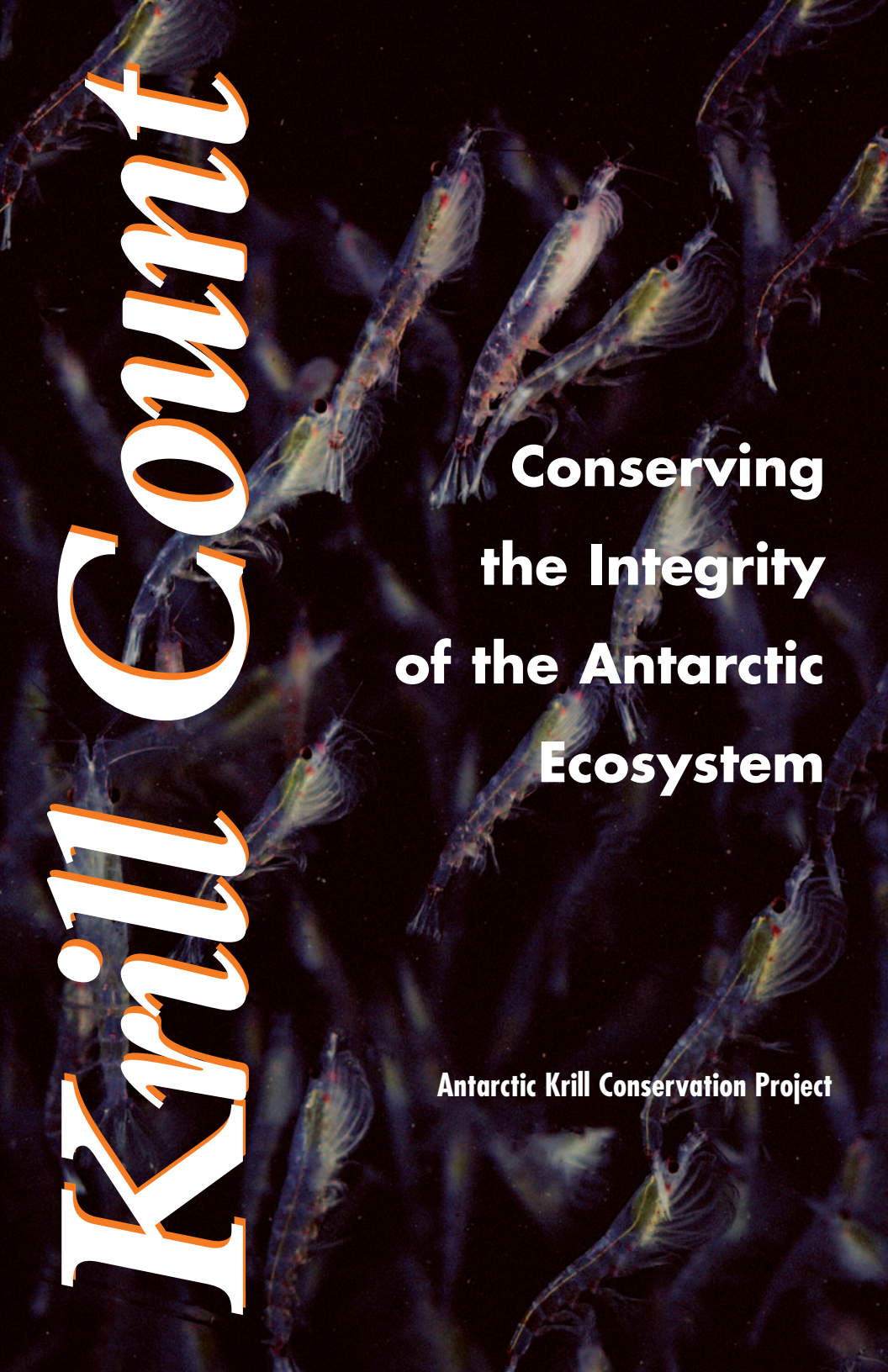
Krill Count
Conserving the Integrity of the Antarctic Ecosystem
Antarctic Krill Conservation Project


Antartic Circle
Filchner Ice Shelf
Larsen Ice Shelf
Ronne Ice Shelf
Palmer Land
Alexander Islamd
Ellsworth Land
Bellingshausen Sea
Amundsen Sea
Marie Byrd Land
Ross Sea

Krill Count

Conserving the Integrity of the Antarctic Ecosystem

Antarctic Krill Conservation Project

The Antarctic Krill Conservation Project is a cooperative effort by conservation organizations worldwide dedicated to the protection of Antarctic krill to conserve the region's marine ecosystem. Core partners are the Pew Charitable Trusts, Antarctic and Southern Ocean Coalition, and National Environmental Trust.

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Executive Summary

Antarctica harbors one of the most extreme yet abundant ecosystems on Earth, supporting vast populations of penguins, seals, whales, and fish that flourish in its frigid waters. These and dozens of other species are sustained by Antarctic krill, small, shrimp-like animals that swim in dense swarms that can extend over many kilometers. Krill are the basis of Antarctica's food web. Without them, this continent and the oceans around it would be a virtual wasteland.

Although covered in ice most of the year and inhabited by few humans, the Antarctic has not escaped exploitation. In the nineteenth century, hunters nearly exterminated the region's seals. In the early twentieth century, tens of thousands of whales were slaughtered. Most recently, some stocks of Patagoniam toothfish (popularly known as Chilean Sea Bass) have been fished almost to extinction.

Antarctic krill may be over-exploited next.

During the past half century as fisheries in the Northern Hemisphere declined, Antarctica's bountiful waters have attracted an increasing array of industrial fishing fleets intent on supplying growing and increasingly lucrative markets. Due to the rapid growth of commercial fishing in the region and the slow pace of international decision making, however, many of these fisheries have been only loosely regulated.

Ironically, the explosive growth of fish farming—primarily salmon—is luring fishermen to this remote region in search of krill as a source of fish oil and meal for the aquaculture industry. Krill's nutrients are also being exploited by the health food and pharmaceutical industries. As industrial fishing vessels trawl for krill in near-shore waters, close to rookeries and feeding grounds, they compete directly with whales, penguins, seals, albatross, and petrels.

Now, a type of technologically sophisticated factory trawler, new to the krill fishery, is poised to increase production of krill products for aquaculture. In addition, melting of the ice cover in the Antarctic due to global warming threatens the entire ecosystem and poses a particular problem for

krill. These pressures make the need for ecologically sound management measures especially urgent. To ensure the sustainability of the Antarctic food web, krill need more protective measures. These must take into account the ecological relationships among krill, dependent species, and commercial fishing.

Antarctic krill are managed under the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), part of the Antarctic Treaty System. Bound by a fundamental commitment to ecosystem-based management and a precautionary approach to the use of marine resources, CCAMLR is gradually moving to establish greater regulatory oversight and better management of krill. But time is of the essence.

International policymakers need to act now within CCAMLR to adopt precautionary management measures to ensure that krill can be fished and still remain an abundant food source for its natural predators.

Therefore, the Antarctic Krill Conservation Project calls on CCAMLR to adopt measures that ensure:

- *Management of Antarctic krill with the same oversight as all other Antarctic fisheries, including the immediate adoption of measures to mandate on-board scientific observers, improved fisheries data reporting, and tamper-proof, satellite-linked Vessel Monitoring Systems.*

- *Division of catch limits on the basis of small-scale management units that ensure krill remain an abundant and available food source for their natural predators.*

- *Improvement of scientific research programs in the Southern Ocean to ensure that decisions are made on the basis of the best scientific information, and that the effects of krill fishing on key species and other ecosystem elements are identified in a timely manner.*

ANTARCTIC KRILL— *EUPHAUSIA SUPERBA*

Antarctica is one of the most remarkable places on Earth. Surrounded entirely by the frigid but biologically rich Southern Ocean, this icy continent is home to a fabled group of birds and mammals, including penguins, whales, albatross, and seals. Critical to the survival of these species and their habitat are a group of tiny crustaceans collectively known as Antarctic krill.

Encompassing over 80 species of open-ocean creatures scientifically classed as Eupausiids, Antarctic krill are about 2 ½ inches long (6 centimeters) and weigh 0.07 ounces or roughly two grams. Yet these little creatures are distinctive on several scores. Krill are one of the world's most abundant multi-celled animals,[1] producers of the most powerful enzymes yet discovered to break down proteins,[2] and collectively thought to be one of the largest aggregations of marine life on the planet.[3]

Krill are considered by many to be the most abundant multi-celled animals on the Earth.

In the water, krill have an exotic appearance, with a translucent, reddish shell and large black eyes. Krill spend most of their 5-7 year lifetime in huge schools or "swarms," living in concentrations so dense and vast that they cover kilometers in every direction with as many as 30,000 krill per cubic meter. Estimates of the total weight of Antarctic krill range from 50 to 500 million metric tonnes.

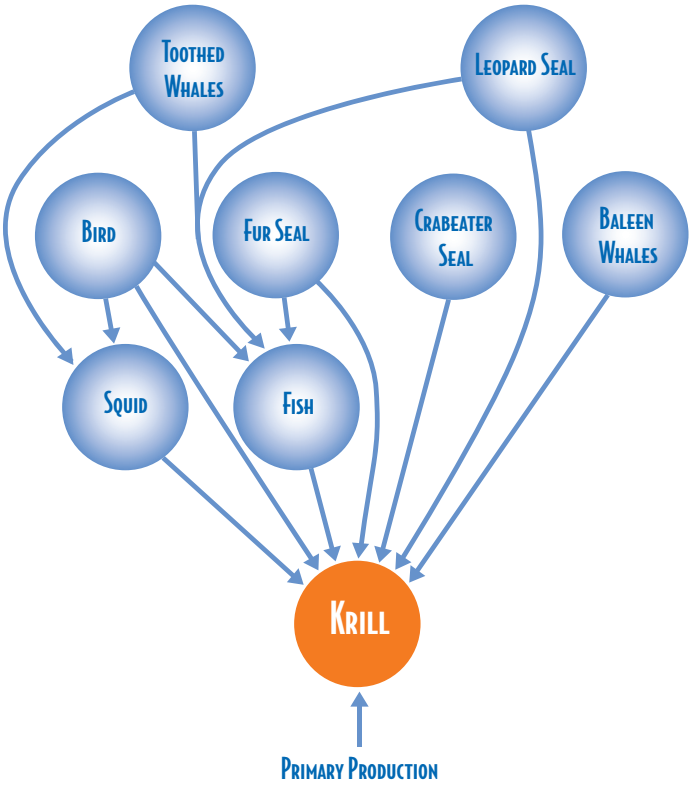
Survivor

How this tiny crustacean can survive the harsh Antarctic winter where land temperatures reach –57° F remains a mystery. Like all crustaceans, krill grow by molting, casting off their old confining shell so that they can expand while the new one is still soft. Krill do not build up large fat reserves, but in the winter they survive on algae that grow on the underside of pack ice. Studies also indicate that krill's survival may be due to their unique ability to withstand as many as 200 days without food by drastically slowing their metabolism.[4]

Sustaining Antarctica's Food Web

Antarctic krill are at the heart of the Southern Ocean and South Atlantic food web, sustaining hundreds of species of fish, squid, whales, penguins, seals, albatross, and petrels.[5] The highest concentrations of krill tend to be within easy reach of land-based breeding colonies of birds and mammals. This provides an accessible food source for both adults and their offspring during the Antarctic summer.

Fig. 1–Simplified Representation of Southern Ocean Food Web Linkages Dependent on Krill



Source: I. Everson, "Role of krill in marine food webs, the Southern Ocean," *Krill: Biology, Ecology and Fisheries* (I. Everson, ed.), Fisheries and Aquatic Resources, Series 6, Oxford: Blackwell Science, 2000.

Major Species Dependent on Krill

Penguins: A symbol of Antarctica, penguins are highly dependent on krill, a major source of food. Specific types include emperor, adelie, chinstrap, macaroni, and gentoo penguins.[6]

Whales: Krill is by far the most important item in the diet of minke whales.[7] Other important consumers of krill are blue, fin, sei, and humpback whales, which migrate to the Southern Ocean during the summer to feed. Blue whales can consume up to four tonnes of krill per day.

Albatross: Forty percent of the diet of black-browed and light-mantled albatross consists of Antarctic krill.[8]

Petrels: In general, petrels feed extensively on Antarctic krill. The percentage of krill in their diet varies depending on the type, but it seems to be very high in smaller petrel species.[9]

Seals: All species of Antarctic seals, except for southern elephant seals, feed on krill. They are the major food for the Southern Ocean's 12 million crabeater seals and make up about 50 percent of the diet of leopard seals. Fur seals also feed extensively on krill, but can survive on fish and squid if krill are scarce.[10]

An Ally Against Global Warming

Recent research has discovered that these tiny creatures also provide another environmental benefit. Krill help sequester carbon dioxide, thus reducing greenhouse gases in the atmosphere. Submerging deep in the ocean to avoid predators during the day, at night these crustaceans rise to the surface where they eat phytoplankton. During feeding, krill periodically dive to great depths, releasing

carbon into the deep sea. One study estimates the amount of CO_2 ultimately transferred to the ocean floor by millions of krill equals the annual emissions of 35 million automobiles.[11]

WARNING SIGNS

A number of convergent factors have the potential to transform the Antarctic krill fishery and these need to be closely monitored. Increasing demand for krill and its by-products, more efficient ways to harvest it, ecosystem changes from global warming, and mounting pressure to protect the Antarctic ecosystem from exploitation are bringing the issue to a head. For almost four decades, the Antarctic krill fishery has been the largest in the Southern Ocean, and now this species may become the most heavily fished in the world.[12]

Until the early 1990s, the Soviet Union led in harvesting Antarctic krill, but following the Republic's break-up in 1991, Japan moved in front, accounting for more than 50 percent of the annual catch; in some years it landed as much as 75 percent.[13] Now, however, Norway is emerging as the undisputed leader in krill fishing.

"Vacuuming" Krill.—Krill's behavior has always made them easy to catch in large numbers. Swimming beneath the ocean's surface, swarms of krill are easy to

This Antarctic panorama shows endless snow-covered mountains surrounded by the Southern Ocean.

spot, remain in the same area for days or even weeks, and tend to return to the same place year after year.[14] The giant aggregations of these tiny crustaceans are no match for today's state-of-the-art industrial trawlers. The latest generation of commercial vessel is literally a floating factory, employing sophisticated methods to land, process, and flash-freeze their catch. Currently, one of these factory trawlers, the *Saga Sea* operated by the Norwegian multi-national corporation Aker ASA, has been outfitted with equipment that enables it to continuously vacuum millions of krill from the ocean, potentially harvesting as much as 120,000 tonnes in a single fishing season. Only Aker is testing this technology at the moment, but other vessel owners and national authorities are keen on adopting it. In addition, these vessels are capable of "continuous trawling . . . for weeks at a time."[15] The use of this technology could significantly increase the total amount of krill harvested in a given year.

Norwegian fishery officials are monitoring operations by placing international and national observers on board the *Saga Sea*. Nevertheless, there is potential for a dramatic increase in overall krill catches with this new technology. This development needs special attention because the fishery operates in small areas overlapping with important foraging grounds for penguins and seals that depend on krill to rear their young.

While the krill catch remained steady at around 100,000 tonnes annually from 1990 to 2000, there has been a clear upward trend since 2001. In the two years

that a "vacuum" trawler was used in Antarctica, it took 25% of the krill catch the first year and 38% the second, although it was only one of nine vessels engaged in this fishery.[16]

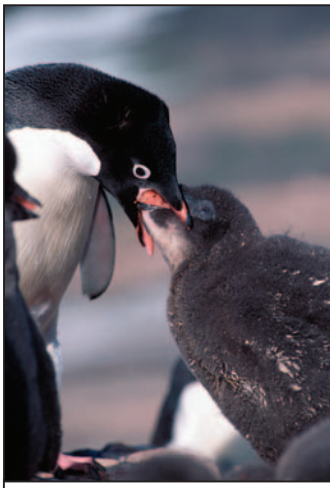
Aquaculture.—The greatest demand today for Antarctic krill comes from the aquaculture industry, which is literally running out of food to sustain its rapid growth. According to the industry's own sources, fish farming already uses about 75 percent of the world's fish oil and 40 percent of its fish meal—numbers that could reach 79 percent and 48 percent respectively by the end of this decade.[17] One aquaculture company executive projects, in fact, that within 10 years the industry could consume all of the available fish meal and fish oil.[18]

With demand exceeding supply and prices rising, fish oil has been labeled "the new blue gold."[19] Many of the fish species historically harvested by aquaculture for fish oil and meal, such as Peruvian anchoveta, are already fully exploited with their harvests capped in many areas. Krill appear to be the perfect alternative. They are very high in protein and essential amino acids. They also have lower levels of pollutants, a problem that has plagued other sources of fish oil and meal up to this point. In addition, krill are an especially desirable feed for salmon aquaculture because their pigment is a natural source of salmon's trademark "pink" color.

Omega-3 Fatty Acids.—Krill have high concentrations of Omega-3 fatty acids that are increasingly marketed as dietary supplements for cardiovascular health and longevity. While Omega-3 can be extracted from other fish, such as menhaden and sardines, an aggressive effort is underway to promote Omega-3 oil from krill as a more powerful antioxidant than other fish oils. Again, the dietary supplement industry touts lower levels of contaminants such as mercury, dioxins, and PCBs in Antarctic krill.[20]

Medicine.—Krill's powerful hydrolytic enzymes have potential in pharmaceutical use as well. Some medical experts now promote krill oil's antioxidants for more rapid healing after surgical procedures. Other researchers have reported excellent results in treating high cholesterol with krill oil.[21]

Competition with Predators.—Not only the increasing size of the krill catch, but also its geographic distribution has raised concerns among scientists. Recent studies show that the industrial harvest of Antarctic krill occurs almost entirely within the foraging ranges of land-based predators such as penguins.[22] There is evidence that competition between fishing vessels and krill predators already exists in some areas, particularly at breeding times when food scarcity impacts reproductive success.[23] For example, in the Antarctic Peninsula, the summer fishery takes place at the same time and in the same areas where penguins and seals forage to feed their young.



An Adelie penguin feeds her chick a slurry of krill. These penguins are so dependent on this crustacean, that scientists use them as an indicator species to monitor the abundance of krill.

Recent field research by the British Antarctic Survey shows that the demand for krill has begun to exceed supply for predator species in some areas of the southwest Atlantic. As a result, there is evidence that penguins and albatross are having difficulty rearing offspring successfully. Monitoring of sea birds and seals over 20 years on South Georgia, an island in the Southern Ocean, also has revealed an increase in the frequency of years when there is insufficient krill to feed seal pups and seabird chicks.[24]

Global Warming.—Scientists have noted a relationship between krill abundance and sea ice coverage. Already one of the world's climate change 'hotspots,' significant temperature increases in Antarctica over the past 30 years have resulted in fewer months of winter sea ice coverage. This has potentially serious consequences for krill, because their key spawning and nursery areas are located near pack ice. The effects of climate change on the Antarctic environment and its inhabitants have not yet been taken into account by Antarctic management regimes.[25]

By-Catch.—Although previously overlooked, conventional krill trawling results in the by-catch of large marine mammals. According to CCAMLR's Scientific

Committee,[26] reports from voluntary observers on board six krill vessels during the 2004 fishing season recorded entrapment of 292 Antarctic fur seals. One of these vessels had caught some 154 seals, of which 142 were killed. These reports do not include undetected marine mammal mortality caused by krill trawlers with no observers on board. CCAMLR's Scientific Committee recommended that all vessels engaged in the krill fishery use seal excluder devices to minimize by-catch and that they carry observers to assess their effectiveness.[27] These recommendations have not yet been adopted as binding measures.

Krill Fishery Closings in the Northern Hemisphere.—The recent closing of krill fisheries in the North Pacific is likely to intensify pressure on Antarctic krill populations. In March 2006, the management council for Pacific fisheries closed U. S. waters to krill harvesting off California, Oregon, and Washington to protect the sustainability of that marine ecosystem.

Ultimately, the combined impact of these factors on krill abundance could outpace efforts to protect krill and the species that depend on them. Increasing harvests by massive trawlers, growing demand by aquaculture, burgeoning dietary and medical interest in krill oil, and the spreading effects of global warming now bring a new urgency to the task of conserving Antarctic krill and the Southern Ocean ecosystem.

CONSERVATION OF KRILL

CCAMLR owes its origins to the realization that the Antarctic's living organisms needed protection from human exploitation.[28] The one species of greatest concern at CCAMLR's founding in the late 1970s was krill. The mandate of the Convention is to conserve marine life for the mutual benefit of the ecosystem and for reasonable human benefit.

CCAMLR: Coming Full Circle

Today, CCAMLR is regarded as a leader in ecosystem management. It was a pioneer in formulating principles for ecosystem-based management and in applying the precautionary principle to its decisions. These tenets require

Blue whales rely on krill for survival. These huge mammals can eat up to four tons of krill in a single day.

decision-makers to take into account the health of the whole marine ecosystem when managing individual fish populations and to prevent or minimize the risk of irreversible harm to the marine environment. Ecosystem-based management and the precautionary principle in fisheries management were later embraced by numerous organizations at the national and international levels, including the United Nation's Food and Agriculture Organization, the United Nations Fish Stock Agreement, the International Council for the Exploration of the Sea, the European Union's Marine Strategy, and the U. S. Oceans Commission. Undercutting CCAMLR's good intentions, however, is the reality of its charter: members are obliged to make decisions by consensus. Thus, one negative vote can block an important conservation measure.

Monitoring, Control, and Surveillance

Despite krill's central role in the Antarctic ecosystem, the fishery is still exempt from most controls applied to other CCAMLR fisheries. Although CCAMLR's own scientific experts continue to call for complete observer data, which is essential for developing proper management advice and is mandatory for all

other vessels fishing in the Southern Ocean, krill trawlers are still exempt from this measure.

Nations engaged in the krill fishery are encouraged to volunteer information on their fishing intentions, but it is not required. CCAMLR's Scientific Committee, however, needs complete fishing plans from all nations operating in the region in order to predict trends and to manage the krill fishery sustainably.

Unlike other fisheries regulated by CCAMLR, krill vessels are not required to be outfitted with an onboard, satellite-linked Vessel Monitoring System (VMS). These devices allow CCAMLR member nations to monitor the position of all of their vessels licensed to fish. Without mandatory electronic monitoring, however, krill vessels are poorly regulated and difficult to track.

Limiting Krill Catch

Currently, CCAMLR conservation measures for Antarctic krill are unable to ensure that no irreversible harm to the ecosystem will occur from fishing. Although harvesting levels for krill are still well below established catch limits, these limits are set for large areas of the ocean and do not take into account the ecological relationships between krill, predators, and fishing operations—interactions that occur on a scale of a few miles, not hundreds.[29]

Half the food consumed by crabeater seals consists of krill.

In 2000, CCAMLR established catch limits for krill in the Atlantic sector of the Southern Ocean, known as Area 48, where the fishery is concentrated. The cap was set at four million tonnes, allocated over four sub-areas. The Area 48 formula was further refined to require that once the total catch reached 620,000 metric

tonnes, it would "trigger" a further subdivision of catch limits into smaller units. This provision, agreed to in 2002, was intended to provide a geographic distribution of the fishing effort to protect the food supply of krill predators from local depletion.[30] In 2002, CCAMLR drew the lines to divide Area 48 into 15 smaller units, but has yet to set specific catch limits for each one.

Presently, a process by CCAMLR's scientific bodies is underway to determine how the catch limit for krill should be allocated among these smaller units. Until this is completed, the industry is allowed to catch up to 620,000 tonnes in the more profitable fishing areas, even though these coincide with important feeding grounds for land-based krill predators.

CHARTING A COURSE FOR ACTION

The future of Antarctica's food web stands at a crossroads. Krill are the prime food source for critical species of fish, birds, and marine mammals found only on this continent. But the potentially insatiable appetite for krill products, coupled with technology now capable of fulfilling it, does not bode well for the future of this vast and unique ecosystem which is also threatened by global warming. CCAMLR's management system has yet to integrate the combined effects of these phenomena into its decision-making.

Prudent steps—if taken soon by CCAMLR—can ensure that this vital marine resource and the Antarctic ecosystem it sustains are protected now and for the future. This offers CCAMLR an unprecedented opportunity to develop a model for marine ecosystem-based management that could be applied to oceans worldwide.

Demand for krill may be exceeding supply for predators such as this black-browed albatross and its chick. Albatross are having difficulty rearing offspring successfully due to the shortage of krill.

The *Antarctic Krill Conservation Project* calls on all CCAMLR member states to enact measures that will ensure:

- Management of Antarctic krill with the same oversight as all other Antarctic fisheries, including the immediate adoption of new measures to mandate on-board scientific observers, to improve fisheries data reporting, and to require tamper-proof Vessel Monitoring Systems on all krill trawlers.

- Establishment of catch limits on the basis of small-scale management units that ensure krill remain an abundant and available food source for natural predators.

- Improvement of scientific research programs in the Southern Ocean to ensure that decisions are made on the basis of the best scientific information, and that the effects of fishing on key species and other ecosystem elements are identified in a timely manner.

To accomplish these objectives, CCAMLR should:

- Enlist the scientific community to undertake enhanced monitoring of sites and predators to better assess the impact of the current and projected krill harvest on the Southern Ocean ecosystem.

- Engage decision makers, scientists, and NGOs to increase the global profile of Antarctic conservation issues, including krill.

- Ensure that the impact of climate change is factored into management decisions pretaining to krill and the species that depend on them.

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