Regional Projection for the Kerguelen Plateau (Heard Island and MacDonald Islands)

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 Australia's Exclusive Economic Zone on the Kerguelen Plateau in the Southern Ocean may look like by 2040. The region is expected to see average water temperatures increase by up to 1.5ºC, with more precipitation and decreased sea ice extent to the south of the region. The oxygen content of surface waters is expected to decrease by up to 10% and waters will become around 30% more acidified.

Primary production, which supports the entire food web, may decrease. Bringing together available knowledge on species and ecosystems in the region it appears that many key species are expected to be moderately to highly sensitive to change.

	Observed change (vs 1950)	Future change (vs today)
OCEAN TEMPERATURE	0.6 - 1.0ºC increase	1.0 - 1.5ºC increase
MARINE HEATWAVE	30 - 35 day increase	>200 day increase
STORMS	Winds are stronger	More intense
SEA ICE	Variable	Decreased extent & season
RAINFALL	Increasing, but variable	Increasing
SEALEVEL RISE	4 - 8cm increase	10 - 20cm increase
OXYGEN	> 2% decrease	5 - 10% decrease
ACIDIFICATION	30% increase	30% increase

Species Vulnerability & Potential Future Change

SPECIES CLIMATE SENSITIVITY	10% highly sensitive, 45% moderately sensitive
TARGET SPECIES	Abundance of key target species decline 15 - 25%

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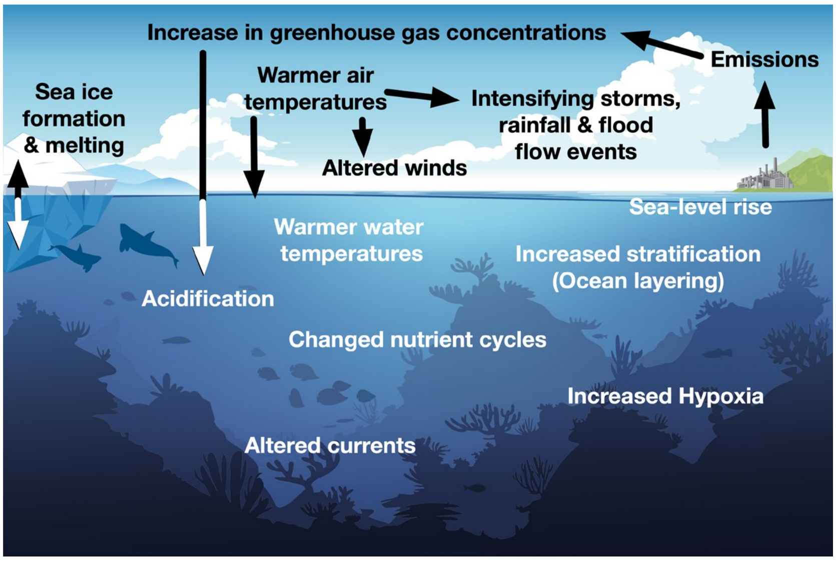
Physical climate

The physical environment of the Southern Ocean 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, affecting sea ice and contributing to sea level rise. As the ocean warms it can become more stratified (layered), which can affect the availability of key nutrients, and it also 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 and sea ice

Water temperature is the most well understood outcome of climate shifts affecting the ocean. The waters at the ocean surface over the Kerguelen Plateau have warmed over recent decades. Summer sea surface temperatures in this region have warmed by 0.1-0.2°C per decade on average since the 1950s, but have cooled slightly in the winter months.

Models of the world climate and oceans indicate that water temperatures over the Kerguelen Plateau could increase by 1-1.5°C (perhaps even 2°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.

Sea ice measurements for the Southern Ocean are incomplete but it is clear that ice extent and season has been variable over the past 50 years. Projections, however, show more consistency, suggesting sea ice extent south of Kerguelen Plateau will decrease by 2040 and that the length of the sea ice season will also contract.

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Extreme events

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

Marine heatwaves have grown in intensity and extent since the 1960s. By 2016 the Kerguelen Plateau region was experiencing stronger heatwave conditions and (on average), seeing up to 30 extra days per year of marine heatwave conditions than in the 1960s. By 2030 these conditions are likely to extend by another 200 days more a year (i.e. to extend for up to 240 days per year). Modelling suggests that permanent marine heatwave conditions (i.e. the conditions will be above the historical temperatures year-round) will exist in the Southern Ocean by 2040. Modelling also 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).

Information on precipitation and storms is hard to find for the region, but global projections suggest annual precipitation and storm intensity will increase into the future.

Other physical features

Temperature and sea ice aren't the only physical features that will change into the future. Changes in oxygen levels, salinity (especially due to rainfall changes), cloudiness, nutrient availability (particularly iron), 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, light and nutrients

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 the Kerguelen Plateau will be less impacted. Oxygen levels will likely drop by 5-10% versus levels observed in 2018.

Increased cloudiness in summer in this region will lead to less sunlight reaching the ocean surface, which is predicted to reduce the amount of primary production. The mechanisms that deliver key nutrients such as iron to phytoplankton in surface waters may also change in the future, with consequences for the rest of the food web.

Ocean acidification (pH)

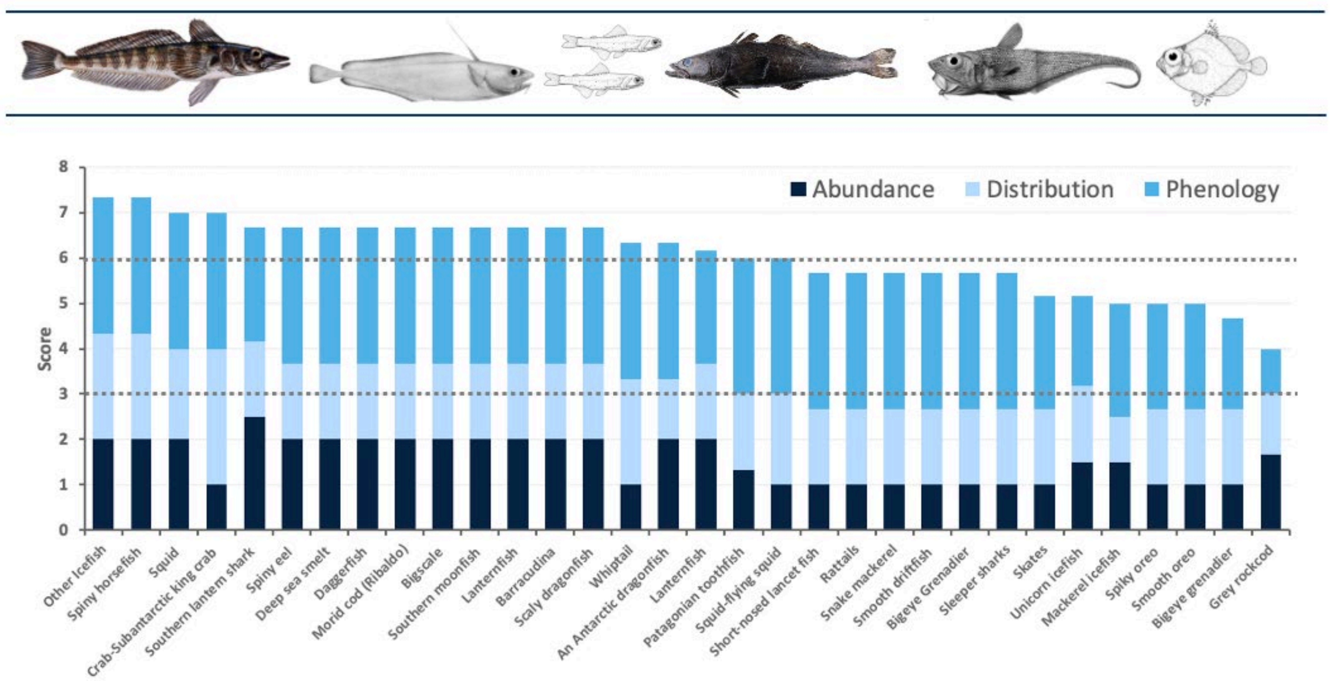
Ocean acidification means that ocean pH has already dropped by up to 0.1 pH units since the 1800s, with most of the drop coming since 1960. This level of drop means that ocean acidification has already increased by up to 30%. By 2030-2040 the predicted pH shift would have gone further. The exact level 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 the ocean could be 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.

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). Using information on these features of species for the Kerguelen Plateau 10% are rated as being highly sensitive to environmental change, with half of all fish species showing moderate sensitivity.



Sensitivity rating for key species on the Kerguelen Plateau

Species Projections

CSIRO has used a simple food web model to look how species and ecosystems may respond into the future. These projections are uncertain and should be used to think about possible levels of change, they should not be used as a confident assessment of future stocks sizes.

Summary of projections for key species on Kerguelen Plateau Low Med High NA

Group	Sensitivity rating	Abundance projection
Patagonian Toothfish	High	20% ↓
Mackerel Icefish	High	20% ↓
Squid	Med	15% ↓
Grenadiers & Whiptails	High	15-25% ↓
Mesopelagics	High	5-25% ↓ (Uncertain).
Penguins & Seabirds	High	>20% ↓
Seals	High	25% ↓
Toothed whales	High	15-20% ↓
Orcas	Low	5% ↑
Baleen whales	Low	>15% ↑

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References and Further Reading

The physical projections discussed in this work have come from the Marine Heatwaves Tracker (www.marineheatwaves.org/tracker.html), IPCC SROCC report (https://www.ipcc.ch/srocc/) and Coupled Model Intercomparison Project (CMIP) projections from the World Climate Research Programme (database available at www.esrl.noaa.gov).
The biological projections were undertaken using CMIP6 climate forcing and an Ecopath with Ecosim model of the region (Subramaniam et al (2020) Time-Dynamic Food Web Modeling to Explore Environmental Drivers of Ecosystem Change on the Kerguelen Plateau. Front. Mar. Sci. 7:641. doi: 10.3389/fmars.2020.00641)

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