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Regional Projection for Western 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 western Australia, from the Pilbara to Albany, 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 15-20%. Bringing together available knowledge on species and ecosystems in the region it appears all the key species targeted by fisheries are expected to be moderately to highly sensitive to change. 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 prawns, as well as bugs may reduce in abundance by 10-20%, while many demersal fish reduce by as much as 20%, as a result of climate related changes. Mackerels and other pelagics may increase. If habitats survive then some large reef fish may also increase.

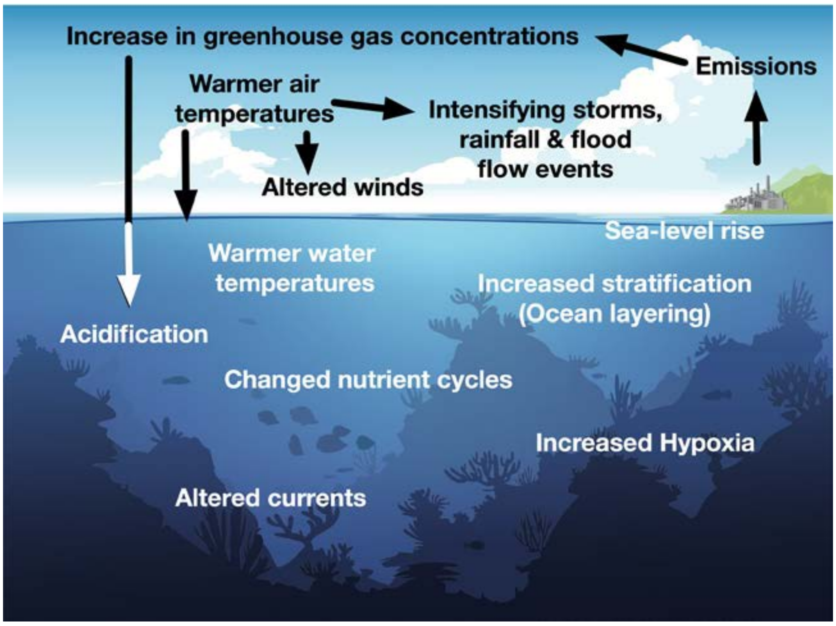
	Observed change (vs 1950)	Future change (vs today)
OCEAN TEMPERATURE	1.0°C increase	0.5 - 1.0°C increase
MARINE HEATWAVE	20 - 35 day increase	>200 day increase
STORMS	Conflicting information	More intense & variable
DROUGHTS	Some increase	Longer, twice as frequent
RAINFALL	9% decrease	3 - 5% decrease
SEALEVEL RISE	20cm increase	10 - 20cm increase
OXYGEN	Approx 2% decrease	5% decrease
ACIDIFICATION	26 - 30% increase	20 - 30% increase

Species Vulnerability & Potential Future Change

SPECIES CLIMATE SENSITIVITY	35% highly sensitive, 65% moderately sensitive
TARGET SPECIES	Abundance of key demersal target species decline 10-20%, pelagic species may increase

Physical climate

The physical environment of western 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 or increase in strength, as has happened for the westward flow of the Leeuwin Current along the southern coast of the Great Australian Bight. 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.



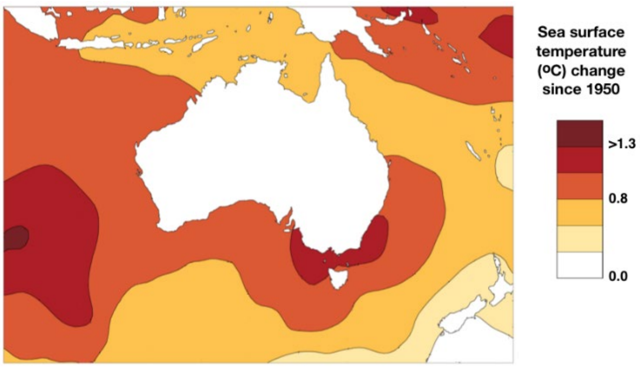
Not everything is linked to temperature. As the additional carbon dioxide in the atmosphere dissolves into the ocean it reacts with the water causing ocean acidification.

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.

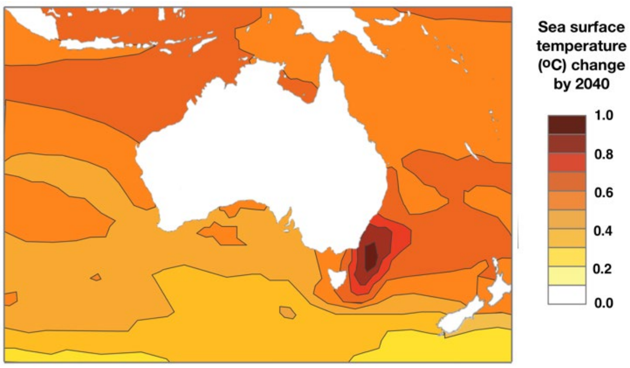
Temperature

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.

Models of the world climate and oceans indicate that water temperatures off western Australia could increase by 0.5-1.0°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

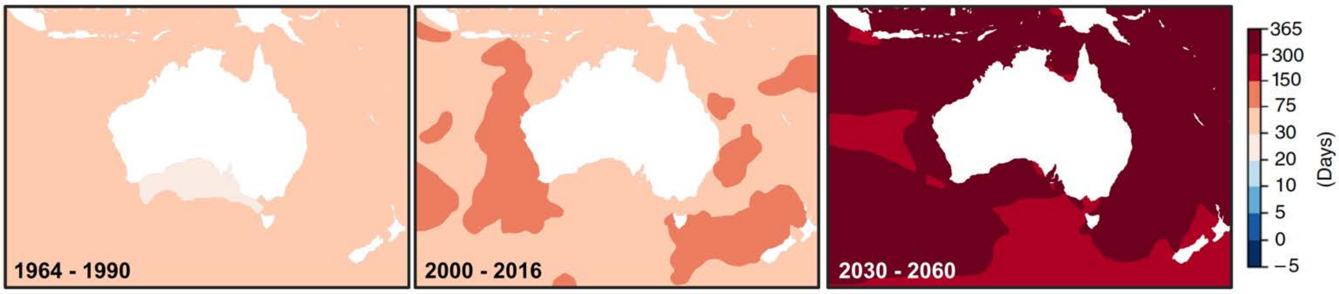


Water temperature change 2015 - 2040.
Data from www.esrl.noaa.gov data

Land surface temperatures can also be important in western 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 1-1.2°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, especially in desert influenced areas.

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. Western Australia has been one of the most severely affected regions in Australia. By 2016 the region had experienced severe and even extreme (the highest level) marine heatwaves and (on average) was seeing 30 or more extra 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 Western Australia by 2040.

Up until 2000-2005 most marine heatwaves were moderate (1-2°C above normal), but as early as 1999 severe marine heatwaves (>2°C above normal) were recorded in the region and in 2011 an extreme event registering >4°C above normal occurred. 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 or even treble over the next 20 years with length of the droughts potentially also increasing by 18 months to 2 years.

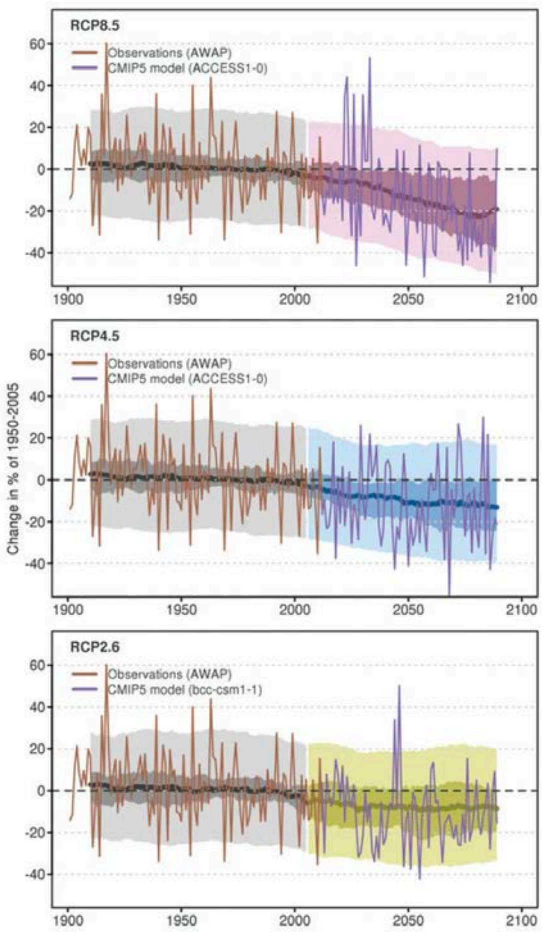
Other physical features

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

Ocean acidification (pH)



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

Ocean acidification means 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 25-30% 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.

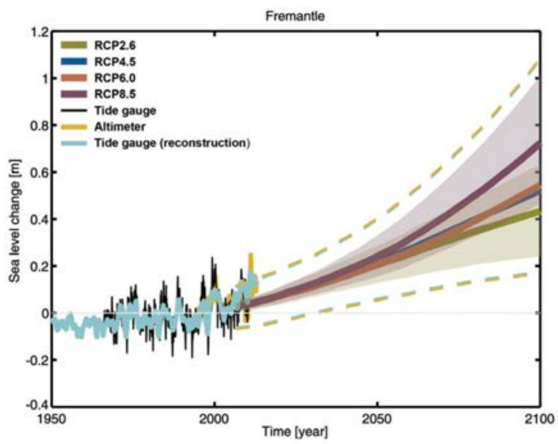
Rainfall, Storms & River Flow

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 target species (prawns and fish) that rely on river flow and productivity, particularly for recruitment. The mean across models of future rainfall suggest mean rainfall may drop right along the coast of Western Australia (although it is likely to drop less in the north than in the south and there is a lot of uncertainty with some models show an increase in rainfall and others decreases). All models agree, however, that variability will likely grow into the future – with an increased likelihood of more intense rainfall events.

The level of uncertainty around flows and rainfall means it is hard to say what generally happens to salinity in the area. Projections indicate salinity will likely increase by a small amount in temperate waters while it may decrease by a small amount in tropical waters. In both cases, inshore waters will still be heavily influenced by local rainfall and river flow.

Sea level Rise

Models of future sea level rise project as much as 10-20cm rise in average heights across western Australia. 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. Extreme coastal sea levels caused by



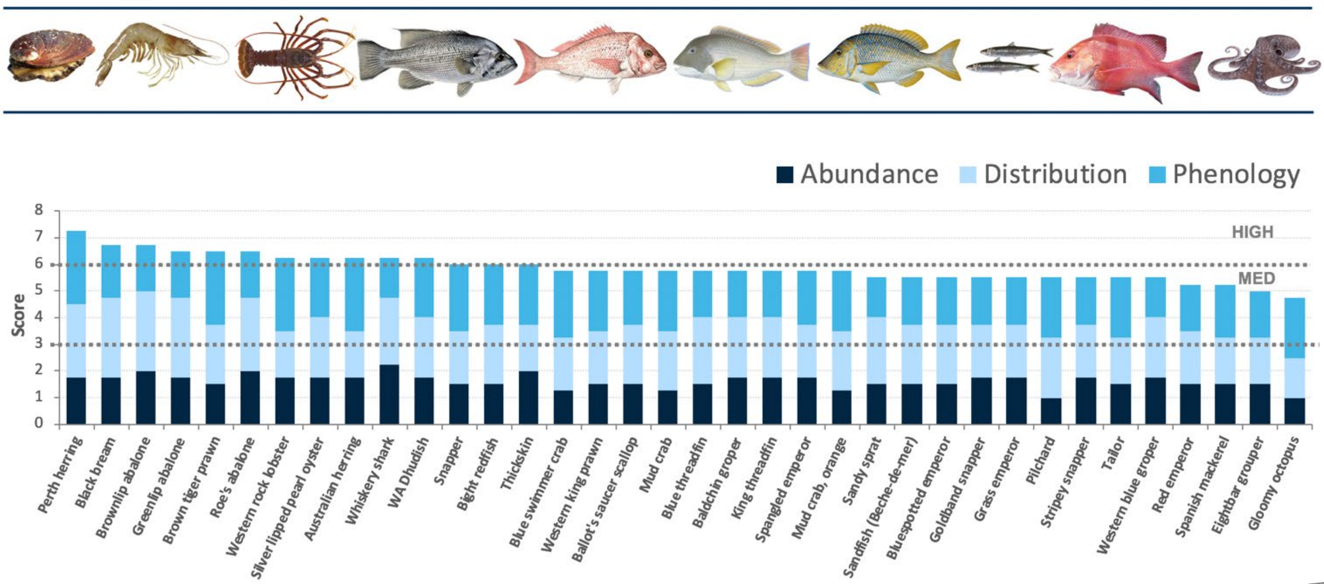
Observed and modelled sea level height for Fremantle. Image from CSIRO & BOM 2015 report. The coloured bands show the spread of model results across the different emission scenarios storm surges associated with tropical cyclones (on the north) or the passage of cold fronts (during the winter months in the south) may acerbate any intrusion.

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 western Australia rated 36 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 Western 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 western Australia

Low Med High NA

Group	Sensitivity rating	Abundance projection	Distribution
Tiger, king and endeavour prawns	High	10->20% ⬇ (food web & seagrass effect). Higher with extreme events	General decrease, especially in the eastern Exmouth Gulf
Bug	High	>20% ⬇ (food web interactions may buffer this)	General decrease, especially in the north
Rock lobster	High	15+% ⬇	General drop
Abalone	High	20+% ⬇	General drop
Orange roughy	High	40+% ⬇ (food web interactions may buffer this to some extent)	General drop
Pink ling	Med	15% ⬇ (food web interactions may accentuate this drop)	General drop
Bight Redfish	Med	20-40% ⬇	
Blue Grenadier	High	15% ⬇	General drop
Blue-eye Trevalla	Med	Vary within 5% of current levels (food web interactions could lead to an increase instead)	General drop
Gemfish	Med	No long term change	
Jackass Morwong	Med	20% ⬇	General drop
Warehou (Silver and Blue)	Med	20% ⬇ (food web might buffer this)	General drop, but particularly severe on northern edge of their range
Other temperate shallow demersal fish	High	10-40% ⬇ (food web might buffer this for some species)	Decrease down west coast, especially at northern extent.
Lutjanids	High	20% ⬇	General drop, especially in the north
Serranids and Lethrinids	Med	20% ⬆ (so long as suitable habitat remains, otherwise they decline)	General drop, especially in the north
Nemipterids and Saurids	NA	20+% ⬆	
School shark	High	15% ⬇	General drop
Demersal sharks	High	10% ⬇	Decrease everywhere (and more so than in the east).
Blue Mackerel	Med	Uncertain (10% ⬇ to 300% ⬆)	Same pattern across the western extent of the species
Jack Mackerel	Med	Uncertain (<25% ⬇ to 200% ⬆)	No spatial pattern change

Group	Sensitivity rating	Abundance projection	Distribution
Bigeye tuna		No real change	
Dolphins		20-40% ⬇	General drop

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 Rangelands and Southern and South-Western Cluster Reports (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

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