COMMENT

PAUL SUTHERLAND/NATIONAL GEOGRAPHIC/GETTY

Wandering albatrosses follow a vessel as it fishes for toothfish.

Watch over Antarctic waters

In a rapidly changing climate, fisheries in the Southern Ocean must be managed cautiously in response to data, warn **Cassandra Brooks** and colleagues.

Antartica is a "natural reserve, devoted to peace and science", according to the Antarctic Treaty System. This complex set of agreements collectively takes a firm stance on conservation, exemplified by the Convention on the Conservation of Marine Living Resources. Adopted in 1980, this convention was negotiated rapidly in response to expanding trawling of Antarctic krill (*Euphausia superba*). Krill are at the base of the region's marine food web, so there were worries that a dearth of the small crustaceans would threaten the whole ecosystem, especially whales.

The aim of the convention is to conserve all biota and ecosystems in the Southern Ocean. Although fishing is allowed, it is not a right and does not trump responsibility for conservation. The convention's provisions are strict, precautionary and science-based. Nations that are signatories must avoid significant or irreversible damage to fish and other animals that depend on them.

But the convention is failing to protect the Southern Ocean from overfishing and the impacts of climate change.

Up to 20 nations fish in these icy waters[1]. Antarctic krill and Patagonian and Antarctic toothfish (*Dissostichus eleginoides* and *Dissostichus mawsoni*) are the main quarry. More vessels and more-efficient fishing technologies are now able to catch more animals (see 'Antarctic fisheries'). Vessels using vacuum pumps can suck up 800 tonnes of krill in one day[2]. The vessels compete with birds and mammals for food, especially in the most accessible waters.

At the same time, ocean temperatures, currents and weather patterns are changing[3]. The northwest coast of the Antarctic Peninsula is one of the fastest-warming places on Earth — summer mean temperatures are on average 3 °C higher than they were in 1950. Diminishing sea ice also means fewer algae, krill and Antarctic silverfish (*Pleuragramma antarctica*). Cumulative impacts of historical and current fishing combined with environmental change have been linked to declines in populations of Chinstrap[4] and Gentoo penguins[5] (*Pygoscelis antarctica* and *Pygoscelis papua*).

Because of the convention's strict provisions, its 25-member implementing body — the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) — is widely seen as a leader in high-seas fisheries management. ▶

But some fishing states are now trying to weaken the convention's rules. China, CCAMLR's newest member (as of 2007), argues that the convention enshrines nations' rights to fish, rather than a responsibility to conserve[6]. China has also insisted that no-fishing zones are contrary to the convention, even though they are expressly included. And it has proposed that scientific evidence of a threat is required before an area is closed to fishing. Some other fishing nations, such as Russia, support this view[7].

Because CCAMLR operates by consensus, any state can block a measure that it perceives is not in its interests. For instance, in 2011, South Korea prevented the blacklisting of one of its vessels that was caught fishing illegally[8].

If fishing carries on at its current pace amid rapid climate change, prime Antarctic fisheries and marine ecosystems could collapse, as has happened elsewhere[9]. For example, in the 1990s, after politicians failed to act on scientists' warnings, the abundance of Atlantic cod (*Gadus morhua*) declined to less than 1% of historical levels[9].

We urge CCAMLR to better protect fisheries in the Southern Ocean. The impacts of climate change on populations now and in the future should be factored into decision-making, to avoid crashes in populations. CCAMLR may need to reduce or stop fishing in threatened areas or where there is high uncertainty about adverse effects. Marine reserves must be well designed, and more of them must be implemented.

CCAMLR should also do more to support basic research that is independent of the fishing enterprise. Such studies will lead to greater understanding of the dynamics of targeted species and their vulnerabilities to environmental change and overfishing.

An emperor penguin and an ice-breaker in the Ross Sea.

JOHN B. WELLER

FISHING PRESSURE

Antarctic waters have long been plundered (see also page 184). Species driven almost to extinction include elephant seals (*Mirounga leonina*), blue whales (*Balaenoptera musculus*), king penguins (*Aptenodytes patagonica*) and marbled rockcod (*Notothenia rossii*)[10]. Some have bounced back; others haven't, such as the rockcod. Even so, remoteness and harsh conditions have protected animals in the seas around Antarctica, in comparison with those elsewhere.

In the Southern Ocean, more krill are caught than any other species (by weight). About 300,000 tonnes are caught annually. They are mainly destined for omega-fatty-acid supplements and fishmeal. Most krill are caught off the Antarctic Peninsula. The industry says that such catches are small, compared with the more than 300 million tonnes of krill estimated to reside in circumpolar waters[2].

Patagonian and Antarctic toothfish each support relatively small fisheries in the Southern Ocean (see 'Antarctic fisheries'). Owing to high prices, this is lucrative. Exploitation rocketed in the 1990s, when toothfish, rebranded as Chilean sea bass, became popular in top restaurants. Illegal, unreported and unregulated fishing soared and ravaged populations; illegal fishers took six times more fish than did legal vessels[11]. CCAMLR turned this situation around by documenting catches, monitoring vessels and black-listing those that did not comply. Illegal catches fell from 33,000 tonnes in 1996 to less than 2,000 tonnes by 2007 (ref. 11). Nonetheless, many Patagonian toothfish populations crashed, and remain depleted, notably those around the Prince Edward Islands, BANZARE Bank and Kerguelen Plateau.

> *"Some scenarios may require reduced catches, or allocations that are restricted, temporally or spatially."*

The life cycles of toothfish make them particularly vulnerable, as well as difficult to study. They mature late, grow slowly and can live for 50 years. No one knows how many there are in the Ross Sea, the main international fishery for toothfish. Nor does anyone know when, where or how often they spawn[9]. They are the top fish predator in the Southern Ocean, and they are also key prey of Weddell seals (*Leptonychotes weddellii*) and killer whales (*Orcinus orca*), and compete for smaller fish with Adélie penguins (*Pygoscelis adeliae*).

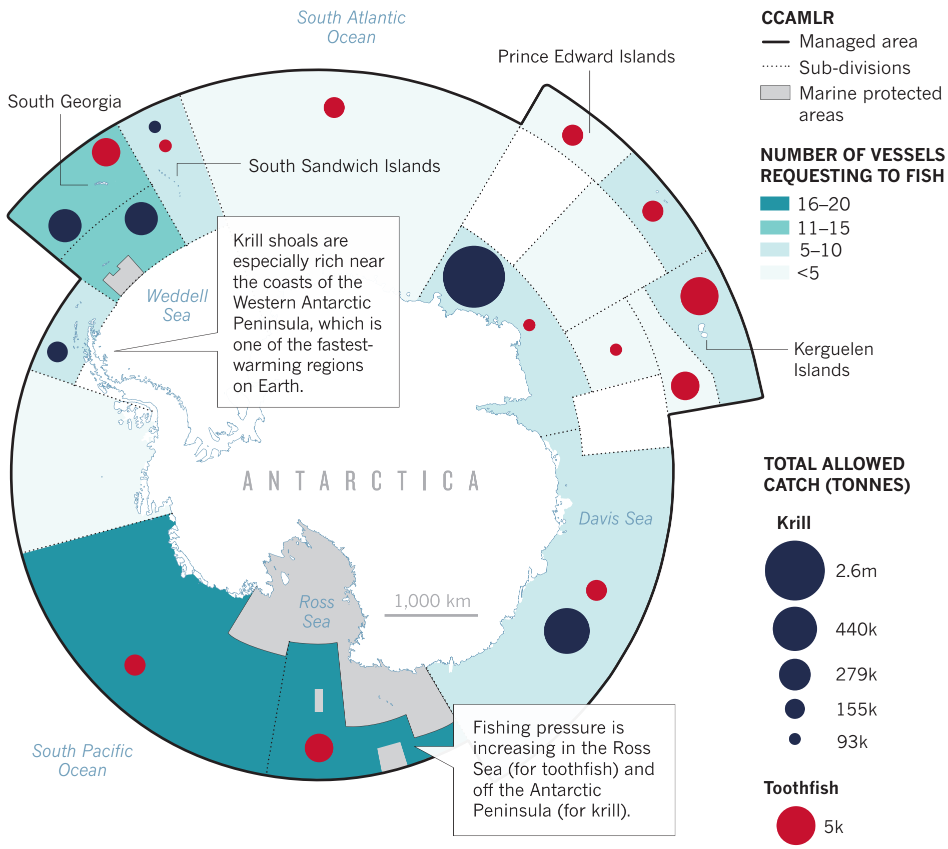
Fishing states want more. Russia is trying to increase its toothfish catch and send its fleets into unfished areas such as the Weddell Sea[5]. Ukraine wants to capture more krill[5]. New Zealand and Australia, among others, have extended their reach into toothfish areas[1]. Other nations, including Namibia and Uruguay, signed the convention to gain fishing and market access[1].

KNOWLEDGE GAPS

Climate change compounds the problem. But environmental effects are difficult to disentangle from the consequences of fishing. For example, scientists do not know whether toothfish fishing or encroaching ice is behind the changing prevalence of killer whales in the southern Ross Sea[12].

More data would help. But research in the Southern Ocean is difficult and expensive. Much of what is known about toothfish is gathered by the fishing industry, which does not collect environmental data. There are many gaps. We have much to learn about the life histories and population dynamics of the species being caught and how environmental changes affect their birth and death rates. There are few quantitative studies of connections among targeted organisms in the food web.

The long-term ecological research (LTER) programme, based at Palmer Station on the west of the Antarctic Peninsula, is unparalleled in its multi-faceted approach. It gathers information, for example, on how fluctuating sea ice influences krill and other small organisms. CCAMLR also has an ecosystem



ANTARCTIC FISHERIES

Krill and toothfish received the largest catch allowances in the Southern Ocean in 2017–18. They are increasingly exploited in spite of tight management by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

SOURCE: WWW.CCAMLR.ORG

monitoring programme designed to study krill-fishing impacts on land-breeding marine predators. However, these data are not effectively incorporated into decision-making.

CCAMLR acknowledges that it must account for the impacts of global warming in its policies. In 2017, it produced a Climate Change Response Work Programme to specify research and monitoring requirements and potential actions[13]. It says it will engage climate-change experts. But progress is slow, and climate change is not. CCAMLR's rules and catch allocations are still based on models that do not consider climate-change scenarios.

ADAPTIVE ANALOGUES

Responsive, ecosystem-based fisheries management is still being developed. Lessons are emerging from around the world. CCAMLR already has the policy tools to benefit.

Adaptive management is in place off the US West Coast. Since 2015, on the basis of stock surveys and climate indicators, the Pacific Fisheries Management Council has temporarily banned fishing of sardines (*Sardinops sagax*). The closure of this large fishery (109,000 tonnes in 2012) is bringing hardship now. But higher levels of fishing may be possible in future when indicators allow.

A moratorium on fishing in the polar waters of the Arctic is relevant to the Southern Ocean. The 2.8-million-square-kilometre area was not fished before 2017 because it was frozen for much of the year. Now, as around the Antarctic Peninsula, reductions in summer ice are making the area more accessible. In 2017, states bordering the Central Arctic Ocean adopted the Arctic agreement, pledging not to fish there for 16 years, to allow scientists to study of the impacts of climate change first.

In other words, countries can come together to protect sensitive fisheries and the environment, and to support research. The moratorium came about because bordering nations were concerned about over-harvesting. For example, Bering Sea pollock (*Gadus chalcogrammus*) has yet to recover from stock depletion in the 1980s and 1990s. This prompted 2,000 scientists to petition for a fishing ban in 2012. Three years later, the ban was implemented by the United States, Norway, Denmark, Canada and Russia. China, Japan, Korea, Iceland and the European Union have joined since.

Such multi-national cooperation bodes well for the development of strategies for future Arctic fishing that are precautionary and ecosystem-based. Most of these countries are also CCAMLR members. Their willingness to show restraint in the face of uncertainty in the north could be paralleled in the south.

THREE SOLUTIONS

Given the threat posed by climate change, what are the conditions under which fishing can continue and still meet the precautionary provisions of the convention? To avoid passing tipping points in the marine food web, CCAMLR needs to take the following three steps.

Implement more and better-designed marine reserves. CCAMLR has established two, one in the Ross Sea and one in the South Orkney Islands Southern Shelf, off the eastern tip of the Antarctic Peninsula.

Neither includes comparable reference areas for monitoring fishing against environmental impacts. The Ross Sea protections are set to expire 35 years after they began, which is less than the lifespans of many of the animals intended for protection, such as toothfish. Future closures must ban fishing in the most ecologically crucial areas. The protections should last at least as long as the life expectancies of the animals being safeguarded. And they should include comparable reference areas outside the no-fishing zone.

Incorporate climate-change scenarios into decision rules. Current management measures, including catch quotas, are based on models that do not include climate-change scenarios. An environmental shift could cause a population crash in the harvested species or some other species in its food web. To protect against these crashes — and to comply with the provisions of the convention — CCAMLR must be more precautionary and adaptive. This may mean that quotas are reduced, or that allocations are more temporally and spatially explicit. If the threat of overfishing is deemed readily apparent, or if the level of uncertainty is too high, then CCAMLR may need to temporarily close regions of the Southern Ocean to fishing.

Develop more-robust research and monitoring programmes. The Scientific Committee on Antarctic Research (SCAR) should first compile the available information and ongoing research regarding the effects of climate change and fish populations in Southern Ocean ecosystems. The committee undertook these analyses for krill, before establishing the CCAMLR convention. SCAR should then work with CCAMLR scientists, independent experts and non-governmental organizations to identify crucial questions, and what is required to answer them. CCAMLR needs to be more transparent and to invite SCAR and other independent experts into its scientific working groups, from which they are currently excluded.

Governments that are part of CCAMLR will need to fund the research and monitoring efforts, which must be independent of the fishing industry. The Palmer LTER programme shows that the techniques are available, but investment is needed to expand the scientific reach.

CCAMLR states have acted quickly in the past, but change is accelerating in the Southern Ocean. Countries must rise swiftly to this challenge. ■ SEE INSIGHT P.199

Cassandra M. Brooks *is an assistant professor in the Environmental Studies Program, University of Colorado Boulder.* **David G. Ainley, Peter A. Abrams, Paul K. Dayton, Robert J. Hofman, Jennifer Jacquet, Donald B. Siniff.**
e-mail: cassandra.brooks@colorado.edu

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Pandemics: spend on surveillance, not prediction

Trust is undermined when scientists make overblown promises about disease prevention, warn **Edward C. Holmes**, **Andrew Rambaut** and **Kristian G. Andersen**.

The resurgence of Ebola virus in the Democratic Republic of the Congo this May is a stark reminder that no amount of DNA sequencing can tell us when or where the next virus outbreak will appear. More genome sequence data were obtained for the 2013–16 Ebola epidemic than for any other single disease outbreak. Still, health workers in Mbandaka, the country's northwestern provincial capital, are scrambling to contain a growing number of cases.

Over the past 15 years or so, outbreaks caused by viruses such as Ebola, SARS and Zika have cost governments billions of US dollars. Combined with a perception among scientists, health workers and citizens that responses to outbreaks have been inadequate, this has fuelled what seems like a compelling idea. Namely, that if researchers can identify the next pandemic virus before the first case appears, communities could drastically improve strategies for control, and even stop a virus from taking hold[1,2]. Indeed, since 2009, the US Agency for International Development has spent US$170 million on evaluating the "feasibility of preemptively mitigating pandemic threats"[1].

Various experts have flagged up problems with this approach (including the three of us)[3,4]. Nonetheless, an ambitious biodiversity-based approach to outbreak prediction — the Global Virome Project — was announced in February this year, with its proponents soliciting $1.2 billion in funding from around the world (see 'High stakes'). They estimate that other mammals and birds contain 1.67 million unknown viruses from the families of viruses that are most likely to jump to humans, and will use the funding to conduct a genomic survey of these unknown viruses, with the aim of predicting which might infect people[1].

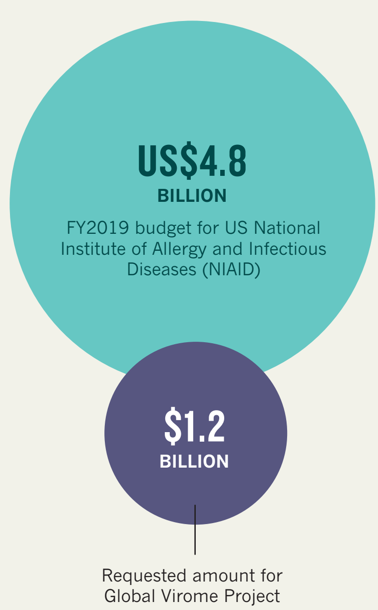
Broad genomic surveys of animal viruses will almost certainly advance our understanding of virus diversity and evolution. In our view, they will be of little practical value when it comes to understanding and mitigating the emergence of disease.

We urge those working on infectious disease to focus funds and efforts on a much simpler and more cost-effective way to mitigate outbreaks — proactive, real-time surveillance of human populations.

The public has increasingly questioned the scientific credibility of researchers working on outbreaks. In the 2013–16 Ebola epidemic, for instance, the international response was repeatedly criticized for being too slow. And during the 2009 H1N1 influenza epidemic, people asked whether the severity of the virus had been overblown, and if the stockpiling of pharmaceuticals was even necessary[5]. Making promises about disease prevention

HIGH STAKES

Estimated cost of surveying 1.67 million animal viruses is equal to one-quarter of the NIAID's budget for infectious-diseases research.



SOURCES: NIH; GLOBAL VIROME PROJECT