Adapting ecosystems to climate change

Australian ecosystems face diverse (and most probably negative) future climate change impacts depending on their geographic location and current climatic conditions.

Key Points

Ecosystems are complex and highly interconnected. While they have a natural capacity to adapt to change (e.g. through redistribution, behavioural changes or extinction), the ever-increasing rate of climate change means that ecosystems are expected to be fundamentally altered.

Ultimately, minimising changes in ecosystems can only be achieved through rapid and effective reduction of carbon emissions. Adaptation policy settings and management actions can help build ecosystem resilience, and achieve better ecosystem outcomes by instigating adaptation actions by different sectors (e.g. water, coastal management). Adaptation actions need to be guided by the desired outcomes of any intervention (e.g. to maintain ecosystem function or preserve individual species).

Key needs to support the future of well adapted ecosystems include:

- Coordinated approaches across all levels of government, recognising the importance and function of ecosystems at a landscape scale.
- Addressing conservation needs, irrespective of whether these are within public protected, privately owned or cross-border areas.
- Minimisation of existing stressors to maximise adaptive capacity of ecosystems.
- Long-term monitoring to identify rapid changes and, where these occur, capacity to set up flexible pro-active planning, conservation and management programs.
- Community engagement and effective communication, as the foundation of successful management programs and evidence-based policy-making.

Market mechanisms and incentives have a role in ecosystem management, but must be used wisely.

NCCARF's evidence-based Policy Guidance Briefs address key challenges to effectively adapting Australia to a variable and changing climate. They provide high-level policy advice designed for use by policy makers at Commonwealth and State level. This Guidance Brief deals with the challenge of managing Australia's ecosystems (terrestrial, marine and freshwater) to ensure conservation and function under climate change.

Ecosystems – the variety of living organisms and their environment – provide services that include food, fibre, fuel, air quality, recreation and tourism. Australian ecosystems face diverse (and most probably negative) future climate change impacts depending on their geographic location and current climatic conditions. About 80% of Australia's vertebrate and plant species are not found anywhere else in the world. Climate change is likely to result in extinction of many species and changes to the diversity of ecosystems and their services.

1 The climate context

Projected changes in Australian climate include (Whetton, 2011):

- Annual average warming by 2030 of approximately 1.0°C (above 1990 temperatures) across Australia, with warming of 0.7 to 0.9°C in coastal areas and 1 to 1.2°C inland.
- Drying in southern areas of Australia, especially in winter, and in southern and eastern areas in spring. Changes in summer tropical rainfall in northern Australia remain highly uncertain.
- Intense rainfall events in most locations will become more extreme, driven by a warmer, wetter atmosphere. Drying plus increased evaporation means soil moisture is likely to decline over much of southern Australia. An increase in fire-weather risk is likely.

In terrestrial ecosystems, organisms will be exposed to higher atmospheric concentrations of CO_2, which should make plants grow faster. This can be demonstrated in controlled environments such as in laboratory experiments. However, it is unlikely to be the case in natural settings, where the effect will be reduced or negated by existing nutrient limitations and changes in temperature, water availability and other atmospheric gases due to climate change.

Australia's marine environment is at risk from changes to ocean temperature, salinity, sea level, mixed layer depth, circulation, pH, turbidity and from changes in atmospheric radiation and extreme climate events. Rates of warming of the waters in south-east and west Australia are already substantially higher than the global average warming rate (Figure 1). Sea surface temperatures in south-east Australian waters are projected to be at least 2.5°C warmer by 2100. The East Australian Current (EAC) is expected to continue to increase in strength, bringing more persistent warm, salty and low nutrient waters off Tasmania's east coast. Increasing atmospheric CO_2 concentrations are associated with increased CO_2 uptake by the oceans and ocean acidification. Between 1751 and 1994, the acidity of the world's oceans increased by close to 30%. The most recent estimate of sea-level rise from the Intergovernmental Panel on Climate Change (IPCC, 2007) is for an increase of 18-59 cm by 2090-99 compared to 1990. In a more recent paper (Church et al., 2011), taking into account 'rapid ice flow', models estimate a rise of 80 cm by 2100 compared to 1990.

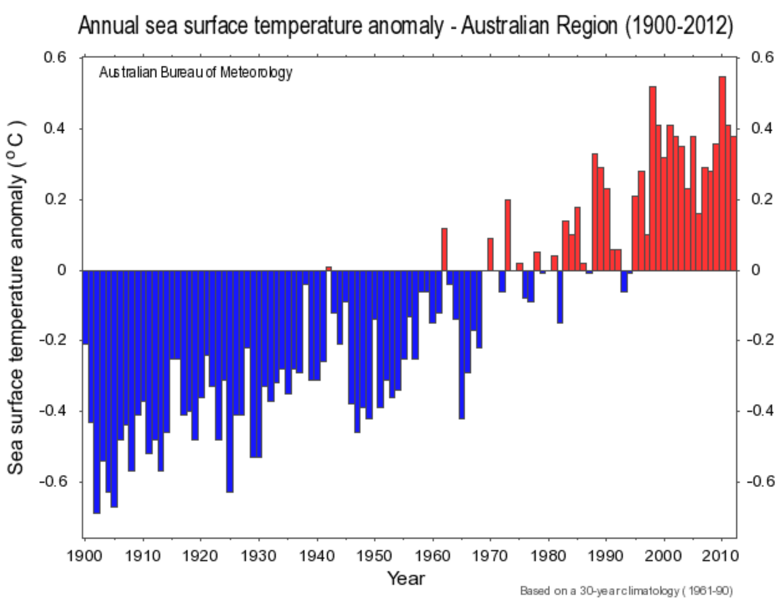


Figure 1: Annual sea surface temperature anomalies in the Australian region (1900-2012). Source: Australian Bureau of Meteorology

2 Current effects, impacts and issues

Australia's ecosystems have been under increasing pressure from disturbance since European settlement, as outlined below.

Terrestrial ecosystems: Vegetation clearance, mainly for urban and agricultural development, is a key threatening process for most of Australia's terrestrial ecosystems. It results in loss of species and soil, and leads to habitat fragmentation and degradation. Across Northern Australia, changed fire regimes, grazing and feral predators pose greater threats. Other pressures include feral animals, weeds, disease and pollution, as well as population depletion and loss of genetic diversity due to clearance.

Freshwater ecosystems: Freshwater ecosystems have been influenced in both urban and rural environments by land clearing, and changes to flows. They have been negatively impacted by: erosion, sedimentation, pollution, eutrophication (high concentrations of nutrients such as nitrates and phosphates leading, for example, to algal blooms), cattle encroachment, construction of barriers (dams, weirs, culverts etc.), stream diversions, channelisation, and the introduction of noxious and non-indigenous plant and animal pest species (e.g. Gambusia fish, carp, tilapia, feral pigs, salvinia etc.). All of these affect water quality, which is one of the most significant issues in ecosystem health.

Coastal ecosystems: Coasts are the interface between marine and terrestrial ecosystems and are shaped by physical processes. Many coastal ecosystems tend to be highly productive and support a very diverse range of species. More than 80% of Australia's population lives on or near the coast, and coastal ecosystems are under pressure from many non-climatic stresses including: coastal development and habitat loss or disturbance, changes to nutrient and sediment dynamics (e.g. runoff, sea protection that prevents natural sediment deposition), invasive species and harvesting (e.g. both recreational and commercial fishing).

Marine ecosystems: Many marine ecosystems have been influenced by extractive industries, such as mining and fishing, and by contaminated runoff (for example, by fertilizers) from neighbouring land surfaces. There has been extensive coral loss on the Great Barrier Reef (GBR) due to expansion in numbers of the coral-feeding crown-of-thorns starfish.

Already climate change has resulted in increased strength and extent of the EAC, which has led to range expansion of certain species of fish and invertebrates, and associated impacts on southern reefs. Coral bleaching events in the GBR have occurred during times of very high water temperatures.

3 Future effects, impacts and issues

For plant and animal species alike, differing physiological tolerances, resilience and adaptive ability will lead to changes in their distribution, abundance, and community structure with changes in the physical environment (e.g. terrestrial: air temperature, water availability, CO_2 enrichment; marine: water temperature and ocean chemistry).

Terrestrial ecosystems: Terrestrial species have already responded to observed climatic changes, globally and in Australia. The geographic ranges of many species have changed in location and size and some species are displaying altered timing of life cycle processes such as migration and breeding. Some species also show altered behavioural, genetic, and physiological traits. Further and more extensive changes of this nature are expected under future climate change. For example, Garnett et al., (2013) predict that the "climate space" (i.e. the suitable climate) for 101 bird species will be lost by 2085.

Terrestrial species at greatest risk include many that are already endangered or rare. These species commonly have restricted or fragmented geographic distributions or habitats. They may have specialised ecological requirements and narrow climatic tolerances. Examples of known fragile ecosystems include high-altitude cool refugia and alpine areas, which are increasingly vulnerable in a warming climate, and the biodiversity hotspots of south-west Western Australia already experiencing significant drying.

Extreme events such as heat-waves, droughts and wildfires will likely have catastrophic impacts. For example, mass die-offs of possums and flying foxes have already been observed following prolonged episodes of high temperature.

Freshwater ecosystems: Drought can lead to lower flows and sea-level rise increased salt-water intrusion. When combined with existing stresses (e.g. habitat loss, invasive species, water extraction and channelisation of creeks and rivers), changes in composition, structure, function and connectivity of freshwater ecosystems can result. This will increase the risk of species extinctions.

Water temperatures are expected to increase significantly in many systems, with associated impacts on species composition and population dynamics. The majority of our native freshwater fish rely on environmental triggers to spawn and migrate. Certain fish can only spawn within narrow temperature ranges or habitats. Changing their environment will limit opportunities for reproduction and dispersal, potentially causing the destruction of entire fish populations.

Coastal ecosystems: Saltwater inundation as a result of rising sea-levels, storm-surge and more intense cyclones will change species composition of mangroves and coastal wetlands. Sandy beach ecosystems will likewise be impacted by these events, through erosion and inundation. Increased turbidity levels from wave activity due to cyclones, increased flooding events and sea-level rise will impact on seagrass ecosystems.

Rising sea-levels will force colonisation of salt marsh and mangroves inland, although where there is coastal development this will prevent success. The ultimate outcome is likely to be habitat narrowing and eventual loss of these systems.

Future effects, impacts and issues ... continued

Estuarine nursery habitat for many vertebrate and invertebrate species will be reduced in size or destroyed, where sea level rises faster than the rate of marine plant growth.

Marine ecosystems: Like terrestrial ecosystems, changes in species distribution and behaviour and survivorship have already been observed. Examples include coral bleaching and increased occurrence of tropical species (fish & urchins) in southern seas. Ecosystems such as kelp forests will be impacted by changes to the distribution of critical predators such as sea-urchins and the replacement by south moving predator species. Ocean acidification is expected to affect the physiology and metabolism of marine organisms with carbonate body parts, such as corals and shellfish. The range of toxic algal blooms can be expected to expand; e.g. the dinoflagellate, *Noctiluca scintillans*, has expanded its range from Sydney into southern Tasmanian waters, causing problems for the salmon farm industry.

4

Adaptation: what this means for managing the sector

Human planned adaptation and management of ecosystems to address the challenge of climate change will be largely focused on building resilience.

Current practice to manage existing pressures: Existing knowledge, skills and management principles will continue to be at the core of managing ecosystems under climate change. These principles include:

- identifying, protecting and planning for refugia,
- maintaining appropriate connectivity of habitats and landscapes,
- managing and implementing biosecurity measures,
- managing existing threats (e.g. feral species, disease, tree clearing) and pressures (e.g. excess sediment loads, nutrients and pesticides into waterways), and
- effective monitoring of change and timely and appropriate responses.

Nevertheless, stronger additional measures may be required:

- *Consolidation of information* Considerable effort is being directed towards impact assessment, spatial mapping, understanding of ecosystem services and flow-on effects under different levels of climate change. Bringing this information together will improve understanding and direct prioritisation of management actions.
- *Stronger enforcement of laws and regulations, and effective implementation of current management recommendations* will improve ecosystem resilience, for example, implementation of species recovery plans.
- *Low-regrets actions* Given the uncertainty around projected changes and our limited understanding of species/ecosystem responses, low-regrets actions can build resilience without committing to pathways that may become maladaptive. Low-regrets options include strengthening traditional biodiversity management actions (e.g. increase protected areas, minimise clearing, restore ecosystems, reduce grazing pressure).
- *Maintain awareness of the differences between ideal solutions and what is possible* While logical analysis may identify ideal solutions for ecosystems to adapt, reality may prevent their implementation (e.g. limited resources, socio-economic considerations). As an example, mangroves are often described as 'winners' under climate change because they can colonise new areas as sea-level rises, but this ignores the fact that coastal areas are highly developed thus preventing colonisation.

Risks and challenges: Considerable challenges and barriers exist to implementing adaptation actions and planning for ecosystem outcomes. These include:

- *Uncertainty* Site- or species-specific processes are often poorly known and hence management responses are uncertain (e.g. what might colonise or successfully grow in an area in the future under climate change).
- *Resources and scale* Current biodiversity management is often reactive and regional – responding to immediate threats and impacts in local areas. The challenge of adaptation demands a landscape-scale planning approach – building corridors, identifying refugia etc. There is a need to reconfigure funding models to match the required scale of strategic planning.
- *Some known solutions are unpalatable or risky* Potential adaptations include translocation of threatened species to new areas and genetically engineered solutions. These solutions may create new problems or challenges and are often met with community resistance.
- *Actions in one ecosystem may add stress to another* Some potential adaptation actions have wider risks or flow-on effects. For example, herbicide is an effective control mechanism for weeds but in runoff to the ocean some herbicides threaten seagrass beds.
- *Limits to adaptation* Australia's ecosystems are already changing in response to changes in climate. While management can slow or facilitate changes (e.g. migration) the reality is that unchecked climate change will fundamentally alter Australia's ecosystems. This is a very different adaptation challenge to that facing other sectors (e.g. infrastructure, emergency management etc.). Ecosystems are the areas of climate vulnerability that stands to benefit the most from efforts to reduce carbon emissions and slow the warming trend.

Adaptation: what this means for managing the sector ... continued

Scale of management: Ecosystems and their component species do not recognise human constructs such as state or territory boundaries and should be managed accordingly. Planning at landscape scales is required. Managing pressures outside the boundaries of protected conservation areas can help to build resilience but requires a coordinated management approach with landowners (in both rural and urban areas). Additional actions may need to be undertaken which offset biodiversity loss or account for changed distributions and optimise the biodiversity outcomes. For example, in a study of threatened plant species, Maggini et al., (2013) identified the area of natural areas to conserve and to restore that would provide optimal protection for those species under climate change.

Monitoring for change: The full range of possible effects of climate change and of individual species response are not known. Moreover, the effectiveness of many adaptation actions remain largely untested, making it very difficult to define a coherent operational adaptation strategy for natural ecosystems. Effectively monitoring the status of individual organisms, species and ecosystems is crucial in order to detect shifts, capture thresholds, modify management strategies and build the evidence base for long-term decision-making. Monitoring must be incorporated into adaptive management processes and the results must be used to adjust management and policy settings.

5 Implications for policy

Meet the mitigation challenge: The adaptive capacity of Australia's ecosystems is limited, making strong emissions mitigation essential. Where ecosystem-based mitigation efforts (e.g. vegetation management) can, they should seek to deliver adaptation benefits (e.g. corridors and replanting riparian vegetation). Cross-sector policies can link mitigation opportunities with adaptation outcomes for multiple benefits and resource efficiency, for example exploring the opportunities for valuing carbon in ecosystems, especially for marine systems.

Define adaptation goals: Ecosystem adaptation needs to be underpinned by a clear and community-agreed definition of what we are adapting for in order to drive direction and approaches. For example, if the adaptation goal is to maintain existing ecosystem structure and communities (i.e. preserving species in place), then existing statutory obligations and policies may not be appropriate. Responsive policy frameworks are needed, that allow for adaptive management.

Create national scale adaptation policy, to ensure recognition of the diversity of ecosystems and their changing distributions at a continental scale. Planning for adaptation must be based on cross-jurisdictional cooperation and coordination, aligning policy across all levels of government and with consistent strategic plans in place.

Embed consideration of climate change impacts on biodiversity in policy-making across all sectors: This will help to avoid sector-based decisions leading to negative outcomes for ecosystems. For example, water management for urban security should also consider environmental flows.

Target key habitats and species for protection and pre-identify the compatibility of these with present and future activities. Policy should also provide temporal and spatial flexibility to allow adaptation to rapid shifts. In a 'worst-case scenario', it may be necessary to adopt a triage approach in which resources are focussed on ecosystems that are most likely to survive through the effects of climate. This policy would require substantial community engagement and support.

Obtain community engagement, support and understanding, as the foundation of effective management programs: People are an integral part of Australian ecosystems. Policy-makers may consider:

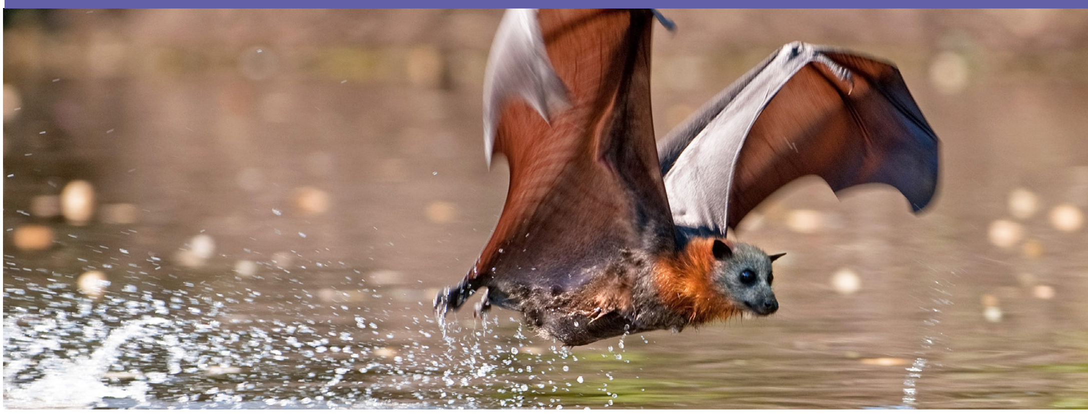
- Finding the right communication approaches and levers to ensure action. This may include recognising effects on iconic species, or using extreme event impacts to raise awareness.
- The use of market mechanisms and incentives including payments for ecosystem and environmental services.
- The use of other tools (e.g. regulation, taxes, subsidies) to encourage adaptation actions amongst private landholders.

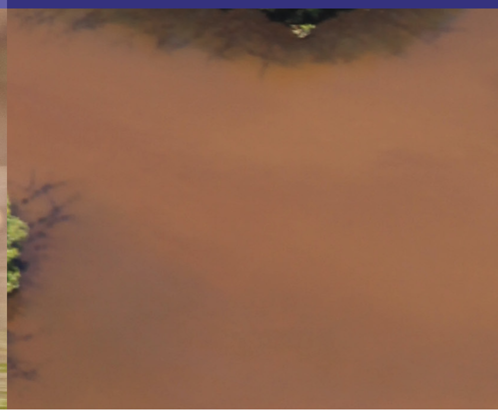
Allocate funding and resources for scientific investigation and monitoring programs to identify ecosystems at risk, rates of change, and effectiveness of adaptation actions. The results from monitoring programs should inform subsequent decision-making around adaptation. Scientific knowledge must be effectively communicated to top-level politicians and policy makers to support evidence-based policy.

Approach

The policy guidance provided in this brief was developed at a workshop held in Townsville in March 2013. The workshop was attended by policy makers and managers from Queensland Environment and Heritage Protection, Wet Tropics Management Authority and other Queensland State Government departments, Townsville Council, Australian Wildlife Conservancy (AWC), Seagrass Watch, Great Barrier Reef Marine Park Authority, private consultants, scientists including Morgan Pratchett (JCU), Yvette Williams (JCU) and April Reside (JCU), Rob Kay (Adaptive Futures) and NCCARF staff.

NCCARF's research programs have delivered over 140 reports on climate change adaptation, many of which address the topics of the Policy Guidance Briefs.
For more information, see: www.nccarf.edu.au/publications





NCCARF is producing a portfolio of twelve Policy Guidance Briefs in 2012–13 on critical climate change adaptation topics. For a complete list of available Policy Guidance Briefs, please go to: www.nccarf.edu.au/publications/policy-guidance-briefs

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