Regional Projection for Northern Australia

Oceans and climate are tightly tied together. This means that as the world's climate change some of the biggest signatures of that will be in our oceans, affecting the ecosystems and fisheries there. Understanding what that means for specific locations can be difficult, but we have some idea about what northern Australia, from the Pilbara to Cape York and the Torres Strait, may look like by 2040. The region is expected to see average water temperatures increase by up to 1°C and conditions seen only in marine heatwaves now will extend throughout most of the year (>300 days per year). Extreme events – cyclones, droughts – will likely also become more intense.

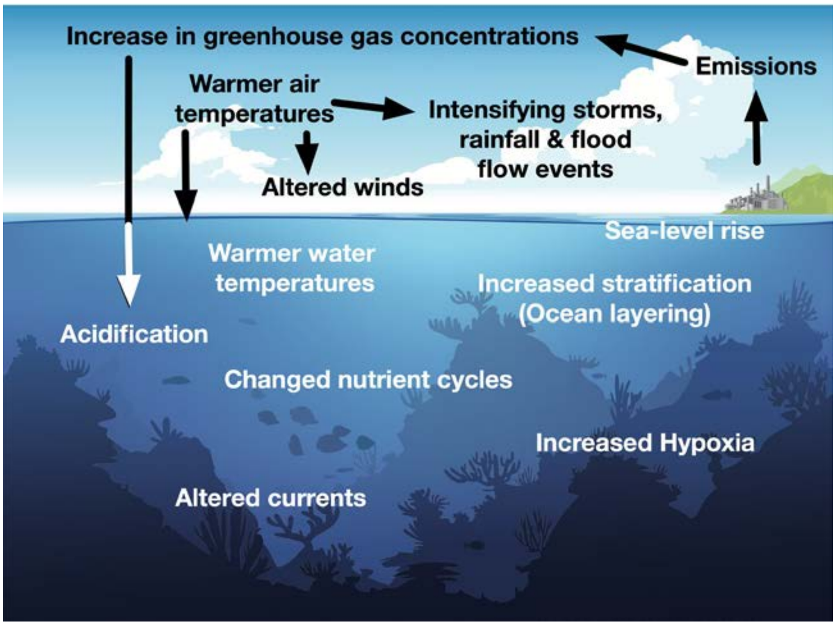
Primary production, which supports the entire food web, may drop by as much as 25%. Bringing together available knowledge on species and ecosystems in the region it appears that more than 90% of species are expected to be moderately to highly sensitive to change, including all of the species targeted by the Northern Prawn Fishery. Model based projections are less clear on what that sensitivity means, as it depends on individual species responses and how those interact across entire food webs. Most models agree that an increase in year-to-year variability of fish stocks and catches is likely. The majority of models also indicate that Banana, Endeavour and Tiger prawns, as well as bugs may reduce in abundance by 10-20% as a result of climate related changes.

	Observed change (vs 1950)	Future change (vs today)
OCEAN TEMPERATURE	0.6 - 0.8°C increase	0.6 - 1.0°C increase
MARINE HEATWAVE	15 - 20 day increase	>200 day increase
STORMS	Conflicting information	Stronger & more variable
DROUGHTS	Shorter, more intense	Longer, twice as frequent
RAINFALL	Roughly steady	Roughly steady
SEALEVEL RISE	20cm increase	20 - 40cm increase
OXYGEN	Approx 2% decrease	5% decrease
ACIDIFICATION	30% increase	20 - 120% increase

Species Vulnerability & Potential Future Change

SPECIES CLIMATE SENSITIVITY	>35% highly sensitive, 55% moderately sensitive
TARGET SPECIES	Abundance of key target species decline 10-20%

Physical climate



Major ocean-climate processes

The physical environment of northern Australia is changing, as climate change influences a number of physical environmental processes. As increased greenhouse gas concentrations trap more heat in the atmosphere this is transferred to the ocean. Indeed 90% of the additional heat has been taken up by the oceans, increasing water temperatures and contributing to sea level rise. It can also cause ocean currents to shift location, as has happened off eastern Australia, but this does not appear to be as important in northern Australia. As the ocean warms it can become more stratified (layered) and it holds less oxygen. The extra energy in the ocean-climate system also intensifies storms and rainfall events.

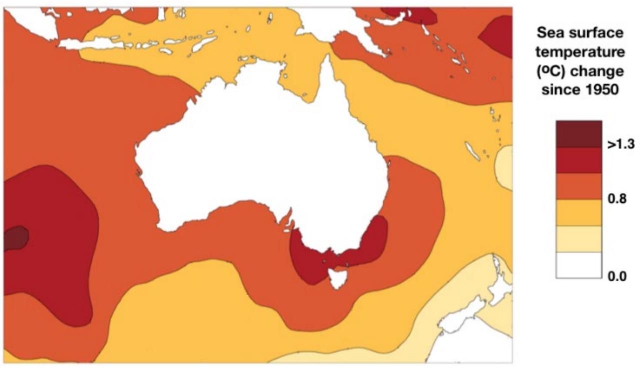
Not everything is linked to temperature. As the additional carbon dioxide in the atmosphere dissolves into the ocean it reacts with the water causing ocean acidification.

All these physical changes influence how comfortable species find the local conditions, which can change how productive they are and what the food webs and ecosystems look like. Therefore it is important to understand the kinds of changes expected for a region

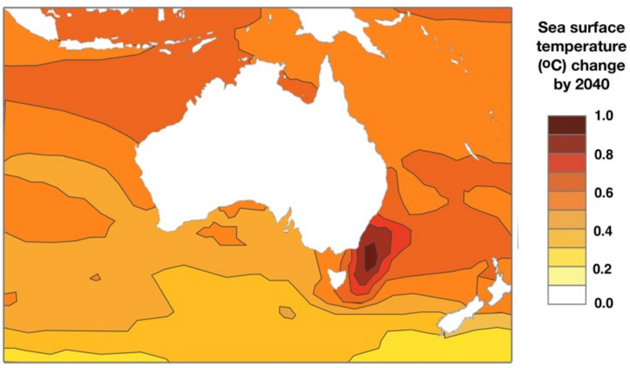
Temperature

Water temperature is the most well understood outcome of climate shifts affecting the ocean. The waters at the ocean surface around Australia have warmed over recent decades. Sea surface temperature in the Australian region has warmed by around 1°C since 1910, with eight of the ten warmest years on record occurring since 2010. In the north of Australia temperatures haven't risen as rapidly as elsewhere around Australia, but have still increased by 0.6-0.8°C since 1950.

Models of the world climate and oceans indicate that water temperatures off northern Australia could increase by 0.6-1.0°C by 2040. Beyond 2040 model results differ on the potential level of change as it depends on what emission scenarios (the level of overall emissions globally) are considered.



Water temperature change 1950 - 2017.
Image updated from BOM data

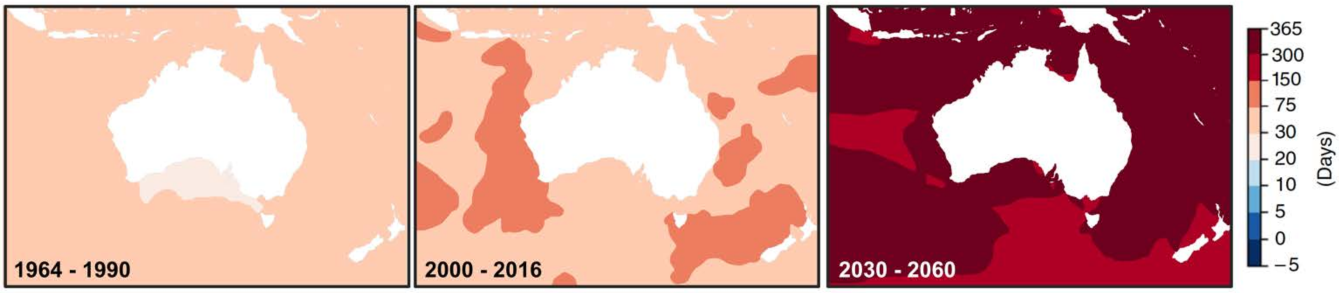


Water temperature change 2015 - 2040.
Data from www.esrl.noaa.gov data

Land surface temperatures can also be important in northern Australia given the importance of mangroves and other estuarine habitats to species such as prawns and the downstream marine food webs. Models indicate that over the next 10-20 years change locked in by past emissions will see the area's surface air temperatures increase by 0.5-1°C. Beyond 2040 the level of change depends on the level of global emissions, with temperatures rising more than 2°C beyond today if emissions are not reduced.

Extreme events

Extreme events – such as marine heatwaves (where water temperatures are much higher than average), cyclones, severe storms – can see conditions go beyond historical levels of natural variation for days to weeks at a time.



The number of days per year where water temperature exceeds the top 10% of historical temperatures.

Marine heatwaves have grown in intensity and extent since the 1960s. Northern Australia has not been as affected as elsewhere in Australia. Nevertheless, by 2016 the region was experiencing strong heatwave events and (on average) was seeing 5-10 more days per year of marine heatwave conditions than in the 1960s. However, by 2030 these conditions are likely to extend for more than 300 days a year. Modelling suggests that permanent marine heatwave conditions (i.e. the conditions will be above the historical temperatures year round) will exist in northern Australia by 2040.

Up until 2000-2005 most marine heatwaves were moderate (1-2°C above normal), but since then more strong marine heatwaves have occurred in the region (e.g. in 2016). Modelling suggests that by 2040 at least a third of all marine heatwaves will be strong, with severe and extreme events also becoming more common (together making up about 10% of all events).

The strength of storms and cyclone events is also likely to increase into the future (although it is currently uncertain whether the number of storms and cyclones per year will change by 2030-2040). Modelling of the likelihood of droughts shows that the frequency of drought is likely to double over the next 20 years with length of the droughts potentially also increasing by up to a year.

Other physical features

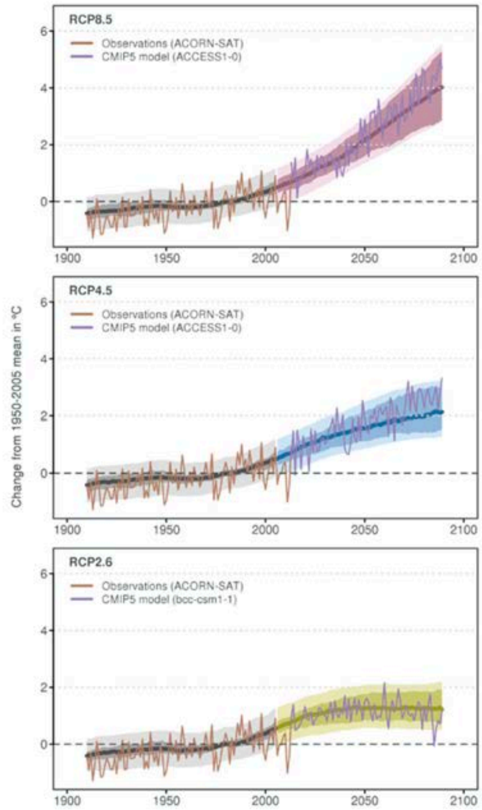
Temperature isn't the only physical feature that will change into the future. Changes in oxygen levels, salinity (especially due to rainfall changes), pH and resulting primary production also appear likely to occur. Most model results focus on 2100, but it is possible to get guidance on time scales of more use to fisheries and management decisions.

Oxygen

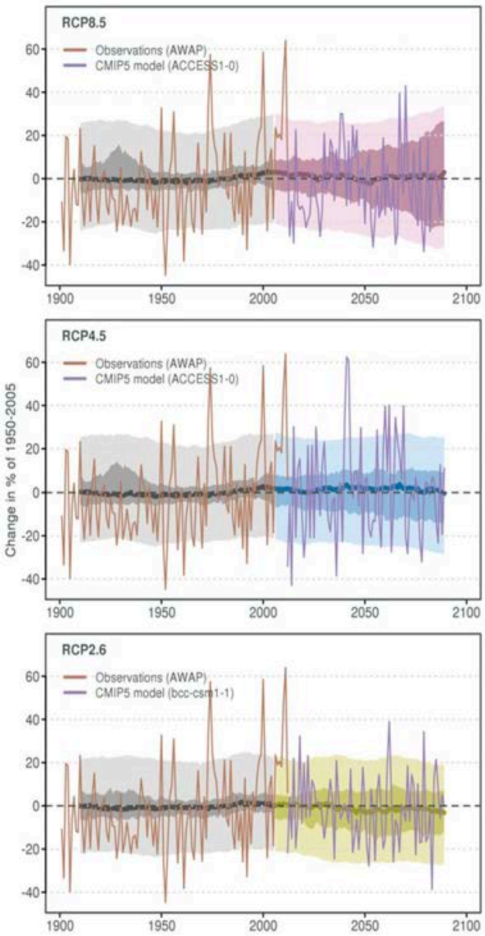
Deoxygenation of the oceans (drop in the amount of oxygen stored in seawater) will be a significant concern in some locations in the ocean, but so far it seems northern Australia will be less impacted. Oxygen levels will likely drop by 5% versus levels observed in 2018.

Ocean acidification (pH)

Ocean acidification means ocean pH has already dropped by up to 0.1 pH units since the 1800s, with most of the drop coming since 1960. As the pH drops the ocean becomes more acidified, so this level of drop means that ocean acidification has already increased by up to 30%. By 2030-2040 the predicted pH shift would have gone further. The exact level is uncertain as there is a lot of variation across climate models (this is a much newer part of these models than temperature), but potentially another 20-120% more acidified than it is today. That level of change means different things for different species – some will be unaffected; others will start to struggle (as certain behaviours and internal physiological processes will become more difficult). Some vulnerable species or ages may start to suffer additional mortality or slower growth. The current scientific advice is that temperature is a bigger effect on ocean species, but pH can add additional pressure.



Modelled increase in average annual surface air temperature across the monsoonal north of Australia. Image from CSIRO & BOM 2015 report. The coloured bands show the spread of model results across the different emission scenarios. RCP 8.5 has the highest emissions, with RCP 2.6 the lowest and RCP 4.5 in between.



Modelled future rainfall patterns through time across the monsoonal north of Australia. Image from CSIRO & BOM 2015 report. The coloured bands show the spread of model results across the different emission scenarios.

Rainfall & River Flow

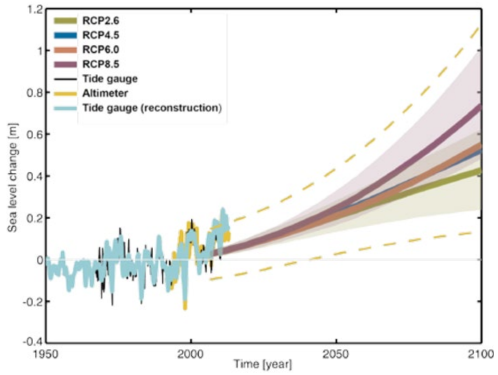
Understanding the future of river flow will be important to the region given the role of rivers in the food web and particularly the life history of many key target species – both fish and prawn species. The mean across models of future rainfall suggest mean rainfall may not change (although there is a lot of uncertainty with some models show an increase in rainfall and others decreases), but all agree variability will likely grow into the future – with an increased likelihood of more intense rainfall events.

River flow can be affected by both rainfall and developments along the rivers and on the catchments that modify flow. The implications of damming specific northern rivers are not yet clear as it depends on how flow management is implemented. Past studies have suggested minor effects for some rivers and flow regimes but much larger impacts for other rivers. This is an active area of research and modelling and results should become clearer in the next couple of years.

All of this uncertainty means it is hard to say what happens to salinity more generally in the area. However, it is clear that during major flood events that large river plumes will see increased turbidity and delivery of debris from the rivers systems into the Gulf of Carpentaria. Large freshwater layers coming from the floods could also increase stratification (layering) of the areas the plume extends over.

Sea level Rise

Models of future sea level rise project as much as 40cm rise in average heights across northern Australia, though 20cm is more likely. It is certainly a sea level rise hotspot with even those modest levels of rise potentially inundating large areas (see the circled areas on the map showing potential changes to the coastline).



Observed and modelled sea level height for Darwin. Image from CSIRO & BOM 2015 report. The coloured bands show the spread of model results across the different emission scenarios.

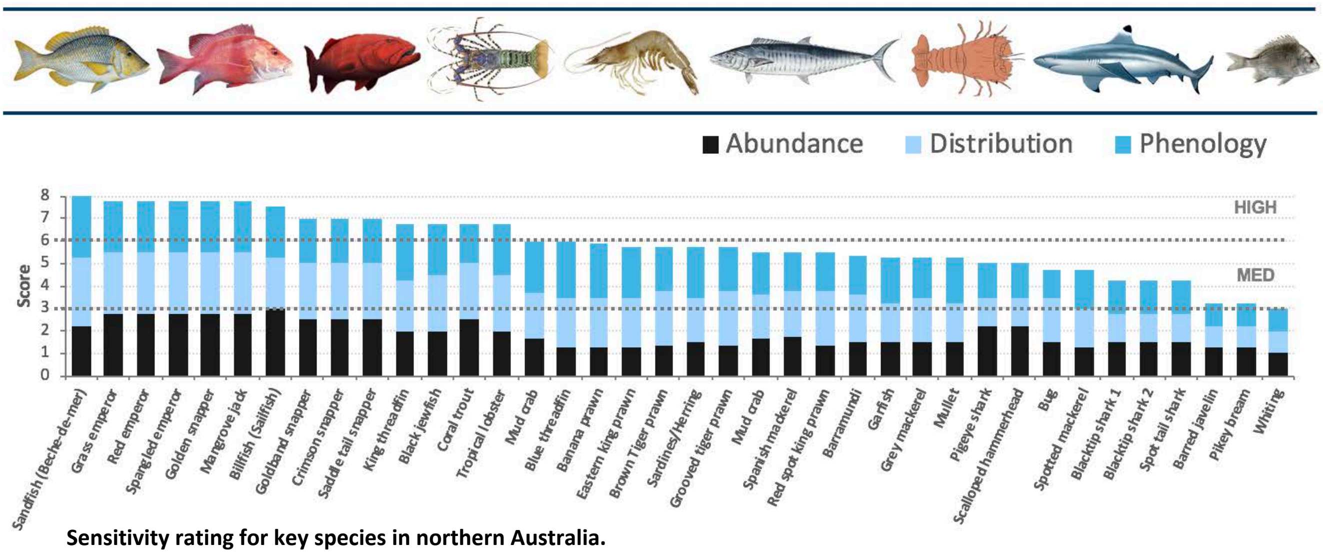
Map of inundation under future sea level rise through to 2030-2040. Saltwater intrusion and erosion could see these areas extend further inland.

Species shifts and ecosystem change

Changing environments influence individual species in five ways:

- **Abundance** – due to changes in the number of offspring surviving, mortality (e.g. due to unfavourable physical conditions or changed habitats, food sources or predators)
- **Distribution** – as species may move to more favourable environmental conditions (if they have the capacity to move, either while still larvae or at later juvenile or adult stages)
- **Phenology** – the timing of events (like reproduction, major migrations or metamorphosis). This has the potential to also influence the abundance or distribution
- **Physiology** – when the animals condition changes. They may be fatter/healthier if environmental conditions are more favourable, or in a poorer state if the environment is not as suitable or food availability has declined
- **Variability** – High environmental variability may see species numbers, location, condition etc become much more variable than in the past.

The first three of these potential influences can be rapidly assessed based on what is known about their life history (where they live, what they eat, what habitats they use, how and when they reproduce or migrate etc). Experts on species of northern Australia rated 38 species of fisheries (either to Commonwealth, State, recreational or Indigenous fisheries). Of these >35% are rated as being highly sensitive to environmental change.



Sensitivity rating for key species in northern Australia.

Species Projections

CSIRO has used four different kinds of models to look how species and ecosystems may respond into the future. Just looking at environmental conditions the species currently prefer suggests many species will decline in abundance. However, food web interactions (where prey increase or predators decrease) mean that some species may actually increase in abundance instead.

Summary of projections for key species in northern Australia Low Med High

Group	Sensitivity rating	Abundance projection (2020 – 2040)	Distribution (2020 – 2040)
Banana prawn		10% ⬇. Higher with variable rainfall, mangrove loss or dammed river flow.	Decrease across their range, but especially in the Gulf (and mangrove areas if they die-off)
Tiger prawn		10-20% ⬇ (food web & seagrass effect). Higher with extreme events (if dams don't buffer flows)	General decrease, not as bad in central gulf or the NW extent of the NPF
Endeavour prawn		> 20% ⬇	General decrease, especially in northern extent of NPF
Bug, Lobster		15->20% ⬇ (food web interactions may buffer this)	Drops across Gulf and west end of NPF (NT end)
Mud crab		10% ⬇ (food web effect). Higher with variable rainfall, mangrove loss or dammed river flow.	Largest drops across southern gulf and coasts (Gulf and NT).]
Cods, Emperor, Spanish Mackerel		10-20% ⬇ (food web effect). Estuarine species depends on river flow.	Bigger along coastlines. Some hotspots (e.g. off Groote)
Trevally		10+% ⬆	
Dugong, Dolphins, Sharks, Seabirds, Sea snakes, Turtles		10-30% ⬇ Turtles could see collapse through egg inundation.	General drop, especially in east and south Gulf.
Crocodiles		10+% ⬆	

References and Further Reading

The physical projections discussed in this work have come from the Oceans section of the CSIRO-BOM State of Environment reporting (www.csiro.au/en/Research/Environment/Oceans-and-coasts/Oceans-climate), the CSIRO-BOM 2015 Monsoonal North Cluster Report (available from www.climatechangeinaustralia.gov.au) and the Marine Heatwaves Tracker (www.marineheatwaves.org/tracker.html). Additional information on future temperature maps was also sourced from the international CMIP (global climate model intercomparison) database - www.esrl.noaa.gov.

The biological projections have previously been summarised in the 2018 FRDC report on Decadal scale projection of changes in Australian fisheries stocks under climate change.

www.frdc.com.au/Archived-Reports/FRDC%20Projects/2016-139-DLD.pdf

Photos from CSIRO and shutterstock.

CONTACT US

t 1300 363 400
+61 3 9545 2176
e csiroenquiries@csiro.au
w www.csiro.au

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FOR FURTHER INFORMATION

Oceans & Atmosphere
Beth Fulton
t +61 3 6232 5018
m +61 4 2856 4183
e beth.fulton@csiro.au
w www.csiro.au