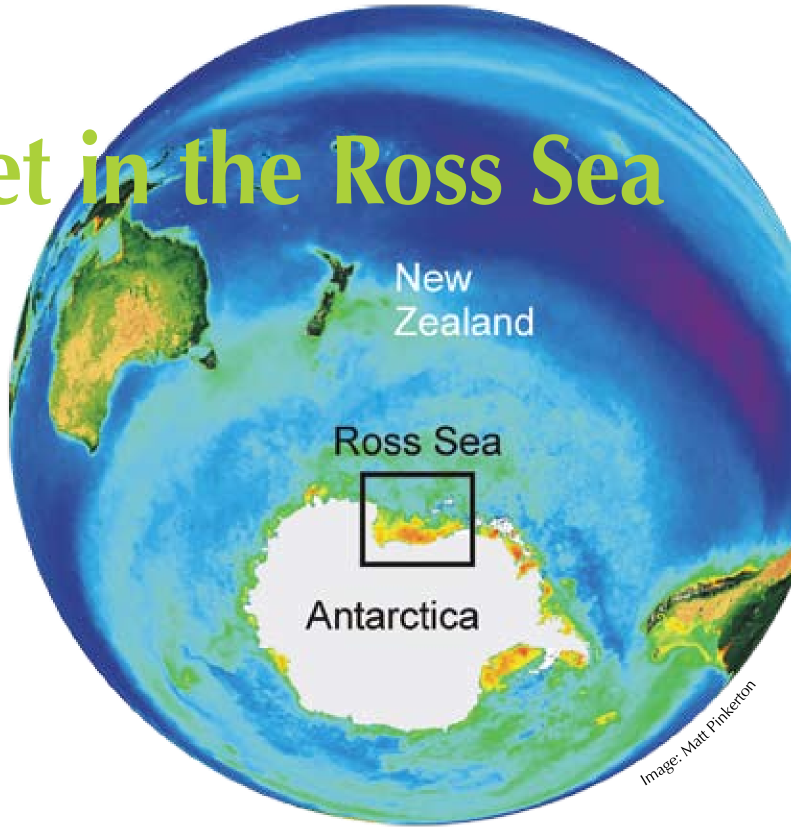
Marine Ecosystems

Making ends meet in the Ross Sea

***Matt Pinkerton, Janet Bradford-Grieve** and **Stuart Hanchet** are developing a mass-balance model to learn how animals fit together in the Ross Sea ecosystem.*



Based on data from NASA satellites, this image shows the average phytoplankton concentration in the Ross Sea during summer. High concentrations are shown in green and red, lower concentrations are blue and purple.
Data used courtesy of NASA.

After braving some of the worst sea ice in decades, NIWA scientists returned in late March from a seven-week voyage to the Ross Sea region of Antarctica. Among our goals for the voyage was to learn more about the region's predator–prey links and the abundance of some important and poorly understood species.

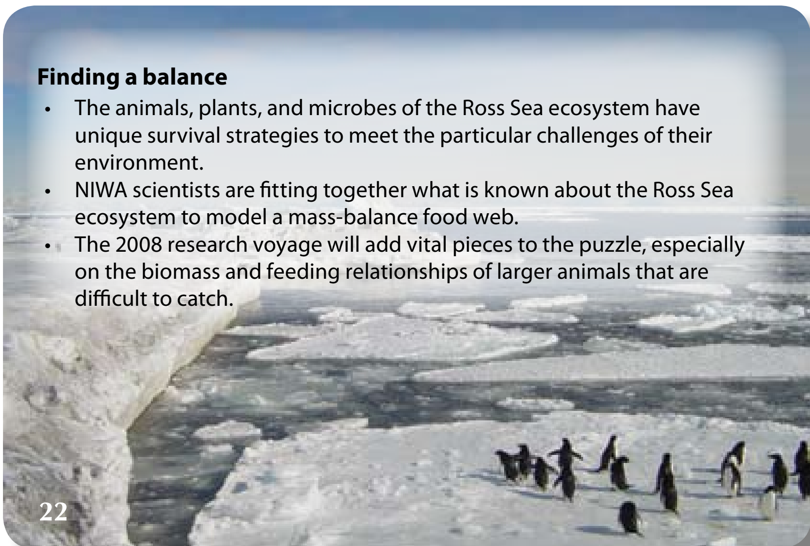
Antarctica's unique ecosystems

Compared to temperate regions, the waters of the Southern Ocean have low primary productivity – the production of organic matter by plants that is the basis of marine food webs. In temperate waters, like those around New Zealand, phytoplankton grows during most of the year. But in the Ross Sea there's a long period between late May and mid July when the region is in 24-hour darkness and no plants can grow. The year's entire primary production happens in brief events in the spring and summer, and these bursts of high productivity are often very localised. Another challenge for Antarctic animals is dramatic change through the year to the available environment, as sea ice forms in the autumn and then melts in the spring.

These special conditions seem to be associated with particular characteristics in Antarctic animals and plants. Animals living in Antarctic waters have a relatively low number of species and many are endemic to the region; that is, they don't live anywhere else and are specialised to the Antarctic conditions. Some species of fish have developed anti-freeze in their blood that allows them to survive in freezing conditions. And Antarctic organisms are often larger and slower-growing than similar animals in warmer waters.

Survival strategies

Animals living in the Ross Sea have developed various strategies for survival when food is scare. Entire populations of some the larger, mobile animals leave the region completely during winter, including minke whales, most seals, petrels, and Adélie penguins. Some larger animals tough it out, relying on having built up enough reserves to see them through. Emperor penguins, for example, incubate their egg over winter to take advantage of the plentiful food in the spring and summer when it's time to feed the newly hatched chicks. This is a risky strategy: while incubating the egg through the winter, the males lose more than 40% of their body weight and come close to starvation. Other less mobile organisms store oil in their body during the summer and use this for energy while in a quiescent (low-energy) stage during winter. Still other animals have expanded the things they can eat, live slower but longer, or can adjust their breeding cycles to take advantage of occasional peaks of food availability.



Finding a balance

- The animals, plants, and microbes of the Ross Sea ecosystem have unique survival strategies to meet the particular challenges of their environment.
- NIWA scientists are fitting together what is known about the Ross Sea ecosystem to model a mass-balance food web.
- The 2008 research voyage will add vital pieces to the puzzle, especially on the biomass and feeding relationships of larger animals that are difficult to catch.

Photo: Peter Wilson

Modelling a mass-balance food web

At NIWA we're fitting together what's known about the Ross Sea ecosystem into a consistent picture. Data about the ecosystem have been produced over many years by a number of nations and it has been a mammoth task to pull all this information together and make sense of it. We have particularly been interested in data that measure the quantity of organisms (biomass), the amount of food an animal needs to survive and grow, the rate at which it grows, and how the numbers of predators and prey affect each other.

To confirm our understanding of how the food web works, we're developing a mass-balance model of the Ross Sea. The model is based on the balance

The big picture: a simplified Ross Sea food web

Growth of phytoplankton makes up the largest contribution to primary production in the region, though there is some primary production by sea-ice algae. Bursts of growth occur in the spring and summer along the coast, in polynya (large open-water areas within the sea ice), and in the waters left as the sea ice melts. Primary production is channelled through copepods, the most common type of zooplankton, and a number of smaller species of zooplankton. Algae that are not consumed can fall to the sea-floor, often in large amounts. This food source, and the growth of coralline macroalgae in coastal regions, provides nutrition for the benthic (bottom-dwelling) invertebrates. These benthic animals have varied feeding strategies and include: grazers, such as urchins, sea cucumbers, and snails; predators, such as the Antarctic whelk and seastars; filter-feeders, such as Antarctic scallops, bivalves, anemones, soft corals, and sponges; and scavengers, such as large worms.

Two species of krill are found in the Ross Sea: the larger Antarctic krill north of the Ross Sea proper, and smaller crystal krill in waters over the continental shelf to the south. Krill abundance tends to be much lower in the Ross Sea than in other parts of the Southern Ocean, and Antarctic silverfish fill the gap as key species in the food web. Silverfish grow to a length of about 30 cm, occur throughout the Ross Sea, and are found in the diet of almost all large predators. They, in their turn, feed on the smaller copepod crustaceans. Other fish in the Ross Sea include the 2-m-long Antarctic toothfish, 'cryopelagic' fish that live on the underside of sea ice (cryo=freezing, pelagic=open waters), as well as grenadiers or rat-tails, skates, deep-sea and moray cods, dragonfishes, and icefishes. A number of species of squid and octopus live in the Ross Sea, including the colossal squid that can grow to more than 4 m in length. It's this last group that we knew least about before the recent voyage.

Image by Matt Pinkerton including photos by Suze Baird, Ken Grange, Stuart Hanchet, Cathy Kilroy, Peter McMillan, John Mitchell, Rob Murdoch, Katja Riedel, and Peter Wilson.

The arrows go from prey species (these get eaten) to their predators (the hunters).

In the Ross Sea region, there are an estimated 40 000 breeding pairs of emperor penguins and about 1 million breeding pairs of Adélie penguins (38% of the world population). Several other species of birds breed in the region, including Antarctic petrels, snow petrels, and the south-polar skua, which preys on penguin chicks. Many other birds visit in summer, including two species of albatross.

Seals are the most common marine mammals in the Ross Sea in summer, with more than 200 000 crabeater seals, 40 000 Weddell seals, 8000 leopard seals, and 5000 Ross seals. Baleen whales in the outer Ross Sea include dwarf minke whales, Antarctic minke whales, and smaller numbers of fin, humpback, sei, and blue whales. Toothed whales sighted in the Ross Sea include orca (killer whales), sperm whales, southern bottlenose whales, and Arnoux's beaked whales.

between growth and death in various groups of animals over time. We know that no more production can come out of the Ross Sea system than is put in by the primary producers, and that there will be losses in biomass at each step.

Some aspects of the ecosystem are quite well known, while other pieces need new data or, failing this, force us to make educated guesses. New research becomes available all the time, so this is a constantly shifting target. The model checks that the available numbers make sense when put together.

Last year we presented a preliminary balanced model to CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources), the organisation that regulates fishing in the Antarctic. We're using our model to help investigate how the organisms fit together in the ecosystem and to decide which are the important questions for future research. The model should also suggest potential impacts on the Ross Sea ecosystem of fishing, climate variability, and climate change.

Further reading

Hanchet, S.; Judd, W. (2006). The Ross Sea toothfish fishery. *New Zealand Geographic 79*: 16–20.

Pinkerton, M.H.; S. Hanchet; J. Bradford-Grieve. (2007). Finding the role of Antarctic toothfish in the Ross Sea ecosystem. *Water & Atmosphere 15(1)*: 10–11.

Scott, M. (1991). Antarctica, a New Zealand perspective. *New Zealand Geographic 9*: 52–83.

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This project is supported by the Ministry of Fisheries programme on 'Ecosystem Effects of Fishing in the Ross Sea', and the Foundation for Research, Science & Technology 'Ross Sea Sustainability' programme.