Life in a changing ocean: pelagic species in Antarctica's Ross Sea

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The oceans around Antarctica are home to complex and productive ecosystems. These ecosystems are characterised by species found nowhere else in the world and a food web specially-adapted to the extreme environment.

The Southern Ocean ecosystem is under pressure from fishing and a changing climate. In future, we expect the surface waters around Antarctica to be warmer and fresher (less salty), sea ice to decline, and the ocean currents to strengthen.

Understanding how these changes will impact ocean productivity and 'keystone' species (those especially important in the food web) will help the international community prepare for, and respond to, these changes.

About this document

This summary aims to inform policy makers and scientific peers about pelagic research conducted in the Ross Sea region by New Zealand's Antarctic Science Platform (ASP). This research synthesis:

- shares information about primary production (the growth of tiny algae that absorb sunlight) and the pelagic food web of the Ross Sea region
- highlights the effects of a changing climate on pelagic species and communities in the Ross Sea region
- provides critical baselines and new insights to understand pelagic biodiversity and biogeography in a warming world
- supports the application of research by domestic and international stakeholders and collaborators to advance environmental management and promote ecosystem resilience.

Key points

- Modelling and measurements show that growth rates of Antarctic phytoplankton and sea-ice algae will be affected by climate change. We've developed new ways to use satellite images to anticipate and observe these changes.
- Impacts of changes in production of phytoplankton and sea-ice algae will cascade through the marine food web.
- Sea ice is a crucial habitat for 'keystone' groups of organisms including small midwater fish, krill, and mesozooplankton. These groups have special ecological importance in the Antarctic marine environment where they act as a 'buffer' between climate effects and higher-level predators, like seabirds, marine mammals and large fish, like toothfish.
- We've developed field techniques and instruments, including new eDNA sampling approaches for analysis of species presence and genetic diversity, and a giant sea-ice corer to sample animals in platelet ice.
- The Ross Sea region Marine Protected Area (MPA) can help fishing for Antarctic toothfish to be done with less risk to other species.

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Phytoplankton and sea-ice algae are the foundation of the marine food web

The open ocean around Antarctica is a complex and productive environment, characterised by unique species that are specially adapted to the extreme conditions. The Ross Sea has some of the highest primary production rates in the Southern Ocean. Primary productivity is the rate at which producers within an ecosystem, such as plants and algae, create organic matter by capturing sunlight. These tiny photosynthetic marine and sea-ice algae sustain the Antarctic food web, supporting a diverse array of Antarctic life, from zooplankton to fish, seabed corals, and higher level predators, including seals, whales, and penguins.

Our research has investigated patterns in primary production in the Ross Sea region and changes over time. The growth and abundance of phytoplankton and sea-ice algae is affected by:

- nutrients like nitrate, silicate, and phosphate
- trace elements like iron
- light
- temperature
- grazing pressures from zooplankton.

These driving factors are, in turn, affected by changes to the physical and chemical environment, such as:

- the vertical mixing of the water column
- the formation and melting of sea ice
- meltwater from Antarctica's glaciers
- cloud formation and rates of snowfall
- ocean currents.

Climate variability and changes can affect the total amount of primary production and can also alter the species of phytoplankton present, and the timing of growth – all of which can impact the wider Antarctic pelagic ecosystems.

Antarctic phytoplankton communities are changing

Our research used satellite observations to show that the mass of phytoplankton in the upper most part of the ocean increased over the last 20 years in most, but not all, parts of the Southern Ocean.

We analysed 26 years of phytoplankton 'pigments', which are coloured chemicals produced by phytoplankton in their cells and used for photosynthesis. By bringing together data from over 50 New Zealand and international oceanographic voyages, our analysis revealed a circumpolar 'class divide' around the Southern Ocean. We showed that the Antarctic Polar Front (a belt surrounding Antarctica where cold and warm waters meet) separates two different, distinctive phytoplankton communities. A group of phytoplankton called diatoms were generally dominant to the south, but not north, of the divide.

This natural boundary is important because it implies different photosynthetic rates, different contributions to carbon export, and different responses to climate change of phytoplankton communities to the north and to the south. This analysis was the largest assessment of Southern Ocean phytoplankton identification pigments ever carried out.

Our research also developed satellite methods to track changes in different Southern Ocean phytoplankton communities over time. We found that the gradual increase in Antarctic sea ice between 1997–2016 was accompanied by a change of phytoplankton community. And as sea ice decreased from 2016–2023, the phytoplankton community changed again.

Changes to sea ice have ecological consequences

Antarctica's pelagic environment undergoes one of the biggest environmental changes in the world, with 18 million km^2 of sea ice forming and melting each year. The extent of annual-average Antarctic sea ice has recently declined after several years of small increases. This change is likely due to a combination of increasing ocean temperatures, atmospheric warming, and stronger winds – all linked to climate change.

We developed a new index of primary production by sea-ice algae, based on satellite observations between 1987 and 2017. This index is to understand how changing ice conditions will affect sea-ice algae and the species that depend on this form of primary production. Our research showed that primary production by sea-ice algae increased in the Ross Sea in line with increasing sea ice but with reductions in sea ice, this food source will reduce.

Declining sea ice and its associated primary productivity on Antarctic marine ecosystems includes the following effects.

- Some keystone species (like krill, silverfish, and some species of mesozooplankton) use sea ice as a breeding or nursery habitat. Less sea ice means less habitat and less sea-ice algae available as a food source.
- Melting sea ice in Spring tends to lead to intense blooms of phytoplankton in the adjacent water column. This crucial dynamic could be affected by changes to the patterns and extent of sea ice.
- Some predators have life cycles that need sea ice. For example, emperor penguins stand on sea ice while moulting their feathers.

Flow-on effects are felt through the food web

Environmental changes affect Antarctic marine species directly, and will also bring about changes to the food webs of the Southern Ocean.

Antarctic species and food webs are different from those elsewhere in the world because of the intense variation in conditions throughout the year.

The annual formation and melting of sea ice in the Southern Ocean is the biggest annual habitat change in the world, and Antarctica's biology is especially adapted to cope with this. Our research has advanced food web models as a vital platform for understanding how these complex interconnections amongst species could cascade through the food web and affect Antarctic life into the future.

'Bottom up' ecosystem effects will come from changes to the amount, timing, spatial patterns, and species mix of phytoplankton and sea-ice algae. Changes to primary producers will affect the microscopic grazers and then the larger animals that feed on these in turn. Mesopelagic species, such as silverfish, lanternfish, krill, and mesozooplankton, live in the Ross Sea's intermediate depths. Our research shows these are keystone species (particularly important for resilience) and act as a 'buffer' between bottom-up climate effects and higher-level predators that all rely on abundant prey species. Several of these keystone species have life phases dependent on sea ice, and we developed a new sea ice coring instrument to improve our knowledge of the associations between these species and sub-habitats within sea ice.

Zooplankton are crucial for Ross Sea region resilience

Zooplankton occupy a position crucial for maintaining large-scale ecosystem resilience in the Ross Sea region. How higher-level consumers like penguins, seals, and whales are affected by climate change depends on the transfer of energy and matter through zooplankton.

With Fisheries NZ, MPI, and Sanford Ltd, we analysed and reported on 15-years of zooplankton and microplastic measurements between New Zealand and the Ross Sea. We found that:

- zooplankton are generally more abundant in the Ross Sea sector than in the rest of the Southern Ocean, by an average of 29 percent
- the abundance of total zooplankton in the Ross Sea sector declined between 2008 and 2023, though some individual taxonomic groups of zooplankton did increase
- we would expect conditions for zooplankton in the Southern Ocean to improve in future but this is not the case of all groups and some will likely decline (especially tiny free-swimming marine snails called pteropods)
- the mean number of plastic pieces (almost all microfibres) in near-surface seawater between New Zealand and the Ross Sea increased 11-fold between 2009 and 2023.

At this stage, we don't know whether microplastics are negatively affecting zooplankton in the Southern Ocean but this is possible.

Pelagic research and food web insights guide marine management

Our research on Antarctica's pelagic ecosystem has helped to support New Zealand's strategic commitment to:

- sustainable stewardship of the Ross Sea region
- supporting the Ross Sea region Marine Protected Area
- identifying and minimising threats related to fishing.

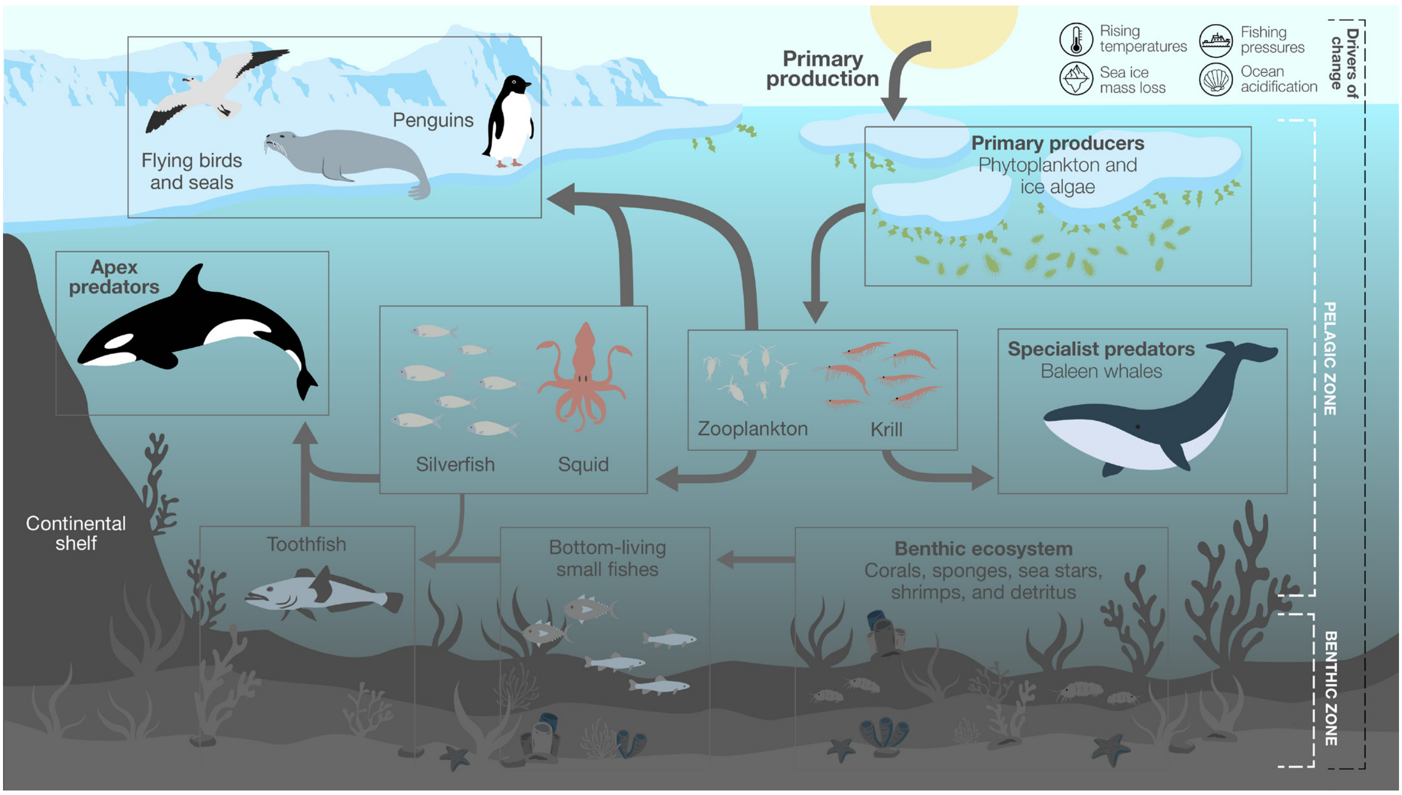

Figure 1: The flow of energy, captured through primary production, through the pelagic ecosystem and beyond.

New Zealand is committed to delivering research to help evaluate the conservation value of the Ross Sea region Marine Protected Area (MPA). New Zealand and USA jointly proposed this MPA to the international Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) and it was established by unanimous vote in 2017.

CCAMLR is responsible for ensuring Antarctic fishing is sustainable, reversible, and does not harm associated species. In the Ross Sea region, fishing toothfish was started by New Zealand in 1997, and now involves over 10 countries, catching about 3,000 tonnes of toothfish each year. The MPA was designed to make sure fishing in the Ross Sea stays within biological limits, even as the area is affected by climate change.

The Ross Sea region MPA relies on research to understand how it's performing. We need high-quality data on the population dynamics of key species and their inter-dependencies to ensure that the 'top-down' effects of fishing on the Ross Sea food web do not compromise ecological resilience. This need for better data presents significant scientific challenges, but also provides an opportunity.

By studying how large, open-ocean ecosystems respond to fishing and climate change, our pelagic food web research helps CCAMLR to improve the management of the toothfish fishery in the Ross Sea region and elsewhere.

Our research on Southern Ocean ecosystems helped to establish a new SCAR action group on Antarctic fish: SCARFISH. New Zealand has positions on the SCARFISH executive committee and joint leadership of the working group for biogeography, modelling, and management.

Definitions

Benthic environment: the seabed and its inhabitants.

Pelagic environment: organisms and environments in the open ocean, away from the shore or seabed.

Primary production: growth of phytoplankton in the water column by photosynthesis.

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