Climate change adaptation in the Australian Alps

Introduction

Adaptation is essential to address climate change impacts. However, the capacity of natural and human systems to adapt is limited, either by the severity of the climatic perturbation, or by vulnerabilities in the system. This is one of six regional case studies of the limits to adaptation that explore the underlying causes and potential to transcend these limits.

Context

The snow-covered mountains of the Australian Alps are nationally and internationally important due to their conservation significance, ecosystem services and economic value. They extend over 500 km between Sydney and Melbourne in south eastern Australia and occupy 25,000 km² or 0.3% of the country. Within the Australian Alps are 11 national parks/reserves that extend across most of the bioregion. These are popular tourism destinations particularly in the summer. There are 10 ski resorts in or adjacent to the protected areas with winter visits worth A$906 million in 2005. There are also population centers dependent to a large extent on jobs and incomes generated from tourism. Agriculture and other productive industries surrounding the Australian Alps are dependent on water from the mountains, including for irrigation. Much of south eastern Australia depends on the Australian Alps for its water resources and hydroelectric power.

Current stresses

Current stressors on the natural values of the region include fire, grazing by feral animals and livestock, weeds and impacts from tourism.

Stressors for the tourism industry include factors which affect their competitiveness, including their remoteness from large centres of population, and the relative costliness of skiing holidays in Australia compared to many overseas competitors. There is competition among Australian ski resorts, from ski resorts overseas and from other types of tourism destinations within Australia.

At the local government scale, general stressors include changes in local land use and demographic changes in local communities.

Future climate

Predicted increases in temperature and decreasing precipitation due to climate change will result in dramatic changes in the region, with snow cover already declining by approximately 30% since 1954. Under the worst case scenario, by 2020 there will be a +1°C temperature increase combined with -8.3% precipitation resulting in a 60% reduction in the area receiving 60 days or more of snow. By 2050 the worst case scenario is for a +2.9°C temperature rise combined with -24% precipitation resulting in a 96% reduction in snow cover.

In addition to these direct changes, there are associated secondary biophysical effects including more cloud free days, lower humidity and increased total solar radiation. More variable and extreme climatic regimes and erratic weather events such as high intensity rain storms can also be expected. Warmer temperatures are expected to lead to increasing frequency and intensity of bushfires.

Impacts of future climate change

The Australian Alps benefit from relatively long term data on climate and detailed modelling of climate change compared with many other locations in Australia. As a result there is reasonably detailed research and modelling of climate change impacts on the biota, water supplies and winter tourism. Because of the close relationship between temperature, precipitation and natural snow cover there is general acceptance by researchers, parks agencies, local government, the tourism industry and tourists that climate change is affecting, and will continue to affect the region.

Published research for the region has identified a range of direct and indirect impacts, the majority of which are ecological/physical (70%) and economic impacts (10%). The most common impacts identified are the loss of snow cover, loss of endemic species and communities, increases in invasive species, increases in the intensity and frequency of fires and decreased winter visitors. Of these, the loss of snow cover, together with the follow-on effects, and the loss of endemic species and communities were considered to be the most significant.
When 16 stakeholders in the region, drawn from parks agencies, local government and researchers, were surveyed, identified impacts were similar to those from published research, i.e., mostly ecological/physical (70%) and economic impacts (18%). The most common were the loss of snow, the loss of endemic species and communities, increased frequency and intensity of fires, and decreased water availability. The biggest impacts of climate change, as identified by the stakeholders, were the loss of snow, together with the follow-on effects, and increases in fire frequency and intensity.

Adaptation: options and barriers
Stakeholders in the region are fairly advanced in planning and utilising a range of climate change adaptation strategies as well as acknowledging a wide range of biophysical, economic and social limits to those strategies. Ecological and physical adaptation strategies revolve around increasing the resilience of the region by controlling/limiting invasive species, rehabilitating disturbed sites, restoring endemic communities and connectivity, establishing assurance populations (off-site conservation of endangered species) for threatened animals and plants, reducing soil erosion and suppressing/controlling fires. Technical/physical strategies included increasing snow cover from activities including snow making and super grooming. Economic strategies included diversifying tourism in winter and summer and increased real estate sales.

Biophysical, economic, ecological and social limits on many of these strategies mean that major impacts of climate change will still occur. Thus, while snow making is the primary climate change adaptation response by the ski tourism industry, it will not be economically or physically viable, or socially acceptable, in the future. Current threats to ecosystems are still likely to impact on the region in future despite adaptation strategies. For example, management strategies for feral animals and plants have only slowed the spread of some species under current conditions, and so are unlikely to adequately deal with increased threats from weeds and feral animals under climate change.

Policy implications: limits to adaptation
Social, governance and knowledge issues play an important but largely under-recognised role in limiting climate change adaptation in the Australian Alps. Given that these limits are fairly flexible or dynamic in nature compared to ecological limits, which are currently the most recognised threshold, there is great potential for them to play a very significant role both positive and negative in the future.

Greater recognition of the national importance of the Alps as a catchment by stakeholders in the region is critical considering the importance of water from the Alps for Australia’s economy. This is an important social limit that was not recognised by many stakeholders who were more focussed on local or regional limits.

While several conflicts have arisen and/or are likely to arise among stakeholders in relation to the flow-on effects of various adaptation strategies such as snow making, there is also a great potential for collaboration in relation to other strategies such as managing fire, weeds and feral animals in the region.

This document summarises key findings from the NCCARF report ‘Climate change adaptation in the Australian Alps: impacts, strategies, limits and management’ by Clare Morrison and Catherine Pickering. Download the report at www.nccarf.edu.au.

Images: This page: Ruth Allison; Vernon Fowler. Overleaf: Amanda Slater; Small; Vernon Fowler.
Climate change adaptation in the Coorong and Lower Lakes

Introduction
Adaptation is essential to address climate change impacts. However, the capacity of natural and human systems to adapt is limited, either by the severity of the climatic perturbation, or by vulnerabilities in the system. This is one of six regional case studies of the limits to adaptation that explore the underlying causes and potential to transcend these limits.

Context
The Coorong and Lakes Region is a large and complex wetland system of international importance located at the end of the River Murray in South Australia, where the river discharges to the Southern Ocean. It includes the mouth and lower end of the River Murray, the Coorong - a barrier lagoon, and Lakes Alexandrina and Albert. The region has been subject to continual environmental change from a range of natural and human drivers. Recent environmentally-damaging human interventions include physical barriers to prevent water flow between parts of the system. The region is highly sensitive to changes in freshwater inflow due to non-climate changes (water extraction upstream) as well as climate variability: it was under immense stress during the 2002-2010 Millennium Drought. The Region is the traditional country of the Ngarrindjeri Nation and supports a variety of communities and industries including agriculture, viticulture, boating, and tourism.

Current stresses
The most important limit or barrier to climate change adaptation and a key current stress concerns water availability and associated arrangements for sharing water at national, state and local levels. The history of "water-sharing" and consequent "adaptation" to changing conditions (such as major technological interventions) illustrates the societal stress created by long-standing disagreements between communities, governments and a range of stakeholder groups. Two further stresses are lack of connection between parallel institutional planning initiatives (governance) as well as lack of capacity to create and maintain trust and effective working relationships between communities, governments and scientists (societal).

Future climate scenarios
A rise in temperature of 2°C
Freshwater inflows into the region from the Murray-Darling Basin are projected to decline drastically under climate change, with higher temperatures and greater evapotranspiration. Reductions of inflows of more than 60% with a 2°C rise in average temperatures are possible (although CSIRO do report the possibility of higher inflows under an extreme wet scenario). Loss of freshwater inflows would result in increasing salinity of the Coorong and Lakes rendering the water too salty for most biota. There would be more instances of drying of the Lakes as droughts become more frequent and inflows decline. This would result in a loss of key biota including aquatic plants, water birds and fish.

A rise in temperature of 4°C
Under a 4°C scenario of warming it is envisioned that the environment of the region would transition to a different, more marine state due to sea level rise and reduced freshwater inflows. With a sea level rise of 85-100 cm the barrages separating the Coorong from the Lakes would be over-topped resulting in inundation of low-lying lands, transition of the Lakes to a more saline condition and constriction of the estuary. Lake Albert and the Coorong would become hypersaline. Species and ecological communities would be lost due to higher salinity. New ecosystems would form, such as mudflat communities on newly inundated lands.

Impacts of future climate change
A number of threatened species and ecological communities in the region would be lost, such as the Coorong sea grass beds, freshwater refuge areas and species of fish. As well as impacts to ecosystems due to decreased freshwater inflows and higher salinity the socio-economic impacts would be substantial. With valued aspects of the ecosystem being progressively lost, such as fisheries, the cultural and economic base of the many communities living in the region would be severely degraded. The Ngarrindjeri Nation would lose culturally important species such as Black Swans, reeds and fish. Recreational and tourism industries would
suffer as declining water levels reduce boat passage and fisheries. Loss of modest areas of low-lying farmlands and infrastructure is likely with sea level rise and saltwater intrusion into formerly freshwater areas. Livestock-based producers around the waterways would be particularly vulnerable.

At different times different thresholds will be crossed which curtail or eliminate valued aspects of the environment, economy or society. For example, shallow habitat for water birds in the south lagoon of the Coorong would become too deep at a particular point of sea level rise, and this will differ from the timing of drying events in the Lakes that prevent passage for recreational boats. Societal tensions and conflict over declining resources are a likely impact of climate change. Such tensions were seen during the Millennium Drought when there was widespread disagreement about the need for and use of technological interventions, such as the temporary barriers between different parts of the Lakes, and about the extent of risk in ecological problems such as lake-bed acidification. Such conflicts are likely to continue under a changing climate and to have a negative impact on societal cohesion and well-being in the Region.

**Adaptation: options and barriers**

In the region, adaptation to upstream water extraction and to climate change are inextricably intertwined. Five key adaptation options have been identified. These are not mutually exclusive but have different benefits, costs, risks and barriers.

1. **Increase environmental flows into the Lakes and Coorong**, which would be the most effective measure for sustaining the environmental, economic and social values. This option is supported by local stakeholders, but not by all interest groups in the broader Murray-Darling Basin.

2. **Manage water more actively through engineering interventions such as weirs and channels**. This would enable the system to be compartmentalised in dry periods into freshwater refuge and sacrifice areas.

3. **Strengthen the barrages to reduce the impact of sea level rise**. The IPCC anticipates an 18-59 cm rise by the end of the century, although faster and higher rises are possible. This option would be expensive.

4. **Focus on better catchment management within the region**, including revegetation, regulating water extraction, and measures to reduce erosion and control salinity.

5. **A vital adaptation option is to create better, longer-term, governance structures which can develop greater community consensus on long-term objectives, rather than the perceived crisis-driven responses witnessed in the Millennium Drought**. Local ecological knowledge and aspirations should underpin management options.

**Policy implications: Limits to adaptation**

With many types of adaptation possible, it becomes unlikely that any single adaptation strategy is acceptable to all stakeholders, nor is a single strategy likely to address all the climate risks that concern all potential stakeholders. A key finding is that adaptation options for the region have not been openly or broadly discussed as part of the “bigger picture” of Murray-Darling Basin management. This is due, in part, to bureaucratic and political constraints, inadequate community engagement, social conflict, several parallel but unconnected planning initiatives, and lack of institutional arrangements to develop a truly long-term perspective. These constraints can be addressed through the establishment of institutions that take a genuinely anticipatory and long-term approach to include two of the major long-term drivers of change: inflows from the Murray-Darling Basin and ongoing climate change.

A new regional institution is recommended, one in which local communities, including the Ngarrindjeri Nation, are respected for their local knowledge and capacity for innovation and can play a major part in formulating and managing an adaptive management vision for the area.
Limits to climate change adaptation in the Great Barrier Reef

Introduction

Adaptation is essential to address climate change impacts. However, the capacity of natural and human systems to adapt is limited, either by the severity of the climatic perturbation, or by vulnerabilities in the system. This is one of six regional case studies of the limits to adaptation that explore the underlying causes and potential to transcend these limits.

Context

Geographic
The 345,000 km² Great Barrier Reef (GBR) and its 425,964 km² catchment lie along 2100 km of the north Queensland coast.

Climatic
The region has experienced the effects of increased atmospheric concentrations of greenhouse gases, directly through ocean acidification and indirectly through sea-level rise and increased air and sea surface water temperatures. These effects are regarded as major long-term threats to the GBR and the communities and industries that depend on it.

Human: economic, social
The ecosystem services provided by the Reef, which underpin tourism, commercial fishing and cultural/recreational activities, contribute an estimated A$6.9 billion to the Australian economy. The adjacent coast supports a population of approximately 850,000, expected to reach one million by 2026. The region has been designated as both a Marine Park (1975) and a World Heritage Area (1981).

Current stresses
The region supports activities including homes, transport, agriculture, tourism, recreation, and fisheries. Research identifies climate change, declining water quality, habitat loss from coastal development and impacts from fishing as major threats to the Reef system. There is evidence of a gradual decline in inshore coral reef habitat, increasing incidence of disease and pest outbreaks, and continued concern over vulnerable iconic species. Nevertheless, the GBR is still considered one of the best-managed reefs in the world.

Future climate
In this report, researchers developed four scenarios for 2050 to explore potential future climate change impacts on the Reef. The scenarios (Figure 1) are framed around two trends: 1) best-case, in which air temperatures rise by less than 1.5°C above 1990 levels (2°C above pre-industrial levels), and 2) worst-case, in which air temperatures rise by more than 2.5°C above 1990 levels (3°C above pre-industrial levels); and two adaptation pathways: 1) ideal ecological and social adaptation, and 2) limited ecological and social adaptation. These scenarios have associated potential impacts, adaptation options, and outcomes, which were elicited through a process of scientific and stakeholder consultation.

Impacts of future climate change

Under Scenario 1 impacts are localised, the Reef experiences temperature spikes once per decade, mid-shelf reefs are more exposed to freshwater run-off, cyclone damage increases moderately, disease and pest outbreaks are more frequent, and ocean acidification slows productivity.

Under Scenario 2 impacts are widespread and extend to deeper waters, the Reef experiences severe hot temperature events at least twice a decade with coral bleaching occurring annually, mid-shelf reefs are increasingly exposed to freshwater run-off, cyclone damage increases substantially, disease and pest outbreaks are more frequent and extensive, and ocean acidification slows productivity and undermines reef structure.

Secondary impacts under Scenarios 1 and 2 depend on how ecological and social systems respond to the changing climate. Under Scenario 1, the Reef remains coral-dominated but, under limited adaptation, coral cover declines and composition shifts to less heat-sensitive corals. The numbers of fish fully dependent on heat-sensitive corals decline considerably and the abundance of other coral-dependent species decline. Mangrove habitat decreases due to chronic erosion and increased extreme events; but, with adaptation,
some new habitat is established shore-ward and southward. Direct effects on fish lead to shifts in distribution southwards and to deeper waters. Under Scenario 2, the Reef fluctuates, depending on management and adaptation, between coral and algal dominance, and coral composition shifts to less heat-sensitive corals. Fish fully dependent on heat-sensitive corals decline and species may be lost; other coral-dependent species decline considerably. Some herbivorous fish benefit. Mangrove habitat decreases significantly, and under limited adaptation little new habitat is established. Direct effects on fish lead to significant shifts in distribution southwards and to deeper waters, increased variability in abundance of rainfall-dependent species and increased productivity and abundance in some other species.

Adaptation: options and barriers

In consultation with representatives of state and local government, the fishing and tourism industries, non-government, and scientific institutions, researchers used the scenarios to investigate adaptation options for the fishing and tourism industries. They considered to what extent diversification, effort management, or migration might have desirable adaptation outcomes, identified by respondents as: ecological sustainability, economic viability and enjoyment of the Reef. They identified a range of limits - factors that render adaptation options ineffective as a response to risk - which hinder improved outcomes. They identified critical limits embedded in a wider political and socio-economic context which, while surmountable, were not easy to overcome at the operator or, in some cases, even the sector or industry scale.

Limits to the common good: Beneficial outcomes for Reef industries and individuals often cannot be achieved through individual action but necessitate co-operation within and between sectors, and with external stakeholders. In the recreational fishery the potential of stewardship strategies to improve outcomes is limited by poor co-ordination within the sector; in the reef finfishery the potential of temporary effort reduction through voluntary quota cuts is perceived to be limited by a lack of co-operation between the commercial and recreational fishery; for fishing as a whole, the potential of stewardship and business management, is limited by actions on land, including agriculture and coastal development.

Limits of a global market: The Reef’s fishing and tourism industries operate in a competitive global market, which can constrain their economic viability. As such, some adaptation strategies are directly limited by market factors. In the reef finfishery the Chinese market prefers live, red coral trout and pays a premium for them. Trout species found in the more southern reefs are redder in colour. Technologies for live capture constrain the depths at which commercial fishers can harvest fish for this market, so demand for red, live trout is perceived to limit the potential of migration north or to deeper reefs to reduce fishers’ vulnerability following climatic events and climate change. In other cases, strategies, such as effort reduction in the trawl fishery, do not address the causes of fisher vulnerability, in this case, low prices for seafood driven by market competition, so fail to improve outcomes or avert climate change impacts.

Limited by reputation: The reputations of the Reef’s fishing and tourism industries were identified as critical limits. In the tourism industry, maintaining the long-term and short-term (after bleaching or storm events) reputation of the Reef is essential to enable effective adaptation through stewardship, business management and diversification. If operators diversify their product they need the market to respond accordingly. However, the reputation of the Reef was perceived to be unfairly eroded by increased research and communication on the damage from bleaching, cyclone events, and other threats, which undermines benefits from adaptation.

Policy implications: limits to adaptation

Key policy implications from this study include:

- Respondents emphasised that other drivers of change including economic volatility, natural disasters, and policy and management decisions are more immediate concerns for the Reef’s industries. Adaptation and limits to adaptation should apply to all types of risk and opportunity, including climate change.
- Policies on economic development, environmental management and adaptation to climate change should be integrated. Respondents highlighted that prioritising climate change research and action independent of other activities, risks undermining progress made on issues such as environmental sustainability. Business management and stewardship should be considered as core climate change adaptation strategies.
- The limits to adaptation identified in this study present real and considerable challenges to adaptation policy and action. They should be accounted for in management and adaptation planning exercises.
- Overcoming limits to adaptation in the Reef’s fishing and tourism industries requires:
  o meaningful action in policy arenas outside these industry sectors
  o integrated regional approaches to coastal development and land-use.

This document summarises key findings from the NCCARF report ‘Climate change adaptation in the Great Barrier Reef’ by Louisa Evans, Pedro Fidelman, Christina Hicks, Charlotte Morgan, Allison Perry and Renae Tobin. Download the report at www.nccarf.edu.au. Images: Overleaf: Richard Ling, Nick Hobgood.
Climate change adaptation in floodplain wetlands: the Macquarie Marshes

Introduction
Adaptation is essential to address climate change impacts. However, the capacity of natural and human systems to adapt is limited, either by the severity of the climatic perturbation, or by vulnerabilities in the system. This is one of six regional case studies of the limits to adaptation that explore the underlying causes and potential to transcend these limits.

Context
Geographic
The Macquarie Marshes is an iconic floodplain wetland, occupying about 200,000 ha in central western New South Wales. Flows to the Macquarie Marshes come primarily from the Macquarie River, fed by five major tributary rivers. Around 10% of the Marshes is protected in the Marshes Nature reserve. The reserve and nearby Wilgara Wetland are listed under the RAMSAR convention due to their international significance, including for waterbird breeding.

Climatic
Located in the arid zone, the Macquarie Marshes receives less than 500 mm rainfall annually. Mean monthly temperatures range from 26.5°C in January to 12°C in July. The highest recorded temperature is 48.9°C and the lowest -4.2°C. Droughts, extended periods of low rainfall and/or low flow, are severe and common.

Human: economic, social
The Macquarie Marshes was traditionally occupied by the Wailwan people, and was culturally significant for traditional ceremonies. In addition to supporting significant ecological values, the Macquarie Marshes, with about 90% of the land privately owned, is also home to an established community of graziers who depend on river flows for their livelihood. There is an irrigation industry mostly upstream of the Macquarie Marshes.

Current stresses
The Macquarie Marshes are severely impacted by regulation that has reduced flooding volumes (by about half) and extended the inter-flood interval from 1-2 years up to 10 years last decade, to the point where the ecological character of the Ramsar site has changed. More than half the area of semi-permanent vegetation is degraded, being replaced by terrestrial plants. As a consequence organic matter and total carbon stores are declining and fundamental cycles at the base of the food web are shifting from dominance by respiration to primary productivity. In the current Marsh, waterbirds seldom breed and their communities contain reduced diversity and densities. Dormant microorganism eggs and aquatic plant seeds are reduced in areas that remain dry for periods longer than 10 years. Grazing productivity is significantly reduced, with long unproductive dry spells, and many families have moved away from the Marshes. Recent floods have resulted in a significant response in most biota, including waterbirds.

Future climate scenarios
Scenarios of a 2°C and 4°C warmer world
This table (left) shows the scenarios underpinning this discussion.

<table>
<thead>
<tr>
<th>Climatic or flow variable</th>
<th>Scenario 1 median</th>
<th>Scenario 2 dry</th>
<th>Scenario 3 wet</th>
<th>Scenario 4 2070</th>
<th>Natural</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature °C</td>
<td>+ 1.03 °C</td>
<td>+ 1.6 °C</td>
<td>+ 0.45 °C</td>
<td>+ 4.0 °C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean annual rainfall</td>
<td>-2 %</td>
<td>-13 %</td>
<td>+ 11 %</td>
<td>n/a</td>
<td>544 mm</td>
<td>547 mm</td>
</tr>
<tr>
<td>Mean annual runoff</td>
<td>-6 %</td>
<td>-25 %</td>
<td>+ 30 %</td>
<td>n/a</td>
<td>35 mm</td>
<td>33 mm</td>
</tr>
<tr>
<td>Mean annual water availability</td>
<td>-8 %</td>
<td>-25 %</td>
<td>+ 25 %</td>
<td>-44 %</td>
<td>1567 GL</td>
<td></td>
</tr>
<tr>
<td>Average Inter Flood Interval (IFI)</td>
<td>+ 10% 5.2 yrs</td>
<td>+ 24% 18 yrs</td>
<td>- 25% 3.5 yrs</td>
<td>n/a</td>
<td>2.2 yrs</td>
<td>+ 114% 4.7 yrs</td>
</tr>
<tr>
<td>Maximum IFI</td>
<td>n/a</td>
<td>+ 20%</td>
<td>n/a</td>
<td>n/a</td>
<td>7 yrs</td>
<td>15 yrs</td>
</tr>
<tr>
<td>Mean winter-spring flood volume/yr</td>
<td>-16% -38%</td>
<td>+ 21%</td>
<td>n/a</td>
<td>118 GL</td>
<td>75 GL</td>
<td></td>
</tr>
<tr>
<td>Mean winter-spring flood volume/event</td>
<td>-5% -6%</td>
<td>+ 5%</td>
<td>n/a</td>
<td>278</td>
<td>322</td>
<td></td>
</tr>
</tbody>
</table>
Impacts of future climate change

With a business-as-usual scenario the future Macquarie Marshes sees a worsening of all ecological and social indicators by 2030 and a marked decline by 2070. This is counterbalanced by increased delivery of environmental flows as a result of purchase of irrigation licences by the NSW and Australian governments.

Based on long term averages, changes by 2030 should be small compared to those already observed with regulation. However, another drought like the 2000-2010 ‘big dry’ would significantly harm already degraded and vulnerable ecological and social systems. Drought incidence is projected to worsen. Nevertheless, the climate change projection for 2030 is within the current range of variability.

By 2070 the combination of markedly increased temperatures and reduced rainfall would see core Marsh areas further reduced and the possible loss of all floodplain with a short IFI (1-2 years). A series of droughts between now and then may destroy all but fringing red gum vegetation. Carbon and dormant egg/seed storage would be comparable to infrequently flooded wetlands on the Darling River and Cooper Creek. Waterbird populations are likely to plummet with few opportunities for recruitment and exotic species will replace many native fish. The 2070 projections would likely lead to few landholders grazing the Marshes and sheep replacing cattle.

Adaptation: options and barriers

The study identified two autonomous adaptations, four physical adaptations, seven institutional/political adaptations and eight land management adaptations. Most of these actions are currently at varying stages of application to counter impacts of loss of flooding due to regulation. At a workshop, stakeholders identified 16 high priority adaptations and discussed their limits and implementation. Water buy-back and environmental flows are key adaptations, but developing an adaptive management plan, social capital, responsive institutional frameworks and preserving free-flowing rivers were also identified.

Landholders graze the Macquarie Marshes using a flexible approach to deal with variability in the system. They identified loss of flooding and loss of variability as key impacts of regulation that reduce their resilience. Landholders have developed many practices to adapt to the loss of flooding that will enable them to adapt to climate change projections at 2030.

The primary adaptation that will transform the Macquarie Marshes ecosystem from its current state of decline is the return of adequate environmental water.

The Macquarie Marshes, like wetlands globally, has experienced significant declines in biodiversity and populations due to regulation, and hence is increasingly vulnerable to projected climate change impacts.

A major limit to adaptation is the lack of capacity of river managers to learn from problems during drought periods and implement water sharing plans that avoid similar losses if climate change increases drought intensity and frequency.

This study examined the types of adaptations that reduce the climate change-induced extension of the IFI for floodplain wetlands. To achieve and sustain this, it is necessary to remove the biophysical drivers and to change the behaviour that causes the biophysical driver. Examples of adaptations that alter the biophysical driver, but not the behaviour, are trucking triage water (buffering), buying back adequate volumes of water and increasing the outlet capacity. However, if the water sharing plan, the main document that governs management of flow for flooding and IFI, is not changed then adaptation is limited.

This document summarises key findings from the NCCARF report ‘Limits to adaptation in floodplain wetlands: the Macquarie Marshes’ by Kim Jenkins, Richard Kingsford, Ben Wolfenden, Stuart Whitten, Hannah Harris, Claire Sives, Rob Rolls and Sylvia Hay. Available at www.nccarf.edu.au.

Images: This page: Cameron Muir. Overleaf: Eyeweed, Cameron Muir.
Introduction
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This case study looks at water trading in the Murray-Darling Basin (MDB) as a market-based instrument (MBI) for climate change adaptation – its strengths, weaknesses, and the potential limits to its capacity to address the challenge of climate change.

Context
Geographic
The MDB covers 14% of mainland Australia and includes four states (New South Wales, Queensland, Victoria and South Australia) as well as the Australia Capital Territory (ACT).

Climatic
The MDB is classified as either arid or semi-arid. Annual rainfall averaged across the MDB is approximately 470 mm per year, but the spatial variability is large with rainfall highest in mountainous areas in the southeast (more than 1500 mm/year) and lowest in the west (typically less than 300 mm/year). Average MDB evaporation is approximately four times the annual mean rainfall. In addition to spatial variability there is large inter-annual to multi-decadal hydroclimatic variability, illustrated by several historic multi-year droughts, including the “Federation Drought” (1895–1902), “World War II Drought” (1937–1945), and “Big Dry” (mid-1990s to 2010).

Human, economic, social
Agriculture in the MDB produces $15 billion worth of produce annually, which is 39% of Australia’s total agricultural production. The MDB contains 65% of Australia’s irrigated land area, 40% of Australia’s farms and is the most agriculturally productive area in Australia.

Current stresses
Several key stresses confront the MDB, rural (inland) communities, and agricultural production:
- Impacts of climate variability (e.g. drought, flood, heatwaves etc.);
- Projected impacts of climate change and uncertainty as to how climate change will alter the magnitude, frequency, location and/or duration of existing hydroclimatic risks;
- Rural demographic shifts and a changing farming industry – this includes the demise of the family farm, pressures from mining, corporatisation of the agriculture industry, deregulation etc.;
- Social stresses associated with changing (or loss of) community, increasing debt levels, ongoing uncertainty, false optimism, stoicism instead of resilience etc.);
- Economic uncertainty around, for example, water markets, commodity prices and the global financial crisis;
- Inadequate, misplaced or failed government support.

Future climate scenarios
For most of the MDB the climate is projected to become warmer, with more hot days (over 30°C) and fewer frosts. The greatest warming is likely to be in summer and the least in winter. Rainfall is projected to decrease in all seasons and this decrease is expected to be the greatest in spring and winter. Potential evaporation is also projected to increase across all seasons, with the most significant changes occurring in winter. Lower rainfalls and higher evaporation rates would result in less soil moisture and lower river flow. This potentially means more ‘rainfall droughts’ and also more
'Irrigation droughts' across the MDB. These projections are, however, associated with significant uncertainties and must be treated as such – that is they provide some insight into what could happen not what will happen (see the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, available from www.ipcc.ch).

Impacts of future climate change
Australia's vulnerability to climate variability and change has been highlighted by the recent prolonged drought (i.e. the Big Dry or Millennium Drought), and by recent flooding across much of eastern Australia during 2011 and 2012. Under future climate change there is the possibility that the frequency, intensity and duration of these extremes may increase, underlining the need for robust adaptation strategies.

Adaptation: options and barriers
In assessing the limitations of water trading, and MBIs in general, as a climate change adaptation tool, it is crucial, although challenging, to separate the impacts and issues attributable to water trading or water policy from those that are caused by drought or other climate impacts.

More research is required to differentiate between changes in water use due to inadequate water policy (or limitations or failure of water policy), and changes due to variable (or permanently changed) hydroclimatic conditions. The two are strongly related in that robust water policy (including a robust water trading scheme) should account for and be able to cope with changes in hydroclimatic conditions. However, to date there has been minimal effort focussed on assessing whether the existing and proposed water trading schemes are robust under the range of historical and projected Australian climate conditions. In fact, it is unclear whether such a 'climatically resilient' water trading scheme is even possible.

The highly variable nature of Australia's climate poses a significant barrier when developing and implementing any water trading scheme.

Policy implications: Limits to adaptation
Water trading has potential as a climate change adaptation strategy with many benefits experienced in previous and current versions of water trading. However, there are also some significant limitations and the people and industries that are negatively impacted by water trading are hit hard.

Water trading can give individual irrigators who understand the system and have the financial capacity to purchase water greater flexibility in making decisions about their priorities for water use. It offers a means of managing risk and cash flow (particularly in dry times), and facilitates business growth and development. However, these benefits are usually limited to the larger, well-educated irrigators at the expense of the smaller 'family-farm' operations which are crucial to the viability of many local communities. Hence, water trading can also have negative social and economic effects for local communities with strong concerns about people “selling up” their water entitlements and exiting the community.

Water trading and the associated redistribution of industry (and jobs and population) has the potential to change rural communities permanently, mostly via an acceleration of the changing demographics already being experienced (e.g. ageing and declining population). These social impacts and limitations of water trading have not been thoroughly investigated and are not well understood.

Similarly, as demonstrated by the ongoing controversy surrounding the Murray-Darling Basin Plan, significant uncertainty also exists around the impacts of water trading on the environment (e.g. changed hydrological regimes, underestimation of sustainable environmental flows etc). Proper quantification of these impacts is needed, but can only be achieved with a proper understanding of what is sustainable and what is not and how to best balance and optimise the water needs of the environment, agriculture, other non-agricultural industry, and human settlements. ‘Cap and trade’ quantity-based MBIs such as water trading will eventually do what they are designed to do (i.e. reallocate a resource to ‘high value’ users). However, given that the ‘low value’ users in this case are agriculture and drinking water supply and the ‘high value’ users are mining, manufacturing, and electricity production (i.e. industries with high greenhouse gas emissions) do we really want the water trading MBI to achieve its objective? And, what would the social and environmental ramifications of such a shift in water use within Australia be? These questions, along with the above-mentioned barriers, limitations and potential implications of using water trading (and MBIs in general) as a climate change adaptation tool, must be carefully considered and rigorously investigated prior to implementation if past drought and water policy failures are not to be repeated.
Limits to climate change adaptation for two low-lying communities in the Torres Strait

Introduction

Adaptation is essential to address climate change impacts. However, the capacity of natural and human systems to adapt is limited, either by the severity of the climatic perturbation, or by vulnerabilities in the system. This is one of six regional case studies of the limits to adaptation that explore the underlying causes and potential to transcend these limits.

Context

Geographic
Over 100 Torres Strait Islands are distributed over 48,000 km² of shallow sea between Papua New Guinea and Cape York. This study worked with communities on two different islands – Boigu and Erub. Boigu is flat and low, formed of mud deposited on an old reef platform. It is 17 km by 6 km but consists mostly of brackish swamps. Mangroves encircle the margins, except for an 800 m by 500 m slightly higher (4-5 m above Lowest Astronomical Tide level) area on the northern coast known as Koedal Boepur, where the village is located. Much of the village already floods on the highest tides. Erub is a 3 km by 2 km volcanic island. Significant infrastructure, housing, and cultural sites lie on the low coastal fringe.

Climatic
The annual average temperature is 26.8°C (December mean: 28.1°C; August mean: 25.3°C) with a warming trend and strong inter-annual variability. Until the mid-1990s the maximum temperature increased by 0.32°C/decade and the minimum by 0.18°C/decade. Between the mid-1990s and 2009 these values increased to 0.67°C/decade and 0.51°C/decade respectively. Rainfall is seasonal, with high annual variability. Average wet season (October-April) rainfall is 1750 mm, and 90 mm during the dry (May-September).

Human: economic and social
Approximately 8700 Islanders inhabit 18 communities across 16 islands, with over 47,000 others on mainland Australia. Torres Strait is home to a unique set of histories, traditions, laws and customs referred to as Ailan Kastom, which pervades daily life through strong cultural, spiritual, economic and social connections with land and sea country. Ailan Kastom provides a governance system that oversees beliefs, rights, responsibilities, and traditional resource management, and reinforces relationships with land, sea, plants, animals, and with others in Torres Strait. Torres Strait is administratively complex with more than 25 government agencies or departments represented. Some Boigu and Erub residents are employed in government or government-sponsored programs, with few private sector opportunities beyond limited commercial fishing and art sales. Remoteness, social and economic disadvantage, and the physical constraints of small island environments may appear to heighten vulnerability to climate change. However, the resourcefulness of these communities and their resilience to past environmental changes mean Torres Strait Islanders have knowledge, skills and resources they are willing to contribute to adaptation.

Current stresses

Major stresses are:
- Inundation during high tides or storm surges on both islands, which threatens traditional lands, cultural sites, infrastructure, and resources such as garden soils and vegetation;
- Coastal erosion: communities have attempted to slow erosion using local resources, but are concerned by lack of government action;
- Changed seasonal climate and disrupted natural cycles, affecting traditional resource use and management;
- Declining marine ecosystems manifested as coral bleaching and reduced reliability of important food resources such as turtle;
- Particularly on Erub, the unreliability of water supply.

Future climate

By 2070 temperatures may be 1-4°C warmer, with consecutive days above 35°C possibly increasing from 6 to 50 days. Rainfall is likely to increase, mostly due to higher wet season falls; dry seasons may become drier (as much as 23% of 1990 levels). Overall, rainfall is expected to become less reliable. Torres Strait may expect more intense tropical cyclones, with higher rainfall intensity but reduced frequency. Sea surface temperatures should increase, and sea levels should rise. Global sea levels are expected to increase by 0.18
to 0.59 m on average by 2100 (90% confidence). Regional sea levels may differ from global, but nevertheless are expected to increase.

**Impacts of future climate change**

Accelerated coastal erosion and seawater inundation were considered the most serious potential impacts on both islands. If sea level rises by 0.59 m by 2100, the present seawall at Boigu will be overtopped 140 times a year (compared to 25 times a year now). On Erub, tidal incursions of at least 0.42 m above the lowest habitable floor level will occur annually. Such events will affect public and personal property and infrastructure function and maintenance, and may contribute to salinisation of water supplies and garden soils. On Boigu the northern shoreline on Koedal Boepur has retreated by up to 50 m over the past 50 years, with the loss of three rows of houses, and the cemetery is presently threatened.

Both communities depend on healthy ecosystems for food, income generation, and ecosystem services such as shoreline protection. A healthy ecosystem is an essential economic and cultural resource, central to Ailan Kastom. For example, coral bleaching and seagrass declines attributed to warming threaten important food resources and cultural activities. Community members raised reduced food and water security as potentially serious impacts (subsistence fishing and hunting for consumption and trade remain important in many Torres Strait communities). Loss of land or productivity due to coastal erosion, seawater inundation, or the need to relocate infrastructure over scarce ‘garden soils’; were considered constraining. Concern was expressed that reduced economic opportunities, and uncertainty regarding the future of community infrastructure, would encourage outmigration of younger people, and that the cultural identity of some community members may be affected as climate change impacts affect Ailan Kastom. These changes threaten the strong social capital, supportive networks and clan groups, which will be invaluable in facing future climate change.

**Adaptation: options and barriers**

The only adaptation option in the short term for Boigu is the construction of appropriate seawalls and infrastructure to protect against inundation and erosion. The community does not consider relocation an option and the low elevation excludes retreat. Erub’s topography offers a buffer, with accommodation, retreat (to higher ground) and protection-type strategies possible. However, some community members felt strongly that protection must be considered – retreat was distressing and would render livelihoods unsustainable.

Communities fear that their views will not be adequately considered in decision-making - a governance issue. Moreover, there is a frustration that action has been slow to follow collaborative assessment of climate change impacts and adaptation strategies.

Strong social capital contributes to adaptive capacity in both communities. Interviewees related how skilled locals had returned after studying or pursuing careers off island, but believed that better infrastructure, services and economic opportunities, must be provided if these people (who are crucial in developing and maintaining adaptive capacity) are to be attracted and retained.

Underperformance is an emerging concern that may have ramifications for engineered solutions. On Erub, infrastructure built to solve water supply problems has not met expectations, and has flattened community confidence in technical solutions. Moreover, there is significant risk that some approaches, such as removing personal responsibility for water conservation and using desalination plants, are maladaptive.

**Policy implications: limits to adaptation**

Engineered fortification of the Boigu shoreline is necessary to sustain livelihoods in a climate-changed future.

There is waning community confidence in the complex governance that oversees climate change impact and adaptation assessment. It is critical to restore confidence, and ensure community involvement in formulating adaptation policy.

The primary goal articulated by Boigu and Erub residents was to continue sustainable livelihoods on traditional lands while maintaining customary practices. Prioritisation of adaptation strategies should reflect views and values determined after consultation and mediation, and acknowledge that traditional owners have the right to decide on the acceptability of risks and solutions.

Strategies to improve adaptive capacity by fostering alternative livelihoods should be explored. Opportunities exist in tourism, aquaculture, natural resource management, and environmental and agency service provision. New opportunities in sectors of increasing demand, such as education, health, and biosecurity and border security compliance, should be developed. Improved support should be given to initiatives that ensure Torres Strait Island communities regain greater control of livelihoods in enterprises dominated by outsiders, such as commercial fishing. Care must be taken to ensure governance does not limit adaptation by inadvertently constraining livelihoods when seeking to address another issue.

This document summarises key findings from the NCCARF report ‘Limits to climate change adaptation for two low-lying communities in the Torres Strait’ by Karen McNamara, Scott Smithers, Ross Westoby and Kevin Parnell. Download the report at www.nccarf.edu.au.

Images: Above: Ewan Bell. Overleaf: Campervan; NASA; Annabel Jones.