCRR 2013). Similarly, there are numerous sparsely populated areas in Western Australia and Northern Territory.

Box 4 Case study – Land acquisition for conservation purposes in Brisbane City Council

Brisbane City Council manages over 8000 hectares of natural areas within a total park estate of more than 14,000 hectares.
Brisbane residents and businesses contribute to protecting Brisbane's natural assets through payment of the Bushland Preservation Levy in their rates account. Funds raised from the levy are used to buy land that supports significant ecosystems, plants and animals through the Bushland Acquisition Program. This land is turned into conservation reserves accessible to the public.
Over 3,000 hectares have been protected since the program started in 1990, including:

- Karawatha Forest
- Brisbane Koala Bushlands
- Tinchi Tamba Wetlands

Source: Brisbane City Council (http://www.brisbane.qld.gov.au/environment-waste/natural-environment/bushland-parklands-wetlands/bushland-preservation-levy/index.htm)

Similarly, councils differ in their revenue raising capacity. For example in 2010-2011 in Queensland rates and charges in Cairns Regional Council (Qld) constituted 78.43 per cent and Fraser Coast Regional Council 73.37 per cent of operating income. In contrast, Barcoo Shire Council secured only 3.27 per cent from rates and charges. Overall, 21 council (out of 59 non-indigenous councils) received less than 20 per cent of their operating income from rates and charges (see DLGCRR 2013a for comparative financial information). In other words, grants and subsidies still play significant role in financial sustainability of remote local governments.

3.5 Land owners and holders

The land is an important asset of Australia's economy. Current distribution of land uses reflects the history and pattern of European settlement built on the use of resources relevant to primary production (SOEC 2011). The dominant land use in Australia, in terms of the extent, is livestock grazing accounting for 55 per cent of terrestrial area (see Table 2 below). It is predominately based on native pastures located in the rangelands of central and northern Australia. Dryland cropping occurs on about 3 per cent of land predominately in temperate and subtropical regions. Production forestry occupies 1.8 per cent while irrigated agriculture accounts for 0.3 per cent of terrestrial area. Other uses such as urban and rural development and mining each require less than 1 per cent (ABARES 2010).

Established land tenure and land uses are the core determinants of regulatory solutions that can be applied to achieve sustainable management and conservation of environmental resources. As already indicated in section 3.2.1 the most of Australia's land resources are managed by individuals and organisations. The overall scope of private land rights can be described under two broad tenure headings—freehold and non-freehold (Crown leasehold).

Freehold title is most secure form of land ownership in Australia. In 'freehold' tenure the landholder holds the title and possession of the land. The landholder is entitled to use the land in any manner subject to restrictions and obligations imposed in the

Crown grant (see section 3.2.1), common law or legislation (Bates 2003). The owners have the right to sell, transfer or mortgage the land and exclude others from its use. Each State and Territory has adopted own legislation regulating freehold tenures. Subject to restrictions imposed by laws (e.g., land use planning), freehold land can be used for different purposes such as agricultural and pastoral production, forest, residential, business and industrial use (Geoscience Australia 2011). Restriction of allocated rights can be subject to compensation.

Table 14: Land use in Australia, 2005-06

Land Use	**Area** million ha	**Proportion of total area** %
Grazing		
native vegetation	356	46%
modified pastures	72	9%
Dryland cropping	26	3%
Irrigated and intensive agriculture		
irrigated cropping	1.3	0.2%
irrigated pastures	1.0	0.1%
irrigated horticulture	0.4	<0.1%
intensive animal and plant production	0.3	<0.1%
dryland horticulture	0.1	<0.1%
Forests and plantations		
native forest	11	1.5%
plantation forest	2	0.3%
Urban and rural development		
intensive (mainly urban) uses	1.6	0.2%
rural residential	0.9	0.1%
Mining and waste	0.2	<0.1%
Water	13	1.6%
Nature conservation and other protected areas (including Indigenous uses)	159	20%
Minimal use	124	16%
Total area(b)	**769**	**100.0**

Source: ABARES (2010)

In ‘leasehold’ tenure the landholder has the right to use (possess) the land, but ownership is retained by the Crown. In Australia, leasehold tenure originates in the pastoral leasehold system introduced by the colonial governments. During the 19th and 20th centuries it became the dominant tenure of land used for pastoral production (ABS 2012). Currently, each State and Territory has own legislation that sets out provisions with regard to the rights and responsibilities of the landholders (see section 3.2.1). Leases generally restrict the landholder’s right to use the land for other purposes than allocated and the land use change requires approval from the Crown (Productivity Commission 2002). Subject to approval from the Crown (i.e., responsible Minister), leasehold interest in land right can be transferred (sold) to others.

Acknowledgement of rights of Indigenous Australians to own the land begun in 1970’s after Australia’s ratification of the International Convention on the Elimination of all Forms of Racial Discrimination. The Racial Discrimination Act 1975 was adopted by the Commonwealth Parliament to ‘make provision for giving effect to’ the Convention. Among the fundamental freedoms the Convention included the right to own property and the right to inherit it (Article 5(d) (v) and (vi)). Subsequently, the Commonwealth enacted Aboriginal Land Rights (Northern Territory) Act 1976 providing for land allocation to Aboriginal Australians. Currently, each State and

Territory has adopted own laws regulating what land and interests in land can be allocated to Indigenous communities and how this land can be claimed. Indigenous land can be both freehold and Crown leasehold.

While the private land resources are mostly used for development or primary production (see Table 2), there has been a growth in the number of land holders participating in environmental management. In this context, the most extensive programme facilitating direct involvement in resource management was the National Landcare Program (NLP). The NLP was initiated in 1989 by the Australian government to support self-organisation of agricultural producers to undertake restoration of agricultural lands and address such issues as salinity and water quality. During the operation of the program (1992-2008) the Australian government committed almost $1 billion to support involvement of a broad range of primary industries across Australia (Australian Government 2009).

Since the end of the 1990' private land conservation has become a widely applied policy solution to biodiversity conservation problems. This type of land use is growing. As of 2009, the extent of private conservation lands in Australia has reached more than 4 million hectares (Australian Government 2009). Each State and Territory has developed a set of instruments that encourage private land owners to protect biodiversity. For example, in NSW funding for conservation is provided through Nature Conservation Trust operating under Nature Conservation Trust Act 2001 (NSW). Long term protection is usually established via covenants or conservation agreements (see e.g., Nature Conservation Act 1992 (Qld) s51 for regulation[4] .

Since the 1970s, there has been a gradual increase in the proportion of land managed by Indigenous communities. As of 2011, the area formally owned and managed by Indigenous Australians has reached 23 per cent of Australia's land area (SOEC 2011). Return of the land has led to increasing participation of Indigenous communities in environmental management and conservation. As of 2013, there are 60 declared Indigenous Protected Areas covering just over 48 million hectares which amounts to 36 per cent of the National Reserve System (DOE 2013). Mechanisms for indigenous participation range from indigenous sole management to joint (co-)management and government management with an indigenous advisory role (Bauman and Smyth 2007).

4. Environmental governance: management of fisheries and their habitat

The States and Northern Territory (in this section further referred to as 'the States') have the jurisdiction over the coastal and inland waters and, consequently, the responsibility for the management of marine and freshwater fisheries and fish habitat areas. This part of the report examines current regulatory and administrative arrangements governing fisheries with particular focus on the arrangements established to protect coastal, estuarine and freshwater habitats.

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[4] Note: since 2001 the Commonwealth government offers taxation incentives for donations and covenants for conservation purposes.

4.1 Legislative framework: regulatory scope and scale

In all States fisheries resources are managed under separate legislative frameworks. Table 3 lists primary legislative and administrative arrangements providing for the management and protection of fisheries resources and habitats at the State level.

As indicated in Table 3, protection of ecological assets required to maintain fisheries resources is regulated under two separate frameworks. All States have adopted legislation specifically providing for protection of marine areas. The major object of this regulation is conservation of marine biodiversity. For example, the object of Marine Parks Act 1997 (NSW) is 'to conserve marine biological diversity and marine habitats' and, where consistent, provide 'for ecologically sustainable use of fish' and opportunities for public enjoyment (s3). Similarly, the main purpose of Marine Parks Act 2004 (Qld) is 'to provide for conservation of the marine environment' (s5(a)). In some jurisdictions (e.g., Northern Territory, Victoria), conservation of marine and terrestrial biodiversity is regulated under the same framework. Marine protected areas contain a variety of zones allowing different types of activities and uses. Most parks form part of marine protected area (MPA) network and fulfil Australia's obligations under the Biodiversity Convention (Australian Government 2009).

Table 15: Regulation of coastal fisheries and their habitat in the States and Northern Territory

Primary statutes	Regulatory scope	Administrating agency
New South Wales		
Fisheries Management Act 1994	fisheries and aquaculture management	Department of Primary Industries
	protection of habitats, protection of marine vegetation	
	declaration and conservation of threatened species	
	declaration and management of aquatic reserves	joint administration with Department for Climate Change, Environment and Water
Marine Parks Act 1997	declaration and management of marine parks	Department of Primary Industries Department for Climate Change and the Environment
Northern Territory		
Fisheries Act 1988	fisheries and aquaculture management, management of aquatic life, including aquatic plants	Department of Primary Industries and Fisheries
Territory Parks and Wildlife Conservation Act 2006	declaration and management of parks and reserves, including marine parks	Parks and Wildlife Commission of the Northern Territory
Queensland		
Fisheries Act 1994	fisheries and aquaculture management	Department of Primary Industries
	protection of marine plants	
	declaration and management of fish habitat areas	Department of National Parks, Sports, Recreation and Racing
Marine Parks Act 2004	declaration and management of marine parks	Department of National Parks, Sports, Recreation and Racing
South Australia		
Fisheries Management Act 2007	fisheries management, protection of aquatic habitats	Department of Primary Industries and Regions
Aquaculture Act 2001	aquaculture management	Department of Primary Industries and Regions
Marine Protection Act 2007	declaration and management of marine parks	Department of Environment, Water and Natural Resources

Victoria		
Fisheries Act 1995	fisheries and aquaculture management, protection of aquatic habitats	Department of Environment and Primary Industries
National Parks Act 1975	declaration and protection of national parks, including marine national parks and sanctuaries	Department of Environment and Primary Industries
National Parks Act 1975 **Crown Land (Reserves) Act 1978** **Wildlife Act 1975**	management of marine protected areas (marine coastal parks, marine parks, marine reserves)	Department of Environment and Primary Industries
Tasmania		
Living Marine Resources Management Act 1995	management of sea fisheries declaration and management of marine protected areas, fish habitat areas	Wild Fisheries Management Branch Department of Primary Industries
Inland Fisheries Act 1995	management of inland fisheries, declaration of fauna reserves	Inland Fisheries Service Department of Primary Industries
Western Australia		
Fish Resources Management Act 1994	fisheries and aquaculture management declaration and management of fish habitat areas	Department of Fisheries
Conservation and Land Management Act 1984	declaration and management of marine protected areas	Department of Parks and Wildlife

Fisheries legislation has a broader range of objectives placing major emphasis on the use values of aquatic resources and supporting habitat. Most of the statutes include 'sustainable development' or 'ecologically sustainable development' as an overarching objective and criterion for the management. Protection of habitats is incorporated as one of the objectives or principles (see Box 5 on the next page) with the major aim to sustain fisheries resources.

Apart from Tasmania, providing for separate regulatory frameworks for inland and marine fisheries resources, the overall scope of the regulation covers both freshwater and marine habitats. For example, the Fisheries Management Act 2007 (SA) (subject to explicitly prescribed limitations) applies 'in relation to all waters that are within the limits if the State' (s5). The Act defines 'waters' as:

a) any sea or inland waters (including any body of water or watercourse of any kind whether occurring naturally or artificially created); and
b) the bed of such waters (s3).

Similar provisions are incorporated in the statutes of other jurisdictions (e.g., Fish Resources Management Act 1994 (WA), s5, Fisheries Management Act 1994 (NSW), s7). In other words, there is a common legislative framework for the management of all fisheries resources in respective jurisdiction.

Box 5 Objectives of the fisheries legislation

***Fisheries Management Act 2007* (SA) (s7)**

(1) An object of this Act is to protect, manage, use and develop the aquatic resources of the State in a manner that is consistent with **ecologically sustainable development** and, to that end, the following principles apply:

(a) proper conservation and management measures are to be implemented to protect the aquatic resources of the State from over-exploitation and ensure that those resources are not endangered;

(b) access to the aquatic resources of the State is to be allocated between users of the resources in a manner that achieves optimum utilisation and equitable distribution of those resources to the benefit of the community;

(c) **aquatic habitats are to be protected and conserved, and aquatic ecosystems and genetic diversity**

are to be maintained and enhanced;

(d) recreational fishing and commercial fishing activities are to be fostered for the benefit of the whole community;

(e) the participation of users of the aquatic resources of the State, and of the community more generally, in the management of fisheries is to be encouraged.

(2) The principle set out in subsection (1)(a) has priority over the other principles.

(3) A further object of this Act is that the aquatic resources of the State are to be managed in an efficient and cost effective manner and targets set for the recovery of management costs.

…

Fisheries Act 1995 **(Vic) (s3)**

The objectives of this Act are—

(a) to provide for the management, development and use of Victoria's fisheries, aquaculture industries and associated aquatic biological resources in an efficient, effective and **ecologically sustainable** manner;

(b) to **protect and conserve fisheries resources, habitats and ecosystems including the maintenance of aquatic ecological processes and genetic diversity**;

(c) to promote sustainable commercial fishing and viable aquaculture industries and quality recreational fishing opportunities for the benefit of present and future generations;

(d) to facilitate access to fisheries resources for commercial, recreational, traditional and non-consumptive uses;

(e) to promote the commercial fishing industry and to facilitate the rationalisation and restructuring of the industry;

(f) to encourage the participation of resource users and the community in fisheries.

Fish Resources Management Act 1994 **(WA) (s3)**

(1) The objects of this Act are —

(a) to develop and manage fisheries and aquaculture in a sustainable way; and

(b) to **share and conserve the State's fish and other aquatic resources and their habitats** for the benefit of present and future generations.

(2) Those objects will be achieved by these means in particular —

(a) **conserving fish and protecting their environment**;

(b) ensuring that the impact of fishing and aquaculture on aquatic fauna and their habitats is ecologically sustainable and that the use of all aquatic resources is carried out in a sustainable manner;

(c) enabling the management of fishing, aquaculture, tourism that is reliant on fishing, aquatic eco-tourism and associated non-extractive activities that are reliant on fish and the aquatic environment;

(d) fostering the sustainable development of commercial and recreational fishing and aquaculture, including the establishment and management of aquaculture facilities for community or commercial purposes;

(e) achieving the optimum economic, social and other benefits from the use of fish resources;

(f) enabling the allocation of fish resources between users of those resources, their reallocation between users from time to time and the management of users in relation to their respective allocations;

(g) providing for the control of foreign interests in fishing, aquaculture and associated industries;

(h) enabling the management of fish habitat protection areas and the Abrolhos Islands reserve.

Fisheries Management Act 1994 **(NSW) (s3)**

(1) The objects of this Act are to **conserve, develop and share the fishery resources** of the State for the benefit of present and future generations.

(2) In particular, the objects of this Act include:

(a) to **conserve fish stocks and key fish habitats**, and

(b) to **conserve threatened species, populations and ecological communities of fish and marine vegetation**, and

(c) to promote ecologically sustainable development, including the conservation of biological diversity,

and, consistently with those objects:

(d) to promote viable commercial fishing and aquaculture industries, and

(e) to promote quality recreational fishing opportunities, and

(f) to appropriately share fisheries resources between the users of those resources, and

(g) to provide social and economic benefits for the wider community of New South Wales, and

(h) to recognise the spiritual, social and customary significance to Aboriginal persons of fisheries resources and to protect, and promote the continuation of, Aboriginal cultural fishing.

Another important determinant of the regulatory scope is an understanding of such concepts as 'fish', 'plants' or 'aquatic vegetation'. Taking into account the overall statutory framework and distribution of regulatory authorities, all jurisdictions apply different definitions of the core concepts (see Box 6). For example, in Tasmania, marine aquatic plants are included in the definition of 'fish'.

Box 6 Definition of 'fish'

***Fisheries Act 1994* (Qld) (s5)**

(1) ***Fish*** means an animal (whether living or dead) of a species that throughout its life cycle usually lives—
(a) in water (whether freshwater or saltwater); or
(b) in or on foreshores; or
(c) in or on land under water.
(2) ***Fish* includes**—
(a) prawns, crayfish, rock lobsters, crabs and other crustaceans; and
(b) scallops, oysters, pearl oysters and other molluscs; and
(c) sponges, annelid worms, bêche-de-mer and other holothurians; and
(d) trochus and green snails.
(3) However, ***fish* does not include**—
(a) crocodiles; or
(b) protected animals under the *Nature Conservation Act 1992*; or
(c) pests under the *Pest Management Act 2001*; or
(d) animals prescribed under a regulation not to be fish.
…

***Fisheries Act 1995* (Vic) (s5)**

(1) In this Act, ***fish*** means—
(a) all species of vertebrate aquatic fauna other than mammals, reptiles, birds and amphibians;
(b) sharks, rays, lampreys and other cartilaginous fish;
(c) oysters and other aquatic molluscs;
(d) aquatic crustaceans;
(e) echinoderms;
(f) any other species of aquatic invertebrate declared to be fish under subsection (2).
…

***Fisheries Management Act 2007* (SA) (s3)**

fish means an **aquatic animal other than**—
(a) an aquatic bird, an aquatic mammal, a reptile or an amphibian; or
(b) an aquatic animal of a kind declared by the regulations to be excluded from the ambit of this definition;

***Living Marine Resources Act 2005* (Tas) (s4)**

(2) Fish includes –
(a) bony fishes of the class *Osteichthyes*; and
(b) sharks, rays, lampreys and other cartilaginous fishes of the classes *Chondrichthyes* and *Agnatha*; and
(c) aquatic reptiles; and
(d) sea squirts and other aquatic chordates; and
(e) sea-stars, sea-urchins, sea-cucumbers and other echinoderms; and
(f) lobsters, crabs, prawns and other aquatic arthropods; and
(g) bristle worms, fan worms, arrowworms and other aquatic annelids, chaetognaths, nematodes, nemerteans and platyhelminths; and
(h) squid, oysters, abalone and other aquatic molluscs and brachiopods; and
(i) seafans, sponges, corals, jelly-fish, salps and other bryozoans, poriferans, coelenterates and ctenophores; and
(j) protozoans and bacteria; and
(k) seagrass, seaweed and other aquatic vascular plants, algae, diatoms, euglenoids and any other **marine plants**.
…

***Fisheries Management Act 1994* (NSW) (s5)**

(1) In this Act, ***fish*** means marine, estuarine or freshwater fish or other aquatic animal life at any stage of their life history (whether alive or dead).
(2) In this Act, ***fish*** includes:
(a) oysters and other aquatic molluscs, and
(b) crustaceans, and
(c) echinoderms, and
(d) beachworms and other aquatic polychaetes.
(3) In this Act, ***fish*** also includes any part of a fish.
(4) However, in this Act, ***fish*** does not include whales, mammals, reptiles, birds, amphibians or other things excluded from the definition by the regulations.

4.2 Fish habitat protection: applicable tools

From the regulatory perspective, consistent achievement of habitat protection objectives is dependent upon two major factors. The first is the level of protection the statutes assign to separate properties of the habitat such as seagrass, mangroves, riverine vegetation and other biotic and abiotic elements (e.g., logs, rocks). The second is the range of management instruments or regulatory tools available to the responsible agency. Each jurisdiction has a different mix of measures that could be applied to achieve habitat protection goals.

4.2.1 Protection of aquatic vegetation

Protection of aquatic vegetation is one of the protection measures. Statutory frameworks differ in the level of protection assigned to aquatic plants. For example, the Fisheries Act 1994 (Qld) prohibits removal, disturbance or destruction of marine plants without authorisation. According to the Act, 'marine plant' is defined as 'a tidal plant that usually grows on, or adjacent to tidal land, whether it is living dead standing or falling' (s8). Consequently, the responsible agency has a right to control impacts of various activities on a wide range of coastal habitat systems, including saltmarsh, mangroves, seagrass and alga irrespective established land tenure (i.e., includes private land). The development application affecting these habitats triggers assessment under the provisions of the Act (s76L).

In NSW, Fisheries Management Act 1994 (NSW) sets out provisions to protect marine vegetation from 'harm'. The protection applies to mangroves, seagrass and any other declared marine vegetation anywhere in the State (s205). According to the Act prevented activities or 'harm' involves 'gather, cut, pull up, destroy, poison, dig up, remove, injure, prevent light from reaching or otherwise harm the marine vegetation, or any part of it' (s204(2)). A permit is required from the regulatory authority (NSW Department of Primary Industries) to harm marine vegetation. The maximum penalty for harming marine vegetation without a permit is $220,000 for a corporation or $110,000 for a person.

In contrast, in Western Australia the regulatory authority has a limited set of measures with regard to protection of aquatic plants. In general, the Fisheries Management Act 1994 (WA) establishes an overarching object to 'share and conserve the State's fish and other aquatic resources and their habitats' (s3(1)(b)). However, achievement of this object is restricted to the regulation of impacts of fisheries activities on the condition of fish habitat and other aquatic resources (see s3(2)(b)). Restriction of other external pressures impacting upon the habitat is limited to fish habitat protection areas and Abrolhos Islands reserve (Part 11). Similarly, in South Australia Fisheries Management Act 2007 (SA) regulates impacts on protected species declared by regulation and plants located in aquatic reserves (ss71, 77). Management of native vegetation, including plants 'growing in or under waters of the sea' is carried out under the Native Vegetation Act 1991 (SA).

In most jurisdictions application of vegetation protection measures is limited to marine vegetation. While definition of 'waters' allows establishing management regimes for both marine and freshwater areas (see section 4.1), the control over riverine habitats is limited. For example, in Queensland destruction of riverine plants

(i.e., freshwater aquatic plants) is regulated separately under the Water Act 2000 (Qld). Permits and self-assessable codes regulating damage to riverine vegetation are prepared by another regulatory authority (the Department of Resources and Mines). Furthermore, the Act does not regulate (i.e., prohibit) grazing impacts or removal of logs. Similarly, in NSW protection measures can be applied in relation to 'marine plants'. According to the Fisheries Management Act 1994 (NSW), 'marine vegetation' is defined as 'any species of plant that at any time in its life must inhabit water (other than fresh water)' (s4).

4.2.2 Protection of habitats

All jurisdictions except for Northern Territory provide for the declaration of 'fish habitat', 'aquatic reserve' or 'fisheries reserve' areas as another management tool to protect fisheries assets. The lengths and level of application of this management tool varies significantly across jurisdictions. For example, in Queensland first fish habitat reserves were declared in Moreton Bay in 1969. As of 2012, protected area network consisted of 70 fish habitat areas covering 1,134,326 ha (DAFF 2012). In South Australia the first aquatic reserve was established in 1971 leading to gradual expansion of the network to 15 reserves (PIRSA 2014). In contrast, Western Australia has only 6 fish habitat areas (DOF 2014). No information could be found on established habitat reserves in Victoria except for aquaculture[5].

There is no formal planning process or approach to habitat identification, valuation or prioritisation. In general, protected habitat areas can be established, altered or revoked by responsible regulatory authority via such instruments as declaration, proclamation or order (see e.g., Fisheries Management Act 2007 (SA), s4, Fisheries Management Act 1994 (NSW), s194). The statutes confer significant discretion upon responsible authorities with regard to the application of this instrument. Most jurisdictions (e.g., NSW, Queensland, Western Australia) require consultation with community and stakeholders, including other regulatory authorities. Each jurisdiction determines own selection criteria and approval system (see e.g., FWA 2001, DNPRSR 2014).

Despite the progress in protection of marine habitats, significant problems remain with freshwater systems. In general, the statutes include provisions enabling responsible authorities to nominate freshwater areas as fisheries habitat and assign special management regime. In practice, however, protected areas are largely constrained to the State controlled land below high water mark. For example, apart from declared Wild River areas regulated under the Wild Rivers Act 2005 (Qld) there are no protected freshwater habitat areas in Queensland. This problem is also evident in other jurisdictions (e.g., Western Australia, South Australia, NSW).

Limited application of habitat protection mechanisms in freshwater systems and in some coastal areas could be attributed to the ownership problem. The coastal zone in populated areas is dominated by private land tenures. The statutes, however, do not allow placing restrictions on the private land without owner's consent (see e.g.,

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[5] Note: the State government website does not provide any information on non-aquaculture fisheries reserves established under section 88 of the *Fisheries Act 1995* (Vic). Such information could not be found via search engines using keywords 'fisheries reserve' and 'Victoria'.

Fisheries Management Act 1994 (NSW) s195). Furthermore, fisheries legislation does not provide any reference to the possible set of tools (e.g., conservation covenants, agreements) or incentive mechanisms that regulatory authority could apply to include private land in fish habitat areas. As the State control over the beds and banks of watercourses is limited to some 'water mark' on the bank (see e.g., Water Act 2000 (Qld)), involvement of adjacent land owners is almost inevitable precondition for freshwater habitat protection.

4.2.3 Management of development impacts

Declaration of protected areas does not imply that fish habitats are fully protected from development activities. Unlike marine protected areas, they can be subject to a broader range of impacts. Therefore, the mechanisms, which allow the regulatory authority to limit or negotiate development impacts, are another important determinant of habitat protection outcomes.

There are significant differences in the level of control allocated to fisheries authorities across jurisdictions[6]. In practice, development impacts upon identical habitats or habitat properties can be subject to rigorous assessment in one jurisdiction and be outside the regulatory scope in another. For example, in NSW and Queensland activities affecting protected marine plants and declared 'fish habitat areas' (Qld) or 'aquatic reserves' (NSW) require permits issued under the respective legislation. Therefore, development approval can be subject to offset or other conditions (see e.g., Fisheries Act 1994 (Qld) ss76I,76IA). Limited protection of marine vegetation and extent of declared fish habitat areas significantly limits formal involvement of fisheries authorities in development assessment in other jurisdictions (e.g., Western Australia, Victoria).

Another important habitat protection measure is the conditions which fisheries authorities can impose upon development of in-stream barriers. In Queensland, development of any in-stream barrier is regulated under the Fisheries Act 1994 (Qld). According to the Fisheries Act 1994 (Qld) and Sustainable Planning Act 2009 (Qld) the responsible fisheries authority (Chief executive) as a concurrence agency can refuse the development application made for the construction of a waterway barrier, if the works do not provide for the movement of fish across the barrier (Fisheries Act 1994 s76G). Similar provisions are incorporated in Fisheries Management Act 1994 (NSW). These regulations however, apply to new developments.

To protect interests of freshwater fisheries, broader control over the barriers is allocated in Tasmania. According to the section 160(1) of the Inland Fisheries Act 1995 the responsible authority (the Director) 'by notice in writing, may require the owner or occupier of a dam placed in or across a river, an outlet or the shores of a lake to make a fish-pass if satisfied that the dam does not permit the free passage of fish.' Non-compliance is subject to penalty. In the latter case the Director may undertake required works and recover the costs from the owner (s161). These rights, however,

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[6] Note: this section focuses on legislative frameworks operating at the State level and therefore does not examine application of the EPBC Act with regard to matters of national environmental significance.

do not apply to developments approved under the Water Management Act 1999 (Tas), as in case of inconsistency the latter prevails (s10).

Limited scope of rights allocated to the fisheries agencies in other jurisdictions does not imply that development impacts on fisheries assets are necessarily ignored. Other mechanisms could be available. However, commonly reported problems with knowledge fragmentation and diversity of interests suggest that such distribution of powers might lead to regulatory gaps. Additional study is required to examine effects on this regulatory approach to habitat protection outcomes.

4.3 Administrative arrangements

4.3.1 Administration structures

Similarly to regulation, each jurisdiction has own administrative framework. In general, fisheries portfolios are administered by the Ministers having executive responsibility for primary industries. In some jurisdictions (Queensland, NSW) administration functions are divided between the Ministers responsible for primary industries and environmental conservation. The structures are dynamic. Natural resource management and environmental conservation portfolios tend to be amalgamated, divided and redistributed on a regular (election cycle) basis.

The Ministers are supported by departments carrying out allocated regulatory and management functions (see Table 3). Departments and their sub-units develop and implement policies and regulatory frameworks and undertake a wide range of management and monitoring functions. The scope of functions is largely determined by the scope of responsibilities allocated to the Minister under the respective regulatory framework.

Each jurisdiction has established management bodies having responsibilities for specific functions. For example, the Fisheries Management Act 2007 (SA) provides for establishment of the Fisheries Council which has responsibilities for the preparation and review of management plans and promotion of co-management, research, education and training. The Council gives advice to the Minister on a range of matters including resource allocation, fees and funding application (ss 11, 16). In Victoria Fisheries Act 1995 (Vic) establishes Fisheries Advisory Council which has the function ‘to advise the Minister on strategic matters relating to the management of fisheries at the request of the Minister’ (ss 90, 91). Advisory bodies (councils, committees) also exist in other jurisdictions (e.g., NSW, Tasmania). Each management authority cooperates with a range of research units supporting monitoring and planning of the resources.

Coordination and cooperation between the departments holding different portfolios[7] occurs both: formally and informally. Formal interactions are prescribed in the statutes which provide that certain scope of activities requires approval of one or several other Ministers or other regulatory authorities. For example, declaration of

[7] Note: this section does not address joint management arrangements established between the Commonwealth and the States with regard to shared fisheries resources

fish habitat areas usually requires approval of the Minister administering legislation portfolio regulating allocation and management of the Crown land (see e.g., Fisheries Management Act 1994 (NSW) s 195). In the context of habitat protection, the most important area of cross-sectoral cooperation is development planning and approval. As already discussed (see section 4.2.3), significant differences exist among jurisdictions in formal involvement of fisheries agencies in development assessment.

4.3.2 Funding provisions and contributions

Each jurisdiction independently determines the level of fees, charges, royalties and other payments for the resource access rights. Most jurisdictions contain statutory provisions for the creation of a separate fund to hold collected revenues and support fisheries sector. For example, in Western Australia the Fish Resources Management Act 1994 (WA) provides for Fisheries Research and Development Account which holds all revenues relating to commercial fishing. The account can be used by the Minister for any of the purposes listed in the Act, including expenses in relation to administration and enhancement of commercial fisheries and aquaculture, research, monitoring and fish habitat protection (s238). Separate Recreational Fishing Account is established to hold funds and support activities of recreational fishers (s239). In Queensland the Fisheries Act 1994 (Qld) provides for a single Fisheries Research Fund which can be spent on research, training and information distribution, fish habitats or other fisheries related activities as decided by the chief executive (s117). Offset payments made for the destruction of fish habitats form part of this fund.

There are no comparative data available on the amount of collected funds the States allocate to the protection, management and maintenance of fish habitats or other funding sources, if any, used for this purpose. Comparability of these data could be further complicated by differing priorities and needs. However, according to the information published on the State government websites, the common problem is limited allocation of resources to support public involvement. Only NSW Department of Primary Industries reports an ongoing engagement in funding allocation to individuals and groups interested in the management and restoration of ecological assets (Box 8).

Box 7 Case study – Habitat Action Grants, NSW Department of Primary Industries

Habitat Action Grants

Angling clubs, individuals, community groups, local councils and organisations interested in rehabilitating fish habitats in freshwater and saltwater areas throughout NSW can apply for grants.

Habitat rehabilitation projects which may be funded include:

- removal or modification of barriers to fish passage
- rehabilitation of riparian lands (river banks, wetlands, mangrove forests, saltmarsh)
- re-snagging waterways with timber structure
- removal of exotic vegetation from waterways
- bank stabilisation works
- reinstatement of natural flow regimes

Habitat Action Grants 2013-2014

Thirty projects were funded in the 2013-2014 Habitat Action Grants. These grants totalling almost $570,000 will assist recreational anglers, local Councils, environmental and community groups and private landholders to enhance and rehabilitate degraded recreational fish habitat through a range of on-ground works. Rehabilitation of fish habitat provides long-term sustainable benefits for native fish stocks and in turn provides substantial benefits

for NSW recreational fishers who will enjoy more healthy productive fisheries. Improvements in fish habitat will also provide more opportunities for rural and regional communities to promote local tourism.

Source: NSW Department of Primary Industries
(http://www.dpi.nsw.gov.au/fisheries/habitat/rehabilitating/ahr-grants-program)

State governments are not the only source of funding for the restoration and maintenance of fish habitats. While comprehensive information is not available, many reported projects suggest that Commonwealth funded NRM management programs make significant contributions to the restoration of ecosystem assets important for the maintenance of fisheries resources (see e.g., Reef Catchments at http://reefcatchments.com.au/water/river-restoration/). As already identified before (see Box 3), contributions have also been made by local governments, non-governmental organisations, industries and individuals. This report, however, cannot examine the level of strategic coordination of these actions and effectiveness of made investments. This requires a separate study.

5. Environmental governance: factors affecting adaptation responses in Australian coastal fisheries

The various approaches to the management and regulation of environmental resources in the Commonwealth and the States and designed administrative frameworks reflect differing histories of political development, resource uses, as well as social, economic and political conditions. This report does not aim to propose an ideal governance model to fisheries management. In practice, such model does not exist. There are nonetheless several common factors that require consideration to pursue long term protection of ecological assets required to sustain Australian coastal fisheries. These include:

5.1 Strategic planning: goals and objectives

'Off-reserve' protection and management of fish habitats and maintenance of catchment-to-coast connectivity has not appeared on the national arena as a separate national or cross-jurisdictional matter. To differing degrees the problem has been incorporated in national policy frameworks addressing land degradation and water quality issues, protection and rehabilitation of the coastal zone and conservation of marine and terrestrial biodiversity. Consequently, there is a lack of common strategic platform that could provide guidance to the development of fish habitat networks required to sustain commercial/recreational fish stocks across Australia.

At the State level, the primary legislation regulating planning and distribution of fisheries resources incorporates habitat protection objectives. Within the scope of allocated authority, the regulators are authorised[8] to pursue the objective via declaration of selected areas as protected habitat. These initiatives, however, are not supported by a strategic framework identifying measurable long term goals and

[8] Except for Northern Territory

objectives[9] for the State or geographical region (e.g., catchment, basin). Many governance responses are developed and implemented at a relatively local level aimed to achieve specific operational outcomes.

To pursue climate change adaptation, there is a need to identify large-scale ecological and biophysical processes which are to be maintained to sustain ecological assets and assess the state of habitat against the key condition variables. Strategic goals and objectives based on sound science and data and 'whole of the landscape' approach are required to direct action plans and make targeted investment decisions.

5.2 Distribution of roles and responsibilities

Australian environmental governance is complex. The management of various environmental assets is shared between the Commonwealth, State and Territory, and local governments, co-management arrangements, regional natural resource management bodies, Indigenous communities, community-based organisations, as well as private land owners and holders. A lack of clear delineation of responsibility boundaries, coordination and cooperation are common and ongoing governance challenges.

In the context of the report, these challenges raise the question of leadership, namely: which governance actor should take a lead role in looking after ecological assets of coastal fisheries. At the current stage, this role to differing degrees is performed by the State government departments holding responsibility for the implementation of fisheries legislation. To this end, NSW Department of Primary Industries can be regarded as a good example of the lead authority establishing cross-jurisdictional linkages, providing financial resources, coordinating habitat restoration activities and mobilising public support. At the same time, the organisational structure of the State governments is highly dynamic and subject to frequent reorganisations and shifts in political directions.

Strategic planning of ecological assets involves long timeframes and requires long-term political commitment. The scope of this report did not include detailed evaluation of the current governance arrangements. However, slow progress in the comprehensive assessment of the state of the assets and protection of freshwater systems in all jurisdictions suggest that existing governance structures face a range of problems. There is a need for more detailed examination of current governance systems to identify their potential to protect and enhance these large-scale public assets over long term.

While strategies need to incorporate large scale, long term goals, implementation actions need to be planned at a relatively local level. Each jurisdiction has a different mix of governmental and non-governmental management bodies which are or can be potentially involved in the protection and maintenance of fish habitat assets. In

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[9] Note: exception is a *Native Fish Strategy for the Murray–Darling Basin 2003–2013* which has a long term goal of rehabilitating native fish communities back to 60% of estimated pre-European fish populations by the year 2050 (MDBMC 2003).

practice, generalized assumptions cannot be made. For example, many reported studies indicate the willingness and capacity of local governments and community organisations to participate in the restoration of the coastal zone and riverine and riparian systems. At the same time, the biggest part of Australia is scarcely populated and a significant proportion of coastal or near coast local governments is struggling with financial and human resources (see e.g., Productivity Commission 2008).

The complexity of Australian environmental governance 'landscape' suggests that application of 'one size fits all' subsidiarity model to implementation will not be possible. Adaptation strategies will need to consider the variety of jurisdictional, geographic, social, economic and cultural contexts defining capacities and interests of particular actors.

5.3 Cross-jurisdictional cooperation and coordination

In all Australian jurisdictions, management of environmental assets follows some 'sectoral' pattern. At the state level, there is a large number of statutes and subordinate legislation providing for the regulation of environmental assets and threatening processes. Government departments or their sub-units administer specific legislation portfolios. Fragmentation of regulation cutting across separate properties of ecosystems is almost unavoidable feature of the current regulatory system. As a result, the regulators may ignore or oversee the interests of other management sectors when they try to address particular resource problem.

Fish habitat protection does not fall neatly within conventional sectoral boundaries. As the review suggests, many regulators responsible for the implementation of fisheries legislation are deficient in authority to achieve stated habitat protection outcomes (e.g., have no control over the impacts on riparian or coastal vegetation, development on private land). Long term protection of fisheries assets, therefore, is dependent upon the level of incorporation of protective measures into other legislative frameworks providing for activities affecting these assets. A range of governance techniques are available to achieve this goal.

Design of an adequate legislation and policy framework enabling protection and enhancement of fisheries assets depends on two other factors. First, it is the interests and priorities of other sectors. Australia's economy strongly depends on other primary industries such as mining and agriculture and related developments producing different pressures on coastal and freshwater ecosystems. Similarly, urban and industrial development is an important part of the economy and revenue stream of national, state and local governments. Incorporated interest 'balance' in legislative frameworks often reflects economic importance of each sector and the ability of industries to promote their interests and gain political and public support.

The second factor is the ability of responsible agency holding 'fisheries portfolio' to form strategic partnerships and negotiate with regulators of other sectors. For example, both NSW and Queensland Departments of Primary Industries have gained considerable level of control over the assessment of development impacts on fisheries habitats. Established linkages also enable the departments to provide best practice guidelines for development activities requiring construction of fish passages.

Adaptation strategies cannot be designed in isolation. They need to take a broader view and consider cross-sectoral interests. Each sector will respond differently to external economic and environmental drivers, including climate change. Therefore, an ongoing engagement and communication with other industries, their regulators and the public is the key to ensure that the threats to fisheries assets are understood and considered. To this end, sound knowledge of fisheries assets, their locations and economic values to the society can become an important determinant of negotiating capacity of coastal fisheries.

5.4 Financial resources and economic solutions

In face of different pressures, there is a need to improve and, possibly, expand ecosystem assets of coastal fisheries. Budget constraint is a common argument for limited implementation of environmental protection measures (see e.g., National ESD Strategy). Distribution and funding sources are important determinants of adaptive responses. However, they also need to be considered in other contexts.

The income from allocation of fisheries resources is collected and distributed by State governments. Fish and other aquatic species are common-pool goods providing benefits for the whole society. From the policy side, a strategic question that remains is: who and to what extent governments could be expected or required to commit resources both in kind and financial to sustain assets required for the provision of these goods? For example, Australian local governments neither distribute extractive resources nor are entitled to collect fees or royalties. Therefore, decisions directed to meet community needs or increase income base may not be in line with large scale public benefit goals. Similarly, private land holders will not be willing to sacrifice their land resources and bear the losses (e.g., decrease in productive capacity or market value) to provide additional coastal habitat (Boer 2010). In practice, private land tenure is one of the core obstacles for the development of freshwater habitat networks and expansion of tidal habitats (R. Quinn, pers. communication).

Currently, the most of the legislative frameworks include provisions for collection and allocation of funds to support monitoring and research of the allocated resource. Application of environmental offset policies in several jurisdictions (e.g., NSW, Queensland) enabled regulators to gain additional funds from the development industries. This report has not examined in detail funding distribution arrangements. However, as applied regulatory mechanisms suggest, there is a limited use of funding to support conservation agreements and covenants which would engage private landowners in the long term protection and management of fisheries assets.

Planning and implementation of adaptation responses (e.g., increase in protected areas, rehabilitation of degraded habitats) requires consideration of broader economic context and established incentive systems shaping interests and priorities of other governance actors. State governments should be prepared to share collected income to support local management initiatives, in particularly when management functions place additional financial burden on local governments. Extension of the scope of applied incentive-based instruments may also be required to align priorities.

6. Conclusions

This report outlined key aspects of Australian environmental governance framing current policy approaches to the management of ecosystem assets relevant for sustained management of coastal fisheries. Based on the analysis of documentary sources the report identified several potential challenges to effective governance responses to climate change adaptation of coastal fisheries common across all jurisdictions. Detailed examination of many problems was restricted due to the wide scope of governance factors covered in the report. However, the point highlighted here is that Australian environmental governance is complex and many factors need to be considered in the planning and implementation of adaptation responses. Understanding and unpacking this complexity allows accounting for multiple factors that can operate as enabling or constraining conditions in particular jurisdictions. This report concludes that, while it is important to continue focusing on responses within particular resource sectors, narrow sectoral view on governance problems will not provide sufficient basis for the design of effective governance responses in such contested and multi-actor space as Australian coastal zones and estuaries.

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Appendix 2: Using expert opinions to elicit enablers and limitations for the adaptive management of estuaries and waterways under climate change

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Executive Summary

Much of the knowledge and experiences of past, recent and ongoing adaptation research for environmental management more often than not resides in the collective experience of key individuals, frequently managers, scientists and stakeholders in general. This expert knowledge has been used and is currently applied to a wide range of cases, localities of many estuarine and coastal ecosystems of Australia, representing also a range of different contexts, complexities and dynamics. In this work we use the expert opinions, knowledge and experiences of a range of experts as a proxy data source to acquire, assess and gain understanding of current practices, drivers, enablers and constrains of the adaptive management of aquatic ecosystem under climate change and variability in Australia. We interviewed 18 senior individuals (managers, scientist, and planners) from a cross-section of various governance structures of Australia's estuarine and coastal ecosystems. These interviewees represented a total of 26 case studies that include specific aquatic systems, research projects and programs, management instruments, local government's actions and planning and management of commercial sectors. Our aim was to gather the interviewees' opinions and experiences on five target themes: (1) motivational drivers, (2) enablers and constrains to success, (3) experiences in specific case-studies, (4) incorporation of climate change, which included enablers and constrains, and (5) the role of governance.

We found that there is a wide range of motivational drivers (n=20), where the more frequent was the public pressure, problems and conflicts (both from the bottom-up), and the operational management needs (from the top-down). Other intuitive drivers like political will and information provision were surprisingly low in their occurrence in the interviews, contradicting mainstream literature on the topic. The enablers of success were also many (n=17), and largely dominated by focused and

coordinated collaboration, strong leaders and champions, as well as good information basis and overall clarity (mandate, goals, challenges, objectives). The limitations and constrains were less (n=13), and also a more or less reverse mirror of those of success –i.e. the lack of clarity, poor information basis, and poor communications, engagement and understanding were the most frequent constrains. However, only the lack of clarity had a frequency of occurrence higher than 50 percent among respondents. Interview data suggests that there is also a wide range of ways to include climate change into the adaptive management (n=19). Here, the clarity of aims and goals for management problems as well as the need for mainstreaming climate change into the governance showed the highest frequency of occurrence. Lastly, a much less number of functions and roles of the governance we elicited through the interviews (n=11). The need for a system view (to reduce fragmentation), a focus on cross-cutting and holistic approach to management (whole-of-government system), as well as emphasis in planning and managing for extreme events were the highest roles identified for the governance of estuaries an coastal ecosystems.

None of these finding are novel, unknown or surprising, but the frequency in which they occur demonstrate some differences from findings from elsewhere, which indicates that adaptive management initiatives should be context-dependent. As a result we believe that this work addresses the core of the FRDC-NARP 2011/040 project's objectives. It provides for the Objective 1 by synthesising and integrating knowledge, for the Objective 2 by building a knowledge base, for the Objective 3 by eliciting the information needed for evaluating likely adaptation strategies. Further, it also addresses both Objectives 2 and 3 by assessing the experiences and approaches for the identification and development of adaptation strategies.

Thus, consistent with the project's objectives, this work produced valuable and nationally-relevant qualitative (and semi-quantitative) information that could contribute to the design of adaptive management initiatives and strategies. With this work we have developed a unique knowledge-basis system that could be used to (i) expand and create a broader information basis via monitoring and evaluation, (ii) it opens up an wide field of socioecological research that will complements environmental management and (iii) will inform and guide administrators in the future development of adaptive management strategies for estuaries, wetlands, and coastal ecosystems of Australia.

Introduction

Climate change is expected to cause substantial changes in Australia's coastal zone, which includes catchments, rivers and coastlines (Commonwealth of Australia 2009). These effects will be exacerbated by existing threats associated with urban and rural development and land-use changes. Population growth, the need to accommodate people, and the associated need to produce food to provide for the growing population frequently lead to negative effects on environmental conditions through contamination of water bodies from catchments to the coast, with consequent adverse impacts on human health and water use. Therefore there is a clear need to consider current and future threats in planning frameworks to deal with climate change and adaptation.

To complicate matters, no single agency manages the catchment-to-coast continuum. There are often multi-level governance arrangements, where different departments are in charge of parts of the coastal zone, often with overlapping mandates. This multi-layered administration setting is known to affect the dynamic interactions that influence natural resources management (Cash et al., 2006) and has been described for different parts of the world (e.g. Brazil (Gerhardinger et al., 2011) and Australia, such as the iconic Great Barrier Reef in Australia (Peterson et al., 2010)). The combination of intricate governance arrangements and the conflict between economic development versus socio-cultural and environmental conservation (Finkl and Charlier, 2003; Folke et al., 2002) poses a major challenge to climate adaptation in Australia's coastal zone.

As a result, the last decade has seen an increasing and active research works and policy developments in relation to the adaptive management of Australia's estuaries, waterways and the near shore coastal environments (e.g. Voice et al. 2006; Howieson et al. 2009; Commonwealth of Australia 2010; Gibbs and Hill 2011; Koehn et al. 2011). This attention has accumulated a wealth of experiences, successes and constrains to a varied number of cases, systems and regions. Therefore, many managers, scientist and stakeholder, across the governance spectrum, have been developing adaptation sciences, planning and management responses related to the environmental and climate variability and change affecting these aquatic systems. In Australia the focus has been largely on environmental health (DOE 2006[10]) and in response to extreme events (Commonwealth of Australia 2013), environmental impacts (Kingsford et al. 2000) and management and planning overall (Harvey and Carlton 2010; Wetland Australia[11]). These efforts have then accumulated significant and useful lessons learnt that could be used to inform national, regional and local adaptation strategies. The Ideal the approach to gather and evaluate the lessons-learnt in these cases often involves dedicated case-study work that is often expensive and time-resource demanding.

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[10] Department of the Environment 2006 www.environment.gov.au/resource/national-water-quality-management-strategy-australian-guidelines-water-recycling-managing-0

[11] Wetlands Australia www.environment.gov.au/node/24877

This was originally scoped for this project as a series of activities originally planned to be assessed and extracted out of a series of national, regional, state, and local face-to-face workshops, all planned for the last portion of the project. However, the cost-efficiency was deemed to be detrimental for the progress of the project, largely due to the high constraints of time-availability from senior managers and its complex logistics. Consequently, we designed an alternative methodology of conducting one-on-one interviews with some key senior managers, researchers and practitioners that represented that various layers of the system's governance. Thus, instead of putting together these (3-6) workshops in various states to gather relevant national experiences, we conducted a more cost-effective process applied to a subsample of participants that meet the scale and diversity conditions and requirements of the project.

By targeting individuals we also gained to access the different layers of the governance and research structures conducting adaptive management actions and in relations to climate change affecting estuarine and coastal ecosystems. This approach also allows us to represent the variations and differences among jurisdictions and management bodies, and among case studies from the different regions and states. So the assumption here is that the accumulated knowledge and experiences in Australia so far is expected to represent a wide range of case studies, addressing multiple challenges and accounting for the intrinsic variability encountered by the on-the-ground adaptive management of these aquatic ecosystems.

In this project we decide to systematically acquire and assess a representative, but not comprehensive, subset of this collective knowledge and experiences of senior managers, scientists and stakeholders. This approach will represent a robust descriptive and synthetic way to acquire this dispersed know-how not incorporated in mainstream adaptive management. We believe that the data and results will be nationally relevant for the describing some of the existing adaptive management strategies underway for estuarine and coastal ecosystems

Objectives

This work was developed as a cost-efficient way for the FRDC-DCCEE Project 2011/040 to quickly gather the knowledge and experiences from individual that have and are working in representative aquatic systems of Australia. It was not intended to be a comprehensive national assessment, but a representative sub-sample of experienced individual practitioners across Australia. The specific objectives are to:

A. Design a cross-governance and sectorial elicitation process to acquire learning and experiences on impact management and adaptation strategies in case studies (Commonwealth, QLD, WA, TAS)

B. Summarize qualitatively the know-how and experiences of managers, scientists and stakeholders in dealing with estuarine, waterways and aquatic environmental management

C. Bring together national-scale relevant knowledge of managers and practitioners of adaptive management of estuarine, aquatic and coastal systems under climate change and variability

Methods

In order to address the project objectives we interviewed senior managers, planners and scientists across the governance spectrum who were charged with planning, managing and conducting applied research on Australia's estuaries, waterways and near shore coastal systems under climate change and variability. The interview schedule was designed to gather information on the drivers of success or constrains, based on their individual experiences and knowledge from their recent past and present activities, that have or is informing (or limiting) the development or implementation climate change adaptive plans and actions.

We then developed a targeted person-to-person set of semi-structured interviews (Appendix 1) aimed at various senior individuals representing a range of organisational (federal, state, council, academic, private, etc.) and varied spatial scales (national, regional, local), and coming from a diverse but punctual group of representative sectors and roles (Table 1). The design was to target efficiently a small but significant number of interviewees (n=18) coming from the various governance layers of these aquatic systems.

Table 1. The overall metadata of the elicited individuals, stating their various nature, types, geography, sector and roles.

Code #	Organisation	Type	State	Scale	Sector	Roles
1	Queensland DAFF	State Agency	Queensland	State	Government	Senior manager
2	GBRMPA	Federal Authority	Commonwealth	Federal	Government	Senior manager
3	GBRMPA	Federal Authority	Commonwealth	Federal	Government	Senior manager
4	CSIRO	Research & Development	Commonwealth	Federal	Government	Researcher
5	Consulting	NGO	Queensland	Local	Private	Consultant
6	SEQHWW	Regional Agency	Queensland	Regional	Planner	Senior manager
7	Queensland DSITIA	State Agency	Queensland	State	Government	Senior manager
8	Logan City Council	Local Government	Queensland	Regional	Council	Senior manager
9	Tasmania Planning Commission	Regional Agency	Tasmania	Regional	Planner	Senior manager
10	James Cook University	University	Queensland	State	Academia	Researcher
11	Queensland EHP	State Agency	Queensland	State	Government	Senior manager
12	Eberhard Consulting	NGO	Queensland	Local	Private	Consultant
13	Blue Planet Marine (BMP)	NGO	Western Australia	Local	Private	Researcher
14	University of Tasmania	University	Tasmania	State	Academia	Researcher
15	Derwent Estuary Program	Regional Agency	Tasmania	Local	Planner	Senior manager
16	Norther Wet Tropics NRM	Regional Agency	Queensland	Regional	Planner	Senior manager
17	Townsville City Council	Local Government	Queensland	Local	Council	Senior manager
18	Terrain Natural Resource Management	NGO	Queensland	Regional	NGO	Senior manager

The collective information derived from the above interviews represented a total of 26 case-studies (Table 2). These ranged from specific local systems, research experiences in projects, the implementation of management instruments, actions of

local governments, to the planning and management of commercial sectors (Table 2). These case studies represent aquatic and marine ecosystem of varies scales and complexities.

Table 2. Summary of the types and jurisdiction of the representative case-studies.

#	Case Study	Type	Jurisdiction
1	SEQ HWW Partnership	Bridging Organisation	Queensland
2	Derwent Estuary Program	Mangement Instrument	Tasmania
3	Gladstone Partnership	Bridging Organisation	Queensland
4	Qld Coastal Plan	Mangement Instrument	Queensland
5	Yasi Recovery	Management Action	Queensland
6	Catchment Management GBR	Mangement Instrument	Commonwealth
7	GBR Marine Aquarium Industry	Sector	Commonwealth
8	GBR Trawl Fishery	Sector	Commonwealth
9	GBR Line Fishery	Sector	Commonwealth
10	GBR CC Action Plan	Mangement Instrument	Commonwealth
11	GBR Extreme Events	Mangement Instrument	Commonwealth
12	SEQCARI	Project	Queensland
13	SEQ Councils Extreme Event Mangement	Mangement Instrument	Queensland
14	GBR Mananagement	Mangement Instrument	Commonwealth
15	Logan City Council	Local Government	Queensland
16	Logan River Recovery	Mangement Instrument	Queensland
17	Sleek Creek Catchment Recovery	Mangement Instrument	Queensland
18	Logan Stormwater Mangement	Mangement Instrument	Queensland
19	Clarence City Council	Local Government	Tasmania
20	Lauderdale Quay	Project	Tasmania
21	Ralph Bay Marina	Project	Tasmania
22	Fitzroy 12-Mile Wetland Repair	Project	Queensland
23	Qld Reef Plan	Mangement Instrument	Queensland
24	Pilbara Coast Surveys	Project	Western Australia
25	Murray-Darling Basin	Bridging Organisation	Commonwealth
26	Fitzroy Partnership	Bridging Organisation	Queensland

We followed ethical considerations by both James Cook University Human Research Ethics Committee (Appendix 2) and endorsed by CSIRO's Ethical Conduct in Human Research procedures and policy. The interviews were conducted between November 2013 and February 2014, where a total of 18 interviews were conducted about case studies in Queensland (11), Tasmania (3), Western Australia (1) and the Commonwealth (3). Prior to each interview, an information a consent letter was sent to targeted interviewees explaining the aim and objectives (Appendix 3). The interview consisted of one senior project member meeting and interviewing one person at the time, using a 5 theme template to guide the interview (Appendix 1) and digitally recording the interviews in an audio file, for quality and transcription uses (see Appendix 4 as example transcript). Following ethical considerations all interview material will be deleted at the end of its use for the project. For ethical and private law reasons, none of the individuals interviewed have been identified.

The interviews were semi-structured, lasted from 30 to 90 minutes and focused on the five general themes and sub-topics (or prompts) which the interviewees were asked about:

(1) **Their high-level motivations for their management and research in these systems, including own professional and career experiences.** Here we look for the identification of the high-level drivers that may trigger adaptive management, whether it is a top-down (regulatory and jurisdictional) or bottom-up (public pressure, individual champions, etc.) processes.

(2) **The factors and conditions that could act as enablers or constraints for successful management, including the resource level, political networks, information basis, etc.** Particular emphasis was given to elicit the roles of strategic planning and tactical responses to management. The results are presented per separate.

(3) **Their experiences and specific examples of waterways and estuarine system management that illustrate their contributions** to the objectives (1) and (2) above. Here we simply focus on elicit the nature and diversity of case-studies presented by the interviewees (plans, projects, and directions), whose outputs and outcomes, particularly what did and did not work, was captured in the themes 1, 2, 4 and 5. No descriptive analysis was conducted to this theme.

(4) **Their explicit or implicit (or none) inclusion of climate change (CC) and variability of the systems and examples of their management and research experiences.** Here we asked whether CC was addressed, how and what instruments or information basis was considered or not. Important here was the elicitation of personal preferences on how to deal with CC for such systems.

(5) **Their views, experiences and roles of the likely adaptive management strategies for estuaries, wetlands, and ecosystems**. Here we elicit the roles of institutions, their strengths and weaknesses, resource levels and more importantly, their own opinion on how adaptive management for CC in estuaries should happen and reside.

The resulting materials out of the interviews and its use are summarized in the Table 3. The reduction, synthesis and analyses of the information followed a 3-stage process:

i). The notes, audio and transcripts were tabulated and reduced to the major messages and issues elicited, and those were then matched and grouped to each of the 5 themes and topics for each individual interviewed.

ii). The resulting table was then synthesized further to a reduced number of common key topics, factors and issues that were then scores binary (0 or 1) for each individual interviewed.

iii). The resulting binary matrix was then used to represent in a relative (%) manner, the overall frequency of occurrence and the proportion of respondents that responded for each topic in each of the 5 major themes.

Table 3. Resulting metadata and the materials generated out of each of the interviews.

Code #	Audio File	Transcript (Doc)	Nvivo (Txt)	Interview Notes	Analyses
1	No	No	No	Yes	Yes
2	No	No	No	Yes	Yes
3	Yes	Yes	Yes	No	Yes
4	Yes	Yes	Yes	Yes	Yes
5	Yes	Yes	Yes	Yes	Yes
6	Yes	Yes	Yes	Yes	Yes
7	Yes	Yes	Yes	Yes	Yes
8	Yes	Yes	Yes	Yes	Yes
9	Yes	Yes	Yes	Yes	Yes
10	Yes	Yes	Yes	Yes	Yes
11	Yes	Yes	Yes	Yes	Yes
12	Yes	Yes	Yes	Yes	Yes
13	No	No	No	No	Yes
14	Yes	Yes	Yes	No	Yes
15	Yes	Yes	Yes	No	Yes
16	Yes	Yes	Yes	No	Yes
17	No	No	No	No	Yes
18	No	No	No	No	Yes

We used then semi-quantitative and descriptive analyses for each of the 5 themes listed above. Since the aim was to elicit individual's knowledge and experiences from a subset of senior managers, scientists and experts, there was no attempt to compare and conduct contrasting and detailed analyses among and between them. Similarly, the analyses are focus only on each individual theme and no comparison among themes was made. The focus was then to gather for each interviewee and for the whole sample, the emergent topics, factors or issues that collectively describe each of the 5 themes. The data is presented in tabulated form and presented in the results sections as summary table of their relative contributions.

Results & Discussion

Motivational Drivers

Interviewees mentioned that there were both bottom-up (Red in 4) and top-down (blue in 4) motivational drivers to trigger climate change planning frameworks and research. Public pressure, existing problems and conflicts were the two most frequent bottom-up motivations (4), mentioned all in half of the interviews. The high importance of these two bottom-up drivers shows the importance of public

opinion (and perceptions) and recognised problems in triggering adaptive management initiatives. Existing operational management or planning frameworks in place, which is a top-down motivational driver, can support the bottom-up drivers for adaptive management focusing on climate change and adaptation. This shows that adaptive management should include a mix of bottom-up and top-down approaches to be more effective.

Legislative, leaders and "champions", extreme events and communications are motivational drivers always mentioned in the literature and planning and management discussions, however these were not on the top of the occurrences of responses (Table 4). Interestingly, most practitioners reckon that political will and networks are highly important, but again these were not at the top of the list (Table 4). Similarly, data and information is not also highly regarded as a motivational driver for adaptive management. This can be for two reasons. The first is that in Australia (or at least in the case studies our work explored) there are already effective mechanisms in place (e.g. monitoring programs) that are effective and used to support decisions.

Table 4. Motivational drivers and their relative occurrences in the grand total of responses (n=68) and among the interviewees (n=18).

Motivations	**Frequency of occurrence (%)**	**% of interviewees that mentioned the motivation**
Public Pressure	10.3	50
Problem or Conflict-based	10.3	50
Operational Management and Plans	10.3	50
Legislation	7.4	36
Objective-Planning/Policy	7.4	36
Resources Availability	5.9	29
Non-coordination and Need whole-of-government Approach	5.9	29
Impacts, Vulnerability, Public Safety	5.9	29
Leaders and Champions	4.4	21
Objective- Conservation Management	4.4	21

Objective- Development and Economy	4.4	21
Extreme Events	4.4	21
Personal, Moral and Ethical	4.4	21
Communication, Bridging and Value-adding	4.4	21
Data and Information Provisioning	2.9	14
Political Will and Networks	1.5	7
Objective- Social	1.5	7
Advice to Managers and Planners	1.5	7
Change User's Behaviours	1.5	7
Opportunities	1.5	7

Enablers of Success

The majority of interviewees (>50%) mentioned that adaptive management requires the following ingredients for its successful implementation (Table 5a): (a) Focus, coordination, cohesiveness and collaboration, (b) strong leaders and champions, (c) good initial information basis and data, (c) Clarity on mandate and problems, objectives and agreements, (d) Communication, learning and understanding, and (e) effective provision of advice. For example, in the context of SE Queensland Dutra et al. (under review) suggest that decisions to design and implement plans depend on strong leadership working in collaboration with industry, government and communities. Leaders use their negotiation skills and networks as part of their communication strategy to influence decisions. Leaders are described as champions who establish a vision and work together with the community and other stakeholders to achieve this vision. Therefore, these enablers of success elicited from the interviews come with no surprise, as there are several theoretical and empirical studies that support these as key elements of adaptive management (Dutra et al., 2011; Brugnach, 2010; Fernandez-Gimenez et al., 2008; McNie 2007; Timmerman et al. 2010).

We expected that political will and netwroks would play a major role in successful adaptive management initiatives in Australian coastal zone because of the strong power influence political groups play in decision-making processes (see Gregory et al., 2006). However, the interview data suggests that this was not as influential as anticipated.

Table 5a. Enablers of success and their relative occurrences in the grand total of responses (n=92) and among the interviewees (n=18).

Enablers of Success	**Frequency of occurrence (%)**	**% of interviewees that mentioned the topic**
Focus, Coordination, Cohesiveness & Collaboration	12	79
Leaders and Champions	10	64
Good Start Information Basis/Data	10	64
Clarity on: Mandate, Problems, Objectives and Agreements	9	57
Communication, Learning, Understanding	9	57

Effective Provisioning of Advice	9	57
Political Will, Networks	7	43
Wide Stakeholder Engagement, Ownership	5	36
Good Narrative and Stories	5	36
Resources Availability	5	36
Good Planning, Implementation	4	29
Opportunities, Flexibility, Adaptive Systems	3	21
Science Ready for CC	3	21
Magnification of Goals and Outcomes	3	21
Bridging-Honest Broker, Accountability	2	14
Holistic Values and Wider Considerations	2	14
Full-cycle Engagement	1	7

Constrains to Success

The constraints to success of adaptive management (Table 5b) are not as clear as the enablers of success. This is probably because the constraints seem to be more context-related; i.e. specific issues (political, governance, environmental) that affect the location in which the adaptive management initiative under discussion. The most evident constrain of success (mentioned by >50% of the interviewees) is the lack of clear roles, vision, and jurisdictions, which can potential lead to an 'institutional void', where "there are no clear rules and norms according to which politics is to be conducted and policy measures are to be agreed upon" (Hajer 2003). One consequence of the "institutional void" generated by the lack of clear roles, vision, and jurisdictions usually encountered in NRM is the lack of a clear process to define what kind of information is required for management, and how or whether the information should be used and acted upon (Dutra et al., under review). A second consequence of the "institutional void" is that there may be a long time-delay (years to decades) between problem recognition and gathering of financial and administrative support from governments to address NRM problems (Pister 1992:7).

Table5b. Limits and constrains to success and their relative occurrences in the grand total of responses (n=50) and among the interviewees (n=18).

Limitations and Constrains to Success	Frequency of occurrence (%)	% of interviewees that mentioned the constrain
No Clear-Roles, Vision, Definitions, Jurisdictions	14	50
Lack-Low-Biased Information, Data Basis	10	36
Poor Communication, Learning, Understanding, Engagement	10	36
Weak Decision-making, Political Interference	10	36
Resource Limitations (people-$)	8	29
Fragmentation, Disconnection	8	29
Individual Agendas (Personalities, Agencies)	8	29
Slow, Low-Development, Implementation	6	21
Short-term Cycles, Management	6	21
Too High-level and/or Hard Decisions	6	21
Poor Legislation	6	21
Narrow Focus-Issue, Wrong Scale	6	21
No Engagement Private-Industry ($)	2	7

Dealing with Climate Change and Adaptive Management

The interviewees offered a wide range (n=19) of ways, factors, and issues (in cases barriers) to deal and incorporate CC into the adaptive management of estuaries and coasts (Table 6). This greater number may be a reflection of the diversity of views and may also reflect higher complexity and lack of clarity among the respondents. The two highest occurrences in total and with > 50% of the respondents, were the clarity of goals, aims and management problems and the need to mainstream CC into the governance and environmental planning (Table 6). These findings are consistent with similar works that identified theses as barriers to adaptation and the need to create adaptive processes that contains steps to address these issues (e.g. Moser and Ekstrom 2010; Kates et al. 2012). Similarly, the two next in the ranking were the notion the CC adaptation is no more than adaptive management through

time under CC, and the need for effective communication and education (Table 6). These again are recurrent topics in the mainstream literature that were also reflected in the respondent's views and experiences. Despite the fact that often CC adaptation is regularly stated that it is not well defined (e.g. Smith et al. 2000; Giddens 2009; Moser and Ekstrom 2010), this was nearly at the bottom of ranks (Table 6). This may reflect either a good and shared knowledge of understanding or the definition is not important and/or overlooked. Although CC uncertainty is one of the greater scientific challenges of our times, and it is regularly cited as a major barrier for action, this was only stated in less than a third of the respondents and with only 5% of the occurrences (Table 6). This is maybe consistent with the emergent concepts of social phycology research of motivated reasoning, confirmation bias and 'finite pool of worry' (Whitmarsh 2011).

Table 6. Issues and ways to incorporate CC into the adaptive management and their relative occurrences in the grand total of responses (n=85) and among the interviewees (n=18).

Climate Change (CC) and Adaptive Management	**Frequency of occurrence (%)**	**% of interviewees that mentioned the motivation**
Clear Aims, Goals (for Management-Problems)	14	86
Embedded in Governance, Environmental Planning (Mainstream)	11	64
CC Adaptation = Adaptive Management Ext. Events through Time	8	50
Effective Information, Communication, Education	8	50
Focus on CC Impacts, Stressor, Extreme Events	7	43
Good Demonstrative Tools	6	36
CC Information at Right-scale	6	36
Long-term Focus, Directions	5	29
Develop Good CC Narratives, Stories	5	29
Better Understanding of Uncertainty	5	29

Synthesis of Large CC Information	4	21
Greater CC Sciences, Data, Information	4	21
Need for Bridging CC Agency, Authority (Honest Broker)	4	21
CC Products for Management Uptake (Local, Regional, national)	4	21
Link CC Ecosystem Resilience	4	21
Link CC & Social Sciences	4	21
Link CC & Risk-Based Management	2	14
Clear Definition of Adaptation	1	7
CC as Legally Opportunistic	1	7

Role of Governance

This theme was the one that attracted the fewer number of roles and functions (n=11) identified for the governance of the estuarine and coastal ecosystems (Table 7). We believe that this may indicate a relative low number of possible roles, and clarity and consistency of opinions among the interviewed practitioners. Three roles accounted with ca. 40% of the total occurrences (Table 7), where the interviewees stated that the governance should focus on; the reduction of the fragmentation of responsibilities, promote an integrative and holistic system view, and focus on planning and management of extreme events –with 71%, 71%, and 57% respectively (Table 7). These finding are again consistent with the current literature where these have been found to be critical for the governance of natural environment under CC (e.g. Pahl-Wostl 2007; Folke et al. 2007; Adger 2010). Other important roles were the prioritising and coordination of funds, the emphasis on communication and information, and the development of policies and actions that support and complement local adaptive CC management actions (Table 7).

These are clear and consistent messages that can inform and foster intergovernmental collaboration and the whole-of-government approaches. It also confirms the need for, nature and functions of bridging organisations, such as the SEQ HWW and Gladstone partnerships, whose core roles are similar to the found here.

The lowest role was found to be the avoidance of individual agenda (Table 7), for both individuals and agencies. This somehow contradicts other common notions that were informally expressed during the interviews, where this has been and impediment to the effectiveness governance.

Interesting, the great majority of interviews for this theme responded with the negative aspects (lack of, reduce, eliminate, etc.) and barriers that in their opinion was affecting their work and the governance systems where they are part. During the interviews, synthesis and analyses these negatives responses were turned as a post-hoc action into the positive as part of the interviewee's aspirational views of the roles and functions of these governance systems.

Table 7. Roles and functions of the Governance in relation to CC and their relative occurrences in the grand total of responses (n=71) and among the interviewees (n=18).

Role of Governance	Frequency of occurrence (%)	% of interviewees that mentioned the motivation
Reduce Fragmentation, Disconnection (promote system view)	14	71
Focus on Cross-Cutting, Integrative Approaches (holistic)	14	71
Planning, Management-Extreme Events	11	57
Prioritising and Coordinating of Funding	10	50
Communication and Information	10	50
Policies-Support Local Actions	10	50
Clear-Roles, Vision, Definitions, Jurisdictions	8	43
Foster Science-Based Support	8	43
Bridging CC Agency, Authority (Honest Broker)	6	29
Adaptive Roles, Change Through Time	6	29
Avoid Individual Agendas (Personalities, Agencies)	3	14

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APPENDICES

APPENDIX 1: Template and guide for conducting the interviews

Semi-structured Interview -- NARP-FRDC Project

Climate Change & Extreme Events Management for Estuaries & Near shore Coastal Ecosystems (EEME)

Aim: *to elicit the practical and personal experiences on waterways management from a range of cross-governance layers of mangers and practitioner.*

<table>
<tr><td colspan="4">0. Metadata
Name:
Institution:</td></tr>
<tr><td>Age:
( ) 20-30 ( ) 30-40 ( ) 40-50
( ) 50-60 ( ) >60</td><td>Occupation &
Background:</td><td>Time in current occupation:</td><td>Decision Area:</td></tr>
</table>

1. Motivations	**Notes**
Top-down ←→ Bottom-up	
Management mandate, strategic-tactical actions?	
People's voice, Industry needs/pressure	
Legislation, allocation of responsibilities→ jurisdiction	
Demands & directions	
Other Role of "Political" networks Individual's roles "Champions".	

2. Success & (constrains) to EEME	**Notes**
What did (& not) work?	
Enablers of (limitations)? • Data-Info & knowledge basis • Coordination (one-whole approach)	
Political & structures	
Resources, manpower	
Clear • Strategic planning? • Operational & tactical directions? • Coordination and info flows?	
Other	

3. Some specific implementation actions to EEME **(examples, names)**	**Notes**
Projects, op-plans, directions?	
Outputs & outcomes out of?	
Changes on directions, attitudes, resources basis?	
What did (& not) work?	
Other	

4. How to deal (or not) w CC and the adaptive management of EEME	**Notes**
How the actions (above) contribute to?	
How CC is (or not) used/addressed? • Info basis (IPPC, QCCEE, Consultants, others) • Tools, models & platforms • Projections, scenarios & timelines? • Others? •	
Roles of institution for implementation? • Coordination between mangers & stakeholders? • Information flows?	
What do/would YOU (think) should be done? ➔ realistic	
Other	

5. Role of governance for the adaptive management of EEME (how to?)	**Notes**
Institutions for the implementation adaption management? • Current structures (strengths & weakness)? • Own structure & relation to others? •	
Resourcing levels for? • Funding, people, • Science support? • Communications & dissemination support?	
Where CC & adaptation management should reside? • In the current (or future) structure? • Central vs dispersed? • New, within, else? •	
What would YOU do different?	
Other	

APPENDIX 2: Approval Form from the JCU Human Research Ethics Committee

JAMES COOK UNIVERSITY AUSTRALIA

James Cook University
Townsville Qld. 4811 Australia
Tina Langford, Manager, Research Ethics & Grants
Research Services Ph: 47815011; Fax: 47815521
email: ethics@jcu.edu.au

Human Research Ethics Committee ***APPROVAL FOR RESEARCH OR TEACHING INVOLVING HUMAN SUBJECTS***	Application ID **H5114**

PRINCIPAL INVESTIGATOR	Marcus Sheaves				Staff
SCHOOL	Marine Biology				
CO-INVESTIGATOR(S)	Cathy Dichmont, Rodrigo Busamante and Martha Brians				
SUPERVISOR(S)					
PROJECT TITLE	NARP - Climate change adaptation for Australia's estuaries				
APPROVAL DATE:	**12/06/2013**	**EXPIRY DATE:**	**31/05/2014**	**CATEGORY:**	**1**

This project has been allocated Ethics Approval Number H5114, with the following conditions:

1. All subsequent records and correspondence relating to this project must refer to this number.

2. That there is NO departure from the approved protocols unless prior approval has been sought from the Human Research Ethics Committee.

3. The Principal Investigator must advise the responsible Human Ethics Advisor:
   - periodically of the progress of the project,
   - when the project is completed, suspended or prematurely terminated for any reason,
   - within 48 hours of any adverse effects on participants,
   - of any unforeseen events that might affect continued ethical acceptability of the project.

4. In compliance with the National Health and Medical Research Council (NHMRC) "National Statement on Ethical Conduct in Human Research" (2007), it is MANDATORY that you provide an annual report on the progress and conduct of your project. This report must detail compliance with approvals granted and any unexpected events or serious adverse effects that may have occurred during the study.

Human Ethics Advisor :	Cinner, Joshua
Email :	joshua.cinner@jcu.edu.au

This project was Approved by Executive on 12 Jun 2013

Dr Anne Swinbourne
Chair, Human Research Ethics Committee

APPENDIX 3: Invitation and communication letter to interviewees.

Climate Change Adaptation for Australia's Estuaries

You are invited to take part in a research project about climate change effects in Australian coastal waters, and how to adapt assessment and management strategies for estuarine and coastal marine ecosystems. The study is being conducted by **Associate Professor Marcus Sheaves (of JCU)** and **Dr. Cathy Dichmont and Dr. Rodrigo Bustamante (of CSIRO)** will contribute to important research at James Cook University and the Commonwealth Scientific and Industrial Research Organisation.

This study aims to:

1. To obtain background, development, and implementation information regarding climate change adaptation plans either underway or implemented across Australia

If you agree to be involved in the study, you will be invited to be interviewed. The interview should only take approximately 1 hour of your time. The interview will be conducted at the School of Marine and Tropical Biology at James Cook University, or a venue of your choice.

Participation in this study is completely voluntary and you terminate your participation at any time without explanation or prejudice.

Your responses and contact details will be strictly confidential. The data from the study will be de-identified and destroyed after it is summarised, The de-identified data will be used in research publications, reports, and management schemes. You will not be identified in any way in these publications, and no information will be retained that could link you to any information you supply.

If you have any questions about the study, please contact **Marcus Sheaves.**

Principal Investigator:

Marcus Sheaves

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If you have any concerns regarding the ethical conduct of the study, please contact:

Human Ethics, Research Office

James Cook University, Townsville, Qld, 4811

Phone: (07) 4781 5011 (ethics@jcu.edu.au)

APPENDIX 4. Example transcript of the case-studies interviews.

FILE DETAILS

Audio Length: *59 minutes*

Audio Quality: ☐ *High* ☒ *Average* ☐ *Low*

Number of Facilitators: *One*

Number of Interviewees: *On*

Difficult Interviewee Accents: ☐ *Yes* ☒ *No*

Other Comments: *Low level background noise throughout.*

[Aside discussion]

Facilitator: Okay, so I'm going to take some notes while we do this interview and thank you first of all, for agreeing to be here.

Interviewee: No problem.

Facilitator: I've just got to find some - ask you some personal information, one of which is your name and where you work.

Interviewee: Okay, ****, I'm senior Planning Advisor at the **** Planning Commission.

Facilitator: Okay. You've been there for a while?

Interviewee: I've been at the Commission for nine years or its predecessors in some form in government and in that role for a couple of years.

Facilitator: So can you just briefly outline how your work is connected to coastal issues in the marine environment and the estuarine environment, I guess, which is the focus of the study?

Interviewee: Yeah, well my job's essentially to advise government and local councils and other stakeholders on land use planning policy and land use planning policy intersects with a whole range of activities including coastal planning development and management issues and particularly in this day and age, impacts of climate change, which use and development has to have regard to. In Tasmania we have, of course, a legislative requirement under the State Coastal Policy to interpret and implement that through the planning system.

So land use planning may sound a little distant from estuarine issues or other coastal issues and adaptation but it's actually pretty central when you think about the sorts of things that impact on those marine environments. So although we don't control necessarily what happens in the marine environments themselves, the surrounding land use is a pretty big issue in terms of achieving those outcomes, yes.

Facilitator: Okay, thank you for that. Now, the way the interview is structured is basically - and I have explained this briefly before but there's five main questions. The first two focus on a general overview of what makes environmental management in estuarine areas happen and then the second question is about what promotes it and what sort of inhibits action. The third part is about some specific examples of estuarine management or coastal management that are successful or unsuccessful. Then in the fourth part we want to take the climate change issue into consideration into that as well, how that features in that equation. The last one is about adaptive management.

Now, if there's any issues that you don't feel you know about or it's not your area of expertise then we just skip those. Other than that just answer as much as you can and I'll prompt you a little bit if I have to, in terms of what I've got on my sheet here.

Interviewee: Sure, if I'm wandering off on a tangent, for example…

Facilitator: Oh, I'll pull you into line, don't worry. Okay, so the first question is really about your opinion about what figures this environment management. So what makes action happen? Is it something that is demanded by people or is it something that the legislation accounts for?

Interviewee: Well I think they probably interconnect here. The legislation, the coastal policy in Tasmania, particularly, is clearly a response to a community-driven expectation that coastal issues are important and need to be addressed. Interestingly it was the first of any state policy that was developed since 1993 when the legislation came in and seen as a particularly critically important one because of the complexity of the issues that interact on the coast. Tasmania is a very coastal environment and I heard a stat on the ABC radio the other morning about the proportion of the population that lives within 50 kilometres of the coast and Tasmania has the highest proportion. So…

Facilitator: Wow, I'm surprised you knew that.

Interviewee: Yes. Just goes to show when you listen to the radio - and it has an extremely long coastline and given that, when you've got a

whole bunch of land use activities impacting on the coast, relatively pristine coastal environments in some situations or perhaps they're modified coastal environments but they are environments then, that need to be monitored and managed according to best environmental practice to ensure that we don't destroy the values that people actually are really interested in. those values are natural, social, cultural, environment, you know, the whole economic, the whole - economic, the whole box and dice. They all come together in a very wicked problem in terms of coastal use and development and the things surrounding it.

Facilitator: So do you think there's political will to address those issues? Like is the framework in the political context adequate or…

Interviewee: It's a complicated framework that we've got here and it's been - it's a framework that's undergoing a fair bit of change through government over the last couple of years but I don't think that's a reflection of the importance of the issue so much as a misunderstanding or a lack of maturity about the mechanisms and the way they should work and the way they interact. So there's a political move away from this whole notion of state policies at the moment, which is essentially embedded in a reaction to political hotspots and pressures on those coastal issues rather than a concern about the structural mechanisms.

So it's still getting a bit confused but I don't think you'll find anyone in this state who doesn't say that coastal issues are important. The problem we have is that…

Facilitator: They're unimportant?

Interviewee: Well, yes, sorry, yes. The problem is that everyone will then interpret that in a different way so when you get down to the nuts and bolts of implementing policy, the whole thing tends to fall apart because it means different things to different people, different places and they all have a different understanding about what sustainable might mean or what you do in different places. The problem we've had is that the policy has been ambiguous and fairly high-level and with not much implementation and we get into lots of legal arguments about what it actually means on the ground in a day to day situation.

Facilitator: So what about the role of industry in that? Is there a - so you walked about the people driving virtually the existence of the coastal policy and the implementation of the coastal policy being quite complex and the interpretation of it being quite diverse. What is the role of industry in that equation? Are they part of the people…

[Over speaking]

Interviewee: Yeah, I mean they're stakeholders. I suspect we've got a relatively different situation in Tasmania with industry because historically a lot of industry is located on the coast and you wouldn't necessarily allow them to do that now and in fact - so we're in a situation of really managing existing industry in coastal locations. We don't have a lot of pressure to establish new industries on coastal locations and generally I think industry's pretty content not to go there unless it has to go there. So one of the essential principles in the coastal policy is about coastal dependency.

Again, you can get into arguments about whether things are dependent or not but clearly if you've got port facilities and loading facilities then the resource is going out on ships and so forth, it's coastally dependent because you can't do it somewhere else but residential activity, on the coast being coastally dependent is…

Facilitator: Debatable.

Interviewee: Well, indeed but you'd be surprised how many people argue that of course it's dependent on the coast because it's got a coastal view and you couldn't have it anywhere else, which rather is a sort of self-serving argument, in a way but…

Facilitator: So in your view is the definition of coastal dependence, somewhat easier for industry than it is for residential [unclear]?

Interviewee: Yeah, absolutely. You could well argue that residential is in no way dependent on the coast. I mean, a house is a house and whether it's two kilometres inland from the coast or on the coast, it essentially serves the same function. One of them might have a view of a mountain and a valley and the other one might have a view of the beach. That's a sort of decorative element to the main function. It doesn't need to be on the coast for its primary function. It can be anywhere for that.

Where it gets complicated is when you get urban settlements on the coast, as we're sitting in right now in Hobart, where it's historically been developed around a port and residential activity and so forth takes place over a hundred-odd years around that port. Then you get a situation where the dependency is not directly related to the coast but it's directly related to the economic activity of the settlement that's on the coast. So it becomes quite confused about what's going on.

Facilitator: Just around that sort of first question off - actually there's two aspects to this and that follows on from what you were talking about before. What do you think determines the demand for environmental management of estuaries, per se? So…

Interviewee: Oh well, I think estuaries - I mean I'm not a natural scientist or an ecologist or anything like that but I think it's pretty well known that estuaries have a - and literal areas generally have complexities of natural environmental values and they have increased pressure flowing from that for recreational use and so forth.

So you've got a whole perfect storm of issues that can impact on estuaries, which tend to focus a lot of planners attentions because the surrounding land use is going - the proximity of the surrounding land use gives you not much opportunity to mitigate and intervene before the estuary might be impacted. So stormwater runoff is a classic situation. So they are the areas where you tend to get a lot of conflicting land uses potentially occurring.

Facilitator: So what I'm hearing you say is that it's the multiple use aspect of the estuaries that are creating sort of resource access and resourcing issues?

Interviewee: Well it comes - yes, that, but then the estuary itself is a complex ecosystem, which is important to the health of the marine environment generally. So you put the two things together and you've got a lot of complex issues, which will then come unstuck.

Facilitator: Now, at the bottom of my page here I've got what's the role of things like political networks, et cetera in making these environmental management of estuaries happen in your experience? You don't have to answer that if you don't…

Interviewee: I'm not quite sure what it means.

Facilitator: [Unclear] champions. Like is it about a person pushing these issues or is it about - does that impact the - does it trigger anything?

Interviewee: Yeah, it's a bit hard for me to say, I think. Because I think we operate in an environment with a strong legislative framework in place, the role of pressure groups or individuals trying to effect change or get attention on particular issues, it's sort of filtered through that legislative framework anyway. So you don't get large campaigns against a sort of insensitive status quo of management regimes because the system provides those

checks and balances or [technical], theoretically, through the application and development process.

Facilitator: So I might come back to that one in the third question, in a sense that that - I was wondering if we could just briefly talk about that example down in…

Interviewee: Lauderdale?

Facilitator: The development - yeah, Lauderdale. Anyhow…

Interviewee: Yes.

Facilitator: …we'll just trigger that one later on. So we'll go onto the next part of the questions and basically that is about the - hold on [unclear] on the wrong page. Here I am. You've covered a lot of this already. It's about what makes things work in terms of environmental management of estuaries. Is it about information is it about people, is it about resources? Those sorts of things.

Interviewee: Yeah well, it sounds a bit simplistic but it's probably on a number of levels. I tend to think that I observe, I guess, programs that seem to be quite effective in managing estuaries and so forth, based on building substantial information and making or assisting guidance and decision making around that but that sits somewhat apart from the bigger land use decisions that may have all sorts of other implications on the health of the estuary. There's a sort of tyranny of small decisions that can impact on the estuary if they're not done correctly.

So in a way, all the good work that an estuary program might set up establishing water quality monitoring and all that stuff, could all come unstuck if there's a major proposal in a catchment, which is not properly managed because the runoff and the stormwater quality et cetera can completely ruin what they've been doing in a more limited way. So the issue then, is well how do you get an integrated approach across a whole range of decisions? That's going to reinforce the exact impact in a particular place.

Facilitator: So the way that I'm understanding what you're saying is that there's almost like this immovable object, which is the planning system, that it works quite effectively in most cases. There's a coastal policy within that, which lays out clear boundaries to what you can do and what you can't do, in a way, moveable boundaries?

Interviewee: Well, your description of a framework's pretty good but the problem with the coastal policy is it doesn't set clear guidelines

about what it means and where we've fallen down with this policy, which is now nearly pushing 20 years old, is that it hasn't been codified or implemented strategically in a consistent way. So in some ways it gets sort of left off. It's too high-level, people don't know what it means and it can easily get left behind or it gets dragged out at the last minute and applied incorrectly to an individual development, which is not what it's designed to do.

Facilitator: So within that - thank you for explaining that but - so that within that context the programs that work, say, underneath that, the coastal policy, the planning scheme, are - and I don't know whether I'm interpreting correctly, they seem to happen without much consideration of the greater picture or is that - or sometimes are unable to exist in…

Interviewee: Well, the only - I think it's a matter of degree, but they only - the reason that they may operate in isolation of a higher - you know, the bigger picture is because the bigger picture hasn't been properly implemented down there. I don't think it happens in a terribly bad way, but you still get examples emerging, which are unclear and you get into a lot of argument about what is good coastal management for a particular project, for example. So I think the framework's there, it's just it's questionable whether it's thorough.

Facilitator: So what about the information that's available to - so accepting that the framework's there, is there enough information currently to make that framework happen, for instance? Or is there a lack of…

Interviewee: Oh no, I think we're almost in information overload in terms of coastal issues. I mean the extraordinary amount of work and, dare I say, the resources going into physically mapping, at high levels of detail, coastal issues, particularly coastal geomorphology, sea level rise impacts, storm surge combined with sea level rise, I mean it's just extraordinary.

Facilitator: So what about human uses within the catchments, are they mapped?

Interviewee: Well, no to the same degree and in a way, there's almost this sort of enormous body of science that we don't quite know what to do with. Yet we keep investing in more and more, better and better mapping. From a planning point of view there's not a lot of point in having really detailed information, Lidar information about a section of the west coast, which no one's ever going to do anything on but you need detailed information where you've got settlements planned or existing

because that's where the developments going to be impacted on by those things.

Facilitator: So is that done in a…

[Over speaking]

Interviewee: So it should be more targeted in my view, about where we go.

Facilitator: So is that done adequately as in terms of doing some scenario analysis and where…

Interviewee: Yeah it's huge. Yeah, masses of information on - I mean you can - and it's publicly available. I mean you can bring up layers on the list, which show you different sea level rise scenarios, there's more work going on about storm surge and the combination of those. There's coastal erosions - different coastlines and geomorphological systems. It's all mapped. It's an enormous amount of work and that's fine but when you come to apply that to a particular place, you can then get into the economic/social complications around what that means and it's not the same in two different places.

Facilitator: Is that information available, the socio-economic?

Interviewee: No, that's what we haven't done and…

Facilitator: Oh, I can do that for you.

Interviewee: Yeah. Good luck. I mean it's starting to be done but you know, if you look at - I don't know the figures here but I reckon if you looked at the amount of money spent on mapping the data, getting the data for issues as opposed to working out what that's going to be for particular places, it would be 90 to 10 per cent.

Facilitator: Yeah, it falls apart a bit. Yeah, yeah, okay, so is that resources, do you reckon? Is it manpower that actually limits that or is it [unclear]?

Interviewee: No, it's an - dare I say it in these hallowed scientific halls but frankly it's a tyranny of environment science. I mean I never thought I'd use the term and I use it quite a lot these days. We're in a sort of stage, I think, where there's just this obsessing with collecting data and collecting more and more data because it appears the right thing to do. There's a truckload of stuff and no one knows what the implications are. That's for somebody else to worry about. That's for planners to worry about and there's a handful of planners.

Facilitator: Right, okay, thank you for that. I'll pass that on to my colleagues in the science area. Okay, so that probably just about wraps up that question about the things that promote and inhibit success and constraints at a general level, though we didn't talk very much about the success but that might come up a bit more later.

Interviewee: Yes.

Facilitator: So is there any examples where specific issues have been addressed in estuarine sort of contexts and estuary management and can you think of an example and discuss the - basically bring together the previous two questions about what made it work, what didn't, what triggered it.

Interviewee: Yeah, well you mentioned earlier the Lauderdale Quay, Ralphs Bay Marina residential - I don't quite know how to describe it because it's pretty unclear what it was, in some ways. This was a major project at Lauderdale just east of here in a very shallow bay called Ralphs Bay for effectively a dredged and then sort of reclaimed land, residential estate with marina frontages.

Facilitator: This was a private developer?

Interviewee: A Canal Estate. This is Walker Corporation. The reason it achieved prominence here is because it was nominated as a project of state significance in our planning system, which elevates it to above the planning schemes and to an integrated assessment by what was then the Resource Planning Development Commission, the predecessor of the organisation I work for. They carry out a scrupulously independent integrated assessment of all the issues associated with that. Primary amongst those, of course, was the consideration of the state coastal policy, what that meant.

So a whole string of environment issues associated with that location and not the least of which was the potential of the Spotted Handfish, a rare and endangered species, heavy metal contamination, disturbance through the dredging, but then, you know, a whole bunch of recreational social values and so forth. I think what I found difficult and other planners found difficult was that the threshold planning issues were sort of down the agenda and almost not relevant to the way it was looked at.

So the primacy of discussion and argument and evidence was all around the environmental things as though the planning things weren't important at all and that you could fix the environmental things or you could address the environmental things through engineering solutions and mitigation and

environmental management, irrespective of broader strategic issues. So the problem was that it took months and months and months and you got vast amounts of money spent addressing whether the Handfish was there or not and if [unclear] show them what numbers and would it be affected and all this stuff.

The threshold question was do we want 500 houses in that location irrespective of whether it was in the Bay or on the land next door? Was that a critical threshold issue in the first place? I think what these things often miss is that you get into these complex arguments about detail when the threshold issue might make a determination earlier on. So ultimately the project was recommended for refusal because there were a sort of cumulative number of environmental impacts but it was also the planning issues were not properly addressed. Interestingly - and I argued that that canal estate was coastally dependent, which is sort of self-evident in a way.

Facilitator: Being a canal estate.

Interviewee: …but whether you needed 500 houses there when there was a vast amount of undeveloped residential land close by and within the Greater Hobart region, which had been zoned for that purpose. What's the issues of creating more land where there isn't land and arguing that it has to be there because it's coastally dependent. So that brought together a whole bunch of issues and focused them all in one process, [into a graduated] assessment process.

At the end of the day I think you have to say it was successful because it determined that certain values were important and this was not required and the issues could not be addressed, but the other issues there were things like the local council, which initially being in support of it, started to get really worried about who was going to have the ongoing maintenance…

Facilitator: Of the project.

Interviewee: …obligations of the foreshores and the services and so forth. That's where the dollar hits the road, if you like, and they started to get quite concerned, yeah.

Facilitator: That's an interesting addition. So that's a specific planning issue and sort of covers a lot of that environmental concern, I suppose, for estuarine environments. Do you know of any programs that work - environmental programs that are working in an estuarine environment in the south east of Tas, I suppose, that are either successful or unsuccessful and do you know what makes them that way?

Interviewee: Well I know there's the Derwent Estuary Program. I don't know - I'm not in a position to say whether it's successful or not. If you're judging success by is the water quality up to scratch and so forth and it may well be achieving those objectives but I guess the issue is how are they going about that, given that they don't have any statutory role in planning decisions beyond or even to do with the river itself?

So what we have to do is make sure that those issues are built into the strategic planning of the city, around the estuary and going quite a long way back, and that the values are sort of codified and integrated into planning schemes so that decisions are made in accordance with the outcomes without directly calling up the program itself all the time.

So you do, through having codes that deal with water quality, runoff and stormwater management programs at a council level. You get those in place and then you should be protecting the values of the ecosystem of the estuary through the runoff issue.

Facilitator: So just outside of that a little bit, I guess, do you think in terms of people's awareness of issues in the Derwent Estuary, do you think that the program may have achieved some outcomes there?

Interviewee: Oh look, I suspect so and I think the primary one there is probably a recreational use. You know, there were days not so long ago when beaches were quite regularly closed for water quality issues. I'm not a fisherman but it seems to be an awful lot of recreational boat users and fishermen and fisherpersons - fisherwomen - fishers yeah, who are concerned about water quality in the estuary and the fish, whether you can eat the fish and all that sort of stuff. So I'm sure they're very important.

Facilitator: The fishermen or the programs, the outcomes?

Interviewee: Well, eating fish, that's good for you.

Facilitator: It's good for your brain.

Interviewee: It's good for your brain. I probably need some more.

Facilitator: I won't keep you much longer. There's only two questions to go.

Interviewee: That's all right.

Facilitator: Okay, so we're on to question four now, and we're going to take climate change into consideration now. The title of the question

is how to deal or not, with climate change and the adaptive management of estuarine issues.

Interviewee: Right. Well, I'll have to come tangentially at it, I guess. I mean one of the issues emerging in land use planning and strategic land use planning is whether you should start taking into account the notion of retreating or changing estuarine physical areas with rising sea level and plan to allow those areas to expand where they're not at the moment. That's difficult and that's contentious because it's based on suppositions and projections about the way that may occur and how far it might go and you've got contesting land uses in those areas in the short term.

So wherever you've got that pressure of people wanting to develop, live, you know, establish settlements in close proximity to the coast and then you've got changing coastal edges, you've got the recipe for a difficult situation. Unfortunately with planning and development issues, there's no single fixed point that you can make judgements about because you get a fairly simplistic argument, I think, in the literature to some degree, that talks about the lifespan of buildings as though you, if you determine the lifespan of a house it's 60 years, 50 years, 60 years, 70 years, you can sort of put some triggers in over time or you can establish the life of a permit for that period and then you can review where the sea level is and whether you need to let that continue or not.

That's fine if the world was one house on one block of land - a new one - you could do that, but we live in complex cities, which have been evolving over many, many years and incrementally change every day. So where's the point in time that you work back from? You just can't do it. So to think that you can establish lifetime permits with limited lives and then go back and review and stop something happening at that point is a bit simplistic. Then it's further compounded by the fact that it's sort of what I call a Faustian bargain that people would enter into where they say - you say to somebody now, look, we'll let you build your house on the edge of that estuary now but in 70 years' time or 50 years' time we'll need to review whether the estuary's shifted and you might need to vacate your house. Are you happy to do that?

They'll say oh yeah, 70 years, yeah, I reckon it's okay. In 70 years' time you go back there and you say I'm sorry the estuary's at the front door now, you've got to get out, they're going to say no way, I'm not going to get out now. You say but you said you would. Yeah well I'm not doing that now. I need

you to defend my house from the rising sea level and the encroaching estuary or whatever and they're not going to go and government is then - so I think it's a very simplistic notion to think that you can manage human behaviour by setting now timeframes they think they might agree to but somebody else may not when it gets to it. That's a really wicked problem.

Facilitator: So how do you see those things happening?

Interviewee: Well, I think what you've got to do is acknowledge that certain places will always have settlement and it may - well, you're from Holland, you've seen it at work. What do they do? They build great big things to keep the water out and they actually reclaimed more land. Holland's bigger now than it has ever been, in terms of land mass because they keep reclaiming more but you look at the New Orleans example, you know, seriously after Hurricane whatever it was, yes - Katrina.

Facilitator: Katrina.

Interviewee: Should we be living here at all? You can't ask that question of a city. The city is not going to move. It's not a single organism that can get up and walk away.

Facilitator: But then the engineering solutions aren't going to fix it, are they?

Interviewee: Yes exactly, no, but they will mitigate some of it. So you're into a mix of engineering solutions to deal with it to some degree. There's always a high-level risk and the government here and the emergencies - trying to think what they're called now - part of the Premier and Cabinet that deals with emergencies and…

Facilitator: Emergency services? Hazards?

Interviewee: Anyway they're doing a huge amount of work on hazards and building a risk methodology to put this into the planning system and it's essentially based around - and if you want to I'd be very happy to give you the name of a guy who's done this really good work on - and in fact, there's a good paper put out…

Facilitator: What's his name?

Interviewee: **** you're looking at very unlikely risks of catastrophic impact you basically can't plan for but you deal with through emergency management at the time. Then down the other end, quite probable risks but you can…

Facilitator: Control.

Interviewee: …control even through building engineering solutions or strategic planning solutions. So there's a whole - and what we're trying to do is take those and put those into a planning and building system so that you end up with a sort of banding of things. So there's areas where you say no one can go and build; there's areas where you say people that exist there at the moment, they should be allowed to extend their house a bit more because they're already there…

Facilitator: At their own risk.

Interviewee: …at their own risk, et cetera. So there's some interesting approaches. I feel like I've wandered from the subject a bit but the other work that's going on around the coastal policy review, the coastal planning and management framework or whatever it's called, is the notion of determining the different typology for different parts of the coast. This is something they've done in Scotland and it's a really interesting approach because it means you do a sort of strategic approach to different values and you end up then prescribing different management and planning regimes to deal with it.

Facilitator: These are human values or environment values? Both?

Interviewee: No, a mix, a mix. So…

Facilitator: Economic values as well as - yes.

Interviewee: Yeah so you may have had your three coastal typologies, natural coast, which is essentially environmental values take precedence. The other extreme, developed coast, where we're sitting right now…

[Over speaking]

Interviewee: …where economic and social cultural values take precedence and in between is a modified coast where there's some change to the natural coast but there's still some natural values and yeah, that would be large chunks of the east coast of Tasmania with rural land running pretty much to a coastal reserve.

Facilitator: So this is a values mapping exercise.

Interviewee: Yes, that's [unclear] and then from that, you end up with - you can then prescribe different planning and management regimes to deal with each of those. You're not going to treat where we are now in the middle of Sullivans Cove at Hobart in the same way they're going to treat something at St Helens or something at Bathurst Harbour. They're different values and they require

different responses and different things will be allowed under different circumstances.

Facilitator: So really what you're saying is that it would be nice to have some sort of - and I hate the word framework but I'm going to use it anyhow…

Interviewee: No, that's what it - yeah.

Facilitator: So it's about the decision makers having some readily accessible, easily understood framework to stream - it's almost like a decision tree. If hits, then maybe you have to look at that. If you're in this area, then these values apply so this would be one of the things that you have to look at when you're…

Interviewee: Yeah, yeah, except what we would do in the planning system is actually take that decision tree and through the zoning of land and through the requirements for development to address, you actually build that into those documents, into those tools. So it's not open slather every time someone comes along and then follow a framework, what is allowed to even be considered is already the result of that framework in action down to a certain level.

Facilitator: Okay, that makes sense.

Interviewee: So you just don't zone natural areas on the coast, which have got high environmental values for things where development can impact on those values. The planning system says no. Only in extreme, rare circumstances would anything occur there and it can only be done under these very tight, codified requirements.

Facilitator: Thank you, that was clear.

Interviewee: Good.

Facilitator: …and insightful. So, last question is about adaptive management. So if you go back to the high-level specifics, I suppose, we just wanted to find out the governance, the role of governance for adaptive management. So I guess, or the inverse of that: how important is adaptive management and governance of these estuarine areas? I assume you're very familiar with what adaptive management is?

Interviewee: Mm, well, to some degree. I think it flows, to some extent, from what we were just talking about, in the area I work in, because the critical thing is to determine what the future of certain areas - what the preferred future of those areas will be and to ensure that you have I guess, different adaptive management

regimes for those different paths. So - this is pulling a few things together and I might be missing the point here a little bit but the - so you're going to apply different solutions in different places and the adaptive management of an existing low-lying settlement on the coast - Kingston Beach is a good example if you look at the projected sea level rise, storm surge impacts, it basically just disappears.

Facilitator: Oh really?

Interviewee: Yeah but who's going to walk away from that? So you know, when you roll in the social/economic values of those places, then you're going to get a different decision about the response that you would in an area without much habitation. Some areas are just - I mean the other ones, which spring to mind, which are difficult is Cremorne, which is just - the spit of Cremorne is just…

Facilitator: Goes under.

Interviewee: …just going to be completely washed away and it's got houses all over it. So you have to - and Lauderdale's another one where there are different impacts in different parts of it. So governments, councils and the community need to have some sort of decision-making framework about what the future of those places is going to be.

Facilitator: So do they have that at the moment?

Interviewee: No, it's not clear and there's a reluctance to go there because it requires some very tough decisions. You're basically going to say we're going to defend this one, we're going to retreat from that one and we're going to not go there. These are really difficult situations.

Facilitator: So this is about the differential implications that you have to argue that you're going to have different actions in different places based on some sort of logic…

Interviewee: Yes.

Facilitator: …but does the current system allow for that to happen at all?

Interviewee: Yes it does, theoretically. There's no reason that a local council, for example, could not say we have determined, looking at the evidence of sea level rise, encroachment of salt marshes et cetera into this area, that we will not allow new development there. Where it gets tricky is where there's existing development or some existing development and some land

that's developable and the pressure is on to defend. Then there's an issue of liability, ongoing liability.

If more development is then allowed, there's a threshold question there where once you determine that defence of an area is warranted because of what's there already, if you then allow more development there, do you then increase the risk profile undermining the decision you made in the first place? Invermay in Launceston is a really good example of this. They've done some really good work up there in Launceston about a detailed look at Invermay and the - it's almost like a precinct approach where certain things are allowed but only to an extent, but they recognise that it's there and it's not going to go away. So what do you do about it?

Facilitator: So is there currently enough scientific information and funding support for this type of adaptive management to take place? You've said that the legislative structure is there. That might not be so much…

Interviewee: Oh, yeah. No, I think you've got the legislative structure; you've got a lot of money thrown at scientific research into the actual…

Facilitator: Biophysical…

Interviewee: …biophysical attributes and projections. It's the bit in the middle that's the problem.

Facilitator: So is the projections about what humans are going to do in that environment?

Interviewee: No, no. It's projections about what the climate will do, what the sea level will do, where the water will go, what cliffs and soft, sandy things will be eroded along the way.

Facilitator: But is it available or not available?

Interviewee: Huge amount available, masses, masses of detail.

Facilitator: That's what I was - yeah, I guess that's what I was saying, that it's about what the humans are going to do in their - like it's about projecting population change, what activities.

Interviewee: Oh yeah, that's the stuff that's not done, yeah.

Facilitator: Yeah no, I understood it correctly, yeah.

Interviewee: That's what I mean about the tyranny of science. It's like - I'm trying to think of a metaphor. It's this thing about constantly

building the information base and it sounds a bit trite but that's almost easy to do because it's not politically and socially…

Facilitator: Yeah, it's stating the facts.

Interviewee: …it's just sooner or later you've got to say we've got enough information and as a planner, you don't need all that detailed stuff because planning only makes the call to a certain level. It doesn't often say a complete no or a complete yes. It says if you want to go there you're going to have to address some of these issues and we'll look at it at that time. There's shades of grey there so you just don't need detailed projections to the millimetre of sea level rise in areas.

You just need to know roughly whether it's going to be an issue and then you've got to start making some - so we need to do a lot more work with coastal communities about the values that are there, knowing what we do in the science, to make some political, social planning calls on whether we defend or retreat. We're not doing enough of that. It's too tough and it's politically hot, really hot.

Facilitator: Yeah, and it's not an easy thing to do, either, I mean to…

Interviewee: Oh. God yeah.

Facilitator: …have an aspect of human behaviour and try and predict and…

Interviewee: No, no, it's not. It's horrendously complicated but it's not going to go away.

Facilitator: Now, one last question to wind it up and that's - one of the things that it says here: where should climate change adaptation management - the management of climate change in an adaptive concept, where should that reside in a centralised authority, or should it reside in science? It's a little bit of a vague question but it's more about whether this adaptive management approach can be decentralised or centralised and your opinion on that.

Interviewee: Yeah, it's tough, isn't it? I would think in a way it needs to be - well I'm not sure if it's decentralised or centralised but it has implications across a whole range of activity in government and so forth. Getting the information together is one thing but you need some area that says where it should go, who's going to use it and what purpose. I think the way it's sort of structured at the moment is quite good because you've got - Department of Premier and Cabinet's got an Office of Climate Change and

there's a lot of work coming out of there and they just deal with other agencies and on other issues.

Facilitator: What about the science? Is it…

Interviewee: Well they often will - what's the word - fund or sponsor particular research for…

Facilitator: In fact, this one is…

Interviewee: …particular purposes, yeah, yeah. So you know, mapping sea level rise on the coast is a consequence of that decision because we know what the impact need to be but it's then how's that used, it's still the missing bit. So ultimately a lot of decisions in government need to take those things into account and I think that - in the planning world it's reasonably straightforward because we have as you say, a framework, which does that. So if you utilise the framework properly you build policies, you build strategic planning layers and planning schemes and codified standards for construction in certain places and so on and so forth. You sort of bring it in at various levels.

That's the only way I can work in the planning system. It's got to be embedded at every level so that it's reinforcing all the way down. The reason these things in the planning system get neglected or become controversial is because they're dragged in at the last minute to inform a development decision not built into the strategic land use planning in the first place. Part of the problem here is that there's a tension between an environment management view of the world and an engineering solutions view of the world and a planning view of the world because the engineering and environmental management is more about case-by-case, site-by-site response in fixing things.

So environmental management probably sits in the middle and says well, these sorts of things will occur, you can mitigate them by doing x, y, and z and the engineers will go and do it. The planners are left out of the loop and the planners would say well if we didn't go there in the first place none of you guys would need to worry about it.

Facilitator: …and you'd be out of a job.

Interviewee: Well, you know, so there's - the danger is if you produce all this science about individual specific place impacts and then you hand it, effectively, to anyone, the engineers will just go to town because that's what engineers do.

Facilitator: Yeah, so there's a fine line between centralisation and decentralisation, is what I'm hearing, is it? It's about connecting…

Interviewee: I think you need to centralise how it's used because you need someone to be able to make sure it's delivered across the platform. If it only goes in one direction you end up with a whole lot of engineers with fantastic ideas about defending coastal locations and ensuring certain things occur across the community of fortune and if they fail then you've got major problems. Planning gets left out of the loop because people always want to pretend that there are fixes for things instead of just leaving it alone. In planning we get a lot of people saying we just want certainty in the planning system. Well, you can have certainty in the planning system: the answer's no.

Facilitator: That's a bit harsh.

Interviewee: Well, there are occasions where you have to say no but there are a lot of occasions where you can say yes if you do it a certain way but where those cut off points are, I think we've - in recent years there's been an explosion of complex and sophisticated solutions to things that's effectively to say you can go anywhere and do anything as long as you mitigate the effects.

Facilitator: Well…

Interviewee: There you go.

Facilitator: Thank you very much for that.

Interviewee: That's all right.

Facilitator: I don't have any further questions; do you have any questions for me?

Interviewee: Well, I'm intrigued to know the inevitable question, what will happen?

Facilitator: What will you do with…

Interviewee: What are you going to do with it?

Facilitator: Okay. So we have several people that are being interviewed and basically then we'll analyse the types of responses that we've got to each of the questions and we'll use some - it's like a - it's a word analysis package, basically, that we use to see whether there's similarities and divergences in opinions and whether they can be classified in any way.

Interviewee: Okay.

Facilitator: We then are putting together a report for this project that basically tries to find a way of doing the exact thing that we ask questions about: adaptive management in coastal estuarine systems and basically coming up with examples and ideas about what would make it work and what would make it not work in the sort of context of climate change. So that's what will happen. Now, whether this ends up being a report that ends up on a shelf somewhere or whether it ends up being heavily promoted and taken up is always a bit of a random thing but hopefully, of course, we'll try to make a difference but we'll keep you in the loop.

Interviewee: All right, good, and if you want any referrals to planners who are far more experienced than I am in this area I can give you some names.

Facilitator: Okay, that'll be good. Thank you **** and I'm going to stop the recorder right now.

[Aside discussion]

Appendix 3: Assessment of local government progress

in marine climate change adaptation in Australia

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Abstract

Coastal communities are vulnerable to a diversity of marine climate change impacts, ranging from the effects of sea level rise on coastlines and infrastructure, to biological and physical changes in marine ecosystems and the flow on effects for marine resource users. The way that marine climate change manifests in coastal communities will be dependent on local conditions and systems, and adaptation responses will need to be tailored to suit individual communities. The responsibility of adaptation planning is therefore largely placed on municipal councils, as they are situated to organise action at

the local level. While the need to track and understand the progress of adaptation is becoming increasingly apparent, much goes unreported in the peer-reviewed literature. Our study provides an assessment of local government progress in adaptation to marine climate change in Australia's coastal communities.

In general, progress in climate change adaptation in Australia is in the early stages. Many councils have no plans, and the presence of plans seems to be related to the magnitude of council income as well as participation in regional or international adaptation networks. Of those councils that do have plans, only half have progressed beyond the understanding phase. Additionally, the focus of marine adaptation planning is largely restricted to one driver – sea level rise. Changing sea surface temperatures and ocean acidification were largely ignored, despite predicted impacts on coastal ecosystems and the communities that interact and depend on them. While it is often assumed that the developed world has the capacity to adapt to climate change, this study indicates that for some important aspects of marine change in Australia, this capacity has not necessarily translated into action among all actors, in this case councils. The development and refinement of progress indicators such as those used in this study will be increasingly important as tools for establishing baselines and tracking adaptation into the future.

1. Background

Evidence is growing that climate change is impacting the bio-physical characteristics of the oceans; including sea surface temperature change, sea level rise, and acidification (Burrows et al. 2011). In consequence, coastal communities are vulnerable to a range of climate change impacts, both from changes to sea-levels and coastlines, and from changes in the marine ecosystems they depend on. However, by far the most widely acknowledged and discussed element of marine climate change faced by Australia's coastal communities is inundation and loss of land from sea level rise {Abel, 2011 #2268}. This is often experienced through acutely damaging flood events caused by a combination of high tide levels and increased storm activity (Field et al. 2012). These changes are increasingly impacting marine ecosystems, and flowing on to impact marine socio-ecological systems (Neuheimer et al. 2011) and the coastal communities that form part of these coupled systems (van Putten et al in press). Socio-ecological systems are impacted in complex ways; both through threats to infrastructure, and through threats to livelihoods and industries.

The nature of threats to socio-ecological systems

Threats to infrastructure are fairly straightforward. Nationally, more than $226 billion in commercial, industrial, road and rail, and residential assets are potentially exposed to inundation and erosion from climate change. As a result, the ability to provide critical infrastructure and essential community services such as electricity generation, emergency services and waste management is likely to be severely impacted (DCC 2009, DCCEE 2011).

Threats to livelihoods and industries are more complex. Because changes in marine conditions are tightly linked to changes in marine ecosystems, they are predicted to have far ranging impacts on industries such as aquaculture, fishing and tourism that depend on marine resources, and on the coastal communities that rely on these industries. For instance, changes in marine conditions will increase vulnerability in the aquaculture industry, both generally through increases in incidence and impact of diseases, and site specifically by reducing the suitability of certain areas because of inundation, unpredictable fluctuations in salinity and temperature, and increased risk of damaging storm events (De silva and Soto 2009). Furthermore, changes in primary and secondary productivity and species range shifts will alter the availability and abundance of wild caught marine species, where and how they are accessed and who is able access them (Daw et al 2009). Historically, fluctuations in fish stocks have had major economic impacts on societies, with communities dependent on a limited range of species or a limited area being most vulnerable. The exact nature of changes in fisheries due to climate change is difficult to predict given the complexity of these systems (Brander 2010). What is clear is that many fisheries are highly susceptible (Lehodey et al. 2006) and this brings increased uncertainty to the Australian fishing industry (DCC 2009) and the many coastal communities that rely on this sector. Coastal tourism is also likely to be affected, with roughly a third of Australia's tourism industry centred around regions highly vulnerable to climate change (Hoegh-Guldberg 2008), most notably the Great Barrier Reef (Wilson et al. 2011). Nature tourism is an important feature of many coastal economies, and mostly consists of small operators vulnerable to changing tourist preferences and perceptions of 'pristine nature' (DCC 2009).

In general, coastal communities are likely to face pervasive loss of business and employment due to the relocation of firms and industries away from the coast as climate change related disruptions become more common. The diverse and well publicised risks associated with climate change, whether perceived or actual, could seriously damage the economies of many coastal communities (Linnenluecke et al. 2011).

The manifestation of marine climate impacts

The way that climate change in the marine environment manifests in coastal communities will be dependent on local conditions and systems. Australia's coastline spans the tropics, the subtropics and the temperate zone, presenting a vast array of coastal ecosystems and oceanographic features. Global climate change has, and will, continue to manifest locally in radically different ways due to this variety of climates and location-specific circumstance, such as an ocean warming hotspot in the southern state of Tasmania (Poloczanska et al. 2012).

While the localised impacts from changing coastlines are reasonably tangible, impacts from changing marine ecosystems are often complicated by the response of interacting social systems. Understanding coastal communities as parts of social-ecological systems (Liu et al. 2007) is important to recognise not only the way changes in the marine environment impact human systems, but also the consequences of human responses on the marine environment. These reciprocal impacts and feedback systems change the way adaptation to change is dealt with (Perry & Ommer 2010). For example, the way a community responds to ecological change can have either a dampening or compounding effect on the way this change manifests in ecological systems (Cinner et al. 2011). Not only are marine climate change impacts and adaptation responses specific to particular marine systems and given locations, they will also be peculiar to the nature of interaction a community has with these marine systems and also how that interaction is likely to change. For instance, climate driven marine range shift (Chen et al. 2011) may encourage the development of new charter fishing opportunities in north east Tasmania (Metcalf et al. 2014) In contrast, range shifting marine jellyfish species such as Irukandji, may cause the southward relocation of tourism activities in Queensland (Crowley-Cyr 2012).

Implementation of adaptation action

The responsibility of implementing adaptation action has thus far largely fallen on local government. As locally specific responses are needed, municipal governments are widely considered best positioned to understand, interpret and predict the local implications of global climate change. Local governments are often perceived as the most appropriate level of government to implement adaptation initiatives (Ford et al. 2011). The Australian federal government has positioned local councils on the 'frontline' of national adaptation (Pillora 2011) and as the key agencies of community change.

While this seems like a logical arrangement, the management of marine and coastal areas, their natural resources and the human activities (both proximate and distant) that influence resource condition fall under a diverse range of institutional arrangements from multiple levels of government. This situation is complicated further when attempting to manage ecological and social-economic systems whose boundaries do not mirror the spatial division of municipal or state jurisdictions.

Assessing and reporting adaptation action

While the need to track and understand the progress of adaptation is becoming increasingly apparent, much activity goes unreported in the peer-reviewed literature. To understand the nature of the challenge and address deficiencies in a coordinated and logical way, the progress and pace of adaptation must be assessed and reported (Berrang-Ford et al. 2011). How this progress relates to projected climate change impacts and understandings of community resilience can inform policy and direct further research (Ford et al. 2013). Previous reporting of adaptation progress has assessed only the peer-reviewed literature, yet much information is contained in the so-called grey literature, with a particular lack of studies from Australia (Ford et al. 2011). It seems prudent to develop ways to systematically include grey literature in analyses of adaptation progress.

With debates over climate change action becoming increasingly politicised, it is important to measure how progress in policy and planning relates to expected impacts in a logical and systematic way. Our study provides an assessment of local government progress in adaptation to marine climate change in Australia. We systematically examined the official adaptation plans of coastal local governments relating to marine climate change along representative stretches of Australia's coastline to evaluate 'adaptation progress' (Moser & Ekstrom 2010). This meta-analysis of official local government documentation and publicly available information provides a rapid assessment of adaptation progress. This work provides an indication of adaptation progress at the regional level for three contrasting Australian coastal regions, and so offers a proxy for progress in coastal climate change adaption. The development and refinement of methodologies such as this will be increasingly important as tools for establishing baselines and tracking adaptation progress and pace into the future.

2. Methods

Stretches of Australian coastline were selected as case studies. The regions represented a variety of council sizes (with at least one large urban center) and different demographic and economic characteristics. Moreover a wide variety of the coastal environments and conditions was represented. The selected areas were in southern West Australia (from Perth to Albany), eastern Tasmania (from Hobart to Dorset), and eastern Queensland (from Brisbane to Townsville). Western Australia, Tasmania and Queensland were also the subject of another climate change related study (See Metcalf et al. (2014) and van Putten et al (in press)) which aided in the interpretation of the result.

A total of 67 councils present along these stretches of coastline were included in the study. For each local council, all official documentation (such as strategic plans, management plans) that mentioned the words 'climate' and/or 'change' were identified (using a whole domain word search of the official council website). These documents were then searched for specific statements related to coastal marine climate change adaptation. Only official documentation was used as these are a functional part of the adaptation process, whereas other council published sources such as newsletters and web pages describing council activities are not.

The information gathered was used to determine the adaptation phase of each council and the nature of the adaptations being planned. To this end, specific statements made by an individual council related to marine climate change adaptation were assessed according to; (i) the climate change drivers that were addressed, with the following categories; a) changing sea surface temperatures b) ocean acidification c) simple sea level rise (A change in the position of the coastline due to sea level rise) and d) sea level rise complex (addressing at least one of the associated effects of sea level rise such as salt-water intrusion or increased storm surge height) (ii) what phase of the adaptation process a council was in, with the following categories; a) whether the gathering of understanding for potential future adaptive action was planned, or b) actual adaptive action was planned (iii) whether these plans related to; a) economic or b) infrastructural adaptation.

In addition to the above main data, a range of council characteristics were recorded in order to perform analyses that may elucidate certain factors important in the development of adaptation plans. Information on income from 2011/2012 rates and total expenditure was gathered from individual council budgets. Information on membership of councils to associations facilitating adaptation was gathered from individual council websites or the website representing the regional, state, or international organisation. Information for each local council was also retrieved from the Australian Bureau of statistics 2011 census database, including population size, percent of the population involved in the agriculture, forestry and fishing industries.

Finally, whether drought featured as the main driver in their adaptation plans was also recorded.

The assessment undertaken does not allow us to assess the sophistication of the process each council has gone through in developing their plans. A process of developing robust criteria for action that takes into account the inherent uncertainty of marine climate change is essential in a successful adaptation process. Consideration of uncertainty ensures resources are used in a more appropriate and effective way as response to changes (Harris 2009). However, a council may release detailed implementation plans without having gone through the essential step of assessing uncertainty, and therefore may artificially appear further progressed through the adaptation process.

An aspect that could not be measured as part of this analysis was the quality and appropriateness of the adaptation response, because that would have required an in-depth understanding of each local situation. For instance, after a detailed assessment and the implementation of monitoring systems, it may be appropriate to postpone further planning until a point in the future when certain indicators of change have been reached. Given the purpose of this study was to provide a rapid assessment and give a proxy for the current adaptation status, it is unable to provide detail or analysis of the process each council had undergone in the development of their adaptation plans. Therefore, we have simply measured a council's present stage in the adaptation process, and the results should not be understood as a judgment of the quality of a council's response.

3. Results

This study of council marine adaptation plans shows that while many councils had released official adaptation plans or had adaptation statements within their general planning documents, they were at very different stages of the adaptation process. In fact, most councils were aiming to get a better understanding of the potential impact of climate change in the marine environment and the effects on infrastructure and their communities and had not begun actual planning of on-ground adaptation actions.

3.1 Adaptation Progress

Most coastal communities were in the early stages of the adaptation process, meaning that most had not yet implemented any form of adaptation, and were still either gathering information in order to understand the local impact of climate change in the marine environment, or were still planning the kind of action they would undertake in the future. Of the 67 councils in this study, 42% did not have any official marine adaptation plans or the plans were in preparation and existed in draft form only (25 and 3 councils respectively).

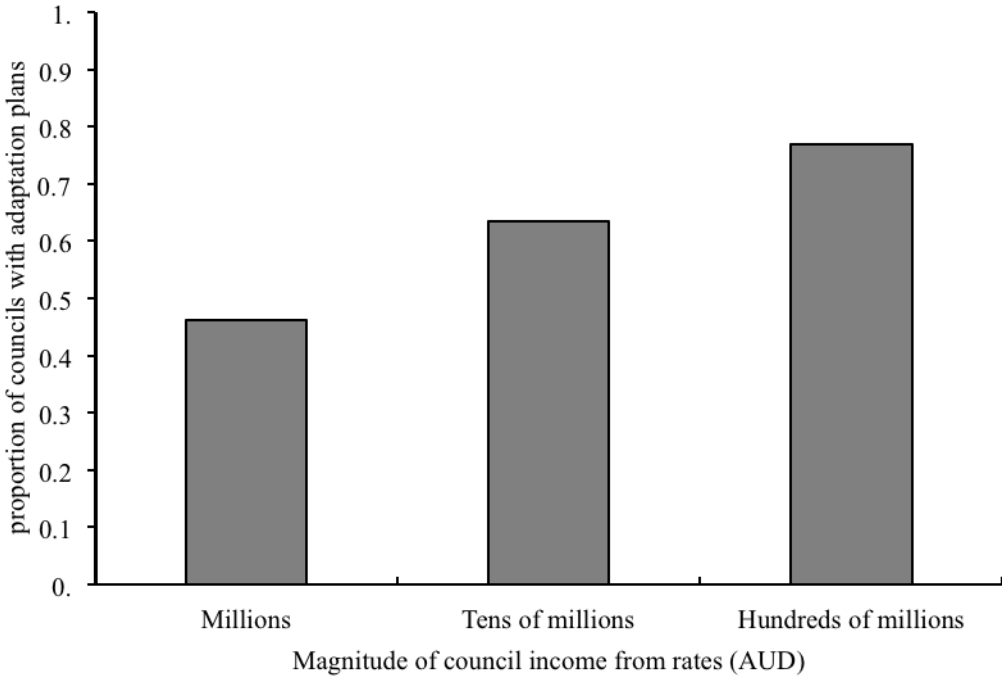

Figure 1: The proportion of councils with marine climate change adaptation plans grouped according to magnitude of income from municipal rates paid by home owners. Millions (1-9 million) Tens of millions (10-99 million) and Hundreds of millions (100 million and over).

It may be hypothesised that the population size and concurrent municipal rates-base and the associated value of funds available to a local council may have an impact on the ability of the council to develop and carry out adaptation plans. In our sample of councils the average rates base was around $66 million in 2013, with the smallest council at $1.2 million (Nannup in WA) and the largest at $871 million (Brisbane in QLD). Our results show a relationship between higher total income from rates and the presence of marine adaptation plans (Fig 1). As expected this same relationship applies to population size and total spending, as the correlation of these two variables with income from rates is 0.973 and 0.958 respectively.

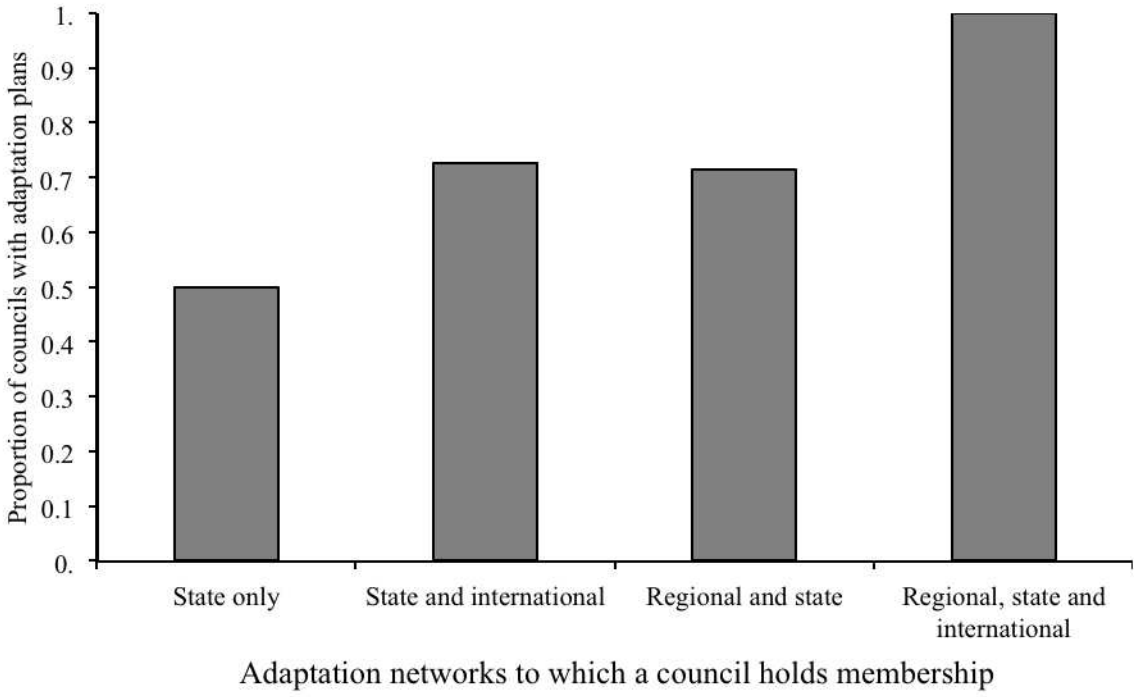

Figure 2: Proportion of councils with adaptation plans according to their membership to regional, state and international adaptation networks.

The presence of organisational membership and information networks appeared to have a positive influence on the development of marine adaptation plans (Fig. 2). In total 35 councils were members of organisations that had as a stated aim the facilitation of local adaptation to climate change (this did not include membership of state council associations, to which all councils belong). Councils that were voluntary members of regional (ROCs) or international networks (ICLEI) mostly had marine adaptation plans.

3.2 Stage of the adaptation process

Of the 42 councils that had official adaptation plans, just under half (18) were in the initial phase aimed at 'understanding the problem'. These councils were still in the process of identifying and understanding marine climate change impacts, and actual adaptation planning had not yet commenced. Their activities were aimed at understanding the local impacts of marine climate change included modelling and forecasting, as well as assessments of how these projections relate to existing infrastructure or land use. For example in Fremantle, WA, the Climate Adaptation Plan states that "The City has commenced a detailed modelling exercise of sea level rise" and "will also conduct a risk assessment and begin detailed adaptation planning" (pg 6). Similarly the Sunshine Coast, QLD, council Climate Change and Peak Oil Strategy states that it will "undertake initial vulnerability and hazard mapping to identify major risk areas due to climate change" (pg 51).

A total of twenty councils had undertaken initial research assessments and were now in the so-called 'planning adaptation options' phase. The plans of the councils in this phase detail the ways in which they will incorporate understanding of the impacts of marine climate change, and thus identifying the circumstances where adaptation will take place. The plans identify areas that require special consideration, such as "Development located near a shore line, creek line, river line or waterway is to be undertaken in a manner… which takes into account possible future sea level rise and the associated impacts" (Rockhampton, QLD, Natural Hazards and Climate Change Study, pg 7). The plans also outline when and under what circumstances certain adaptation options will be used, for example, "Shoreline erosion protection measures will only be utilised to protect essential constructed public infrastructure where it is both economic to do so and where there is limited opportunity to relocate the infrastructure at risk" (Fraser Coast, QLD, Shoreline Erosion Protection Structures, pg 3). This indicates that these councils have engaged with the critical step of developing robust criteria for action. Ten of these councils had detailed plans that addressed specific impacts or identified particular impacted areas. For example Break O'Day council, TAS, had detailed plans to address the inundation of sewage treatment ponds due to sea level rise and increased storm tide heights, which shut down aquaculture in the bay for a month after each event. In the short term the council plans to "ensure tanks are emptied regularly through education or through a local council funded service" and "waterproof current pumps". In the long term the council plans to "remove tanks" and in either "relocate facility or use alternate form of [sewage] treatment" (climate change strategy, pg 2).

It is clear that some councils within this phase appear further developed than others due to the presence of specific plans as opposed to less specific decision criteria. However, for reasons detailed in our methods section, in some situations councils may have prudently adopted an 'abandon' approach or a 'wait and see' approach, both of which are unlikely to be included as part of official adaptation action plans. Drawing a distinction between groups with detailed decision criteria but no specific plans, and those with specific plans would be premature without a more detailed assessment of their internal decision making process – a task beyond the scope of this study.

3.3 Breadth of focus in adaptation plans

Marine adaptation plans often focus on only one driver of climate change. Of the 42 councils with marine adaptation plans, 36 restrict their attention to sea level rise. Of the councils that focus on sea level rise 18 specifically address the breadth of associated impacts such as increases in storm surge frequency and height, coastal erosion, and salt-water intrusion. In general, the way councils plan for sea level rise is to acknowledge the potential impact and outline how future conditions may be incorporated into current management practices or how current management practices may need to be adjusted. Greater Geelong council states that it will "incorporate consideration of climate change in coastal planning decisions through existing planning tools" (Climate Change Adaptation Strategy, pg 25). Eurobodalla shire council will achieve this by using "a one hundred year planning period… for all development, operational and strategic decisions that may be impacted by sea level rise" (Interim Sea Level Rise Adaptation Policy, pg 3). The use of current town planning and land zoning practices proved to be a common method of dealing with predicted inundation, for instance Bega Valley, NSW, states that "in urban areas… council may have to look at the delineation of a coastal hazard line or zone and either prohibit/restrict development in these areas" (Natural Resource Planning, pg 6).

While sea level rise is commonly addressed in council marine adaptation plans, the implications of other important marine climate drivers are much less frequently addressed. Only 4 councils addressed sea surface temperature (SST) increase in their adaptation plans, and none of the

councils addressed ocean acidification. While for those councils in the implementation stage this may simply reflect the results of prior vulnerability and risk assessments, the absence of the investigation of these drivers among councils in the understanding phase suggests a pervasive lack of focus on these other aspects of marine climate change.

The impacts of SST changes were mainly discussed in terms of the potential impact on marine industries and resource users. For instance, the Sunshine Coast council, QLD, focused on the acute impact of SST increase on the "emergent health risks" from the southward spread of Irukandji stingers (pg 32). The South Perth council, WA, was taking a holistic approach to improve their "understanding of how fishes and their supporting ecosystems respond to changes and how these changes impact biodiversity, recreational and commercial values" (Climate Change Strategy 2010 – 2015, pg 16). There was one council that had final adaptation plans for increased SST, Break O'Day, TAS. While the South Perth council actively aims to support the resilience of the fisheries resource, the Tasmanian Break O'Day council's adaptation actions is of a more 'responsive' type. The stated aim of the Break O'Day plan was to facilitate fisheries and aquaculture industries adapt to the changes in species of fish available/suitable under future conditions. The adaptation plan indicates that the potential barriers to change are "government regulations such as species-specific licenses and catch limits" (pg 2). Even though an adaptive management approach and institutional change may be one adaptation measure to marine ecosystem change, the Council plans did not discuss this adaptation option.

Council adaptation plans were generally focused on council assets and town infrastructure (33 and 38 respectively), with little attention paid to the impact of climate change on local economies via its impacts on marine ecosystems, marine resources or tourism. Only five councils discussed the predicted effect of future marine climate change on local businesses and the potential economic and social flow-on effects. The way in which these five councils planned to assist local businesses adapt was by means of treating the symptoms including, for instance, "programs that encourage and assist" the development of relevant skills (Bayswater, WA, Regional Climate Change Adaptation Action Plan, pg 31) or by ensuring "appropriate planning and policy mechanisms are able to support business" through the "identification of new industries & businesses, urban design & investment in infrastructure" (Belmont, WA, Local Climate Change Adaptation Action Plan, pg 24). In contrast the council of Mandurah takes a further step to treating symptoms and develops actions to reduce the problem. The council of Mandurah had focused adaptation measures for the tourism industry, and sought to "incorporate climate change considerations into long-term tourism strategies", "collect data on coastal recreation demand" and "support research and works for conservation of nature based tourist attractions" (pg 11). Consideration of economic impacts was found only among those councils that considered multiple impacts of climate change beyond sea level rise, and proportionally more common among those that considered more than one driver (i.e. sea level rise and increasing SST) (Table 1).

Table 1: Count of councils according to drivers addressed and whether their adaptation plans related to the economic impacts of marine climate change or just infrastructural impacts. Associated impacts include; coastal erosion, salt water intrusion and increased storm surge intensity and frequency.

Drivers addressed	Adaptation related to infrastructural impacts	Adaptation related to infrastructural AND economic impacts
Sea level rise	15	0

Sea level rise and associated impacts	15	4
Sea level rise, associated impacts AND sea surface temperature increase	2	2

3.4 Adaptation plans and council attributes

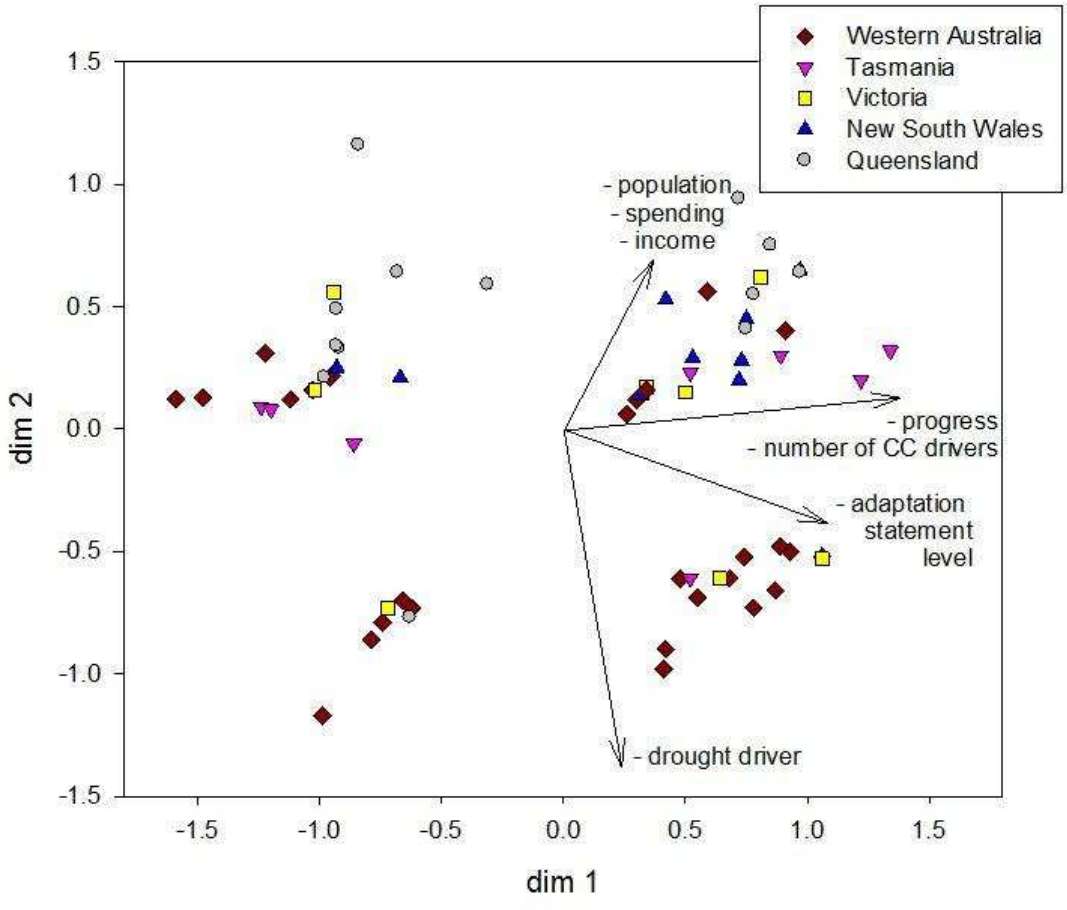

Figure 3. MDS ordination plot of all 67 councils according to all attributes gathered in this study. Samples are coded according to state. Vectors indicate the direction in which council attributes correlate most substantially with the ordination space. Stress = 0.08.

Councils were found to form four distinct groups that relate strongly to certain council characteristics (Fig. 3). These groups are distinguished from each other by three important factors – councils 'size' (the highly correlated variables of population, total spending and income from rates), the degree to which their adaptation plans were developed (the strength of their adaptation statements, their progress in terms of stage reached in the adaptation

process), and whether drought was the dominant driver addressed in their adaptation plans. The group found within the positive area of both dimension one and two are large councils with well-developed adaptation plans. However, many large councils also had poorly developed adaptation plans, and these form a separate group. In addition, not all councils that had well-developed plans were large, with smaller councils mainly from WA forming a separate group, distinguished also by the dominance of drought in their adaptation plans if these were present. Finally, small councils that had poorly developed plans formed a separate group. These four groupings demonstrate that the degree to which adaptation plans are developed is decoupled from council size and access to resources in an important way. Taken together with the results presented above (Fig. 1) this suggests that while income seems to have an impact on whether a council develop plans in the first place, it does not seem to have an impact on how well developed those plans are.

4. Discussion

4.1 Progress is in the early stages

The results of this study indicate that Australian coastal communities are in the early stages of progress in marine climate change adaptation planning. Despite local governments being positioned 'on the front line' of responding to climate change, not all councils had considered marine drivers. Of those coastal councils who had considered it, few had progressed beyond the understanding and planning phases. This is mirrored in developed countries world-wide; actual intervention is rare, and where it is occurring, it is typically in the early stages (Moser & Ekstrom 2010). Importantly, the presumed high adaptive capacity of developed nations such as Australia may not necessarily translate into adaptation action (Ford et al. 2011). The various barriers that constrain the local adaptation process and result in this global pattern of inaction are the subject of continued scholarship (Moser & Ekstrom 2010). Our study provides some evidence of two widely reported barriers; a lack of resources and a lack of connections to relevant organisations that provide information and assist in communication. These two factors may be contributing to the slow progress of adaptation planning, and translating planning into action, in Australia's coastal communities.

The correlation between financial rate base and planning on marine climate change adaptation found in this study indicates that access to adequate funds is an important prerequisite for progress. Councils may be more likely to act if their financial throughput is above a certain threshold, with financially smaller councils unable to manage the redirection of funding away from other activities. A lack of resources, whether absolute or perceived, may limit actors that would otherwise progress adaptation (Tribbia & Moser 2008).

The ordination of councils according to their attributes demonstrated that when variables relating to the development or sophistication of plans are examined, income is no longer an important determining factor. This suggests that resources are only important up to a point. Once councils have enough resources to begin developing plans, other factors not examined in this study may become more significant. Certain attributes of council staff such as level of education and specific climate change adaptation training, as well as institutional culture have emerged as important enablers of action in other developed countries (Burch 2010). Additionally, the presence of a champion in the council or nearby in the social and political landscape can be crucial to the development and progress of adaptation (Roberts 2008). Finally, the level of climate change impact being felt (or perceived) in that local area may have a huge motivating or legitimating influence on adaptation actions. Given the large disparity in felt impacts across the Australian continent this may be more important in creating some of the observed differences in action between councils than in other, spatially smaller countries.

Effective communication, particularly between and across different levels of government in the coordination of adaptation efforts, has been identified as a major barrier to action within European countries (Biesbroek et al. 2010). An aid to overcome this may be participation in adaptation-focused networks, which emerged as being closely linked with marine adaptation plans in our study. Participation in adaptation-focused networks seems especially pertinent in regional initiatives that link several local governments in a geographical area. Regional organisations of councils (ROCs) are voluntary partnerships between several (usually neighbouring) councils in a region, dedicated to cooperatively perusing certain agendas by sharing resources, information and responsibilities across jurisdictional boundaries. Many have developed into sophisticated regional governing networks (Marshall et al. 2003). Some have taken up the challenge of regional adaptation, and serve as the hub for the development of member council adaptation plans. This may be particularly important in advancing adaptation if the social-ecological system of concern functions at a larger spatial scale than local government areas (Moser & Ekstrom 2010). In this circumstance functional relationships between councils will be crucial to avoid serious barriers (Cash et al. 2006).

4.2 Narrow breadth of focus in adaptation plans:

In the context of climate driven change in the marine environment, it seems most councils focus solely on sea level rise with an obvious lack in accounting for the multiple drivers involved. Given the wide range of impacts for coastal communities associated with the effect of increased sea surface temperatures and ocean acidification on marine ecosystems, this appears to be a major gap in Australia's overall preparedness for predicted climate change. As many of the economic impacts of marine climate change are linked to these other drivers, it is somewhat surprising that few councils have plans to adapt to the economic aspects of marine climate change. This is a trend throughout the developed world – adaptation is overwhelmingly in relation to transportation, infrastructure, and utilities sectors – areas where investments have a long lifespan (Ford et al. 2011). In our study all 37 council marine adaptation plans involved some mention of infrastructural adaptation, while only 5 also involved economic adaptation. For coastal communities, impacts on livelihoods through changes in fisheries and tourism especially are likely to be significant, yet this remains a neglected area in council adaptation plans. The reasons for this could be the intangible nature of predicted impacts and the adaptation required. In addition, the comparatively strong incentives for action that are associated with sea level rise seem to be lacking for these more indirect impacts.

While the results of a sea level rise impact assessment are relatively simple to translate into council policy, much of the research surrounding the impact of climate change on marine based livelihoods cannot deliver tangible predictions. Instead, the emphasis is on unpredictable system behaviour, where feedbacks, thresholds and nonlinearities inherent in these systems produce unexpected outcomes. Sea level rise is fairly straightforward to respond to with the management tools commonly used by councils, such as rezoning areas of development and residence, and as evidenced in this study, this is how councils are proceeding. Other aspect of marine climate change adaptation (especially where dynamic social-ecological systems like fisheries are involved) such as building adaptive capacity (Madin et al. 2012), developing institutions and instruments for reflexive and adaptive management (Brander 2010) and building and diversifying the livelihood asset base of the community (Badjeck et al. 2010) explicitly require the use and sometimes the development of new management tools. Scholarship on ways in which to operationalise resilience (Davidson et al. 2013) is available, yet it seems these types of approaches have not yet been widely adopted by councils.

While councils have been positioned on the 'front line' of implementing local change, there seems to be a duality to their involvement in adaptation activities. On one hand there is the well-established legal and institutional impetus to properly manage their own assets and

responsibilities in the face of change, and on the other is the relatively recent high-level directive of their role in providing leadership in adaptation. The former may be a more immediate incentive for councils. Legal responsibility in the face of climate change impacts was a stated concern of councils (Pillora 2011), and a report by the legal firm Baker & McKenzie (2011) was commissioned by the Australian Local Government Association. Councils face legal liability if they have '*unreasonably*' failed to take into account the effects of climate change in their service, planning and development activities. Effectively, this leaves them open to liability from tangible impacts, but not from less tangible and predictable impacts such as those reported for ecosystem change. Responsibility may play a key role in decision making for councils, especially in the prioritisation of actions. For example, the climate change risk report (Travers et al. 2009) commissioned by Mandurah, WA, to determine their adaptation response categorised the council's level of responsibility for implementation for each adaptation option. Aspects of marine climate change adaptation that are clearly the responsibility of councils (legally or otherwise) may be receiving the bulk of what resources are available, while other aspects of adaptation where responsibility remains ambiguous may be falling by the wayside.

4.3 Adaptation as a uniquely local process

From the perusal of council documents it is clear that every situation will be qualitatively and quantitatively different; each problem unique; the focus of adaptation, the stage of development of plans and actions different; the purposes varied (e.g. some aimed at determining vulnerabilities, others aimed at determine future options, others aimed at specific actions); and each system typologically different and of different spatial extent. Councils are not equivalent, and given that the process of adaptation must be unique, each council will necessarily progress through this at different rates. More important is the quality of the process, which rests heavily on the reasoning used in decision making. The basis on which these decisions are made is the locus of adaptive success. Having robust criteria that take into account both the dynamic nature of the social ecological system in question, and the seemingly obvious but often unacknowledged requirement that adaptation plans must necessarily be 'adaptive', can help ensure that action taken is appropriate in the long term. Key aspects of this process take place during closed meetings and communication, as well as being part of the social and political context in which all council processes are embedded. So, while difficult to assess and well beyond the scope of this study, these are probably the areas where the most fertile improvements can be made.

5. Conclusion

No other study has carried out a comprehensive assessment of climate change adaptation planning and actions for coastal council around Australia. Our findings give insight into current progress of adaptation and the consideration of marine climate change drivers nationally, indicating some potential drivers of plan development amongst councils and highlighting significant climate change planning gaps that may be of future concern nationally. Not all councils have undertaken to understand marine climate change effects in their area, and of those who have, only half have progressed into the planning of actions phase. Larger councils with a larger financial base are more likely to have a plan, however this seems to have little influence on the progress or sophistication of their plans, with other, most likely institutional, factors becoming important. There is little difference between the States in terms of adaptation progress, yet the only evidence of adaptation planning for the economic flow on effect of marine climate drivers other than sea level rise is in the south-east, which is a marine climate change hotspot. The economic impacts of marine climate change are likely to have significant future implications yet may fall into 'the adaptation gap' because it is not a clear council responsibility and also somewhat removed from State and Federal responsibility. The future implications of

these existing gaps are of national significance. It is clear that councils with a more sophisticated understanding of the problem are likely to have more encompassing responses, and are much more likely to develop Robust Strategies (sensu Lempert et al. 2010) that minimise harm from climate change impacts spreading to other sectors and assets.

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Appendix 4: Adaptation strategies for optimised public benefits from Australia's estuarine and coastal marine ecosystems: 9 principles

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Contents

Background:

The underlying goal of publically developed adaptation strategies must be to manage the impacts of climate change and sea level rise to optimise overall public benefits[12]. This trade-off is particularly complex in estuarine and coastal marine ecosystems (ECMEs: estuaries, nearshore marine waters, tidal wetlands and coastal freshwater systems) because of their diverse environmental values and extensive human utilisation, and the complex socio-ecological systems[13] (SESs) (Redman et al. 2004) they support.

The estuarine and coastal marine space is complex environmentally, economically and socially. Much of the world's population is concentrated along coasts and around estuaries – this is particularly true of Australia. Along with that goes extensive agricultural, urban, industrial and port development. At the same time, ECMEs are areas of high conservation and biodiversity values. Sites of high ecological value, like Kakadu and Hinchinbrook Island National Parks, demonstrate the direct conservation value of ECMEs, but their value extends far beyond this. ECMEs occupy a pivotal location between land and sea and perform important roles in moderating seaward flows of nutrients (Ford et al. 2005, Webster et al. 2005) and pollutants (Brodie et al. 2003, Haynes et al. 2007), making them vital to the health and wellbeing of offshore natural assets such as the Great Barrier Reef. In addition, the high productivity and nursery value of coastal aquatic ecosystems means they are critical to the resilience[14] and long-term health of Australia's coastal fisheries, with many commercially and recreationally valuable fisheries occurring in and around ECMEs, and many offshore fisheries depend on ECME nursery grounds and productivity.

These vital roles mean that damage to estuaries and coastal wetlands threatens key linkages in life-cycle and productivity chains, threatening the robustness and resilience of both fisheries and assets of national and international significance. ***Here we focus on the issue of developing adaptation strategies that optimise the ecosystem services provided by estuarine and coastal marine ecosystems, while harmonising with other facets of the public benefit.*** We address ***adaptation strategies*** (the large-scale conceptual vision of alternative adaption pathways) rather than the ***adaptation plans*** or ***actions*** that are informed by adaptation strategies. We present nine key principals for developing adaptation strategies for Australia's estuarine and coastal marine ecosystems. The principles are aimed at an overarching strategic level but are supported by research, case studies and reviews (Appendices 1-6) that provide a range of tactics and options for operationalizing the principles depending on local typological and spatial factors.

[12] **Public benefits:** Benefits stemming from resources that are available to all, as opposed to resources where access is limited to particular individuals.

[13] **SES:** The interaction of biophysical and social factors in a resilient and sustainable manner (Redman et al. 2004).

[14] **Resilience:** The capacity to retain identity & function in the face of disturbance & change (Folke et al. 2010)

Principles:

1: Successful adaptation strategies need a to be developed in a broad, holistic context

Climate Change is only one of a broad suite of factors that impact coastal systems with many of the impacts of Climate Change only representing changes in the frequency of stressors that have been active for millennia. Strategies need to be developed in a SES landscape where there are many competing interests to be considered; for example, actions that might be good for shoreline protection might negatively impact industry, livelihoods, fisheries, tourism or the environment. The embedding of Climate Change in an array of stressors and the need to consider the multiple ways in which any action can impact other facets of the SES, together with the need to consider short- and long-term goals and effects, means strategies need to be developed in a broad, holistic context.

2: Focus on whole-of-system, long-term transformative outcomes for socio-ecological systems

From a broad range of perspectives, maximum public benefit accrues from maintaining and restoring resilient ecosystems that provide healthy human living environments, support optimal biodiversity and underpin robust and productive fisheries. This is best achieved by focussing on long-term transformative outcomes at a whole-of-system scale that provide on-going benefits by enhancing resilience and reducing vulnerability into the future. Focussing at a whole-of-system scale reduces the chance of local level actions producing contradictory outcomes. Focussing on maintaining and enhancing ecosystem resilience provides long term durability and availability of resources because it supports continued ecosystem functioning in the face of substantial change; in essence future-proofing the system. In addition, because ecological systems are intimately influenced by the social systems that rely on them ensuring resource resilience needs to focus on the socio-ecological system as a whole.

3: Employ robust strategies that minimise harm across human and natural systems

Strategies need to be considered with respect to the life-time of their consequences; decisions with short term consequences are usually only taken in the context of the current climate or with a short-term change horizon. In contrast, adaptation decisions aimed at long term outcomes need to accommodate future predicted change. In the absence of the ability to look into the future and choose desirable rather than maladaptive pathways, decision makers need to adopt strategies that limit the risks of unforeseen consequences. This requires the development of robust strategies that recognise the intrinsic uncertainty of our knowledge of the future and the consequent limitations on our ability to predict future events and the consequences of actions. These strategies should be robust across the range of future possibilities, and not rely on tightly predicted outcomes but are robust in the sense that they do no harm if an unexpected course of events occurs, and do not close off the possibility of future actions.

4: Acknowledge a multi-scale vision and incorporate a multi-scale approach

The coastal space is by nature complex; it has a large range of stakeholders with very different and, potentially, conflicting objectives. Furthermore, governance systems are fractionated into different tiers of government and local bodies, making a co-ordinated approach to management difficult. Furthermore, the adaptive management loop may show up the benefit of an action at totally different time and spatial scales than was originally intended. In fact, due to the long-term nature of some climate adaptations, the system response to an action may be well beyond the life cycle of a management body. Consequently, comprehensive adaptation strategies need a vision that embraces multiple scales and leads to decisions and actions that embrace multi-scale understanding.

5: Ensure Fair, Representative and Equitable Stakeholder Engagement

Comprehensive stakeholder engagement is important to achieve natural resource outcomes in the context of adaptation to Climate Change. Engagement of all stake-holders in strategy development in a participatory approach combining top-down and bottom-up perspectives provides both a richer suite of perspectives and legitimacy through participation and consideration of stakeholder aspirations. Stakeholder involvement needs to occur from beginning to end to ensure translation of large scale objectives to local solutions. Keeping stakeholders engaged requires facilitation of on-going stakeholder interest and involvement through mentoring and championing, and ensuring they are intimately involved in decision-making.

6: Harmonise legislation, policy and actions to achieve large-scale, long-term public benefits

Harmonising actions and public benefit will involve increasing the concordance between the scales at which ecological and biophysical processes occur, the scales at which legislation and policy are made (central government), and the scales where actions are taken (local governments/regional bodies).

7: Effective Governance that is clear, consistency and complementary

The complexity of governance relating to Climate Change, and responses to it, means there is a need for clarity, consistency and complementary in defining responsibilities and policy implementation of different management/governance authorities. Consequently, substantial success requires integration of top-down (State, Commonwealth) policies and legislation, and bottom-up (local, community) level actions; together with a clear definition of roles and responsibilities.

8: Focus on achievable and realistic delivery of adaptation strategy outcomes and outcome-support tools

Do no fixate on different frameworks; this is a side-track and the strict structure of a framework can lead to unrealistic outcomes. Rather, concentrate on what is needed for the task at hand and only choose a framework if it helps achieve a specific, realistic and achievable outcome.

9: Optimise outcomes by employing adaptive feed-back cycles appropriately

Adaptation options that include adaptive management cycles should be seen as the "normal" way to do business: flexible adaptive management that allows whole of system approach across different management levels. An adaptive framework should be adopted because, although complex relationships between cause and effect (a “wicked problem”) usually mean that optimal solutions are impossible, adaptive frameworks allow movement towards a defined goal.

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Appendix 5: Review and assessment of tools to support climate adaptation for estuaries

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Review and assessment of tools to support climate adaptation for estuaries

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Abstract

Many of the world's estuaries are vulnerable to climate impacts (e.g. sea level rise) leading to a need for rigorous adaptations strategies. A review of climate adaptation tools using attributes such as the relative availability of the tool, the skills required to use the tool and the amount of data needed to use the tool is undertaken. Tools are defined as an instrument (model, GIS interface, software or web site, description or template) that helps managers develop climate adaptation options and identify trade-offs in the estuarine space. Risk and vulnerability assessment tools tended to be quantitative, whereas those for decision support tend to be spread between all categories of qualitative, semi-quantitative and quantitative. Across all the 44 tools reviewed, they exist in various formats, mainly as documentation, online platforms and computer software. Only 8 (18%) were free downloadable software with open source licenses. Many of the tools required high capability inputs (dollars, skill, and time). Based on scoring attributes, the qualitative methods perform well and may be preferred given their use of stakeholders and lower capability inputs. However, it is clear that there is a need for a diversity of tools, since no one method stands out across all the attributes.

Keywords

Climate adaptation; estuaries; tools; vulnerability assessment; risk assessment; decision support tools; review

Introduction

Estuaries can be defined as a partially enclosed water body along the coast in a transition area where rivers and streams meet and mix with salt water from the ocean. The estuarine and coastal marine space is complex environmentally, economically and socially (Sheaves et al. 2014). Many key habitats can be found here, such as wetlands, salt marshes, seagrass, mangroves and RAMSAR bird sites. Iconic or threatened species (turtles, dugong, inshore dolphin) are dependent on these habitats for key parts of their life cycle, so too, many commercially exploited animals such as crabs. Commercially this area also supports many industries, including fishing and ports – indeed many of the world's largest cities surround estuaries. Much of the world's population is concentrated along coasts and around estuaries, for example, more than 80 million people live in the coastal areas of Europe (ETC/ACC 2010).

Estuaries are one of the most impacted marine ecosystems (Halpern et al. 2009; Lotze et al. 2006), often experiencing cumulative impacts of more than 15 stressors (Halpern et al. 2009). In that context, climate change is likely to further impact these areas through sea level rise, temperature increases or extreme weather events (Lotze et al. 2006). Globally, many local management bodies are developing climate adaptation strategies, but it is arguably time to move from strategies to implementation. However, one of the important needs to move from high level strategies to on-the-ground action are tools that help management understand the necessary trade-offs. Developing tools are the mainstay of many natural resource management occupations such as Management Strategy Evaluation and other tools in fisheries (Dichmont et al. 2008; Fulton et al. 2007; Plaganyi et al. 2011; Smith et al. 2007), water budgets for inland water systems (Yang and Wang 2009) and risk assessments in fisheries (Hobday et al. 2011). Like many fields, there are numerous tools available for climate adaptation work (see reviews such as (ETC/ACC 2010)), but in many respects the very large numbers of tools mean that it is helpful to place these in some context of where in the Climate adaptation process they apply and in which context.

Klein et al. (1999) developed a generic climate adaptation framework that, at its core, was an iterative process of i) information awareness, ii) planning design, iii) implementation and iv) monitoring/evaluation. Inherently, this process conformed to the adaptive management loop of using a structured process of making robust decisions in the face of uncertainty, and learning from doing (Holling 1978; Walters 2007).

In the context of Klein et al. (1999), this paper undertakes a critical review of tools that could be applied to assist with climate adaptation in estuaries. This review uses various metrics and classifications to highlight gaps, strengths and weaknesses of the classes of tools available. It builds on existing reviews done by others, especially (ETC/ACC 2010) and UNFCCC Secretariat (2008), by providing a link to which component of the above process they apply, but also in relation to several attributes such as availability and ease of use. Unlike many other reviews, some basic summary statistics of the reviewed tools are also provided.

Materials and Methods

A review of tools applicable to climate adaptation in estuaries was undertaken using a staged approach. Here we adapt the definition of the tool from UNFCCC, i.e., a means of instrument by which a specific task is accomplished (UNFCCC Secretariat 2008). Initially, an internet search using Google, Google scholar and Web of Science was undertaken. The keywords used in the search included various combinations of "climate change", "vulnerability assessment", "adaptation methods", "estuary" and "coastal zones". Several web hits were reviews of tools, notably from United Nations Framework Convention on Climate Chang (UNFCCC Secretariat 2008) and European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation (ETC/ACC 2010), which were then used to create a base tool list for this paper. The list was circulated to other CSIRO climate adaptation scientists for feedback – several tools were subsequently added. Despite this review process, the resultant list of major known tools available to address the issue of developing adaptation options for climate change in estuaries is not exhaustive – it was not the intention of this review to capture all methods available on the topic, but rather review and then evaluate easily available tools.

Klein et al. (1999) divided the steps to developing climate adaptation strategy into a series of processes – Information and Awareness, Planning and Design, Implementation, and Monitoring and Evaluation. The list of tools were divided into two steps of this process (Table 16), being (1) a risk assessment ("RA"), (2)a vulnerability assessment ("VA") that fall into the Information and Awareness category, and (3) a decision support tool ("DST") which is part of their Planning and Design process. This review did not investigate tools that fall into the Monitoring and Evaluation categories.

Once the tools were placed in one or more of these steps, they were then grouped into a further ten model categories (Table 16 and Online resource Table S1 for more descriptive detail of these categories).

In addition the tools were scored against nine attributes (Table 16), such as whether they were quantitative or qualitative, available as open source, commercial (and whether a trial version was available) or only as a method description. This was based on the literature reviews and authors' experience.

Those tools that were easily available (either as free- or shareware, or a commercial product available with a trial version, or a well-described quantitative method) were also tested by the team of authors. Based on these tests, comments and notes were recorded and the attributes were refined. Furthermore, the methods were subjectively assessed for the tool attributes on a scale of 1 to 3 (see Online resource Table S 2 for the scoring criteria).

These attributes were used as a basis to carry out basic statistical analyses to glean some common elements of the tools within and between each climate adaptation step.

Results and Discussion

A description of the set of tools and references that were analysed can be found in the Supplementary material Table S 1. Some of these tools are in the form of frameworks, web addresses or method descriptions and as such are not models with associated software'.

The scoring attributes assigned to each model (Online resource Table S 2 and Online material Table S 1) highlighted several points. Although Risk (RA) and vulnerability assessment (VA) tools abound in the literature, only 38% of the tools fell into this category for the review. Most of the tools fell within the decision support tools (DST) class (39% of those found in the review) or were both VA and DST (23%) (Table 17). Climate change RA or VA tools tended to be semi-quantitative (25% or 75%% respectively) or quantitative (33% or 67% respectively), whereas those for decision support tend to be spread between all categories of qualitative (based on Delphic-like methods), semi-quantitative using stakeholder input, and quantitative (47%, 24% and 29% respectively) (Table 17). The tools were in various formats, including published documents, computer software and live online platforms. Among these tools, 23% were either not available or only briefly described in a publication; 7% were available with some restrictions (including fully commercial license, commercial service pack license – but trial versions may be available only for testing purpose); and 70% were available for download or as a useable web browser. These latter tools came in various formats including documents, computer software and online platform, and they respectively represent 43%, 11% and 46% of the total reviewed tools. Within the computer software tools, 40% were open source, 15% were fully or partially under commercial licenses and 45% were not available at all. Since many of the tools came from the two review papers, despite contacting many of the authors the latter group highlighted that many tools that are developed tend to fall by the wayside as they are either not maintained, obsolete or under development. Many of the tools required high capability input – 32% required high modelling skills, 27% were data intensive and 18% would be time consuming to use (Online resource Table S 2). Many of the high modelling skills and time required were for the open source models, often because they tended not to supply training support or high-end GUI interfaces.

Tools are also categorised into 10 categories (Table 16) according their structure, purpose and format. It is partially adapted the classifications from (UNFCCC Secretariat 2008) and from (ETC/ACC 2010) that focus on applications on coastal zone areas. Among those tools reviewed, 27% are "Dynamic computer models", 18% are "Other decision support tools", 16% are "Framework/toolkits" and 11% are "Index methods; Few tools fall into each of the remaining categories.

No single tool scores high for all the attributes (Figure 1 and Online material Table S 1), which mean that tool choice is driven by purposes and resources e.g. whether a data intensive method is required or whether there are serious capacity constraints. In the latter case, the qualitative methods address all components from risk assessment to decision support and may be preferred if capability is an issue, given their use of stakeholders and lower capability inputs.

In terms of uptake of a specific tool (using citations as a surrogate), only 25% had more than 270 citations using Google™; which may be because they are used in several contexts (not exclusively climate adaptation) such as the Ecosystem models EwE

(Christensen and Walters 2004) and Atlantis (Fulton et al. 2011). However, there was no correlation between citation rate and model availability so uptake did not seem to be restricted by financial requirements (Online resource Table S 2).

Many of the models tested were created to respond to the requirements from a wide range of stakeholders – from scientists to managers and policy makers (ETC/ACC 2010). Many models do not take socio-economic factors into account. Some exceptions are SimCLIM, DIVA and Delft3D VA tools and the ecosystem model Atlantis. Even here there are differences between the tools, for instance, DIVA, Delft3D and Atlantis are open source models that are continually being developed as they get applied to more case studies.

Ideally for direct applicability to estuarine systems, the tools should integrate a) the terrestrial and marine environment especially since the maintenance of continuity is key to the successful management of estuaries (Sheaves et al. 2014), as well b) the full socio-ecological system (Österblom et al. 2013). However, few tools are able to do this completely and the most likely are either at the very complex end of modelling (Atlantis) or the least complex – qualitative tools.

When discussing scientific tools to support ecosystem-based fisheries management, (Smith et al. 2007) recommends that a range of tools should be available that covers different scopes, methods and tool types to fully address the complexities of management. When management efforts to implement adaptive management in some North American rivers was reviewed, the conclusion was that effective management needs to incorporate knowledge from multiple sources, support new forms of cooperation among stakeholder but also to make use of multiple systems models (McLain and Lee 1996). Certainly these views are also relevant for climate adaptation tools as no single tool is able to address all the requirements of developing climate adaptation strategies for estuaries.

Conclusions

There are many tools that can be used to address various aspects of climate adaptations. These cover RA, VA and DST; and also use a variety of methods such as multi-criteria decision analysis, indices, GIS and dynamic modelling. A range of tools are already available that are able to undertake most of these tasks. The DST covered the full range of qualitative to quantitative methods, whereas RA and VA tools tended to mostly be quantitative. It would be useful to also expand these into more qualitative approaches.

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Tables

Table 16: Model steps, categories and tool attributes used to classify and evaluate climate adaptation tools. See online material for a further description of Model Category descriptions.

Model Steps	Model Categories	Tool Attributes
1. Risk Assessment	1. Qualitative or semi-quantitative Delphi and stakeholder approaches (”Stakeholder only approaches”)	1. How easy the tool provided enough information, such as documentation, online platform and software to allow its application (“Usability”)
2. Vulnerability Assessment	2. Tools that calculate an index value (“Index methods”)	2. Whether the tool provided enough information that it could be applied to other cases (“Applicability”)
3. Decision Support Tool	3. Tools that use a range of indicators (“Indicator methods”)	3. The degree to which the tool itself is available for use (“Availability”)
	4. Tools that use GIS systems (“GIS based Decision Support Tools”)	4. The amount of user skill required to use the tool (“Skill requirement”)
	5. Non-GIS based Decision Support Tools (“Other Decision Support Tools”)	5. The amount of input data needed to use the tool (“Data intensity”)
	6. Downscaled global climate models (“Downscaled global climate models”)	6. The potential time it might take an appropriately skilled, but new user to apply the tool –based on the research team’s experiences of using the tool (“Time”)
	7. Dynamic computer simulation models (“Dynamic computer models”)	7. The degree of scientific rigour (“Rigour)
	8. Tools that follow the full adaptive management cycle such as Management Strategy Evaluation (“Management Strategy Evaluation tools”)	8. The degree of uptake by other users by measuring the number of citations from Google Scholar and the Web of Science (“Citations”)
	9. Tools that provide guidelines, framework document or toolkits (“Framework/toolkits”)	9. Whether is uses qualitative, semi-quantitative or quantitative method (“Numerical quantification”)

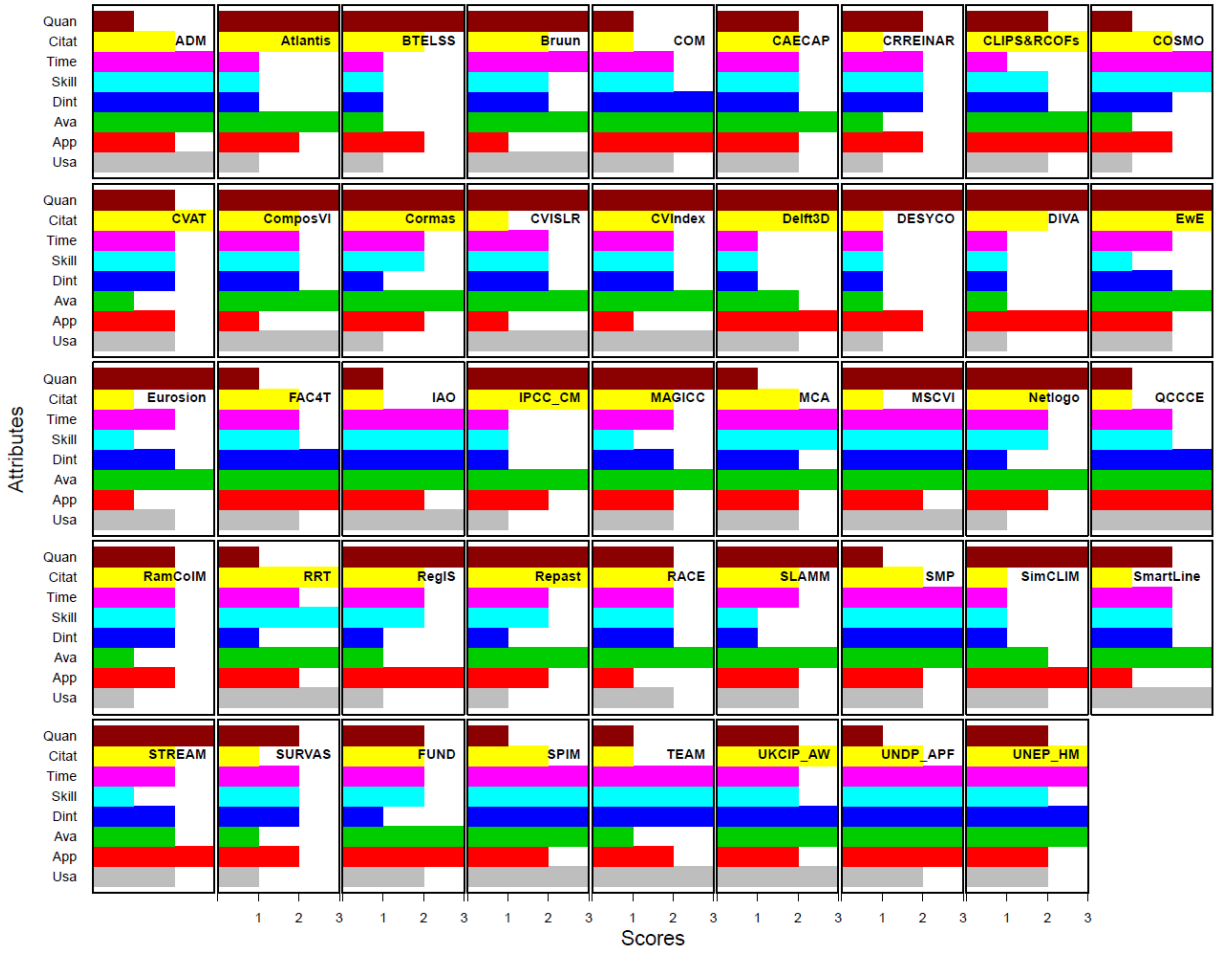
	10. Tool that provide agent based model environment (“agent based model”)	

Table 17: The number and percentage across rows (except the Total Number column which is totals by column) in the case of the degree of climate adaptation tools that was assessed as qualitative, semi-quantitative or quantitative of by model class (Risk Assessment, Vulnerability Assessment, Decision Support Tool).

Model class (MC)	Qualitative Number (% MC)	Semi-quantitative Number (% MC)	Quantitative Number (% MC)	Total Number (%)
Risk Assessment	0 (0)	2 (25)	6 (75)	8 (18)
Vulnerability Assessment	0 (0)	3 (33)	6 (67)	9 (20)
Vulnerability Assessment and Decision Support Tool	4 (40)	2 (20)	4 (40)	10 (23)
Decision Support Tool	8 (47)	4 (24)	5 (29)	17 (39)
Total	12 (27)	11 (25)	21 (48)	44 (100)

Figures

Figure 1: Tools attribute scores for each tool



Online resources

Review and assessment of tools to support climate adaptation for estuaries

Dichmont, C.M.[1], Deng, R.A.[1], Sheaves, M.[2], Bustamante, R.[1], van Putten, E.I.[3], Dutra, L.[1], McLean, N.[2], Dale, P.[4], Sporne, I.[4], Savina-Rolland, M.[1]

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The full list and description of tools is provided in online material Table S 1. These were obtained from Google searches and also input from CSIRO climate adaptation scientists. The tools were divided into model categories based on the combination of (ETC/ACC 2010) and (UNFCCC Secretariat 2008) and the resultant list (Table 16) are described below.

Tool categories description

Stakeholder only approaches

In the review we found that 'stakeholder only approaches' were those used to elicit information and responses from interested and affected stakeholders; using qualitative or semi-quantitative methods in a reasonably rigorous manner. In most of the cases, these approaches can be used in all the stages of the (Klein et al. 1999) generic climate adaptation framework – i) information awareness, ii) planning design, iii) implementation and iv) monitoring/evaluation– but can also be used in conjunction with the other methods. The references below concentrate on examples where the stakeholder approach was the predominant component of the tool.

Index methods

Index and indicator-based approaches are reasonably different although some overlap does occur. In the context of this review, index-based approaches develop a one-dimensional and often unit-less, risk or vulnerability index that are based on a quantitative or semi-quantitative combination and evaluation of different variables.

Indicator methods

Indicator-based methods express vulnerability by a set of independent elements (called indicators) that characterise, in this case, key coastal issues such as coastal drivers, pressures, state, impacts and responses. In many cases, these indicators are combined into a single value.

GIS based Decision Support System

Risk (RA) and Vulnerability Assessments (VA) are key components of the Climate adaptation tool decision support toolbox. Most of these use GIS based tools, which means they are inherently spatial.

Non GIS based Decision Support Tools (called Other Decision Support Tools)

These are tools that assist in making choices between management options, but are inherently non-spatial and do not use complex modelling systems. Examples are Multi-criterion Decision Analysis tools.

Downscaled global climate models

Global climate models are usually at very large spatial scales, but an estuary is usually a much smaller entity. Downscaling techniques are used to produce small-scale climate outputs often required by impact models and to develop climate scenarios at local and national scales.

Dynamic computer models

Dynamic computer modelling are either sector specific models (e.g. coastal erosion, saltwater intrusion, fisheries) or integrated assessment models (e.g. multiple use models). These often include interactions between components of the socio-ecological system and inherently model the complex, non-linear relationships in the system.

Management Strategy Evaluation models

Management Strategy Evaluation (MSE) has been used for many purposes and case studies – for example, in fisheries (Butterworth and Punt 1999) or coastal zone management (Jones et al. 2011). The key ingredients of an MSE are the simulation of the adaptive management loop and that the simulation model includes a description of the management system (monitoring, assessment and decision) and the "true" simulated underlying human and biological response to the management action.

Agent-based models

Agent-based model is a class of computational models for simulating the actions and interactions of autonomous agents (either as individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole (Wikipedia).

Framework or toolkits

Framework or toolkits are those specifically designed guidelines, documents or a suite of various tools to address the solutions of the issues, which are of general similar natures. The users can follow the guidelines, templates or toolkits to address the issues efficiently.

1. Table S 1: List of climate adaptation tools relevant to estuarine or coastal systems based on a Google review, particularly a compiled list from (ETC/ACC 2010; Ramieri et al. 2011) and (UNFCCC Secretariat 2008). Model descriptions are from the relevant reference. Availability – No: is not available at all either in document or software formats; Yes: is available in the formats of descriptive documents/guidelines, online framework/toolkits or computer software. Some of the software is under Open source (OS) or freeware protocol and some are in the format of commercial source (CS). TG is the total citations from Google searches and TWS is the total from the Web of Science citation search.

Climate Adaptation Step	Method Category	Method Name	Description	Assessment targets and adaptation measures	Main data input	Output	Reference, examples and citations	Review of the method	Quantitative versus qualitative	Format of the method or tool	Availability
DST	Other decision tools	Adaptation Decision Matrix (ADM)	The ADM uses multicriteria assessment techniques to evaluate the relative effectiveness and costs of adaptation options.	when many important benefits of meeting policy objectives cannot be easily monetized or expressed in a common metric	A ranking of how well policy objectives are met using alternative strategies; estimated costs of adaptation measures.	Relative cost-effectiveness of alternative adaptation measures	http://link.springer.com/chapter/10.1007%2F978-1-4613-8471-7_7#page-1 (Mizina et al. 1999) Google (39) WS (0) (Smith 1996) Google (12) WS (3) TG: 51 TWS: 3	No tool/package available Repeatable Qualitative measure Less data intensive Less computing intensive Sound knowledge of the subjects	Qual.	Document	Yes
DST	Management Strategy Evaluation tool	Atlantis	Marine ecosystem modelling supports management that seeks to balance sensible development and resource use with the conservation of biodiversity and functioning marine ecosystems	Marine ecosystem, fisheries	Spatial geographical info; local oceanography, chemistry and biology;	simulating ecological processes; to provide strategic advice to fishery managements	http://atlantis.cmar.csiro.au/ (Fulton et al. 2005) Google (203) WS (128) (Fulton et al. 2007) Google (83) WS (0) (Smith et al. 2007) Google (170) WS (114) TG: 456 TWS: 242	Tool/package are not available directly for download, but can register to developers request the package for free Not repeatable Fishery/marine ecosystem focus Very strong skills set including ecosystem modeling, fishery modeling Data intensive Well published Computing could be very time consuming	Quan.	Software	Yes, OS

VA	Tool based on dynamic computer models	Barataria-Terrebonne Ecosystem Landscape Spatial Simulation (BTELSS)	BTELSS is a landscape model built to investigate and predict the environmental factors and pressures (subsidence, sea-level rise, changes in river discharge, etc.) affecting wetland change over a long term period (30 years) within the Barataria and Terrebonne basins (U.S.A.)	Ecological systems: Wetlands. Not addressed by the model	DEM, bathymetry, climatic data, salinity, river discharges, sediment loads, wetland land cover, habitat maps, specific data on plants (such as growth and mortality, salinity and flooding tolerance).	Maps of land changes (habitat switching), flooded and eroded areas Other maps, related to changes in salinity, sediment balance, plant productivity, etc.	http://ecobas.org/www-server/rem/mdb/btelss.html (Martin et al. 2002) Google (35) WS (13) (Reyes et al. 2000) Google (63) WS (39) TG: 98 TWS: 52	Not repeatable No tool/package available for downloading Some reports of its application and publications Expecting a very skill demanding and data intensive method	Quan.	Software	No
RA	Tool based on dynamic computer models	Bruun Rule	The Bruun rule states that a typical concave-upward beach profile erodes sand from the beach face and deposits it offshore to maintain constant water depth. The Bruun rule estimates the response of the shoreline profile to sea-level rise.	Small scale local sites. A model relating shoreline retreat to an increase in local sea level The Bruun rule can be applied to correlate sea-level rise with eroding beaches.	An increase in sea level, (S), cross shore distance (L) to the water depth (h) taken by Bruun as the depth to which nearshore sediments exist (depth of closure), and B is the height of the dune.	Shoreline recession (in metres relative to sea-level rise).	(Bruun 1988) Google (230) WS (88) TG: 230 TWS: 88	There has been a number of critiques e.g. (Cooper and Pilkey 2004) No existed software, need to programming skills to re-program the model	Quan	Document	Yes
VA;DST	Stakeholder Only Approaches	City of Melbourne	Event cascading consequences map; risk identification and assessment; likelihood, consequences and control plots	Targets at municipal facilities infrastructures, health, communities services Addressed by known control measures to monitor or mitigate the risks occurrence	Climate change scenarios of the variables - key elements to the subjects Socio-Economic Changes data and urban system information Knowledge from experts and stakeholders	Risk identification, assessment and adaptation action plan	https://www.melbourne.vic.gov.au/AboutCouncil/PlansandPublications/strategies/Documents/climate_change_adaptation_strategy.PDF (Council 2009) Google (0) WS (0) (Lorenz et al. 2008) Google (10) WS (0) TG: 10 WS 0	Repeatable Template as tool Need sound knowledge of the subjects Not data intensive. Need objective opinion inputs from wide range of experts, stakeholders No need model computing Qualitative solution Easy to apply	Qual.	Document	Yes

VA;DST	Framework/toolkits	CLIMATE-ADAPT European Climate Adaptation Platform	Its adaptation support tool is to assist users involved in development of climate change adaptation policies	A generic guideline on issues in European sectors and regions. Adaptation response to climate change key elements.	It varies. Case studies provided various applications in different regions and interests	Risk identification, assessment and adaptation policies and plans	http://climate-adapt.eea.europa.eu/ 20000 unique visitors per month 5th most visited EEA domain By aug2012 (Ref: http://www.nordicadaptation2012.net/Doc/Oral_presentations/1.1.1_Isoard.pdf) *couldn't search for citations for this web	Tool kit available online Case studies searching tool Some case study maybe repeatable Need objective opinion inputs from experts, stakeholders Data requirements vary Popular in Europe http://climate-adapt.eea.europa.eu/web/guest/adaptation-support-tool/step-1	Quan	Online platform	Yes
DST	Other decision tools	Climate-Related Risks Estimate as Indicators of Necessity for Adaptation Responses	Adaptation measures could be taken when climate-related risks to economic objects, environment or people's lives arise.	Adaption measure estimation for the given territory the social damage and damage probability under dangerous weather event and climate anomaly	Meteorological data about recurrence and intensity of the dangerous weather events and climate anomalies, cost data including GDP, population in the specific region	A quantitative estimate of climate-related risks for specific objects and processes in various economic and social spheres	http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5330.php (Akentyeva 2006) Google (0)* WS (0) *1 search result rather than citation	No tool and package available Not repeatable Using "Fuzzy set" method for complex risk analysis Both Risk assessment and adaptation measure evaluation Fair data requirement Fair computing requirement Numerous publications	Quan.	Software	No

VA; DST	Framework/toolkits	CLIPS & RCOFs	The CLIPS project is an effective framework within which regional climate variability and change information and the associated adaptation issues can be integrated. RCOFs stimulate the development of climate capacity in the NMHSs and facilitate end-user liaison to generate decisions and activities that mitigate the adverse impacts of climate variability and change and help communities to build appropriate adaptation strategies.	Global and regional climate predictions Climate variability and change associated adaptation issues can be integrated.	National/regional/global climate data, climate prediction products from WMO Global Producing Centres (GPCs) for long range forecasts and WMO Regional Climate Centres (RCCs)/RCC Networks, data on climate-sensitive sectors for impact assessment.	Tailored climate products, regional climate outlooks, guidance on best practices in CLIPS operations, verification and user liaison, consensus-based climate products	http://www.wmo.int/pages/prog/wcp/wcasp/wcasp_home_en.html (Basher et al. 2001) Google (15) WS (0) (Palmer et al. 2004) Google (620) WS (402) TG: 635 TS: 402	It is a forum to connect global works on the Climate Information Prediction System Regional Climate Outlook Forum (such as, PICOF),can be integrated No direct tool/package available for but via the platform and forum, various resources available Depends on the application, varied timing requirement	Quan.	online platform	Yes
DST	Other decision tools	Coastal Zone Simulation Model (COSMO)	COSMO is a decision-support model that allows coastal zone managers to evaluate potential management strategies under different scenarios, including long-term climate change. COSMO demonstrates the main steps in the preparation, analysis and evaluation of Coastal Zone Management (CZM) plans. coastal	Coastal zone determine the advantages and disadvantages of adaptation alternatives	The user's chosen management strategy	The outcome of a range of different management options.	http://www.coastalcooperation.net/part-III/III-3-2-2.pdf (Hoozemans et al. 1993) Google (150) WS (0) TG: 150 TWS:0	Demo package should be downloadable but can't access http://www.netcoast.nl/tools/cosmo.html Not repeatable Site-specific or national scale More knowledge of physical and socioeconomic characteristics of the situation. Less data intensive Less computing intensive There should be a software available for this method, but a few links are broken and indicating it may be out of date and without maintenance support	Qual.	Software	No

VA	Tool based on dynamic computer models	Community Vulnerability Assessment Tool (CVAT)	It supports the linking of environmental, social and economic data in the coastal zone. It is a static GIS map overlay procedure that enables a relative risk or vulnerability analysis of coastal communities to a series of existing threats.	On community level, used to conduct a community vulnerability assessment to a range of hazards (not specifically addressing climate change)	Environmental, social and economic data for the coastal zone in GIS format.	Relative risk or vulnerability analysis of coastal communities to a series of existing threats	(Flax et al. 2002) Google (75) WS (0) (Clark et al. 1998) Google (207) WS (0) (Cutter 1996) Google (969) WS (299) TG: 1251 TWS: 299	Most useful for people who wish to gain an understanding of how to conceptualise community vulnerability. There should be a software available for this method, but a few links are broken and indicating it may be out of date and without maintenance support	Quan	Software	No
RA	Index based method	Composite Vulnerability Index	an index combining a number of separate variables that reflect natural and socio-economic characteristics that contribute to coastal vulnerability due to natural hazards. Selected indicators can differ in number, typology and scales of evaluation according to the study area.	Physical and socioeconomic Targets. Considered in terms of evaluation of coastal protection measures	Natural parameters: coastline length and sinuosity, continentality in terms of coastline density into municipal areas, coastal features (estuarine, beach etc.), coastal protection measures, fluvial drainage, flooding areas. Socioeconomic parameters: population and population affected by floods, density of population, nonlocal population (i.e. born elsewhere but living in considered areas), poverty, municipal wealth	Three different indices: natural, socio-economic and total vulnerability index. Indexes can be represented in maps	(Szlafsztein and Sterr 2007) Google (48) WS (24) TG: 48 TWS: 24	Repeatable No tool/package available for downloading GIS based method, relevant skill suites required Data intensive – maps Semi-quantitative measure	Quan.	Document	Yes
DST	Agent-based model	Cormas	a multi-agent simulation platform specially designed for renewable	Various, i.e., environment, natural and social	Management strategy scenarios to the issue	Maps, plots, indicators to response the	http://cormas.cirad.fr/en/outil/outil.htm	Free software available for downloading	Quan.	Software	Yes,OS

			resource management	aspects		strategy scenarios	(Antona et al. 1998) Google (32) WS (10) (Bousquet et al. 1998) Google(368) WS(0) (Le Page et al. 2000) Google (31) WS (0) TG: 431 TWS: 10	Example can be repeatable Very strong agent based modeling skills Widely used in many field More flexible Maps, plots visualization			
RA	Index based method	CVI (SLR)	a CVI to specifically assess impacts induced by sea level rise. The index is determined through the integration of 5 sub-indices, each one corresponding to a specific sea level rise related impact.	Physical system; some component of the socio-economic (i.e. land use) and ecological systems (i.e. natural protection degradation) are considered. Considered in terms of evaluation of coastal protection structures	12 physical (e.g. geomorphology, sediment budget and water depth at downstream) and 7 human influence (e.g. reduction of sediment supply and land use pattern) parameters	5 CVI sub-indices, each one related to a specific sea level rise impact. These are integrated in a final CVI (SRL) index.	(Özyurt 2007) Google (16) WS (0) (Özyurt and Ergin 2009) Google (8) WS (2) TG: 24 TWS: 2	Repeatable No tool available for download Combines physical + human activities Specialises in coastal zone Scale-able Raw data and model output data Comparable Vulnerability assessment only; not a tool for developing action Can be modified to recalculate CVI to see if adaptation action works Can modify index list and weighting between human and physical impacts; scale remains comparable. Semi-quantitative measure Not clearly demonstrate its vulnerability analyses – confusing with risk analyses Some applications in Europe Physical and social-economic impacts	Quan.	Document	Yes

								are equally weighted. Might need further research for scientific values of the weighting.			
RA	Index based method	CVI Index	The CVI provides a simple numerical basis for ranking sections of coastline in terms of their potential for change that can be used by managers to identify regions where risks may be relatively high	Physical system. Not addressed by the index	Data input depends on key variables used to calculate the CVI index. Most common ones include: geomorphology, geology, elevation, coastal slope, shoreline change rates, significant wave height, relative sea level change, tidal range	CVI tables and maps; CVI is classified in groups using percentage limits	(Gornitz 1991) Google (159) WS (50) Google searching "gornitz costal vulnerability index" TG: 159 TWS: 50	Repeatable No tool available for download Physical activities only Scale-able Raw data and model output data Comparable Vulnerability assessment only; not a tool for developing action Can be modified to recalculate CVI to see if adaptation action works Can modify index list and weighting between human and physical impacts; scale remains comparable. Not clearly demonstrate its vulnerability analyses – confusing with risk analysis	Quan.	Document	Yes
VA; DST	Tool based on dynamic computer models	Delft3D	a 2D/3D modelling suite to investigate hydrodynamics, sediment transport, morphology and water quality for fluvial, estuarine and coastal environments. It has been used for simulation of change in physical conditions along coastlines in several countries, e.g. Netherlands, USA, Hong Kong, Singapore,	Coastal physical system (it performs better on relatively simple topographic and bathymetric conditions). Not directly addressed by the model	Meteorological, hydrological, topographic and bathymetric data, land use and land use planning. Detailed site-specific data are required	Model results can be represented as maps, graphs and tables Delft3D provides a flexible, modelling suite, including visualization tools	http://oss.deltares.nl/web/delft3d (Devriend et al. 1993) Google (193) WS (114) (Lesser et al. 2004) Google (518) WS (284) (Roelvink and Vanbanning 1994) Google (114) WS (18)	Software source codes are available to freely download and claimed as open source Also commercial package available Strong computing skills/resources required to make the model running Example can be repeatable Computing could be	Quan.	Software suite	Yes, Not downloadable of the whole package but core modules (Open Sources) Demonstration version available upon request for

			Australia, Italy, etc.				TG: 825 TWS: 416	time consuming			free Commercial package available
VA	GIS based Decision Support System (DSS)	DESYCO	a Decision Support System for the assessment and management of multiple climate change impacts on coastal areas and related ecosystems (e.g. beaches, wetlands, forests, protected areas, groundwater, urban and agricultural areas).	Socio-economic and ecological targets. Not directly addressed by the method. It is possible to evaluate the efficacy of different adaptation measures (e.g. artificial protections, mobile barriers and dikes) in relation to different sea level rise scenarios	Climatic data, DEM//topography, bathymetry, coastline and coastline variations, land cover and land use, geomorphological maps, relevant areas of environmental interest, river and channels maps, protected areas maps, fish farming data	Hazard maps Exposure maps Susceptibility maps Value maps Vulnerability maps Risk maps Damage maps	(Torresan et al. 2010) Google (0) WS (0) (Rizzi et al. 2011) Google (0) WS (0) (Torresan et al. 2009) Google (3) WS (1) (Torresan 2012) Google (1) WS (0) TG: 4 TWS: 1 Google scholar "DESYCO": 20 results	http://www.cmcc.it/models/desyco Not repeatable No tool/package available for downloading Multiple reports of its application and publications A very skill demanding and data intensive method	Quan.	Software	No
VA; DST	Tool based on dynamic computer models	Dynamic and Interactive Vulnerability Assessment (DIVA)	Dynamic Interactive Vulnerability Assessment (DIVA) is a tool for integrated assessment of coastal zones produced by the EU-funded DINAS-Coast consortium in 2004. It is specifically designed to explore the vulnerability of coastal areas to sea-level rise.	Socio-economic and ecological targets. Addressed by the model	Elevation (SRTM), coastal geomorphology, coastal population, GDP, land use, administrative boundaries	Estimates of population flooded, wetland changes, damage and adaptation costs, amount of land loss	http://www.diva-model.net/ (Hinkel and Klein 2007) Google (39) WS (0) (Hinkel and Klein 2009b) WS (29) Google (63) (Hinkel and Klein 2009a) Google (15) WS (0) (Hinkel et al. 2010) Google (36) WS (18) TG: 153 TWS: 47	Not repeatable No tool/package available for downloading Quite a lot of publications and reports Data intensive Addressed adaptation measure Computing could be time consuming	Quan.	Software	No

DST	Management Strategy Evaluation tool	Ecopath with Ecosim (EwE)	Ecological/ ecosystem modeling software suite, consists of ecopath, ecosim, and ecospace and they function as “static, mass-balanced snapshot of the system”, “time dynamic simulation module for policy exploration”, and “spatial and temporal dynamic module for MPA	Marine ecosystem, fisheries	Habitat area, biomass in habitat area, production/biomass, consumption/biomass, ecotrophic efficiency, production/consumption, Unassimilated consumption, Detritus import, diet composition, detritus fate, other production, fishery, Definition of fleets, landings, discards, discard fate, Market price and non-market price	Basic estimates; Key indices; Mortalities; Mortality coefficients; Predation mortality; Consumption; Respiration; Niche overlap; Electivity; Search rates; Fishery; Flow diagram; and the EwE Network Analysis plugin)	http://www.ecopath.org/ (2644 actual software users by 2011) (Christensen and Pauly 1992) Google (959) WS (508) (Pauly et al. 2000) Google (624) WS (344) (Christensen and Walters 2000) Google (3) WS (0) (Walters et al. 1997) Google (798) WS (394) (Walters et al. 2000) Google (235) WS (144) TG: 2629 TWS: 1390	Tool/package are available for downloading Not repeatable Ecological/ecosystem focus Data intensive Sound knowledge of ecosystem Well published	Quan.	Software	Yes, OS
RA	Indicator based methods	Eurosion	the Eurosion project identified thirteen indicators to support the assessment of coastal erosion risk throughout Europe. The indicator set included nine sensitivity indicators and four impact indicators	Targets represented by the impact indictors, i.e. population, urban and industrial areas and areas of high ecological value. Partially addressed by the indicator “engineered frontage”, also including protection structure	Eurosion database: terrestrial boundaries, maritime boundaries, shoreline, bathymetry, elevation, geomorphology and geology, erosion trends and coastal deference works, hydrograph, infrastructure, wave and wind climate, tidal regime, sea level rise, land cover,	Sensitivity score Impact score Finale score, i.e. exposure to coastal erosion	(Eurosion 2004) Google (7) WS (0) TG: 7 TWS: 0 http://www.eurosion.org/reports-online/part3.pdf	Not repeatable No tool available Broad international cooperation Focus on European regions coastal erosion and flooding Data intensive GIS tools required Experts, stakeholder options required	Quan.	Document	Yes

					areas of high ecological values						
VA;DST	Stakeholder Only Approaches	FAC4T	An overarching framework for a city-wide consolidated and coordinated approach to reducing vulnerability to climate change	Targets at biodiversity, water stress, coastal zones, fire intensity, city infrastructure, health and livelihoods Urban water demand management; Storm water management; Fire management; Coastal zones management; Livelihood and health sectors	Climate change scenarios of the variables - key elements to the subjects Socio-Economic Changes data and urban system information Knowledge from experts and stakeholders	Adaptation strategies against various sectors	http://www.erc.uct.ac.za/Research/publications/06Mukheibir-Ziervoge%20-%20Adaptation%20to%20CC%20in%20Cape%20Town.pdf (Mukheibir and Ziervogel 2007) Google (81) WS (23) TG: 81 TWS: 23	Repeatable Template as tool Need sound knowledge of the subjects Not data intensive Need objective opinion inputs from experts, stakeholders No need model computing Qualitative solution Easy to apply	Qual.	Document	Yes
DST	Other decision tools	Identifying Adaptation Options (IAO) See UKCIP!	Guidance on the identification and selection of adaptation options that can be used to respond to climate risks.	The guidance note explores adaptation options relating them to their intended purpose to help build Adaptive Capacity or Delivering Adaptation Actions.	None required	identify an appropriate set of adaptation options using the other UKCIP tools and guidance.	http://www.ukcip.org.uk/wordpress/wp-content/PDFs/ID_Adapt_options.pdf (Mahmoud et al. 2009) Google (107) WS (50) TG: 107 TWS: 50	The guidance notes in format of document A subclass tool from UKCIP. Need sound knowledge on the subjects to set up adaptation options with the tool Less data intensive Could be easy to conduct with sound knowledge of the subjects	Qual	Document	Yes
VA	Framework/toolkits	Inter-governmental Panel on Climate Change (IPCC) Common Methodology (CM)	Widely used framework for vulnerability assessment first proposed in 1991. CM incorporates expert judgment and data analysis of socioeconomic and physical characteristics to assist the user in estimating a broad spectrum of impacts from sea-level rise, including the value of	This approach is most useful as an initial, baseline analysis for country level studies where little is known about coastal vulnerability	Range from regional to global Physical and socioeconomic characteristics of the study area.	Vulnerability profile and the list of future policy need to adapt both physically and economically. A range of impacts of sea-level rise, including land loss and associated value and uses, wetland loss, etc.	(Klein and Nicholls 1999) Google (259) WS (100) (Subgroup 1992) Google (41) WS (0) (Nicholls 1995) Google (166) WS (0) (Nicholls and Mimura	No established tool available but various document and published papers Requires considerable knowledge on a range of techniques for estimating biophysical and socioeconomic impacts of sea level rise and adaptation. It	Quan	Document	Yes

			land and wetlands lost.				1998) Google (178) WS (55) (Nicholls 1998) Google (18) WS (0) TG: 662 TWS: 155	has been criticised and redesigned by several groups of researchers.			
VA	Climate Downscaling models	MAGICC / SCENGEN	MAGICC is a coupled gas-cycle/climate model. SCENGEN is a regionalization algorithm that uses a scaling method to produce climate and climate change information on a 5° latitude by 5° longitude grid.	Climate change	Emissions scenarios for all gases considered in the SRES (Special Report on Emissions Scenarios) scenarios	MAGICC gives global-mean temp/sea level change; SCENGEN-regional	(Wigley 2008) Google (58) WS (0) (Fordham et al. 2012) Google (26) WS (16) TG: 84 TWS: 16	Example repeatable Free tools/package are available for downloading Fair computer skill required to run the model The package provided built- in scenarios datasets SCENGEN can be integrated into regional application rfw its climate change scenarios Focus only on climate change scenarios Popular	Quan.	Software	Yes (OS)
DST	Other decision tools	Multicriteria Analysis (MCA)	MCA describes any structured approach used to determine overall preferences among alternative options, where the options accomplish several objectives.	Allows decision makers to include a full range of social, environmental, technical, economic, and financial criteria.	Criteria of evaluation as well as relevant metrics for those criteria	A single most preferred option, ranked options, short list of options for further appraisal, or characterization of acceptable or unacceptable possibilities.	http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5440.php (Bell et al. 2003) Google (56) WS (0) TG: 56 TWS: 0 Optional tool: http://www.daff.gov.au/abares/data/mcass/tool	No direct tool/package available for downloading from the relevant publication, but tool from other source available to download for MCA analysis Not repeatable Knowledge of MCA and computer access Less data intensive	Qual.	Document	Yes
RA	Index based method	Multi-scale CVI	a multi-scale CVI, specifically integrating erosion impacts, which can be applied to other	Mainly socio-economic Targets. Not addressed by	Key variables are defined according to the specific application	Three sub-indices: (i) coastal characteristic sub-index, (ii) coastal	(McLaughlin and Cooper 2010) Google (13) WS (4)	Repeatable No tool/package available for downloading	Quan.	Document	Yes

			climate change induced impacts, too. The index integrates three sub-indices:(i) coastal characteristic sub-index,(ii) coastal forcing sub-index,(iii) social-economic sub-index.	the index	(location and scale). Variables refer to: (i) resilience and coastal susceptibility to erosion, (ii) forcing variables contributing to wave-induced erosion, (iii) socio-economic target potentially at risk	forcing sub-index, (iii) socioeconomic sub-index. Final CVI index. Indices can be represented in maps	TG: 13 TWS: 4	GIS based method, relevant skill suites required Data intensive – maps Semi-quantitative measure			
DST	Agent-based model	Netlogo	Agent based model. a programmable modeling environment for simulating natural and social phenomena	Various, i.e., environment, natural and social aspects	Management strategy scenarios to the issue	Maps, plots, indicators to response the strategy scenarios	http://ccl.northwestern.edu/netlogo/ (Wilensky 1999) Google (78) WS (7) (Tisue and Wilensky 2004) Google (121) WS (0) TG: 199 TWS: 7	Free software available for downloading Example can be repeatable Very strong agent based modeling skills Widely used in many field Less flexible Coarser maps, plots visualization	Quan.	Software	Yes, OS
VA;DST	Stakeholder Only Approaches	QCCCE	Risk assessment matrices that identified impacts, vulnerability and prioritize areas for action	Targets at pasture growth, surface cover, plant available water capacity, wind erosion, rural human health and well-being, biodiversity Adaptation response matrix to climate change key elements	Climate change scenarios of the variables - key elements to the subjects Knowledge from experts and stakeholders by various workshops	Risk identification, assessment and adaptation action plan matrices	(Cobon et al. 2009) Google (30) WS (17) (Brundell et al. 2011) Google (0) WS (0) (Morison and Pears 2012) Google (2) WS (0) TG: 32 TWS: 17	Repeatable Template as tool Need sound knowledge of the subjects Not data intensive Need objective opinion inputs from experts, stakeholders No need model computing Qualitative solution Easy to apply Popular	Qual.	Document	Yes
DST	Tool based on dynamic computer models	RamCo and ISLAND MODEL	cell-based decision support tools designed as means of asking structured questions about how external and internal components of coastal zone	Coastal zone, socioeconomic system, boundary conditions external and	The user's chosen scenarios and management strategies	The outcome of a range of different user-defined scenarios and management options	(de Kok et al. 2001) Google (47) WS (22) TG: 47 TWS: 22	No tool/package available for downloading Not repeatable GIS based method Data intensive Cell based tools	Qual.	software	No

			management problems interact.	internal components of coastal zone management problems interact				could be computing intensive If the demo available, the guides are easy to follow Develop new application difficult http://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/ramco_and_island_model.pdf			
DST	Other decision tools	Reef Resilience Toolkit	a 'living' toolkit that provides practitioners with the latest tools, strategies, and protocols to address coral bleaching, conservation of reef fish spawning aggregations, and general principles of adaptive management that are critical to respond to climate change. 2 Toolkit modules: Coral Reefs, Fish Spawning Aggregations.	Tropical coastal and marine resources, coral reef, fisheries. MPA design	In cases where there is limited or no data, expert and local knowledge can be used. There is always a 'low-tech' option for places that have limited information and resources when one is trying to build resilience to climate change into management activities and strategies.	There is no specific output or final product from the R2 Toolkit, given that it is a series of steps and information that helps to guide managers to design and develop sound management practices that are flexible and support adaptive management in the face of climate change.	http://www.reefresilience.org/ (Grimsditch and Salm 2006) Google (70) WS (0) (West and Salm 2003) Google (320) WS (139) TG: 390 TWS: 139	Guidelines Guide line toolkits available online Repeatable of examples Marine system – coral reefs + fishing spawning aggregation modules Sound knowledge of the subjects Experts and stakeholders contribution	Qual.	online platform	Yes
VA; DST	Tool based on dynamic computer models	Regional climate change Impact and response Studies (RegIS)	The aim of the RegIS and RegIS2 projects was to simulate the effects of future climate change and socioeconomic change in two regions of the United Kingdom: East Anglia and North West England.	Socio-economic and ecological targets. Only spontaneous adaptation considered, no proactive adaptation. However, tools are available for assessing the effects of the adaptation response	Flood plain maps, flood risk area, sea defences, elevation, land cover, coastal habitats database, existing and proposed sites for managed realignment, tidal surge data	Maps and graphs of changes in ecosystems, species' ranges and land use in response to scenarios of `socio-economic and climate change	http://www.cranfield.ac.uk/sas/naturalresources/research/projects/regis.html (Holman et al. 2005) Google (150) WS (66) (Holman et al. 2008) Google (35) WS (24) (Mokrech et al. 2008) Google (33) WS (17)	Not repeatable No tool/package available for downloading Quite a lot of publications and reports Data intensive Addressed adaptation measure	Quan.	Software	No

							(Richards et al. 2008) Google (32) WS (19) TG: 250 TWS: 136				
DST	Agent-based model	Repast	Agent based model a programmable modeling environment for simulating natural and social phenomena with enhanced visualization	Various, i.e., environment, natural and social aspects	Management strategy scenarios to the issue	Maps, plots, indicators to response the strategy scenarios	http://repast.sourceforge.net/ (Collier et al. 2012) Google (169) WS (0) (North et al. 2006) Google (554) WS (224) TG: 723 TWS: 224	Free software available for downloading Example can be repeatable Very strong agent based modeling skills Required sufficient Java based OOP programming working knowledge Widely used in many field More flexible Graphical interface, finer maps, plots visualization	Quan.	Software	Yes, OS
RA	Tool based on dynamic computer models	Risk Assessment of Coastal Erosion (RACE)	The aim of the RACE project was to develop and disseminate a robust and consistent probabilistic assessment of the hazard and risk of coastal erosion in the United Kingdom	Private property, built assets and agricultural land. Not directly assessed	Expert judgment on the probability of defence failure and the natural erosion rate, validated by existing data, and field observations where possible	Maps of coastal erosion hazard, overlaid with locations of vulnerable assets to create 'risk' maps	http://cca.eionet.europa.eu/docs/TP_1-2011 (Ltd. 2007) Google (155)* results from searching "Halcrow group"+"Risk assessment of coastal erosion"+"Defra" TG: 155*	Not repeatable No tool/package available for downloading Sound knowledge of the subjects Computer/GIS skills Computing could be time consuming	Qual.	Document	Only document available
VA	Tool based on dynamic computer models	Sea-level Affecting Marshes Model (SLAMM)	The model is based on a decision tree where quantitative and qualitative relationships are established to represent the transfer of land cover coastal classes according to different variables such as elevation, type of habitat, sediments,	Ecological systems: coastal habitats and species Socio-economic component is not included. Not addressed by the model	SLR, tidal data, elevation (DEM and LIDAR), wetland land cover, other detailed wetland information, human infrastructures (e.g. dike location)	Maps of flooding risk for coastal ecosystem and habitats Tables and graphs	http://www.warrenpinnacle.com/prof/SLAMM/ (SLAMM 2010) (Park et al. 1989) Google (72) WS (0) (Lee et al. 1992) Google (47) WS (18)	Example repeatable Tool/package available for download Popular, esp., in US Built in GIS package, so don't need GIS skill or software Freeware: model is downloadable and with good example Coastal zone centric	Quan.	Software	Yes (OS)

			erosion degree, etc. (SLAMM, 2010)				(Park et al. 1991) Google (23) WS (0) TG: 142 TWS: 18	Basics of model is a decision tree by coastal classes, e.g., salt water, mangrove Does not include adaptation/management options directly in the model Computing could be time consuming Popular			
DST	Framework/toolkits	Shoreline Management Planning (SMP)	A generic approach to the strategic management of the combined hazards of erosion and flooding hazards in coastal areas, which are key concerns under climate change and sea-level rise.	Coastal zone SMPs are designed as "living" plans, including regular update, so the whole process will stimulate the development of long-term coastal management appropriate to responding to climate change and sea-level rise	A range of information is required, including, ideally, historical shoreline change, contemporary coastal processes, coastal land use and values, and appropriate scenarios of change.	Strategic approaches for flood and erosion management for the next 50 to 100 years	http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/environment/flooding/documents/policy/guidance/smpguide/vol2appi.pdf (Leafe et al. 1998) Google (67) WS (47) (Burgess et al. 2002) Google(16) WS (0) TG: 83 TWS: 47	No software available Repeatable A generic approach Less data intensive Less computing intensive Sound knowledge of the subjects	Qual.	Document	Yes
VA; DST	Tool based on dynamic computer models	SimCLIM	software package that links data and models in order to simulate the impacts of climatic variations and change, including extreme climatic events, on sectors such as agriculture, health, coasts or water resources.	Socio-economic and ecological targets. Addressed by the model. Adaptation measures can be tested for present day conditions and under future scenarios of climate change and variability.	Elevation, climate data, sea level change scenarios Specific impact models data	Spatial and site-specific scenarios of climate and sea-level changes (including changes in the risks of extreme events) and their sector impacts. Formats include maps, time-series projections, and graphical and tabular output.	http://www.climsystems.com/simclim/ (Warrick et al. 2005) Google (13) WS (1) (Warrick and Cox 2007) Google (2) WS (0) (Warrick 2009) Google (9) WS (1) TG: 24 TWS: 2	No repeatable case study available with trial version Tool/package available commercially User friendly interface Adaptation assessment tools, such as Hydrology, coastal hazard, heat accumulation and water use models. Data intensive Computer skills With a ArcGIS add-in (SimCLIM for ArcGIS commercially available)	Quan.	Software	Yes, (CS) CS-trial available upon request for free

								Computing could be time consuming Numerical application and publications With the cost of the software, data and training.			
RA	Framework/toolkits	SmartLine	The "Smartline" approach is a method of capturing geographical data in a segmented line within a Geographical Information System (GIS).	It rapidly captures a very wide range of information for a coastal zone at different levels of detail. Consequently, the "Smartline" approach is ideal for first pass assessments of coastal vulnerability	The majority of input data may be sourced through aerial photograph and cartographic analysis; this includes data on morphology of coast and geographic setting	GIS based geomorphic map of coastal sensitivity	http://www.ozcoasts.gov.au/coastal/introduction.jsp (Sharples et al. 2009a) Google (14) WS (0) (Sharples et al. 2009b) Google (8) WS (0) TG: 22 TWS: 0	The Smartline tools is easy to manoeuvre and understand, and is supported by a range of practitioners and experts that can be consulted for advice and lessons learned. However, initial development of a Smartline mapping systems requires expert input and training.	Quan	online platform	Yes
VA;DST	GIS based Decision Support System (DSS)	Spatial Tools for River Basins and Environment and Analysis of Management Options (STREAM)	STREAM is a spatial hydrological model that allows for assessing hydrological impacts due to changes in climate and socio economic drivers.	Coastal zone, land and water use of agriculture and urbanization, water storage and flooding control. Hydrological impacts induced by Climate change and socio-economic drivers.	The required input data is: temperature, precipitation, soil types, elevation. And for calibration and validation: runoff data.	spatial hydrological information on water availability in the form of (monthly) soil-humidity and river discharges. The latter outputs can be in either a hydrograph or a spatial GIS based map.	http://www.coastalcooperation.net/part-III/III-3-2-6.pdf (Aerts et al. 1999) Google (63) WS (26) TG: 63 TWS: 26 Demo package http://www.adaptation.nl/ (not accessible, can request demo package from the authors)	Not repeatable; Demo package available under request to developers Water balance model with Salt intrusion module could be used for estuary application GIS based Data intensive Computing intensive Applied to River, basin, regional hydrology	Quan.	Software	Yes, OS (no free downloading, but demo available under request)
VA	Tool based on dynamic computer models	Synthesis and Upscaling of Sea-level Rise Vulnerability Assessment Studies (SURVAS)	a global assessment of vulnerability of the coastal zone using a common assessment methodology, identifying key indicators for the assessment of coastal natural susceptibility	Various scales, for the assessment of coastal natural susceptibility and socio-economic vulnerability and resilience to the impact of climate	Expert knowledge in workshop context	Workshop reports	(Nicholls and de la Vega-Leinert 2000) Google (3) WS (0) (Nicholls and de la Vega-Leinert 2001) Google (6)	There are no detailed document available, links are broken and doesn't look in a proper maintenance condition There should be	Quan	Document	no

			and socio-economic vulnerability and resilience to the impact of climate change, particularly accelerated sea-level rise.	change, particularly accelerated sea-level rise			WS (0) TG: 9 TWS: 0	softwares available for this method, but a few links are broken and indicating it may be out of date and without timely maintenance support. It is even hard find a detailed document for this method			
VA; DST	Tool based on dynamic computer models	The Climate Framework for Uncertainty, Negotiation and Distribution (FUND)	An integrated assessment model of climate change. Although, FUND does not arise from a scientific basis in coastal impacts as other models (such as SLAMM, SimCLIM or DIVA); it has capacity for providing information about climate change in a dynamic context, which makes it a useful and innovative tool	Economic costs and Benefits. Addressed by the model	Population data and scenarios on emissions, climate condition, sea level and other impacts	Rates and statistics for decision makers	http://www.fund-model.org/ (Tol 2006a) Google (49) WS (11) (Tol 2006b) Google (72) WS (11) (Narita et al. 2009) Google (37) WS (12) (Narita et al. 2010) Google (29) WS (9) TG: 187 TWS: 43	Source codes of the model are available for download Not repeatable Need strong computer skill to compile the codes to make it executable No user interface and computer literature focus tool Sound knowledge of the subjects Data intensive	Quan.	Software	Yes,(OS)
DST	Index based method	The South Pacific Island Methodology (SPIM)	An index-based approach that uses relative scores to evaluate different adaptation options in a variety of scenarios. The coastal zone is viewed as six interacting systems.	Particularly useful in coastal settings with limited quantitative data but considerable experience and qualitative knowledge	Expert judgment and qualitative information on the relative performance of various adaptation options.	Defines a sustainable capacity index for the subsystems defined	(Yamada et al. 1995) Google (49) WS (0) Scholar search "Yamada, K. ~ Methodology for the assessment of vulnerability of South Pacific island countries to sea-level rise and climate change" TG: 49 TWS: 0	No tool available Repeatable Less data intensive Less computing intensive Easy to use Experts and stakeholders contribution required regional in scale and most relevant to the South Pacific Islands	Qual.	Document	Yes
DST	Other decision tools	Tool for Environmental Assessment and	This software package creates graphs and tables that allow experts to compare the relative	a wide range of criteria and to explicitly identify unquantifiable and	A ranking of how well policy objectives are met using alternative	Relative effectiveness of alternative adaptation	http://www.epa.gov/eims/global/team1.pdf (Julius and Scheraga	No tool/package available Repeatable Qualitative measure	Qual.	Software	No

		Management (TEAM)	strengths of adaptation strategies using both quantitative and qualitative criteria.	uncertain aspects associated with potential adaptations	strategies	measures across a range of criteria	2000) Google (13) WS (3) TG: 13 TWS: 3	Less data intensive Less computing intensive Sound knowledge of the subjects			
DST	Other decision tools	UKCIP Adaptation Wizard	The Wizard is a tool to help users adapt to climate change. It is a generic, high-level tool that can be used to raise awareness of the adaptation process, and help those who are preparing to adapt. It is more a decision-support than decision-making tool.	it will help users generate the information they need to prepare their own adaptation strategy.	time, participation, climate change scenarios, socio-economic scenario, tools for costing climate impacts and for costing/evaluating adaptation options	An adaptation strategy document that includes: a record of the users' vulnerability to current climatic variability; a prioritized list of climate risks; a list of possible adaptation measures to address those risks; adaptation options appraisal; and an implementation strategy	http://www.ukcip.org.uk/wizard/ (Willows and Connell 2003) Google (283) WS (0) (Connell et al. 2005) Google (4) WS (3) TG: 287 TWS: 3	Online tool available and also offline tool available for downloading High level, generic method/guideline Repeatable Web-based tool and ease to use Less data intensive Less computing intensive Focus on adaption measure Sound knowledge of the subjects	Quan	Online platform	Yes
VA; DST	Framework/toolkits	UNDP Adaptation Policy Framework (APF)	The APF provides guidance on designing and implementing projects that reduce vulnerability to climate change, by both reducing potential negative impacts and enhancing any beneficial consequences of a changing climate.	Global, all sectors. particularly applicable where the integration of adaptation measures into broader sector specific policies, economic development, poverty reduction objectives, or other policy domains is desirable.	Stakeholder derived information is a key input at all stages. Vulnerability mapping, dynamic simulation of sustainable livelihoods, multi-stakeholder analysis, cost-effectiveness, decision trees, multicriteria analysis, among others.	Increased adaptive capacity through prioritized adaptation strategies that can be incorporated into development plans	http://www.preventionweb.net/files/7995_APF.pdf (Lim et al. 2005) Google (231) WS (0) TG: 231 TWS:0	no build up tools available for directly download but document depends on specific application, the skills and knowledge required range vastly	Qual	Document	Yes
DST	Framework/toolkits	UNEP Handbook Methodology	The UNEP methodology establishes a generic framework for thinking about and responding to the problems of sea	This approach is useful in a range of situations, including subnational, or national level	Qualitative or quantitative physical and socioeconomic characteristics of the national coastal	Evaluation of a range of user-selected impacts of sea level rise and potential adaptation strategies	http://www.ivm.vu.nl/en/Images/UNEPhandbookEBA2ED27-994E-4538-B0F0C424C6F619FE_tcm53-102683.pdf	Not computer software or template available, but document	Qual	Document	Yes

			level rise and climate change.	studies. It could comprise the first study, or follow earlier studies such as those completed using the IPCC Common Methodology. The possibility of a quick screening assessment followed by a more detailed vulnerability assessment has been suggested (Klein and Nicholls, 1999). Information gathered with this methodology can then be used as input for future modeling.	zone.	according to both socioeconomic and physical characteristics.	(Feenstra et al. 1998) Google (168) WS (0) (Klein and Nicholls 1999) Google (259) WS (100) (Klein et al. 1999) Google (136) WS (0) (Klein et al. 2001) Google (147) WS (56) (Nicholls 1998) Google (18) WS (0) TG: 728 TWS: 156	Fairly simple framework. As the level of analysis is not prescribed, the ease of use will depend on the level of analysis that is attempted			

2. Table S 2: Attribute names and scores of climate adaptation tools tested. RA is risk assessment, VA is vulnerability assessment and DST is decision support tool. See supplementary material Table S1 for details about the models and their references

Model name	**Climate adaptation step**	**Usability**	**Applicability**	**Availability**	**Skill requirement**	**Data intensity**	**Time**	**Citations**	**Numerical quantification**
Criteria		1: hard to use (no detailed document, online platform or software available or the tool has very	1: RA 2: VA or DST only (we assume VA includes RA) 3: both VA and DST	1: not available (tool not provided and/or tool briefly described) 2: Partially available, i.e. support	1: high skill requirement 2. medium requirement 3. low requirement	1: very intensive 2: medium 3: low	1: very time consuming 2: medium 3: low	1: low citation (within the lower 50 percentile citations of all the tools; median is 22 citations) 2: medium	Degree of quantitative (1-3); 1: fully qualitative (data are fully based on experts' opinions); 2: semi

Model name	**Climate adaptation step**	**Usability** complicated structures) ; 2: medium (limited description of method or the tool has moderate structures); 3:ease to use with the documents or with the software	**Applicability**	**Availability** documents or software only available under commercial license; 3: Fully available with few or no financial resources required (free access web, free download detailed documents or software)	**Skill requirement**	**Data intensity**	**Time**	**Citations** (between the 50 percentile and 75 percentile of the citations of all the method) 3: high (greater than the 75 percentile the citations of all the method which are > 42 citations)	**Numerical quantification** quantitative (combination of experts' opinions and actual data), 3: highly quantitative (mostly actual data)
Adaptation Decision Matrix (ADM)	DST	3	2	3	3	3	3	2	1
Atlantis	DST	1	2	3	1	1	1	3	3
Barataria-Terrebonne Ecosystem Landscape Spatial Simulation (BTELSS)	VA	1	2	1	1	1	1	2	3
Bruun Rule	RA	3	1	3	2	2	3	2	3

Model name	Climate adaptation step	Usability	Applicability	Availability	Skill requirement	Data intensity	Time	Citations	Numerical quantification
City of Melbourne	VA;DST	2	3	3	3	2	2	1	1
CLIMATE-ADAPT European Climate Adaptation Platform	VA	2	2	3	2	2	2	2	2
Climate-Related Risks Estimate as Indicators of Necessity for Adaptation Responses	DST	1	2	1	2	2	2	1	2
CLIPS & RCOFs	VA;DST	2	3	3	2	2	1	3	2
Coastal Zone Simulation Model (COSMO)	DST	1	2	1	2	3	3	2	1
Community Vulnerability Assessment Tool (CVAT)	VA	2	2	1	2	2	2	3	2
Composite Vulnerability Index	RA	3	1	3	2	2	2	2	3
Cormas	DST	1	2	3	1	2	2	3	3
CVI (SLR)	RA	3	1	3	2	2	2	1	3

Model name	Climate adaptation step	Usability	Applicability	Availability	Skill requirement	Data intensity	Time	Citations	Numerical quantification
CVI Index	RA	3	1	3	2	2	2	2	3
Delft3D	VA;DST	2	3	2	1	1	1	3	3
DESYCO	VA	1	2	1	1	1	1	1	3
Dynamic and Interactive Vulnerability Assessment (DIVA)	VA	1	3	1	1	1	1	2	3
Ecopath with Ecosim (EwE)	DST	2	2	3	2	1	2	3	3
Eurosion	RA	2	1	3	2	1	2	1	3
FAC4T	VA;DST	2	3	3	3	2	2	2	1
Identifying Adaptation Options (IAO)	DST	3	2	3	3	3	3	1	1
Inter-governmental Panel on Climate Change (IPCC) Common Methodology (CM)	VA	1	2	3	1	1	1	3	3
MAGICC / SCENGEN	VA	2	2	3	2	1	2	2	3
Multicriteria Analysis (MCA)	DST	2	2	3	2	3	3	2	1
Multi-scale CVI	RA	3	2	3	3	3	3	1	3

Model name	Climate adaptation step	Usability	Applicability	Availability	Skill requirement	Data intensity	Time	Citations	Numerical quantification
Netlogo	DST	1	2	3	1	2	2	2	3
QCCCE	VA;DST	3	3	3	3	2	2	1	1
RamCo and ISLAND MODEL	DST	1	2	1	2	2	2	2	2
Reef Resilience Toolkit	DST	3	2	3	1	3	2	3	1
Regional climate change Impact and response Studies (RegIS)	VA;DST	1	3	1	1	2	2	2	3
Repast	DST	1	2	3	1	2	2	3	3
Risk Assessment of Coastal Erosion (RACE)	RA	2	1	3	2	2	2	2	2
Sea-level Affecting Marshes Model (SLAMM)	VA	2	2	3	1	1	2	2	3
Shoreline Management Planning (SMP)	DST	2	2	3	3	3	3	2	1

Model name	Climate adaptation step	Usability	Applicability	Availability	Skill requirement	Data intensity	Time	Citations	Numerical quantification
SimCLIM	VA;DST	2	3	2	1	1	1	1	3
SmartLine	RA	3	1	3	2	2	2	1	2
Spatial Tools for River Basins and Environment and Analysis of Management Options (STREAM)	VA;DST	2	3	2	2	1	2	2	3
Synthesis and Upscaling of Sea-level Rise Vulnerability Assessment Studies (SURVAS)	VA	1	2	1	2	2	2	1	2
The Climate Framework for Uncertainty, Negotiation and Distribution (FUND)	VA;DST	2	3	3	1	2	2	2	2
The South Pacific Island Methodology (SPIM)	DST	3	2	3	3	3	3	2	1
Tool for Environmental Assessment and Management (TEAM)	DST	3	2	1	3	3	3	1	1
UKCIP Adaptation Wizard	DST	3	2	3	3	2	2	3	2
UNDP Adaptation Policy Framework (APF)	VA;DST	2	3	3	3	3	3	2	1
UNEP Handbook Methodology	DST	2	2	3	3	2	3	3	2

Model name	Climate adaptation step	Usability	Applicability	Availability	Skill requirement	Data intensity	Time	Citations	Numerical quantification
Count of score = 1 (%)	*N/A*	32	16	23	32	27	18	27	27
Count of score = 2 (%)	*N/A*	41	59	7	41	50	57	48	25
Count of score = 3 (%)	*N/A*	27	25	70	27	23	25	25	48

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Appendix 6: A checklist for developing effective adaptation strategies for Australia's estuary ecosystems

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Contents

1. Introduction

Many Climate Change Adaptation Strategies (CAS) concentrate on developing CAS frameworks, however, regardless of which framework works best for a specific system, or whether the choice is to proceed free from the constraints of any framework, the following Adaptation Checklist (Table 1) is aimed at providing a guide to developing an achievable and realistic product. The Adaptation Checklist is intended as a guide rather than a prescription. Consequently, some components may not be necessary in a particular situation, others may be missing, and the order of steps may well change from case to case.

Table 18: A checklist for developing an effective adaptation strategy.

1. Conduct comprehensive forecasting
2. Conduct ecosystem triage
3. Specify an adaptation focus
4. Define specific objectives
5. Identify end-users comprehensively
6. Identify appropriate Climate Change scenarios
7. Assemble all relevant information
8. Assess the quality of available information and identify key gaps
9. Assess and communicate uncertainties
10. Evaluate constraints
11. Assess the range of actions possible in the situation
12. Develop the adaptation strategy
13. Evaluate adaptation outcomes and monitor success
14. Reassess uncertainties
15. Collect additional information as necessary

Each component of the list is explained below, where appropriate with a series of tools that can be used to progress that part of the checklist.

1: Conduct comprehensive forecasting

Effective decision making depends on the accuracy of predictions of the full spectrum of effects of Climate Changes. These need to include forecast of the evolution of ecosystems and social, technological, and economic systems as well as the behaviour of the climate system itself (Lempert and Schlesinger 2000). It is important to understand the limits of the ability to predict trajectories of change because there are many parameters to be estimated (e.g. Climate Change, the behaviour of economic systems, the response of ecosystems), meaning even small errors can magnify uncertainty.

2: Conduct ecosystem triage

Ecosystem triage relates to the process of prioritizing which ecosystems or ecosystem components are the most profitable targets for the expenditure of scarce resources (Lawler 2009). Many approaches and criteria are possible (see Lawler 2009) but these will depend on the exact focus of adaptation and the specific situation, needs and resources. For instance, triage prioritization could be based on evaluation of the value of an ecosystem service relative to the projected severity of impact (Fig. 1).

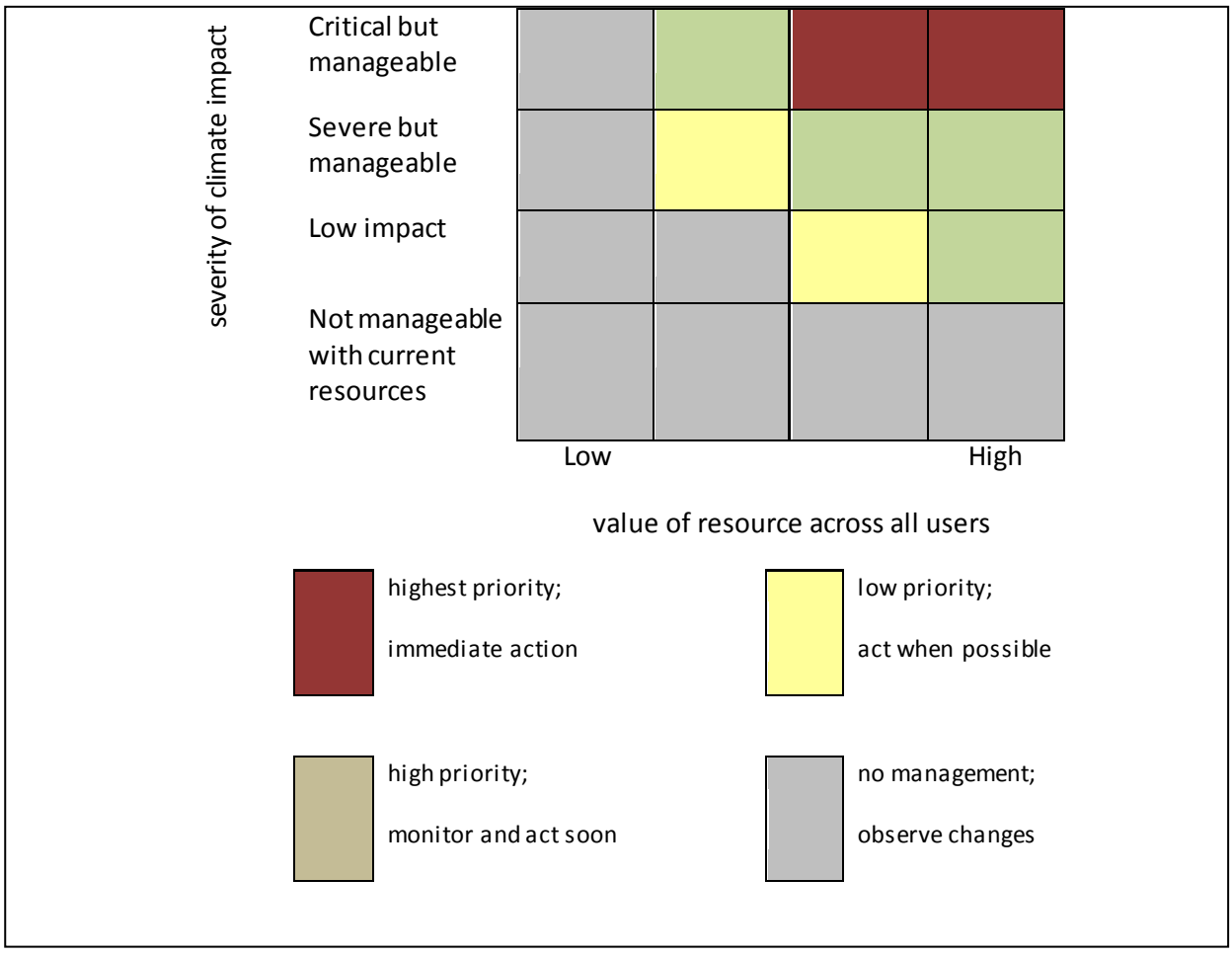

Figure 21: Example of an ecosystem triage classification. Modified after Lawler (2009).

Triage cannot be undertaken lightly because it relies on the complex interplay of a number of factors (Fig. 2).

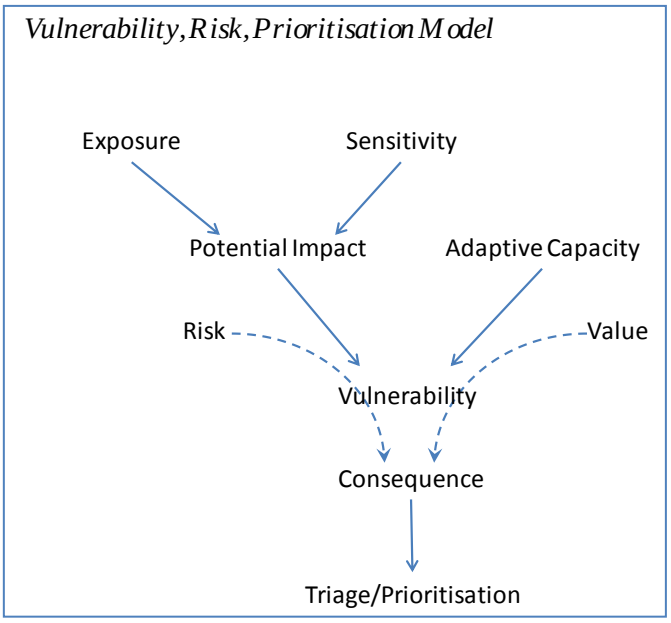

Figure 22: A conceptual model of the factors influencing ecosystem triage decisions.

Definitions: **Adaptive capacity:** the potential or capability of a system to adapt to climatic stimuli; **Exposure:** the extent to which specific events are likely to affect the system; **Resilience:** the ability of a system to rebound or recover from a stimulus; **Responsiveness:** degree to which a system reacts to stimulus; **Risk:** likelihood of negative outcomes relative to consequence of the outcome; **Sensitivity:** degree to which a system is affected by, or responsive to, stimuli; **Vulnerability:** degree to which a system is susceptible to damage or harm: a function of the character, magnitude and rate of exposure; sensitivity; adaptive capacity (based on Holling 1973, Olmos 2002, IPCC 2001, Hills & Bennett 2010, Marshall et al. 2010).

3: Specify an adaptation focus

The success of adaptation is greatly influenced by the focus of the adaptation strategy, so a clearly specified adaptation focus is a key underpinning of success. Two components of the adaptation focus are important:

3. Where the focus is directed along the ***continuum from transformative to targeted change***. Transformative change includes building resilience, reducing vulnerability etc., and is aimed at long-term, sustainable outcomes. Targeted change often represents expedient/band-aid solutions, which usually offer only local gains specific to the target, and so often only lead short-term solutions or solutions that are not necessarily in tune with large scale goals (Lim *et al.* 2004; Folke *et al.* 2010).
4. Whether the focus is ***impact- or vulnerability-driven***. Focussing on reducing impacts can produce substantially different outcomes to a focus on reducing vulnerability. Focussing on impacts will often match with targeted solutions, while focussing on vulnerability will usually match with transformative change (Lim *et al.* 2004; Lawler 2009).

4: Define specific objectives

Along with the need for a specific adaptation focus goes the need to specify goals clearly (Christensen *et al.* 1996; Folke *et al.* 2010). Defining objectives requires a number of components:

- Objectives/Goals need to be explicit e.g. more resilient fisheries at a specified spatio-conceptual scale;
- Objectives need to be relevant to specific impacts and vulnerabilities;
- Identify the assets that require adaptation action;
- Governance objectives need to be defined;
- The spatial limits of the area the strategy is intended to apply to need to be defined;
- All end-users need to be identified;
- The end-user objectives of the strategy need to be identified;
- Any additional constraints for strategy development need to be defined. These could include governance structures or boundaries that are beyond the limits of influence of the strategy.

5: Identify end-users comprehensively

There will usually be a diverse suite of end-users and stakeholders. Comprehensive identification is important because the success of adaptation strategies often relies on the extent of stakeholder engagement (Sen & Hasan 2001), particularly useful when the problem is complex and uncertainty is high (Walters & Holling 1990).

6: Identify appropriate Climate Change scenarios

This step involves defining the exposure to be planned for. The scenario needs to be defined taking into account the key Climate Change threats which will help define the logic of the assumed time horizon.

7: Assemble all relevant information

A key step that includes collection of information on:

- Available GIS;
- Risk assessments;
- User groups (farmers, miners etc.);
- Climate projections;
- Local views on needs;
- Capacity (people, money, infrastructure);
- Governance and Legal situations and constraints;
- The local political context.

8: Assess the quality of available information and identify key gaps

The quality of information available is a critical determinant of the rigour and quality of the adaptation strategy development, and so is an important contributor to outcome uncertainty. If possible any major gaps identified should trigger the collection of additional information and the operation of an adaptive loop.

9: Assess and communicate uncertainties

A clear understanding of the level of uncertainty will help to determine the limits on predictability of the action-outcome link, and (usually) emphasise the extent to which robust strategies are necessary (Harris & Heathwaite 2012). Communicating the nature and extent of uncertainty, and is consequences for the predictability of outcomes is critical in enabling proponents to make effective decisions in the face of the business as usual approach of assuming a particular action will produce a predictable outcome, something that is rarely the case in systems with high levels of uncertainty from multiple sources (Lempert & Collins 2007; Harris & Heathwaite 2012).

10: Evaluate constraints

Constraints of all types should be evaluated because they determine the range of adaptation actions that are possible and consequently the eventual adaptation strategy. Early identification of constraints is valuable because it can provide time to work with stakeholders to overcome some of the issues, freeing up adaptation options. Constraints come in many forms both at the local level (e.g. geography, local climate, local tides, socio-economic, local political imperatives etc.) and at large scales (e.g. legislative requirements, national attitudes to development).

11: Assess the range of actions possible given the situation

This step involves the development of a prospectus of the range of actions available in the context of large scale constraints, local situational constraints, the nature of the threats, and the assets requiring adaptation action.

12: Develop the adaptation strategy

Develop the strategy in the light of available information, constraints, levels of uncertainty and possible actions. This involves consideration of the outcomes of different actions, employing decisions-support tools, considering available recommendations and advice, and prioritisation of actions.

13) Evaluate adaptation outcomes and monitor success

Without detailed evaluation and monitoring there is no way to determine the extent to which any strategy or action has been successful, no way to justify the expenditure of resources, and no way to determine what follow-ups actions might be necessary. Evaluation relies on having extensive, well defined baselines in place before any action is taken. Many aspects need to be included in evaluation, for example:

- Outcomes:
    - how outcomes relate to different end-user needs and aspirations;
    - cost-benefit of adaptation solutions of different complexity (e.g. framework vs. simple determinants model);
- Scales of outcomes:
    - conceptual scale of outcome: transformative, incremental, targeted, expedient (band-aid solution);
    - spatial (whole-of-system vs. individual objectives);
    - areal (local vs. multi system);
    - temporal scale of outcome: short term needs of end-users vs. long term benefits;
    - conceptual (proximal vs. ultimate outcomes);
- Context/Implications:

- outcomes for non-target end-users, interest groups or systems;
- collateral damage/complimentary benefits;
- feasibility.

14) Reassess uncertainties

This is a key step that combines information on uncertainties that have come to light during the process of developing an adaptation strategy. Judgement of the functional magnitude of the accumulated uncertainties will determine if it is suitable to employ the adaptation strategy at this stage or if it is necessary to continue on in an adaptive loop to enable collecting the information needed to reduce uncertainty to an acceptable level.

15) Collect additional information as necessary

Collect any additional information or develop any additional understanding as identified during assessment of information quality or during the strategy development and evaluation process.

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