Climate change impacts on coastal ecosystems

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Impact Sheet 8

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Contents

Australia's coastline includes a diverse range of coastal ecosystems, encompassing marine, estuarine, coastal interface, terrestrial and freshwater environments. Climate change will significantly affect these ecosystems, with consequences for biodiversity and the critical ecosystem services they provide. Continued increases in temperature, sea-level rise, altered weather patterns and ocean currents, and increasing atmospheric carbon dioxide will undoubtedly have major repercussions for these ecosystems.

General impacts

Increasing Temperatures

Increased temperatures, both on land and in the ocean, cause heat stress to plants and animals, and can affect survival, growth, reproduction and evolution. All plants and animals have a temperature range they can tolerate, and species distributions are expected to shift southwards in response to rising temperatures. There are already records of changes to distribution ranges for both marine and terrestrial fauna and flora. Altered species composition creates new interactions between species and is likely to cause complex changes in ecosystem structure and function.

Sea-level rise

Higher sea levels have potential to flood terrestrial habitats and create new areas of inundation. They will also change the salinity regime of estuaries and coastal freshwaters through greater tidal intrusion. There is expected to be coastal erosion and a general landward migration of coastal habitats, with redistribution of shallow marine and intertidal habitats. Increased depth in marine environments may affect light availability to seagrasses and macroalgae. Greater depth over existing reefs may also reduce their effectiveness in dissipating wave energy, affecting coastal erosion and deposition processes.

Altered rainfall patterns

The decline in winter and spring rainfall in Southern Australia, and increased periods of drought expected throughout Australia, will continue to impact aquatic and terrestrial environments in our catchments, affecting coastal ecosystems through connected hydrology and sediment processes. Changes to seasonality of rainfall will change water regimes of freshwater aquatic ecosystems as well as freshwater inputs to estuarine environments, with consequences for life cycles including fish breeding and migration.

Changes in frequency and intensity of extreme weather events

An increase in intense events associated with climate change will have direct physical impacts on the coast, exacerbating coastal erosion. As well as direct physical damage, more intense rainfall events can potentially influence sediment dynamics and quantity and quality of terrestrial runoff. Extreme weather events will damage many vital ecosystem services provided by coastal ecosystems, for example mangrove fish nurseries and wave mitigation. While extreme weather events are a natural disturbance, an increase in frequency may limit ecosystem recovery.

Increased atmospheric carbon dioxide

Carbon dioxide availability affects photosynthesis and respiration of terrestrial plants. Enhanced photosynthesis, in response to greater CO_2 availability, has a positive effect on plant growth. However other climate-related changes, such as increased heat and drought, may limit this 'CO_2 fertilisation'.

There is increasing concern on the effects of ocean acidification that will result from absorption of higher concentrations of carbon dioxide from the atmosphere. An increase in acidity can limit growth of carbonate-dependent organisms, including corals and shellfish.

Major predictions and consequences

The Bureau of Meteorology and CSIRO report biannually on climate trends and predictions in the State of the Climate in Australia (Bureau of Meteorology 2014). The extent of current changes and future predictions vary for different regions of Australia and models are continually being improved with the addition of new information. Up-to-date predictions with information for specific regions can be found on the Climate Change in Australia website (CSIRO and Bureau of Meteorology 2015). The major predictions and consequences are outlined in Box 1 with the information drawn from these two sources. Regional boundaries are NRM clusters.

Box 1: Major predictions and consequences of climate change on coastal ecosystems.
Sources: Bureau of Meteorology 2014; CSIRO and Bureau of Meteorology 2015.

Increasing air temperatures

There is very high confidence in predictions that current trends of warming air temperatures will continue throughout Australia, particularly for southern coastal regions. Very warm months and extremely hot days are more frequent, extremely cold days have declined.

Regardless of emissions mitigation, temperatures will increase by 0.4-1.4°C by 2030.

2090 PREDICTIONS

LOW	MEDIUM	HIGH
0.4-1.4°C	1.2-2.1°C	2.74.2°C

Sea-level rise

There is very high confidence that sea levels will continue to rise throughout Australia, and the height of extreme sea-level events will rise.

Regardless of emissions mitigation, temperatures will increase by 0.06 – 0.19 m by 2030.

2090 PREDICTIONS

LOW	MEDIUM	HIGH
0.08-0.19 m	0.27-0.66 m	0.38-0.89 m

Altered rainfall patterns

Rainfall patterns will be determined mainly by natural variation to 2030, but beyond this they will reflect climate change.

There is very high confidence in predictions of declining winter and spring rainfall in Southern Australia, but less certainty for other parts of Australia.

Increased intensity of extreme rainfall events is predicted throughout Australia.

Decreasing rainfall in southern Australia will directly impact freshwater plants and animals, and alter terrestrial vegetation communities (Kauhanen et al. 2011). The quantity and quality of water reaching coastal ecosystems will be affected.

2090 PREDICTIONS

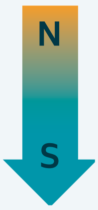
Winter/Spring rainfall in Southern Australia

LOW	MEDIUM	HIGH
-15%	-20%	-30%

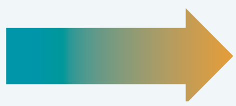
Changes in frequency and intensity of extreme weather events

The intensity of extreme rainfall events is predicted to increase throughout Australia with high confidence, but the magnitude of these changes and alterations to frequency are unclear. Predictions vary regionally.

There is high confidence of greater time spent in drought and increased fire-risk weather



Temperature increases create harsh conditions and affect biophysical processes. Southward shifts in distribution range of plants and animals are expected.



Sea-level rise will force landward migration of marine, intertidal, estuarine and freshwater ecosystems. Coastal habitats will be flooded.

Box 1: Major predictions and consequences of climate change on coastal ecosystems - *continued*. Sources: Bureau of Meteorology 2014; CSIRO and Bureau of Meteorology 2015.

Warming oceans

Surface ocean temperatures are increasing in response to air temperature.

A southern latitudinal shift in sea surface climate of 3° or 350 km has been observed.

2090 PREDICTIONS FOR THE HIGH EMISSIONS SCENARIO ARE:

NORTH	SOUTH	EAST
2.2-4.1°C	1.6-5.1°C	2.1-5.7°C

Increased water temperatures in eastern Australia are linked to intensification of the East Australian Current.

Acidifying oceans

Even a low emissions future could cause acidification at dangerous levels for coral reef development (Hoegh-Guldberg et al. 2007). Coral bleaching will also increase due to rising temperatures.

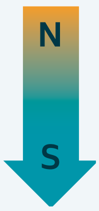
Changes to rainfall and sea-level rise will alter hydrology and salinity regimes of freshwater and estuarine ecosystems.

Rainfall in northern Australia could change greatly, but may increase or decrease

Tropical cyclones in northern Australia may decrease in frequency but increase in intensity (medium confidence).

Rainfall in eastern Australia may increase or decrease, but in southern parts winter/spring rainfall will likely decline.

Ocean acidification is expected to increase in proportion to emissions pathways.



Some marine species will shift southwards due to increasing sea surface temperatures. This response has already been observed for fish and sea urchins (Poloczanska et al 2012). There may be limited capacity for southward migration of important southern macroalgae and seagrass habitats.

Future emissions and ecosystem consequences

Increased atmospheric carbon dioxide concentrations depend on global actions to reduce emissions. Representative concentration pathways (RCPs) are used to assess future climate change scenarios (see Figure 1).

- A 'business-as-usual', **high emissions scenario** (RCP8.5) with continued increase in emissions over time would result in a CO_2 level of 940 ppm by 2100.
- Mitigation actions resulting in a **medium emissions scenario** could limit CO_2 concentrations to 540-660 ppm by 2100.
- A **low emissions future** could limit CO_2 to 420 ppm by 2100, following a peak of 440 ppm in 2040.

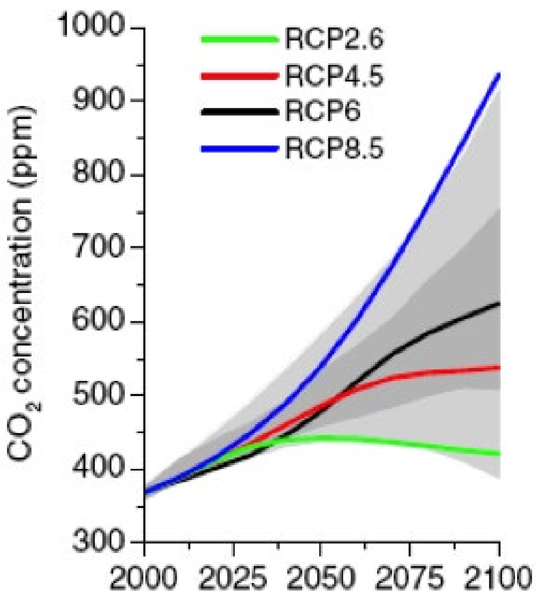


Figure 1: Trends in concentrations of carbon dioxide. Source: Van Vuuren et al. 2011.

The effects of climate change on coastal ecosystems depend on emissions scenarios and time periods, and potential impacts should be considered in this context.

- A **high emissions scenario** will result in very high likelihood of negative impacts and see more rapid change, limiting the capacity of ecosystems to keep pace in adapting to change.
- A **medium emissions scenario** will also have a high likelihood of negative consequences for ecosystems, but may provide greater potential for adaptation in terms of species tolerance limits and increased time to adapt to changing conditions.
- A **low emissions scenario** may restrict the impacts of climate change, but effects are already being observed and are likely to continue.

Temperate reefs and macroalgae

Ocean warming is the major direct impact of climate change on these ecosystems, with significant potential to change species distributions and interactions (Bennett et al. 2015). There is already evidence of southern expansion of habitat ranges for tropical species into southern waters and southward migration of cool-water species. Large areas of this ecosystem type occur along the southern coastline of Australia with limited capacity for range shift, potentially resulting in species extinctions.

Southward migration of new species into these ecosystems can have cascading effects due to changes to species interactions. Two examples have already been observed:

- A southward shift in range extent for the black sea urchin in Tasmania has resulted from higher temperatures and strengthening of the East Australian Current. Black urchins heavily graze macroalgae (Ling et al. 2009). With reduced cover of macroalgae, there can be a shift to a less complex ecosystem in which turf algae dominates.
- In 2011, a 'marine heatwave' in Western Australia had serious negative effects on macroalgal communities (Wernberg et al. 2013) (see Figure 2 for example), and the southern extension in tropical grazing fish has prevented their recovery (Bennett et al. 2015).

Sea-level rise causes increased depth with negative effects on light availability needed for plant growth. Greater depth over reefs may also reduce their capacity to intercept ocean swells, increasing physical disturbance of macroalgae. Although predictions of increased intensity and frequency of extreme events are unclear, this would exacerbate disturbance and limit ecosystem recovery.

No impacts have been attributed as yet to acidification, but continued CO_2 emissions increases may adversely affect carbonate-dependent organisms, including cold-water corals, calcareous algae, crustaceans and molluscs.

Figure 2: Kelp covered landscape in Western Australia. Photo: © Dan Smale.

Seagrass Meadows

Seagrasses occur most extensively in protected waters in southern Australia, with northern distribution limited by high tidal fluctuations and seasonal freshwater inputs. Increasing water temperature and sea level have varying impacts on seagrass meadows, and these are expected to cause an overall decline (Connolly 2012). This has consequences for organisms which depend on these foundation species for habitat and food, including turtles, dugong and many fish species, and will reduce their role in carbon sequestration.

Warming waters are likely to alter species composition and cause a southwards shift in distribution, as already observed for tropical seagrasses on the east coast (Polokzanska et al. 2012), but this shift is limited by suitable habitat. Increased temperatures may enhance seagrass growth within tolerable limits, but may also favour epiphyte growth to the detriment of seagrasses, and cause stress to intertidal tropical species.

Sea-level rise could restrict seagrass growth in some waters due to light limitation, while providing new areas suitable for colonisation. Coastal erosion may reduce water clarity, limiting the depth at which seagrasses can grow. There is potential for greater disturbance owing to reduced wave dissipation by protective reefs (due to depth or loss), which would be exacerbated by increased storm frequency and/or intensity.

While there is potential for elevated CO_2 to increase seagrass productivity, this would likely be offset by negative impacts associated with temperature and sea-level rise. Furthermore, CO_2 may also enhance epiphyte growth and thus have adverse effects. Acidification impacts on carbonate-dependent organisms are also possible.

Coral reefs

Coral growth and distribution is restricted by limitations of temperature and ocean carbonate concentrations, and so coral reefs are highly sensitive to warming and ocean acidification resulting from climate change. Rising water temperatures and sea level also favour macroalgae, with potential negative effects on coral reefs. There is a high risk of loss of coral reef ecosystems due to climate change, even under low emissions scenarios. This has significant implications for biodiversity and coastal protection during storm events.

Increased water temperatures that exceed tolerance levels for symbiotic zooxanthellae lead to coral bleaching with variable capacity for recovery. There have been coral bleaching events in the Ningaloo reef and the Great Barrier Reef (see Figure 3), and these events are expected to increase. Bleached reef structures are more vulnerable to grazing organisms and to storm damage, which in turn would be exacerbated by any future increase in frequency and intensity of extreme weather events.

Figure 3: Bleached Staghorn corals. Photo: © Commonwealth of Australia (GBRMPA).

Ocean acidification is increasingly being considered a major threat to coral reefs, with potential to restrict coral development, impact on existing reefs and adversely affect other carbonate-dependent organisms. Ocean acidification results from excessive atmospheric CO_2 due to formation of carbonic acid (see Figure 4). The additional H^+ ion further combines with carbonate, which becomes less available to calcifying organisms.

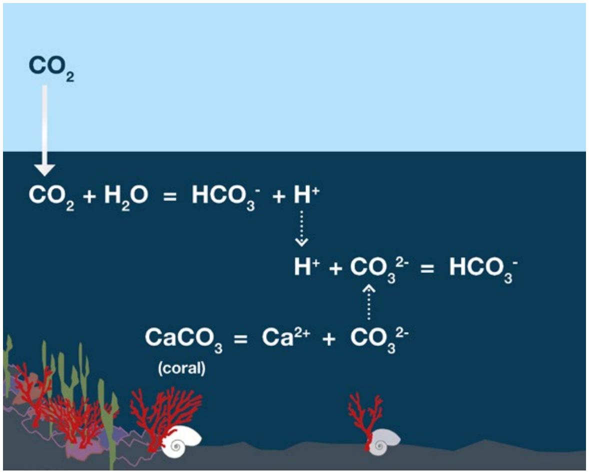


Figure 4: Linkages between the build-up of atmospheric CO_2 and the slowing of coral calcification due to ocean acidification. Source: Adapted from Hoegh-Guldberg et al. 2007.

Mangroves

Mangroves are widespread in northern Australia along the coastline and in estuaries and tidal rivers. Increasing temperatures and sea-level rise have direct implications for species composition and distribution of mangrove communities (Lovelock et al. 2012). Southern range extensions for some species are likely due to temperature increase (already observed but with an unclear link to climate change); also likely is a redistribution in relation to water levels, including potential upstream range increases in tidal rivers. Mangroves are adapted to large salinity and water level fluctuations and may therefore be well suited to natural adaptation in response to climate change. In addition, higher atmospheric CO_2 has potential to enhance mangrove growth, and may facilitate colonisation of new areas.

While these changes may not restrict the long-term occurrence of mangroves generally, and indeed may increase overall distribution, there is a risk that the rate of change may exceed the time required for these plants to colonise new areas. Interim loss of mangrove habitat would have negative consequences for organisms that depend on them for habitat and a detrital food source, including species that are part of adjacent seagrass and reef ecosystems. It would also influence their important functions in intercepting nutrients, pollutants and sediments, and in stabilising soils during intense weather events, which are likely to increase in intensity in northern Australia. Short and long term effects on their considerable value in carbon sequestration are also possible.

Southern estuaries

Wave-dominated estuaries are common in southwest and southeast regions of Australia at the end of river systems prior to discharge into the ocean (e.g. Figure 5, the Murray River mouth). Sea-level rise and increases in extreme sea-level events will have variable effects on tidal intrusion and salinity regimes (Gillanders et al. 2011). Periodic opening of natural sandbars is also likely to change, with additional affects from altered patterns of extreme water events. Potential rainfall reductions in the catchment may restrict estuary opening if flows are substantially reduced.

Water quality may be improved by enhanced flushing of estuarine waters by increased tidal exchange, and reduced nutrient loads from catchments in response to lower flow volumes. However, discharge of accumulated nutrients and sediments may impact receiving marine environments. In some systems, tidal interchange is regulated by physical structures and/or artificial opening, which may present an opportunity to manage the effects of climate change.

Figure 5: The Murray River mouth at the Coorong is a wave dominated estuary. Photo: © Government of South Australia, Department of Environment, Water and Natural Resources, 2016.

The ecological effects of altered hydrology, salinity and water quality will vary across systems and may be positive or negative. Estuaries are generally highly productive and support substantial populations of birds and fish, providing fish nursery habitat and conduits for fish migration. Changes to aquatic plants will affect habitat and food webs. Inundation of land adjacent to the coast and estuaries has implications for fringing vegetation, and habitat for shorebirds may be flooded. Natural migration of these habitats to higher ground may be limited by the extent of adjacent human development.

Coastal interface ecosystems

Coastal interface ecosystems, including rocky shores and headlands, rocky intertidal habitats, sandy beaches and dune systems are distributed according to geology and ocean dynamics. They are directly exposed to sea-level rise and changes in frequency and intensity of extreme events, which will flood some habitats and affect physical coastal processes. Erosion and landward migration of habitats are likely, with redistribution of intertidal habitats. Human development in many coastal areas limits the potential for natural changes, which increases the risk of habitat loss. Coastal environments present harsh and dynamic environments for biota, with shifting physical habitats and extreme conditions of temperature and inundation/drying experienced by biota in the intertidal zone. For some species this broad tolerance range may support resilience to impacts of climate change, but others may already exist at the limits of this tolerance and be vulnerable to further changes.

Significant coastal breeding areas for penguins and other seabirds, seals, sea lions and turtles throughout Australia will be affected by increasing temperatures and habitat changes. Warming creates heat stress on animals and affects the breeding success of seabirds and turtles (Polokzanska et al. 2012). Populations of these species will be confined to smaller areas or need to seek new habitats. There may be limited capacity to find alternative breeding sites and habitats, particularly in the context of existing habitat degradation. Furthermore, species currently restricted to southern Australia have more limited capacity for migration in response to temperature.

Coastal terrestrial vegetation

Coastal vegetation will be negatively affected by increased heat and drought, reduced rainfall and is vulnerable to rising sea levels and increased extreme sea-level events, and exposure to more frequent and intense storm events. Declining vegetation health has consequences for coastal landform stability and for the animals which depend on it for habitat and food, including birds, reptiles and mammals. Landward and southward species shifts for these ecosystems are restricted by coastal development by humans, by a lack of suitable soil types, and competition with other vegetation communities. For example, the critically endangered Western Ringtail Possum is dependent on coastal stands of Peppermint trees (*Agonis flexuosa*), which are already fragmented by urban development and at further risk from climate change.

Increased atmospheric CO_2 may enhance growth of vegetation in some areas, however this is within the context of higher temperatures, increased drought and potentially harsher fire weather. Where other conditions are suitable for growth, it is possible that CO_2 fertilisation will facilitate species distributions to shift in response to climate change.

Coastal freshwaters and floodplains

Increased temperatures and drought will have direct negative consequences for freshwater ecosystems in Australia (Kingsford 2011), particularly in southern regions. There is often limited capacity for natural migration of plants and animals in these environments so there is like to be contraction of existing communities, with a shift to dominance by more tolerant species. There is potential for CO_2 fertilisation within catchments for both natural vegetation and agricultural systems. For many species, this will be outweighed by effects of drought and heat, but it may promote colonisation of new areas south of existing ranges. Freshwater ecosystems provide an important water quality protection service for coastal ecosystems, but in developed catchments they inevitably transport excess nutrient, sediment and pollutant loads. Changes to the timing and volume of freshwater inflows will impact water quality in receiving waters, with confounding effects of impacts on terrestrial vegetation and land use change.

Rising sea levels will change the connectivity of some freshwaters with the coast, and there is potential for for some freshwaters to be converted to saline or estuarine environments, with consequences for plant and animal community composition and migration pathways for fish species. Retraction of lowland freshwater communities upstream may be limited by increased temperatures and drought.

Ecosystem Services

Ecosystem services are defined as the benefits people obtain from ecosystems (MEA 2005). Coastal ecosystems support many services, and the impacts of climate change on natural components and processes within ecosystems will have consequences for these services. Some examples are:

- provisioning services obtained directly from ecosystems: agriculture, aquaculture, water supply, material resources, hydroelectricity
- cultural services through recreational and tourism activities, cultural and spiritual values, research activities
- regulating services that influence our use of the environment by effects on flooding, coastal erosion, water quality, diseases
- supporting services including processes and connections ecosystem within and between ecosystems such as photosynthesis, nutrient cycling, sedimentation, and food web linkages.

Climate adaptation services are the 'benefits to people from ...the capability of ecosystems to moderate and adapt to climate change and variability' (Lavorel et al. 2015). Important examples include protection of coastal areas from erosion and flooding by rising sea levels, carbon sequestration within ecosystems, and provision of new social opportunities.

Invasive species

The potential impacts of invasive species in response to climate change are relevant for all coastal ecosystems (Hellmann et al. 2008). Some native species may also become invasive, if they are able to tolerate high temperatures and there is an expansion of their range. Invasive plants and animals possess growth and reproduction traits that increase their success in new environments. They are a serious threat to biodiversity in many ecosystems through predation and interference with food webs, competition for habitat and resources, and direct health effects on native plants and animals.

Invasive species have broad tolerance of environmental conditions and are capable of rapid colonisation of new areas. Therefore they have high capacity to increase in range and fill niches that are vacated by adversely affected native species, or available following storm or drought disturbances. For native species, as their potential distribution ranges change, their success in new locations may be limited by competition with invasive species. Furthermore, native species will be less competitive if they are under stress due to climate change.

Existing pressures

Impacts of climate change on coastal ecosystems are strongly affected by non-climatic pressures from human activities. These pressures include nutrient enrichment and other pollution, habitat fragmentation, overfishing and harvesting. These pressures are often exacerbated by climate change, and influence the impacts of climate change and how ecosystems adapt. Some examples of these interactions are:

- increased temperatures and drying create harsher conditions for native plants and animals, but also increase human reliance on water abstraction
- overfishing of predatory species can limit their capacity for control of species expanding in their southern distribution limits, with consequences for other ecosystem components
- seagrass communities that are stressed through nutrient enrichment and associated epiphyte growth are more susceptible to physical disturbance and reduced light penetration resulting from increasing temperature, sea levels and physical disturbance
- reduced species diversity and within species genetic variation owing to existing pressures limits the capacity for natural adaptation to climate change
- habitat fragmentation through clearing, physical disturbance and reduced water quality reduces potential dispersal and migration pathways.

Ecosystem resilience is the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change (IPCC 2014). Ecosystem resilience is greater in more intact, diverse ecosystems because there is a greater chance that some organisms possess traits which enable them to resist and recover from disturbance, persist in new conditions, shift to appropriate conditions, or change their ecological role. Management of all coastal ecosystems should focus on reducing anthropogenic pressures to promote resilience to climate change.

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