Regional Projection for Eastern Australia

Oceans and climate are tightly tied together. This means that as the world's climate changes 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 Eastern Australia, from Cape York to Tasmania, may look like by 2040. Eastern Australia is expected to see average water temperatures increase by up to 1°C, especially in the south, and conditions seen only in marine heatwaves now will extend throughout most of the year (>300 days per year). Extreme events – cyclones, storms and droughts – will likely also become more intense.

Primary production, which supports the entire food web, may drop by 10% inshore. Bringing together available knowledge on species and ecosystems in the region it appears that all key species are expected to be moderately to highly sensitive to change. Tuna and bill fish may drop by 10-20%, tropical prawns and bugs may also decline by 20% or more. In the south, many of the target demersal species could potentially decline by 10-20% or more (unless food web interactions change to buffer environmental effects), while small pelagic fish (such as anchovy or mackerels) could see strong increases in biomass. Projected declines are common in the north, with waters off Tasmania and around the Bonnie upwelling potentially seeing increase in fish stock biomasses.

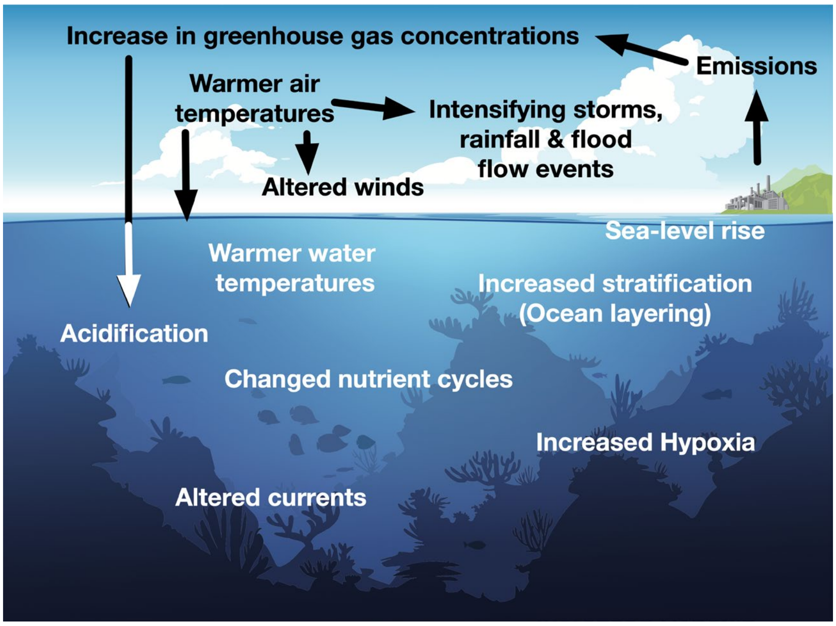
	Observed change (vs 1950)	Future change (vs today)
OCEAN TEMPERATURE	1.0°C increase	0.3 - 1.4°C increase
MARINE HEATWAVE	20 - 35 day increase	>200 day increase
STORMS	Conflicting information	More intense, but fewer
DROUGHTS	Increasing	Longer, twice as frequent
RAINFALL	Roughly steady	3% decrease
SEALEVEL RISE	15cm increase	10 - 20cm increase
OXYGEN	Approx 2% decrease	5% decrease
ACIDIFICATION	26 - 30% increase	20 - 50% increase

Species Vulnerability & Potential Future Change

SPECIES CLIMATE SENSITIVITY	22% highly sensitive, 78% moderately sensitive
TARGET SPECIES	Abundance of many key target species decline 20%, Bonnie Upwelling may be more productive

Physical climate

The physical environment of eastern 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 with the extension of the East Australian Current down to Tasmania. 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.



Major ocean-climate processes

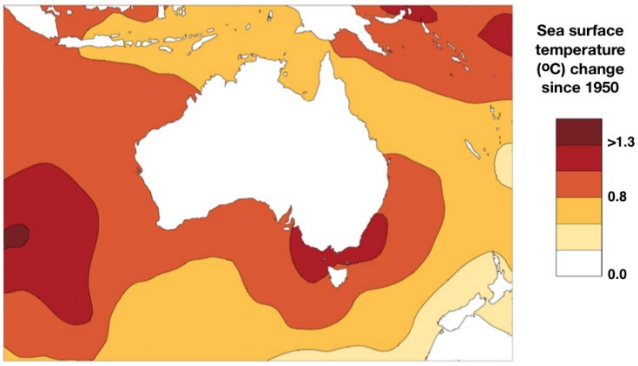
Not everything is linked to temperature. As the additional carbon dioxide in the atmosphere dissolves into the ocean it reacts with the water causing ocean acidification.

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.

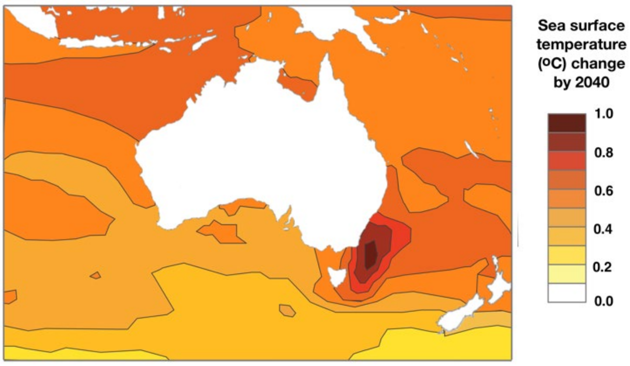
Temperature

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 east of Australia there has been a strong gradient in change as you move south, with southern waters amongst some of the fastest warming places in the world.

Models of the world climate and oceans indicate that water temperatures off eastern Australia could increase by 0.3-1.4°C degree by 2040. Again, the south will warm more than the north (though even the north could warm by 0.5-1°C). 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

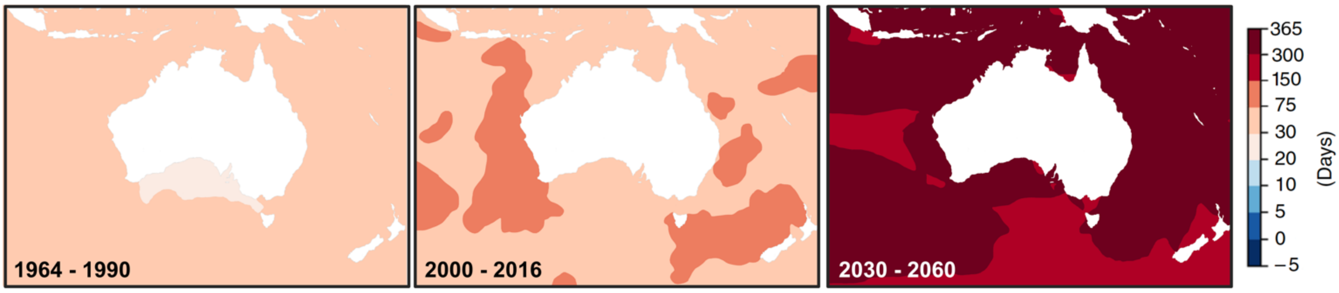


Water temperature change 2015 - 2040.
Data from www.esrl.noaa.gov data

Land surface temperatures can also be important in eastern Australia for species where mangroves and other estuarine habitats are important to one or more life stages (e.g. as a fish nursery). 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 at least 1°C. Beyond 2040 the level of change depends on the level of global emissions, with temperatures rising by 2°C (or more in the tropics) 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. Eastern Australia has been variably affected by these kinds of extreme events. By 2020 the region had experienced strong marine heatwaves, with the Great Barrier Reef undergoing widespread (mass) bleaching three times in five years (2016, 2017, 2020). By 2015 the region was seeing 5-20 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 eastern 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).

Storms are predicted to become more intense along the entire length of the east coast of Australia into the future. Timing of storms may also change, especially in the south – winter winds may decline, but summer and spring winds strengthen. 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 6-10 months.

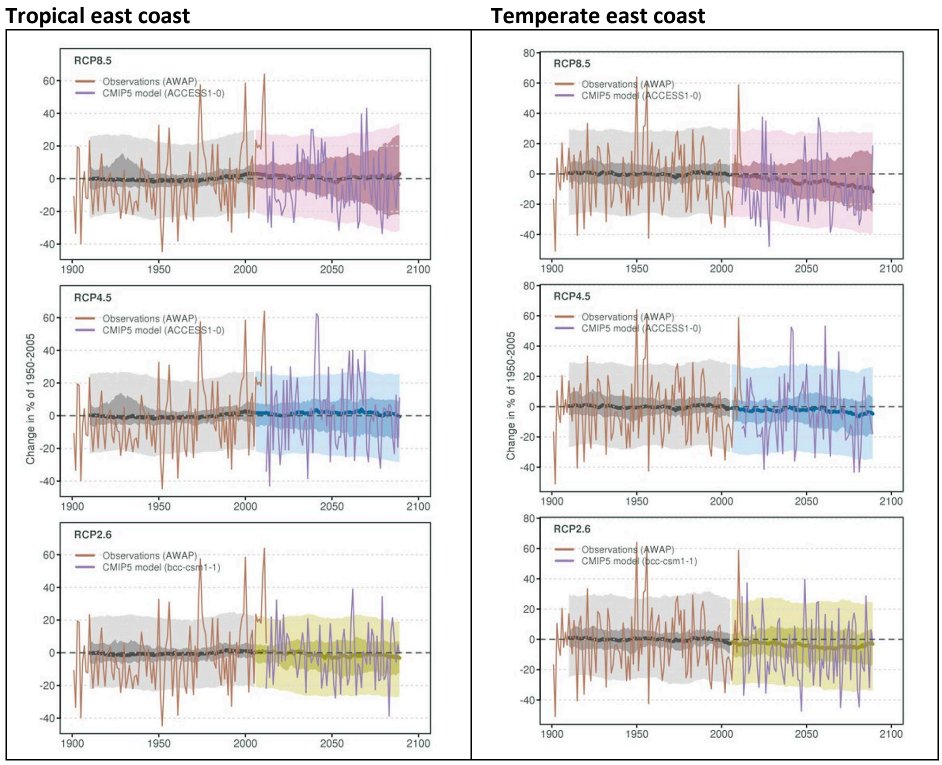
Other physical features

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 eastern Australia will be less impacted. Oxygen levels will likely drop by 5% versus levels observed in 2018.

Rainfall, Storms & River Flow



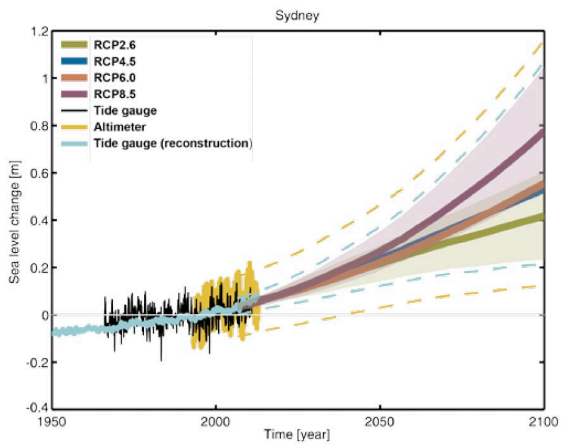
Modelled future rainfall patterns through time across the monsoonal north of Australia and down the east coast. Image from CSIRO & BOM 2015 report. The coloured bands show the spread of model results across the different emission scenarios.

Understanding the future of river flow will be important for coastal species influenced by estuarine river flow. The mean across models of future rainfall suggest mean rainfall in northern Australia may not change, while the mean drops through time along the rest of the east coast. There is a lot of uncertainty with some models showing an increase in rainfall and others decreases, but all agree variability will likely grow into the future. In the north there will be an increased likelihood of more intense rainfall events. Despite declining average annual rainfall for the rest of the east coast, under high emissions scenarios it is possible to also see intensification of individual rainfall events into the future (i.e. more severe falls even if fewer rainfall events occur per year).

The level of uncertainty around flows and rainfall means it is hard to say what happens to salinity in the north, but 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 northern waters. Large freshwater layers coming from the floods could also increase stratification (layering) of the areas the plume extends over. Projections indicate salinity will likely increase by a small amount in temperate waters (though inshore waters will still be heavily influenced by local rainfall and river flow).

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. 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 20-50% 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.



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

Sea level Rise

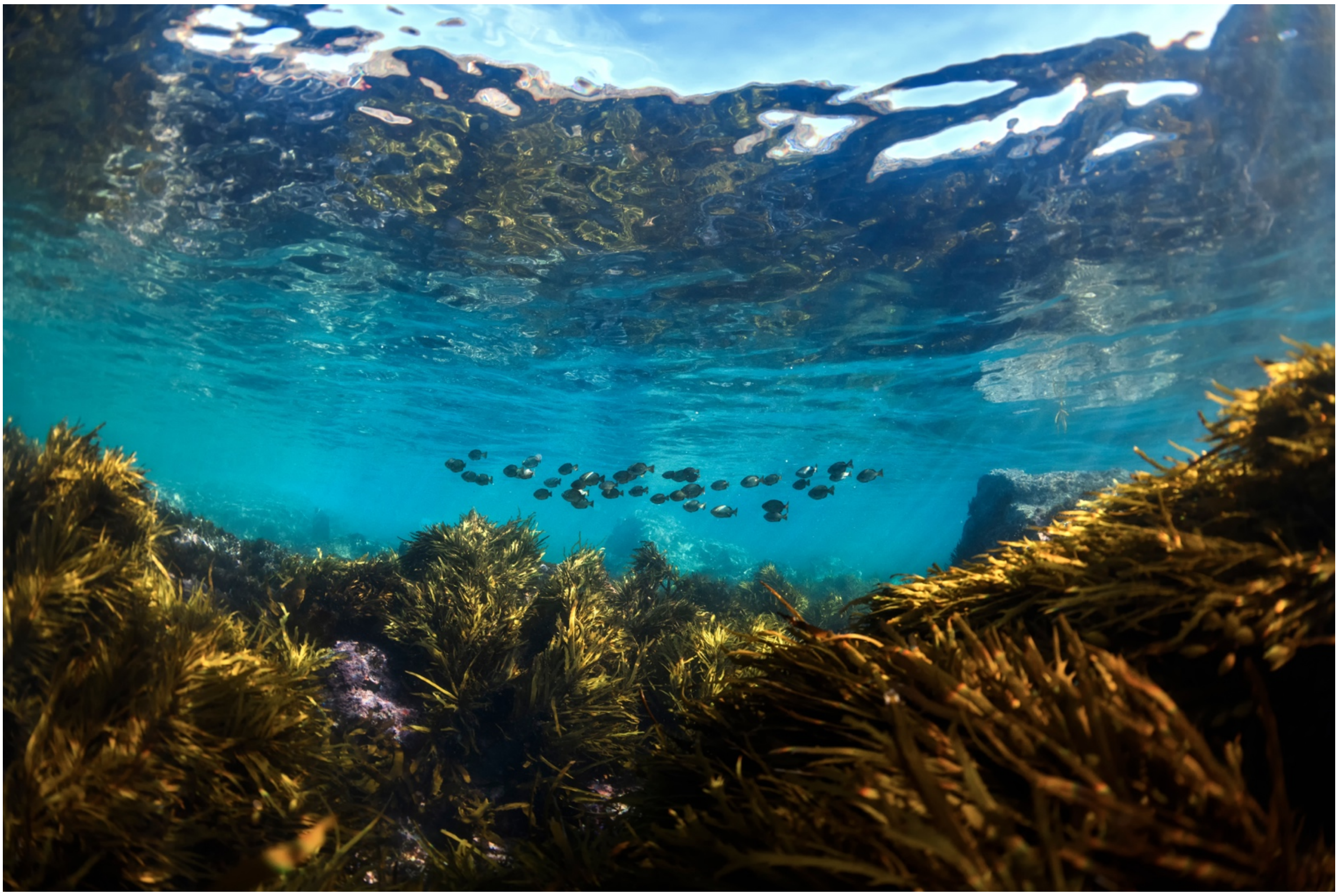
Models of future sea level rise project up to 20cm rise in average heights across eastern Australia, though 10-15cm is more likely. Penetration of inundation inland will not be seen but low lying coastal areas could be inundated (see http://coastalrisk.com.au), which could put local infrastructure at risk.

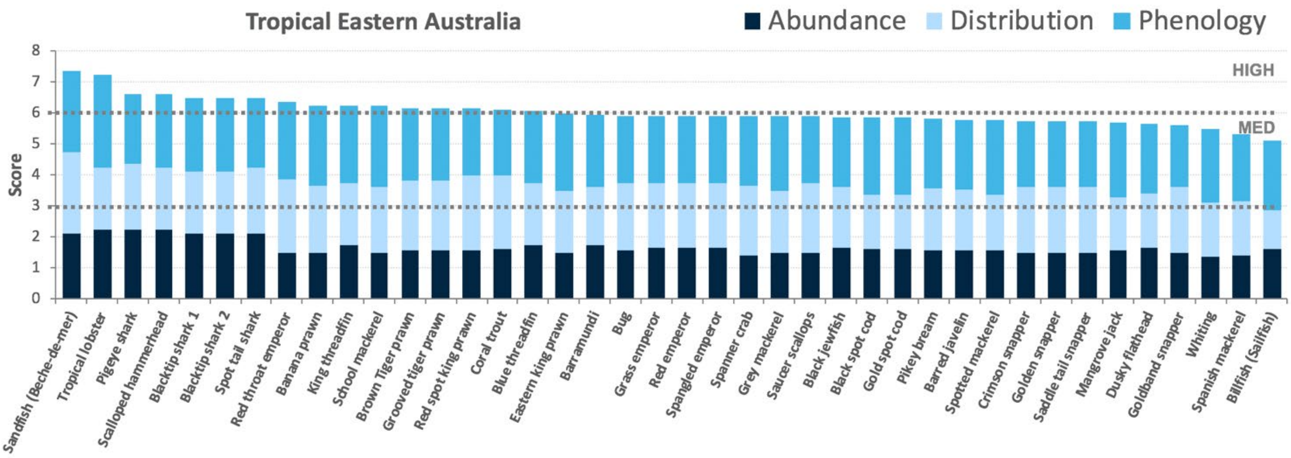
Species shifts and ecosystem change

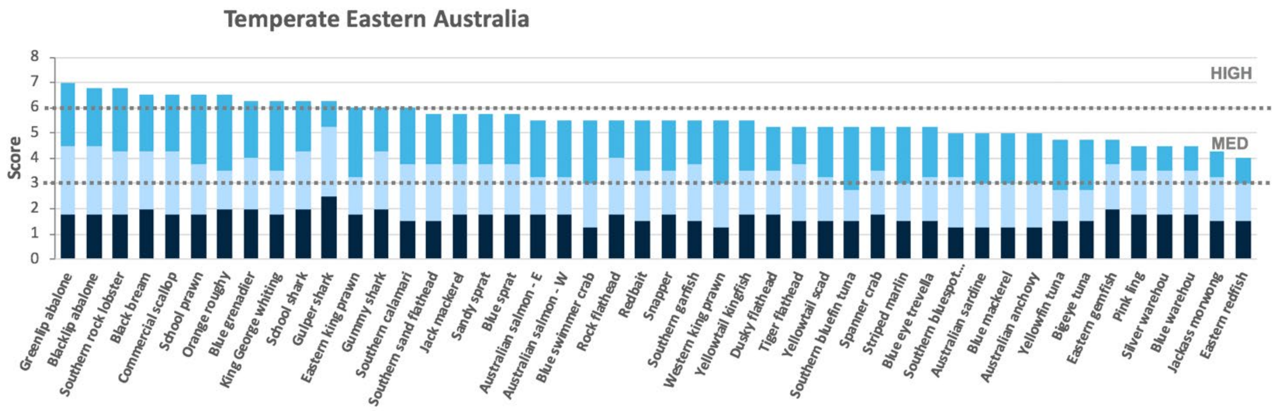
Changing environments influence individual species in five ways:

- **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 eastern Australia rated species present in the tropical north (40 species) or temperate east coast fisheries (46 species) – either Commonwealth, State, recreational or Indigenous fisheries. Of these 32% are rated as being highly sensitive to environmental change, with all others showing moderate sensitivity to further change (noting some of the temperate species have already responded to environmental changes to date).







Sensitivity rating for key species in eastern 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 (especially pelagics) may actually increase in abundance instead.

Summary of projections for key species in eastern Australia — Low | Med | High | NA

Group	Sensitivity rating	Abundance projection	Distribution
Tropical East Australia			
Banana Prawn	Med	10% ↓. Higher with variable rainfall, mangrove loss or dammed river flow.	Decrease across their range, but especially in mangrove areas if they die-off.
Tiger Prawn	Med	10-20% ↓ (food web & seagrass effect). Higher with extreme events (if dams don't buffer flows).	General decrease.
Endeavour Prawn	High	> 20% ↓	General decrease.
Bug, Lobster	High	15->20% ↓ (food web interactions may buffer this).	Decrease off Queensland.
Mud Crab	High	10% ↓ (food web effect). Higher with variable rainfall, mangrove loss or dammed river flow.	General decrease particularly in northern Queensland.
Cods, Emperor, Spanish Mackerel	High	10-20% ↓ (food web effect). Estuarine species depends on river flow.	Bigger drop along coastlines.
Trevally	Low	10+% ↑	
Dugong, Dolphins, Sharks, Seabirds, Sea Snakes, Turtles	Med	10-30% ↓ Turtles could see collapse through egg inundation.	General drop.
Reef sharks and other demersal sharks	High	<30% ↓	Decrease off Queensland coast, especially central GBR.
Crocodiles	Low	10+% ↑	
Tuna	Med	<5-10% ↓ (food web interactions could see small increase instead) .	Decrease off Queensland, increase off Victoria and Tasmania.
Marlin	High	> 20% ↓	General drop.
Temperate East Australia			
Whiptails	High	>20% ↓	General drop.
Blue Grenadier	High	30-40% ↓	General drop.

From FRDC 2016-059: Guidance on Adaptation of Commonwealth Fisheries management to climate change

Group	Sensitivity rating	Abundance projection	Distribution
Deepwater fish (e.g. Orange Roughy and Oreos)		40+% ↓ (food web interactions may buffer this to some extent) .	General drop, though seamounts off eastern Tasmania may be less affected.
Cardinalfish and Ribaldo		> 20-50% ↓ (food web might steady it, or slight increase).	Change occurs in the same way across entire distribution.
Pink Ling		>20% ↓ (food web interactions may accentuate this drop).	General drop.
Redfish		5+% ↑ (level of increase depends on food web interactions).	
Blue-eye Trevalla		Vary within 5% of current levels (food web interactions could lead to an increase instead).	General drop.
Gemfish		No long-term change (Uncertain. <10% ↓ to < 10% ↑. Dependent on food web interactions. Most likely is small initial increase before drop back to original levels).	Same pattern across the entire species distribution.
Flathead		5% ↑ (food web interactions could see larger increases).	
Jackass Morwong		10% ↓ (food web could see the an even larger drop).	Decrease off northern edge of species distribution, Victoria, and NSW. Stable around Tasmania.
Warehou (Silver and Blue)		20% ↓ (food web might buffer this).	General drop, but particularly severe on northern edge of their range.
Other shallow demersal fish		5-40+% ↓ food web might buffer this for some species).	Decrease down east coast, especially at northern extent.
Southern Rock Lobster		15% ↓	Steady or slight decrease off southern Tasmania and deeper edges of Bass Strait. General drop elsewhere.
Abalone		20+% ↓	General drop.
Gummy Shark		Uncertain (<20% ↓ to < 10% ↑)	
School Shark		20% ↓	General drop, especially northern Victoria.
Dogfish and other small demersal sharks		10% ↓ (food web interactions can see small increases instead).	Decrease off Queensland coast, especially central GBR, big drop off Tasmania.

From FRDC 2016-059: Guidance on Adaptation of Commonwealth Fisheries management to climate change

Group	Sensitivity rating	Abundance projection	Distribution
Large demersal sharks		Up to 60% ⬇	General drop.
Pelagic sharks		10%⬇	General drop.
Blue Mackerel		Uncertain (10% ⬇ to 300% ⬆)	Decrease everywhere (especially off NSW), increase around Tasmania.
Jack Mackerel		Uncertain (<25% ⬇ to 200% ⬆)	No spatial pattern change.
Anchovy and Sprat		30-60% ⬆	No spatial pattern change.
Sardine		Mean unchanged, but increased variability.	No spatial pattern change.
Redbait		Uncertain (20% ⬇ to 20% ⬆)	
Southern Bluefin Tuna		20% ⬇ (spawning and grow out temperatures beyond tolerances).	Bass Strait unchanged, but elsewhere decline/contract.
Squid		Uncertain (20% ⬇ to 20% ⬆)	If declines then drop inshore.
Albatross		> 20% ⬇	General drop.
Little Penguin		Uncertain (50% ⬇ to 20% ⬆ depending on prey biomass change).	
Fur seal		150+% ⬆	

References and Further Reading

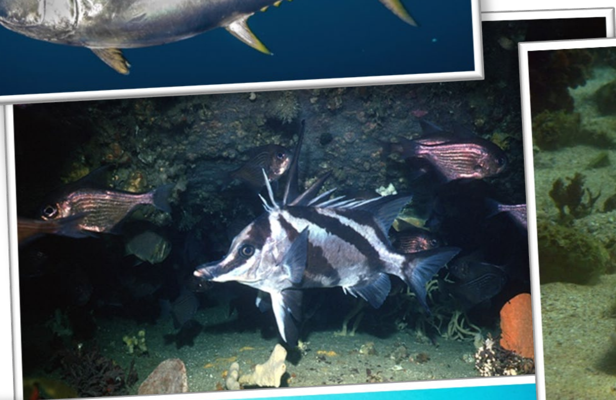
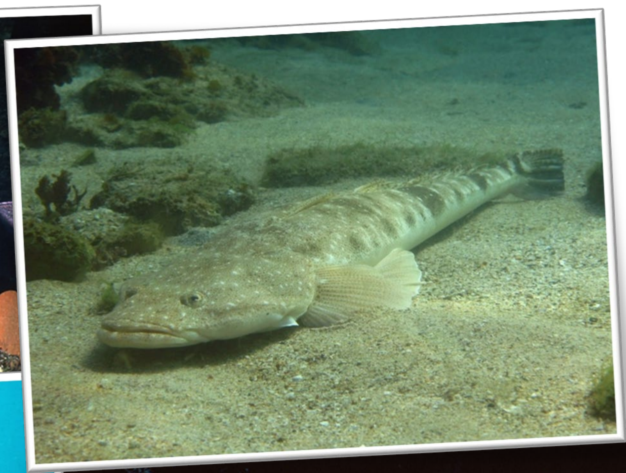
The physical projections discussed in this work have come from the Oceans section of the CSIRO-BOM State of Environment reporting (www.csiro.au/en/Research/Environment/Oceans-and-coasts/Oceans-climate), the CSIRO-BOM 2015 Monsoonal North and East Coast Cluster Reports and the (available from (www.climatechangeinaustralia.gov.au) 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

AT CSIRO, WE DO THE EXTRAORDINARY EVERY DAY

We innovate for tomorrow and help improve today – for our customers, all Australians and the world.
We imagine. We collaborate. We innovate.

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