MARINE FISHERIES

Trophic modelling for sustainable New Zealand fisheries

Matt Pinkerton
Mary Livingston

Managing marine fisheries through a whole-ecosystem approach requires an understanding of how different organisms interact.

As long as people continue to exploit natural fish stocks, fisheries science will be needed to improve our understanding of the workings of fish populations.

Many fisheries around the world are in decline, with over a quarter of exploited fish populations worldwide having been over-fished to some degree. There is a growing sense of urgency to explain why many fisheries that were thought to be managed conservatively using the best available scientific information, have become severely depleted. With recent evidence showing a decline in some of New Zealand's important commercial fisheries, this urgency is now being felt at home. An increasingly important part of fisheries research is to look at all parts of the marine ecosystem and to use modelling to assess how fish populations respond to the varied effects of fishing.

Environmental effects of fishing

Historically, fisheries management has concentrated on the direct effects of fishing on the number of reproducing individuals left in the population. Research shows that fishing also has indirect impacts, which may be vital in managing fishing sustainably. For example, fishing can physically damage the marine habitat (especially trawling the seabed), fish populations may be less viable when depleted, and removing part of a population can change the structure of marine communities.

Many countries, including Canada, USA, Australia and European nations, are now trying to move to ecosystem-based management that acknowledges the indirect effects of fishing. The New Zealand government and fishing industry have already taken steps to protect the marine environment from the indirect effects of fishing by reducing catches, adopting less damaging fishing practices, and establishing marine protected areas. Both here and overseas, one of the key requirements in implementing an integrated ecosystem approach to fisheries is reliable scientific knowledge about what makes up marine ecosystems and how they function.

Trophic modelling

A single model cannot describe all aspects of oceanographic environment that are relevant to fisheries management. A more practical solution is a "nested" approach, in which different types of models are used for different parts of the system. An important part of this approach is a trophic model: this summarises the species present in an ecosystem, their abundances, and the quantities of one species consumed by another.

Trophic models reflect how an ecosystem operates at a range of trophic levels. At the lowest level are phytoplankton, which produce organic matter using photosynthesis. This primary production is the total amount of food available to the ecosystem: its "carrying capacity". Organic matter is then transferred through the next trophic levels (zooplankton, bacteria) to higher trophic levels including fish, squid, seabirds and marine mammals.

We now know that the main linkages among the trophic levels change depending on environmental pressures. One of these pressures is fishing, which causes varying relative abundances of different species. Another is climate variation, which leads to oceanographic changes. The combination of different pressures and the complexity of marine ecosystems means that depleting one species may affect a large number of others.

Key questions

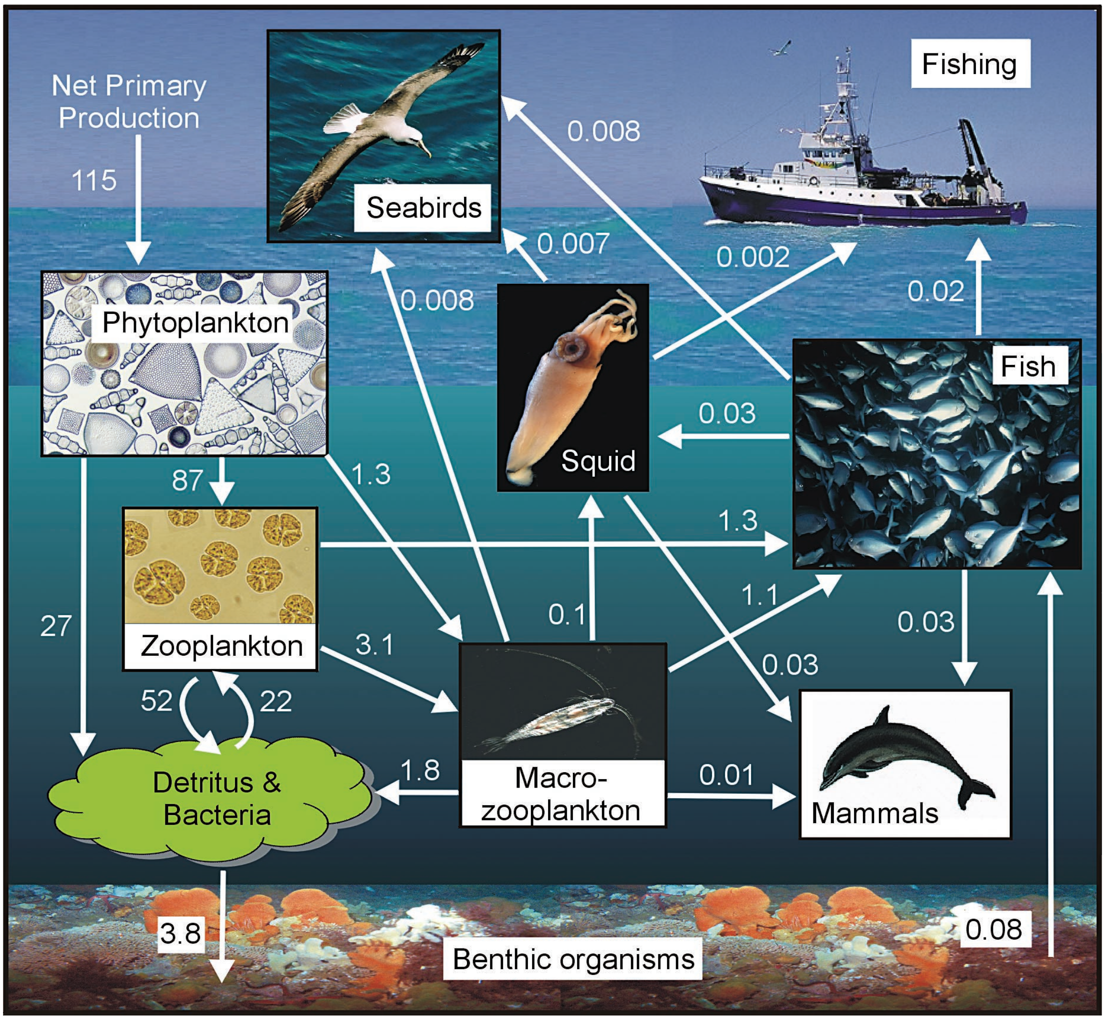
At NIWA we are using trophic modelling to tackle several key questions.

What was New Zealand's marine ecosystem like before industrialised fishing began?

We cannot determine the effects of fishing on the New Zealand marine ecosystem until we know what it was like before human intervention. There has been no research on the state of the marine ecosystem before humans arrived, or even before industrialised fishing began less than 50 years ago. It may be possible to combine an understanding of present-day trophic structure with archae-ological and Maori history sources to visualise New Zealand's pristine marine environment.

Teachers' resource for NCEA AS: Biology 1.4, 2.5; Science 2.2, 3.2. See www.niwa.co.nz/edu/resources

Matt Pinkerton and Mary Livingston are based at NIWA in Wellington.



Trophic model of the Campbell Plateau, south of New Zealand. The numbers in the figure are the amounts of carbon transferred between organisms (millions of tonnes/ year). Net primary production (phytoplankton growth) in this region generates organic matter containing about 115 million tonnes of carbon each year. Organic waste that reaches the sea-bed supports the benthic ecosystem.

This work may also help to determine the relative contributions of climate variations and fishing to changes in the marine ecosystem.

How are different species competing for food in the marine ecosystem today?

A recent NIWA study of the Campbell Plateau combined knowledge of the different parts of this marine ecosystem. One aim was to see whether there were any parts of the system that we really did not understand. The trophic model developed (above) suggested that there is enough food available to support the populations of fish and other large predators only if many of the lower trophic levels (zooplankton and bacteria especially) are more efficient than expected at exploiting the available primary production.

The results indicated that various groups of predators – commercial fishery, squid, seabirds, and marine mammals – each consume similar total quantities of organic matter, but did not show whether they were competing for particular types of fish. In a model currently being developed at NIWA for the Chatham Rise (east of New Zealand), we hope to distinguish individual fish species or groups.

How is trophic structure changing in New Zealand waters?

It is well established that fishing favours lower trophic levels at the expense of higher levels. As fishing pressure increases, the numbers of large fish and marine mammals decrease. Small fish, squid and jellyfish – all of which are more efficient at exploiting available food – then take over. Large fish are disappearing from New Zealand waters and there have been marked changes in the relative abundances of different species caught over the Chatham Rise over the last ten years. Our research aims to determine whether these changes can be explained by trophic modelling.

There is much still to be done to understand the trophic effects of fishing on New Zealand's marine environment. The work is required urgently to assess the current state of the marine environment, to predict the resilience of the ecosystem to fishing pressure, and to show how ecosystem recovery can be promoted. ■

This work was carried out in the FRST-funded programme "Ocean Ecosystems: Their Contribution to New Zealand Marine Productivity" (C01X0223).

Further reading

Bradford-Grieve, J.M. et al. (2003). Pilot trophic model for subantarctic water over the Southern Plateau, New Zealand: a low biomass, high efficiency system. *Journal of Experimental Marine Biology and Ecology 289*: 223–262.

MacDiarmid, A. et al. (2004). Taking stock – assessing the influence of humans on the structure and functioning of New Zealand's marine ecosystem over the last millennium. History of Marine Animal Populations Workshop report and project plan are available online at www.hmap.cmrs.dk/ Default.asp?ID=7 and www.cmrh.dk/HMAP/ NZPilotonepsum.pdf

Pauly, D.; Christensen, V.; Dalsgaard, J.; Froese, R.; Torres, F. (1998). Fishing down marine food webs. *Science 279*: 860–863.

Pitcher, T.J. (2000). Ecosystem goals can reinvigorate fisheries management, help dispute resolution and encourage public support. *Fish and Fisheries 1*: 99–103.