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# Regional Projection for Southern 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 southern Australia may look like by 2040, from Busselton to Tasmania and up the east coast to the Queensland border. The region is expected to see average water temperatures increase by 1°C and conditions seen only in marine heatwaves now will extend throughout most of the year (>300 days per year). Extreme events – storms, droughts – will likely also become more intense.**

**Primary production, which supports the entire food web, may drop by as much as 20%. Bringing together available knowledge on species and ecosystems in the region it appears that all key fisheries species 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. The majority of models also indicate that many of the SESSF target species may decline in abundance by 20 percent or more as a result of climate related changes (although if food web interactions change these effects may be moderated). In contrast, pelagic species may increase.**

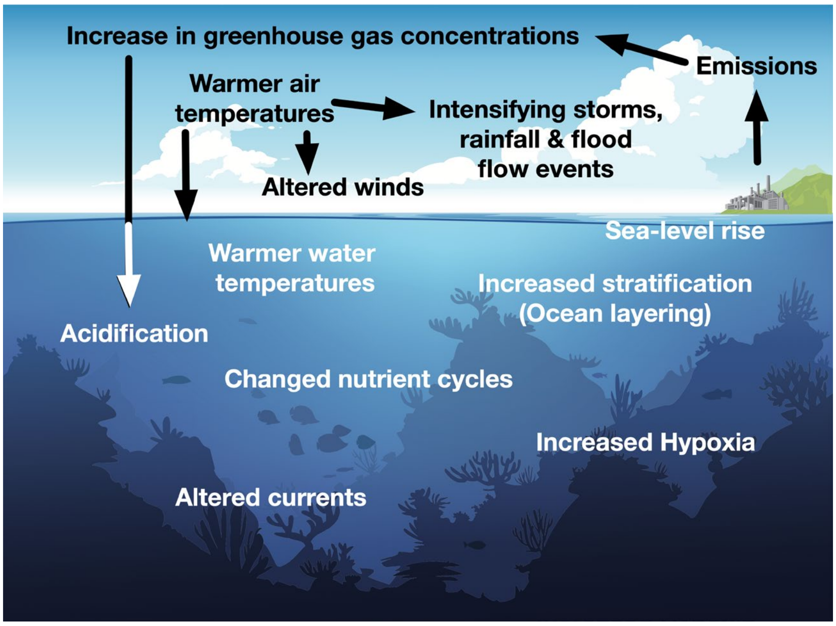
| | Observed change (vs 1950) | Future change (vs today) |
|---|---|---|
| OCEAN TEMPERATURE | 1.2°C increase | 0.3 - 1.2°C increase |
| MARINE HEATWAVE | 20 - 35 day increase | >200 day increase |
| STORMS | Conflicting information | More intense, but fewer |
| DROUGHTS | Increasing | Longer, twice as frequent |
| RAINFALL | 5% decrease | 3% decrease |
| SEALEVEL RISE | 15cm increase | 10 - 20cm increase |
| OXYGEN | Approx 2% decrease | 5% decrease |
| ACIDIFICATION | 26 - 30% increase | 30% increase |

## Species Vulnerability & Potential Future Change

| | |
|---|---|
| SPECIES CLIMATE SENSITIVITY | 20% highly sensitive, 80% moderately sensitive |
| TARGET SPECIES | Abundance of key demersal target species decline 20%, pelagic species may increase |

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

## Physical climate



**Major ocean-climate processes**

The physical environment of southern 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 already happened off Victoria and 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.

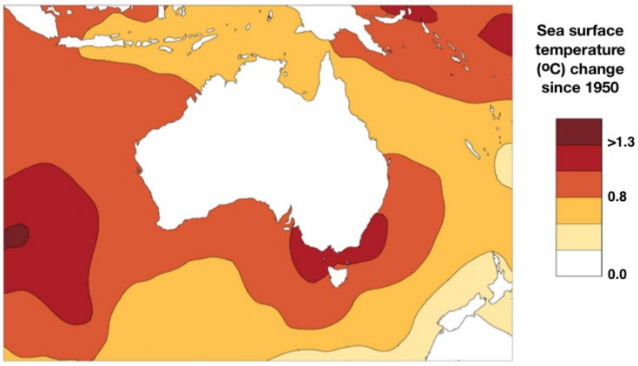
Not everything is linked to temperature. As the additional carbon dioxide in the atmosphere dissolves into the ocean it reacts with the water causing ocean acidification.

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.

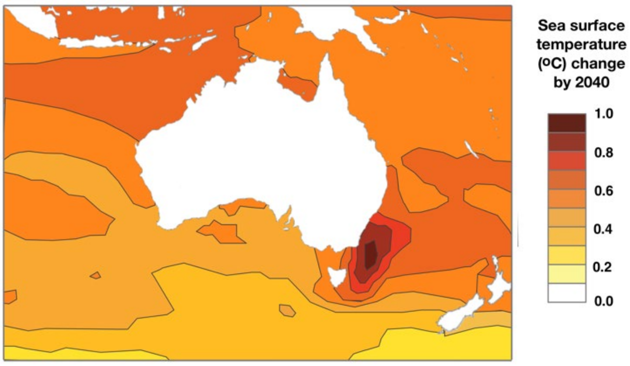
### Temperature

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 southern Australia could increase by 0.3-1.2°C by 2040, with the waters off eastern Victoria and Tasmania seeing the biggest rises. 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

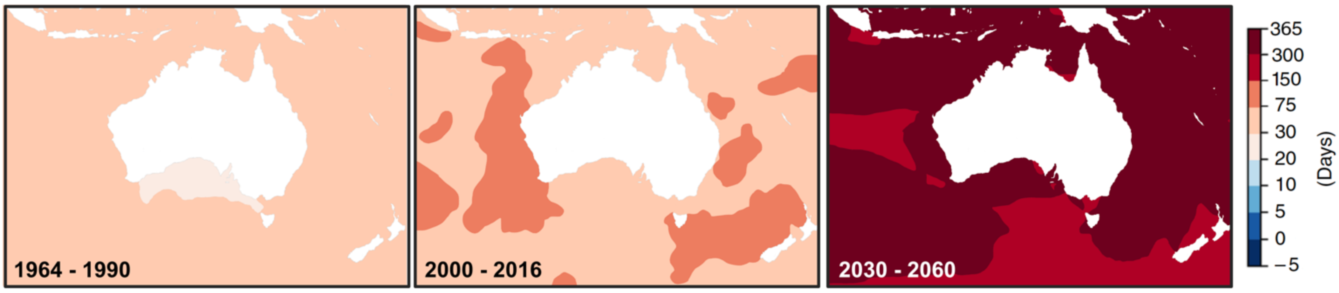


**Water temperature change 2015 - 2040.**
Data from www.esrl.noaa.gov data

Land surface temperatures can also be important in when estuarine habitats are important to the life histories of key fisheries species 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°C. Beyond 2040 the level of change depends on the level of global emissions, with temperatures rising more than $2^{o}$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. Southern Australia has been variably effected by these events. By 2016 the region was experiencing strong heatwave conditions and (on average) and was seeing up to 30 extra days per year of marine heatwave conditions than in the 1960s (particularly around Tasmania and in shallower South Australian waters). 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 southern Australia by 2040.

Up until 2000-2005 most marine heatwaves were moderate (1-$2^{o}$C above normal), but since then strong marine heatwaves have occurred in the region. In 2015 an event, centred in the Tasman Sea, registering >$2^{o}$C above normal lasted for more than 200 days. 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).

Rainfall models indicate that storms in the region may also intensity and even the timing of storms may change. Off NSW winter winds may decline, but summer and spring winds strengthen. While further south winter winds may strengthen instead. 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 or more.

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

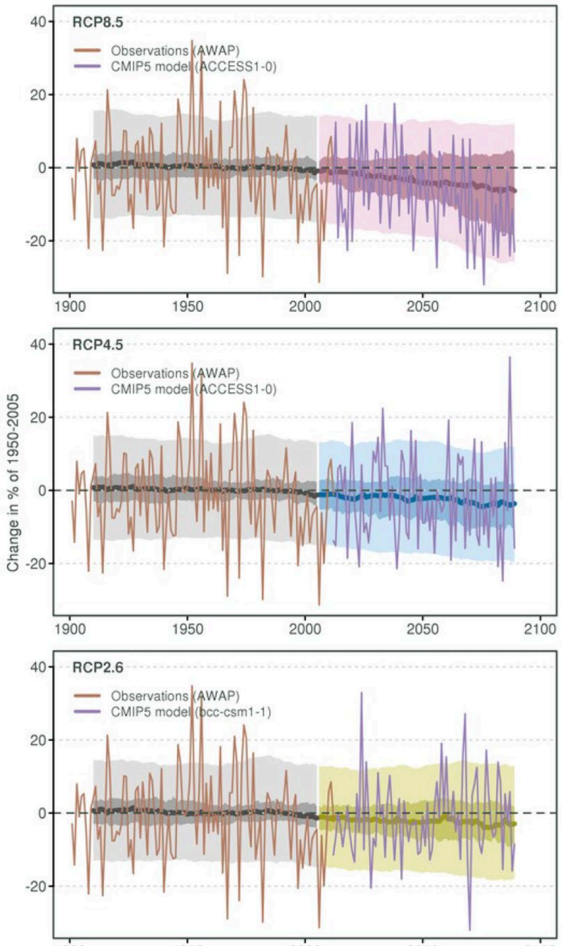
### *Ocean acidification (pH)*

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 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 for coastal species influenced by estuarine river flow. The mean across models of future rainfall suggest the mean drops through time throughout the south of Australia. 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. Despite declining average annual rainfall for 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).

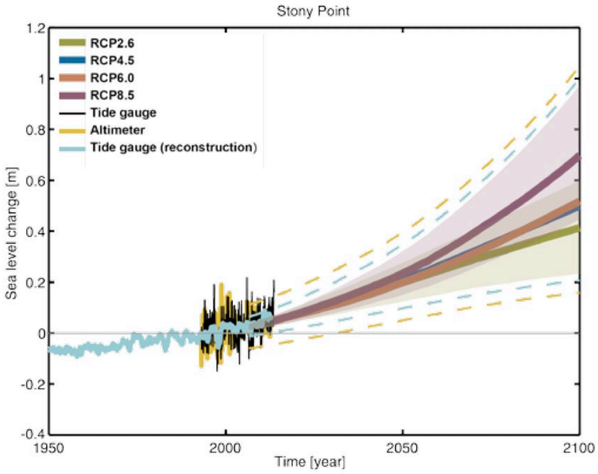
The level of uncertainty around flows and rainfall means it is hard to say what generally happens to salinity in the area. Projections indicate salinity will likely increase by a small amount in temperate waters (though inshore waters will still be heavily influenced by local rainfall and river flow).



**Modelled future rainfall patterns through time across the south of Australia.** 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 10-20cm rise in average heights across southern 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.



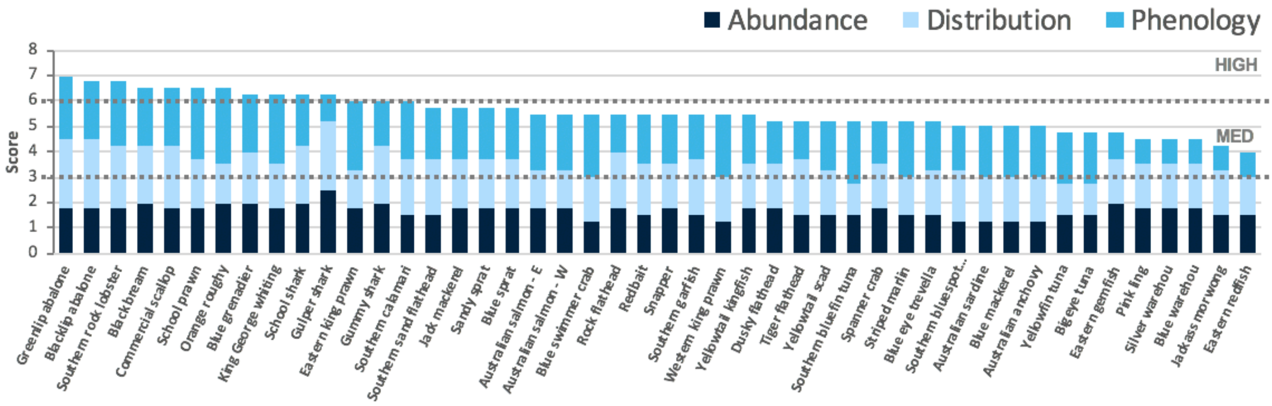
**Observed and modelled sea level height for Stony Pt (Victoria)**. Image from CSIRO & BOM 2015 report. The coloured bands show the spread of model results across the different emission scenarios.

## 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 southern Australia rated 46 species of fisheries (either to Commonwealth, State, recreational or Indigenous fisheries). Of these >20% are rated as being highly sensitive to environmental change.



**Sensitivity rating for key species in southern 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.

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

**Summary of projections for key species in southern Australia**

🟩 Low 🟨 Med 🟧 High ⬜ NA

| 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. |
| **Whiptails** | 🟧 | >20% ⬇ | Decrease everywhere except along the shelf edge / slope off the Bonnie upwelling area. |
| **Pink Ling** | 🟨 | >20% ⬇ (food web interactions may accentuate this drop). | General drop. |
| **Bight Redfish** | 🟨 | 20-40% ⬇ | |
| **Redfish** | 🟨 | 5+% ⬆ (level of increase depends on food web interactions). | |
| **Blue Grenadier** | 🟧 | 30-40% ⬇ | General drop. |
| **Blue-eye Trevalla** | 🟨 | Vary within 5% of current levels (food web interactions could lead to an increase instead). | General drop, except for potential increase in eastern GAB. |
| **Gemfish** | 🟨 | No long-term change (Uncertain. Dependent on food web interactions. Small increase or decrease possible, 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, NSW and western GAB. Stable around Tasmania. |
| **Warehou (Silver and Blue)** | 🟨 | 20% ⬇ (food web might buffer this). | General drop, but particularly severe on northern edge of their range and in central GAB. |
| **Other shallow demersal fish** | 🟧 | 5-40+% ⬇ food web might buffer this for some species). | Decrease down east coast, especially at northern extent, and across west GAB. Increase in eastern GAB, especially around Bonnie coast. |
| **Southern rock lobster** | 🟧 | 15% ⬇ | Steady or slight decrease off southern Tasmania and deeper |

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| Group | Sensitivity rating | Abundance projection | Distribution |
|---|---|---|---|
|  | 🟧 |  | edges of Bass Strait. General drop elsewhere. |
| **Abalone** | 🟧 | 20+% ⬇ | General drop. |
| **Gummy Shark** | 🟨 | Uncertain (<20% ⬇ to < 10% ⬆) |  |
| **School Shark** | 🟧 | 20% ⬇ | General drop, especially central GAB and 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, maybe mild increase in GAB. |
| **Large demersal sharks** | 🟧 | Up to 60% ⬇ | General drop, but increase around the Bonnie coast. |
| **Pelagic sharks** | ▨ | 10%⬇ | General drop except Bonnie coast. |
| **Blue Mackerel** | 🟨 | Uncertain (10% ⬇ to 300% ⬆) | Decrease everywhere (especially at western extent of distribution and off NSW), increase around Tassie and eastern GAB. |
| **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% ⬆ ). | If declines then does so across GAB. |
| **Southern Bluefin Tuna** | 🟨 | 20% ⬇ (spawning and grow out temperatures beyond tolerances). | Bonney upwelling area and Bass Strait unchanged, but elsewhere decline/contract. |
| **Other tuna** | 🟨 | <5-10% ⬇ (food web interactions could see small increase instead). | Decrease off Qld, increase off Victoria and Tasmania. |
| **Marlin** | 🟧 | > 20% ⬇ | General drop. |
| **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+% ⬆ |  |

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## 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 East Coast and Southern Slopes 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.

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