A Look Below the Surface

By Stephen Nicol, PhD

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Antarctic Krill
SUSTAINABILITY

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Antarctic Krill are small crustaceans – like prawns or shrimps – which swim in the Southern Ocean. Species of krill occur in most oceans but it's only around Antarctica that one species, known as Antarctic krill, plays such a dominant role in the marine ecosystem.

Antarctic krill sit in the middle of the ecosystem between the microscopic plants and animals, which form the base of the food chain, and the larger animals such as seals, penguins and whales that depend on them for food. They can reach a length of 6 cm and weigh 2 grams, so they are quite large compared to other krill species.

In terms of behavior, Antarctic krill swim in vast, dense swarms that can stretch for miles, making them a particularly appealing food source for larger animals such as whales. Swarming krill are also attractive to a fishery because they are large, easy to catch and hugely abundant. In fact, there are estimated to be between 120 and 600 million tons of krill, making them amongst the most abundant animal species on the planet (Atkinson et al., 2009).

Where it all begins

Krill start life as microscopic eggs that are spawned to the ocean surface. They then sink to great depths to develop and hatch before swimming to the surface to begin feeding. A female krill can lay thousands of eggs, several times during the short Antarctic summer. When the newly hatched larvae arrive at the ocean surface in autumn they must eat fast, so they can survive the long ice-covered winter.

As far as feeding, krill larvae eat ice-trapped algae, using the complex under-ice habitat as a nursery ground. In spring, the ice melts and the larvae – now juveniles – are released into the open ocean where they begin to form aggregations like those of the adults.

Antarctic krill thus have a complicated life history, changing size, shape and habitat as they grow (Nicol, 2006). They mature at two years old and can live for up to 11 years. Adult krill are now known to be capable of living anywhere in the Southern Ocean – from the very surface layer to the seafloor, and from inshore areas to the deep open ocean. Antarctic krill perform daily migrations, approaching the surface at night and remaining in the dark, deeper waters during the day.

But they are not simple animals and adopt different behaviors in response to a changing seasonal environment, staying deeper in winter and migrating offshore to spawn. Their huge schools or swarms can form or disperse unpredictably in response to subtle environmental cues, and their distribution and abundance is undoubtedly affected by currents, tides and storms. At the same time, there are many aspects of krill behavior that remain a great mystery.

Environmental change and the impact on krill

Because larval Antarctic krill are associated with the sea ice that grows during winter they are thought to be vulnerable to any climatic changes that might affect the amount of ice that forms around the Antarctic continent annually. Krill larvae are also most sensitive to fluctuations in food availability (the adults can tolerate starvation for extended periods) and they have also been shown to be affected by increasing acidity of the ocean (Kawaguchi et al., 2013). Environmental changes that affect krill have repercussions that flow onto the rest of the ecosystem, so considerable research is underway to examine the potential effects of a warmer, more acidic ocean on the populations of krill in the Southern Ocean (Flores et al., 2012).

Antarctic krill exist in a vast area estimated to be at least 19 million Km2 (approx. 7 million square milles), which is more than twice the area of the U.S. (Atkinson et al., 2009). Because the home range of krill is so large it has proved impossible to measure how much is out there at any one time. Further complicating matters, this region is impenetrable for much of the year due to ice cover and the fact that the Southern Ocean is the stormiest in the world. Technical problems also mean that measuring krill is an imprecise science (Nicol and Brierley, 2010). As a result, it is extremely difficult to know with any degree of certainty whether the krill population is increasing or decreasing.

Establishing the modern-day krill fishery

It has been suggested that the removal of the Great Whales (which consumed an estimated 150 million tons of krill a year prior to their exploitation) in the last century would have allowed the krill population to explode and that this would have also allowed populations of other species, such as seals and penguins, to increase dramatically (Ballance et al., 2006). But there is little unambiguous historical data that shows this took place. Experts have also suggested that the krill population crashed in the 1980s, but again it is difficult to find supporting evidence for this theory (Atkinson et al., 2004).

Additionally, regular acoustic surveys of krill biomass off South Georgia and the Antarctic Peninsula have failed to detect any systematic change in the krill population (Reiss et al., 2008, Fielding et al., 2014) over the last 20 years.

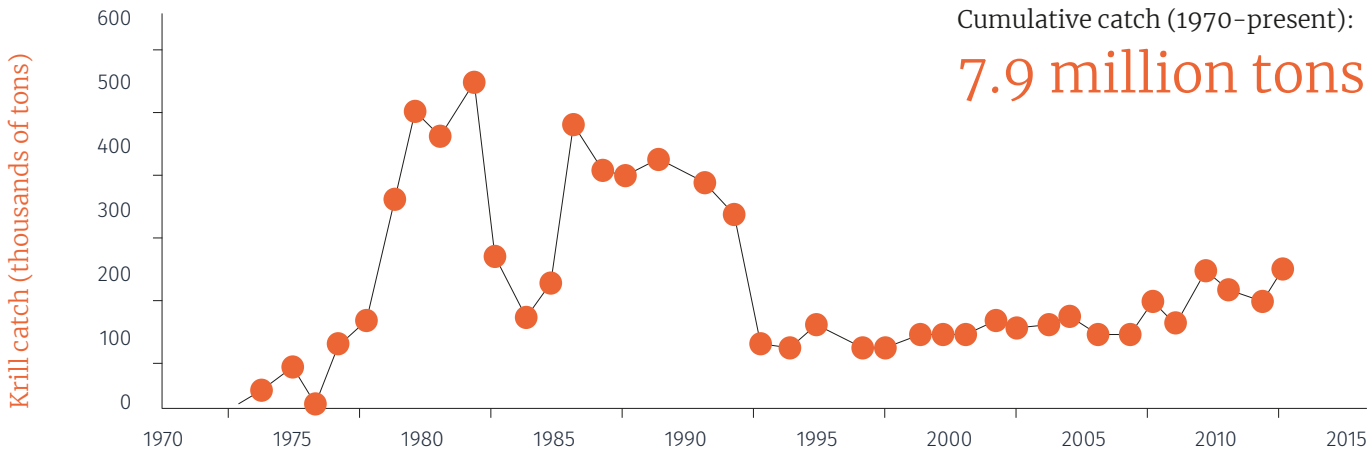
Today, most of the large Antarctic animals that depend on krill as a food source are relatively healthy, with populations of species such as Adelie penguins, fur seals and humpback whales increasing dramatically during the last 30 years. There are penguin populations in some areas that have undergone declines (Trivelpiece et al., 2011) however many populations of Adelie penguins, which feed largely on krill, have undergone considerable increases in population sizes over the last few decades (Southwell et al., 2015, Lynch et al., 2016). The factors that result in changes in the population sizes of penguins are thus complex and not simply related to food supply.

There has been no evidence to suggest that the krill fishery is affecting the krill population to the extent that populations of whales, seals or penguins are suffering.

Krill population sizes vary naturally from year to year, and in extreme circumstances krill shortages at South Georgia have been shown to affect the breeding success of seals and penguins (Heywood et al., 1985). In other regions of the Antarctic it has been difficult to directly link seasonal or annual fluctuations of krill abundance to the health of seal and penguin populations. But one thing is for certain: There has been no evidence to suggest that the krill fishery is affecting the krill population to the extent that populations of whales, seals or penguins are suffering.

= Annual catch of Antarctic krill

Figure 1: *40 years of Krill Harvesting*



Due to uncertainties over krill's total stock size, the fishery is managed using regional estimates of abundance that are very conservative, so that any management action is highly precautionary (Hewitt et al., 2004). Because measuring krill abundance directly is challenging, scientists use multiple approaches so that a realistic range of values can be determined (Atkinson et al., 2012). These approaches can include: direct estimates using nets or echosounders, determining how much krill is required by their predators, working out how much food there is to support a population of krill, and by examining the catches from the fishery.

Forty years of krill harvesting barely exceeds CCAMLR'S annual precautionary catch limit of 5.6 million tons.

The krill fishery has been operating for more than 40 years. Catches peaked in the early 1980s with Japanese and Soviet vessels catching over half a million tons a year (see Figure 1).

Today, about 200,000 tons are caught from the South West Atlantic, largely by Norwegian vessels, producing high-end aquaculture feed and krill oil supplements for human consumption. It has proved very difficult to make a marketable product from krill and harvesting it is very expensive, so the fishery has always been held in check by economic forces (Foster et al., 2011).

When the krill fishery was established there was concern that it might cause irreversible damage to the Antarctic ecosystem, so a unique international treaty was signed to ensure it would be managed using an approach that took into account the needs of the entire ecosystem. This treaty was the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). The management of the krill fishery has been guided by its principles since the early 1980s.

In the 1970s, there was concern that the krill fishery might develop into a multi-million ton fishery and, indeed, the global precautionary catch limits (PCLs) that have been set for the krill fishery currently total over 8 million tons. However, the high level of krill catches in the early 1980s was not sustained and annual catches dropped to less than 100,000 tons in the mid-1990s. Since then, krill catches have slowly increased to around 200,000 tons per year.

How (and why) catch limits are strictly regulated

While the krill fishery is the largest in the Southern Ocean, it is relatively small by world standards.According to FAO statistics, in 2014 krill was the world's 40th largest fishery and the 3rd largest crustacean fishery. By comparison, the top 13 fisheries all caught more than one million tons each.

The world's second largest fishery is Peruvian anchovy, which occupies a similar ecological niche to krill but lives in a much smaller area. In this part of the world, in 2014, 3.1 million tons of anchovy were caught. No other commercially harvested marine species has such a large biomass, such a huge range, and such a high turnover as the krill population.

The Commission for the Conservation of Antarctic Marine Living Resources (also known as CCAMLR) was established to implement the principles of the CCAMLR Convention. It manages the krill fishery because it is responsible for marine conservation in the Antarctic region.

CCAMLR meets annually and adopts conservation measures for all the fisheries operating in the waters around Antarctica (Nicol and Foster, 2016). For krill, the fishery is regulated through a series of measures that specify how much can be caught, where it can be caught, acceptable levels of by-catch and other operational requirements. The amount of krill that can be caught in any one year is set through "Precautionary Catch Limits (PCL)," which is far more conservative than normal fishery quotas because of the difficulties in measuring the Antarctic krill biomass, the animals that depend on it as a food source, and the unique environment in which they live.

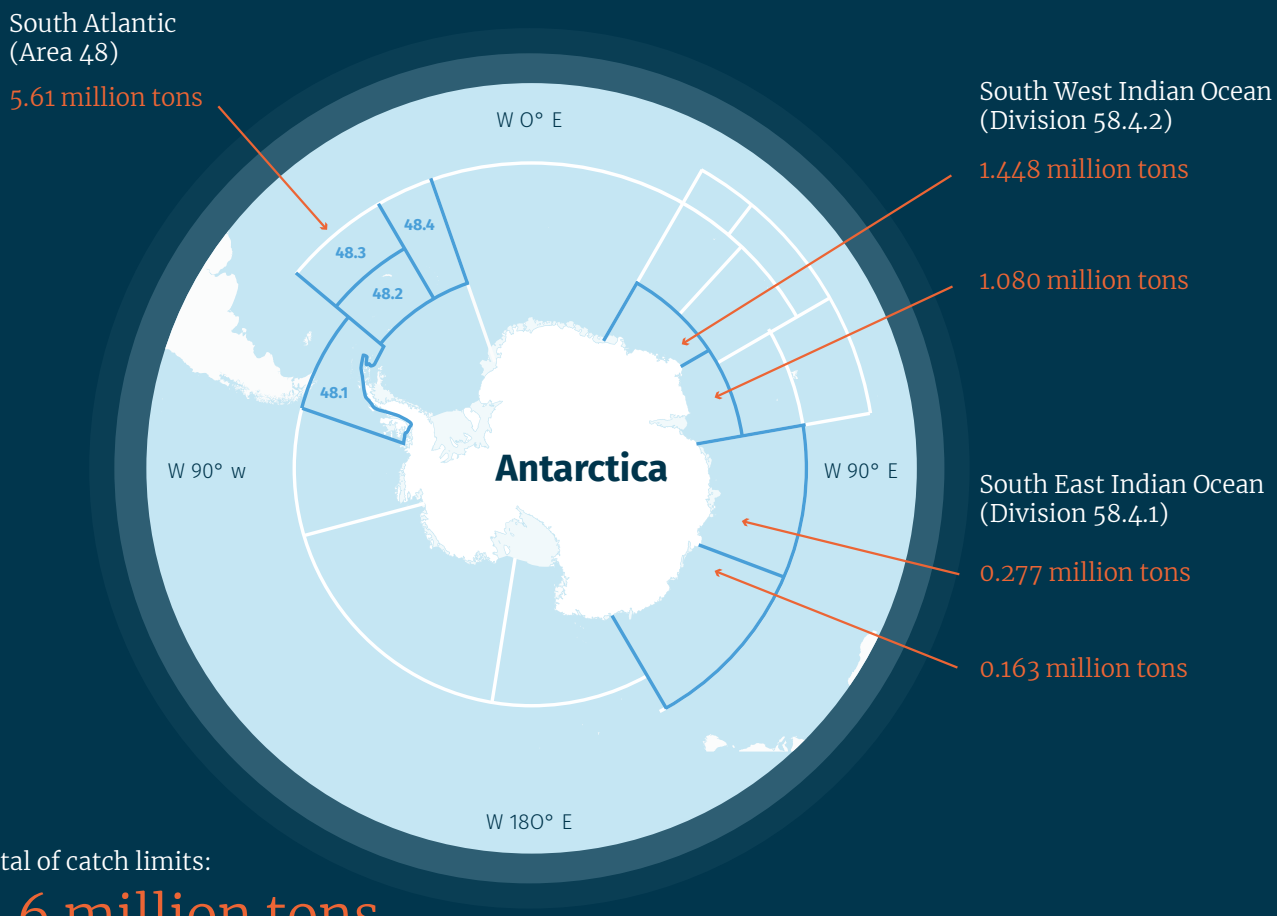
Catch limits are calculated for a particular area by working out how much krill is in that area and by determining the long-term annual yield from that area. The actual catch limit is based on a percentage of that biomass. The annual precautionary quota for Antarctic Krill set by CCAMLR is 5.61 million tonnes and amounts to approximately 10 percent of the total estimated biomass in area 48 of 60.3 million tonnes. The catch is further limited to 620,000 tonnes in any one season. For the 2015/2016 season the recorded krill catch for all vessels fishing for krill was 225,646 tonnes and only 0.3 percent of the total biomass of krill in the South Atlantic.

The krill fishery of 620,000 F(MSC) tons a year, or approximately 1% of the biomass, which is a highly precautionary figure when compared to other fisheries. For example, the Lenfest Forage Fish Task Force recommends that the biomass of lower trophic level species not be allowed to slip below 30-80% of the unfished biomass depending on the level of ecosystem knowledge (Little Fish, Big Impact, 2012). CCAMLR's allocation of less than 10% of the krill biomass to the fishery far exceeds this level of precaution.

PCLs have been set for several large areas of the Southern Ocean, totaling more than 8 million tons per year. The catch limits apply to areas where a recent survey of krill abundance was carried out (see Figure 2). In Area 48, where most of the modern krill fishery operates, there is a PCL of 5.6 million tons.

The krill fishery is currently limited to 620,000 tons a year, or approximately 1% of the biomass, which is a highly precautionary figure when compared to other fisheries.

Figure 2: *Precautionary Catch Limits (PCLs) of Antarctic Krill*



Total of catch limits:

8.6 million tons

All areas currently being fished for krill as well as most areas where fishing has been carried out in the past are now covered by these PCLs. Only very limited experimental fishing is allowed in areas where krill stocks have not yet been surveyed and where there is no established catch limit.

Catch limits are calculated using a projection from a single biomass estimate derived from independent scientific surveys using research vessels equipped with echosounders carried out in 1996, 2000 and 2006.
Although annual surveys are not required to manage the krill fishery, CCAMLR takes into account changes in the krill stocks that are revealed through annual scientific research, some of which is now carried out from krill fishing vessels. Some of the catch limits have also been further subdivided into smaller areas in an effort to ensure that large portions of the annual catch do not come out of restricted areas to the detriment of the ecosystem.

A major focus of CCAMLR is to further spread out the catch so that colony-based predators such as penguins and seals are not affected by catches in their vicinity. As an added element of precaution, CCAMLR has applied a "Trigger Level" of 620,000 tons throughout the main fishing grounds (e.g. Area 48) – a level of catch that cannot be exceeded until the biomass has been evaluated and determined to be healthy enough for fishing to continue. The figure of 620,000 tons was calculated by summing the maximum annual catches from each subarea. Thus the Trigger Level is an arbitrary limit but for each subarea it represents a level of catch that had already been reported.

Developments in krill fishery management are discussed at the annual CCAMLR meetings and any revisions that are made to the way in which the fisheries are managed must be based on the best scientific advice available.
There are 25 members of CCAMLR, including six countries that currently fish for krill, and all decisions are adopted by consensus. Additionally, the annual meetings are attended by a range of other interested parties, including environmental NGOs (non-governmental organizations), fishing industry associations, and other international bodies that have a stake in the conservation of the Antarctic ecosystem.

Making sure history doesn't repeat itself

Several decades ago, there was concern that the overharvesting of whales and seals in the Southern Ocean would be repeated for krill with disastrous ecological consequences. In fact, these events are precisely what led to the creation of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR).

When it was signed in 1980, it was hailed as a groundbreaking approach to resource management because it aimed to ensure the sustainable harvesting of marine resources using an ecosystem approach. CCAMLR has since overseen the management of the krill fishery.

The conservation measures that now regulate the Antarctic krill fishery make up a regime that would be considered comprehensive and innovative in any other environment. Still, because the Antarctic is such a special place and Antarctic krill are such special creatures, the fishery is perpetually under considerable scrutiny.

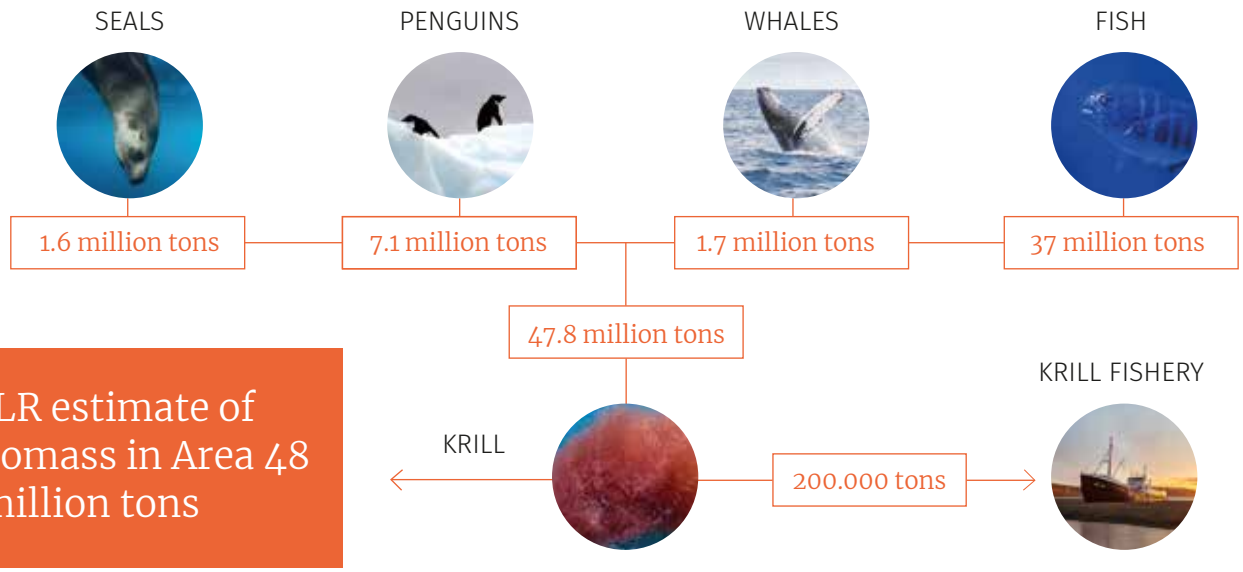
A whole range of measures govern the operation of the krill fishery, including: by-catch regulation, notification rules, environmental stipulations, observer requirements and the establishment of catch limits. Additionally, CCAMLR has implemented an ecosystem monitoring program to detect changes in the status of animals that are dependent on krill and to determine whether these changes might be a result of fishing activity.

Because the krill biomass is so large, estimates of the sustainable harvest are also correspondingly large, despite the high degree of precaution. The current annual catch of krill averages about 200,000 tons a year and most of it comes from the South Atlantic in Area 48. The most recent estimate of the biomass of krill in Area 48 is 60.3 million tons (SC-CCAMLR, 2010).

The biomass in the CCAMLR 2000 survey area is thought to be 28% of the global krill biomass (Atkinson et al., 2009), which is conservatively estimated to be around 215 million tons. The seals, seabirds and whales need about 47.8 million tons of krill for their needs (CCAMLR figures) (see Figure 3). The krill fishery's highly precautionary trigger level of 620,000 tons per year is only 1 % of the biomass. Current estimates of global krill consumption by whales are not available because of uncertainties over the sizes of whale populations, but because they are such mobile predators they are unlikely to be affected by the highly localized and relatively small krill fishery.

So even if the fishery expanded to the current catch limit in the South Atlantic – 5.6 million tons a year – it would still be harvesting less than 10% of the stock. There are few other fisheries in the world where the allowable catch is set at such a low proportion of the biomass and where the actual catch is so much lower than that allowed.

Figure 3: *Estimated Predator Demand of Krill in Area 48*



CCAMLR estimate of krill biomass in Area 48 is 60 million tons

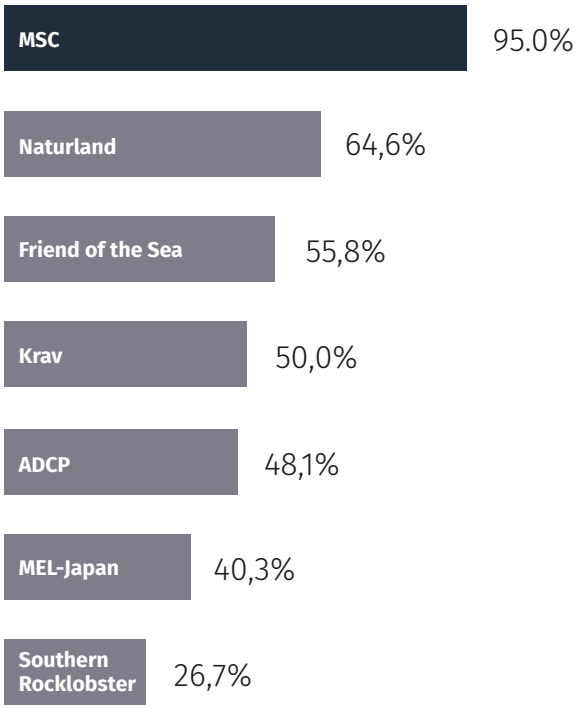
Third party sustainability verification

There has been a trend in the last decade to use independent third party certification to confirm the sustainability of seafood products. The Marine Stewardship Council (MSC) is the premier certifying organization known for its rigorous assessment process and credible standards for sustainable fishing and seafood traceability.

Aker BioMarine's krill fishery was certified as sustainable and 100% traceable in 2010, allowing products from this fishery to carry the distinctive blue eco-label. In 2012, for a second time, MSC was ranked by Accenture as the leading eco-label for seafood products (see Figure 4). Aker's fishery is currently recertified for another five years (2015-2020) and will undergo the MSC re-certification process again in 2019-2020.

To achieve MSC certification a fishery must be assessed against several criteria that address issues such as the fishing methodology, the management of the fishery, and the impact of the fishery on the stock and on the species dependent on krill. The certification comes with several responsibilities, including a commitment to research to ensure the sustainable management of the resource. Aker's commitment to MSC certification indicates that it takes the issue of sustainability seriously, a move that has been recognized by environmental groups such as the World Wild Life Fund for Nature (WWF-Norway).

Figure 4: *Accenture Ranks MSC #1 Eco-Label*



In a 2012 study. Accenture evaluated and ranked various eco-labels according to the stringency of their standards. MSC was ranked highest of all eco-labels surveyed.

WWF-Norway works with Aker BioMarine to help it meet key MSC certification requirements, including mapping its fishing activities against local predator populations and ensuring that its fishing operations do not cause serious harm to the ecosystem.

Environmental NGOs like WWF play an active role within CCAMLR, focusing on the issue of ecosystem management and on the sustainability of the region's fisheries. Aker Biomarine works constructively with these NGOs and has involved WWF-Norway in an initiative to bring together krill fishing companies to work together to ensure that CCAMLR's goals are being met. This initiative – the Association of Responsible Krill (ARK) Fishing Companies – aims to ensure that the industry develops sustainably in support of the long-term viability of the krill stocks and dependent predators.

The need for cooperative research

There are very few scientific research vessels operating around Antarctica and they are only present in the region for short periods each year. In contrast, krill fishing vessels operate on the fishing grounds for most of the year and are extremely well positioned to collect scientific data that can be used in the management of the fishery. Most fishing vessels have the equipment and the capacity to carry out valuable research, which can be used to better understand the biology of krill and provide information on changes in krill stocks.

An initiative of ARK is to conduct annual krill surveys in areas that are not generally accessed by researchers and to encourage the collection of scientific data from fishing vessels. The active involvement of the fishing industry in research will be of benefit to fishers, managers and scientists. Organizations such as ARK can assist with communication between the fishing industry and CCAMLR, so that management action can be adopted seamlessly.

Going above and beyond

Over the course of a decade, Aker BioMarine developed, perfected and patented a technology called Eco-Harvesting®. This technology, using a specially designed trawl system and direct hose connection between the trawl and the vessel, holds a special mechanism that singles out unwanted by-catch (non-krill species) and releases it unharmed.

In terms of its operation, the equipment stays under water while a continuous stream of water flows through the hose, bringing the krill live and fresh directly into the factory vessel, which allows for immediate processing of fresh raw material with superior product quality.

Harvesting krill in a commercially viable and environmentally sound way is challenging. Traditional trawling methods where the catch is hauled up on deck and emptied into holding tanks before processing is unsuitable, as krill contains highly digestive enzymes and basically self-destructs before it can be processed.

Furthermore, unwanted by-catch (e.g. of invertebrates fish and seals), is a problem with regular trawling in the South Atlantic and may pose a threat to fragile marine eco-systems in the Antarctic.

Aker's Eco-Harvesting® fishing system allows the fishing net to stay under water during the entire operation. Independent observers have verified that the proprietary technology and novel harvesting method ensures no bycatch of other species than Euphausia superba.

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Why are all these efforts necessary?

The Antarctic is a special place and industries that work there have a responsibility to ensure its conservation. There have been major ecological catastrophes as a result of earlier harvesting activities (i.e., whales, seals and fish), so it is essential that current and future fishing proceeds in a responsible and sustainable fashion.

The CCAMLR convention provides an excellent framework to ensure the sustainability of the krill fishery, but it is also up to the fishing industry to assist with the task of collecting data and contributing positively to the management process. A krill fishery that is sustainable in the long term is in the best interest of the industry and the ecosystem.

About the author: Stephen Nicol, PhD, is an adjunct professor at the Institute for Marine and Antarctic Studies and an honorary fellow at the Antarctic Climate and Ecosystems Cooperative Research Centre, University of Tasmania. He has extensive experience in krill conservation research, has worked within CCAMLR for more then 25 years, and is a provider of independent scientific advice to ARK.

About Aker BioMarine Antarctic: Aker BioMarine is an integrated biotechnology company dedicated to the sustainable harvest of krill and development of krill-derived biotech products. The company supplies biomarine ingredients through a completely transparent value chain. Aker BioMarine's Superba™ Krill products are provided with 100% traceability from sea to shelf. Currently, Aker BioMarine is the only krill harvesting company to hold the Marine Stewardship Council (MSC) certification (March, 2018).

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AKER BIOMARINE QRILL™ PET SUPERBA Krill ECO Harvesting®

References

ATKINSON A., SIEGEL, V., PAKHOMOV, E. & ROTHERY, P. 2004. Long-term decline in krill stock and increase in slaps within the Southern Ocean.
Nature, 432, 100-103.

ATKINSON, A., SIEGEL, V., PAKHOMOV, E.A., JESSOPP, M.J. & LOEB, V. 2009. A re-appraisal of the total biomass and annual production of Antarctic krill. Deep-Sea Research I, 56 (5), 727-740.

ATKINSON, A. A., NICOL, S., KAWAGUCHI, S., PAKHOMOV, E., QUETIN, L., ROSS, R., HILL, S., REISS, C., SIEGEL, V., & TARLING, G. 2012. Fitting Euphausia superba into Southern Ocean food-web models: a review of data sources and their limitations. CCAMLR Science, 19, 219-245.

ATKINSON, A., S., NICOL, S., KAWAGUCHI, E., PAKHOMOV, L., QUETIN, R., ROSS, S. HILL, C. REISS, AND V. SIEGEL. (2012). Fitting Euphausia superba into Southern ocean Food-web models: a review of data sources and their limitations. CCAMLR Science 19 (2012): 219-245

BALLANCE, L PITMAN, R. L., HEWITT, R. P., SINIFF, D. B., TRIVELPIECE, W. Z., CLAPHAM, P. J., & BROWNELL JR, R. L. 2006. The removal of large whales from the Southern Ocean: evidence for long-term ecosystem effects. In: J. A. ESTES, D. P. DEMASTER, D. F. DOAK, T. E. WILLIAMS AND R. L. BROWNELL, JR., eds. Whales, Whaling and Ocean Ecosystems, 215-230 University of California Press, Berkeley, CA.

KAWAGUCHI, S., A. ISHIDA, R. KING, B. RAYMOND, N. WALLER, A. CONSTABLE, S. NICOL, M. WAKITA, AND A. ISHIMATSU (2013). Risk maps for Antarctic krill under projected Southern Ocean acidification. Nature Climate Change doi:10.1038/nclimate1937

FIELDING, S., WATKINS, J.L., TRATHAN, P.N., ENDERLEIN, P., WALUDA, C.M., STOWASSER, G., TARLING, G.A. AND MURPHY, E.J., 2014. Interannual variability in Antarctic krill (Euphausia superba) density at South Georgia, Southern Ocean: 1997–2013. ICES Journal of Marine Science: Journal du Conseil, 71(9), 2578-2588.

FLORES, H., A. ATKINSON, S. KAWAGUCHI, B. A. KRAFFT, G. MILINEVSKY, S. NICOL, C. REISS, G. A. TARLING, R. WERNER, E. BRAVO REBOLLEDO, V. CIRELLI, J. CUZIN-ROUDY, S. FIELDING, J. J. GROENEVELD, M. HARALDSSON, A. LOMBANA, E. MARSCHOFF, B. MEYER, E. A. PAKHOMOV, E. ROMBOLÁ, K. SCHMIDT, V. SIEGEL, M. TESCHKE, H. TONKES, J. Y. TOULLEC, P. N. TRATHAN, N. TREMBLAY, A. P. VAN DE PUTTE, J. A. VAN FRANEKER, T. WERNER (2012). Impact of climate change on Antarctic krill. Mar Ecol Prog Ser 458:1-19

FOSTER, J., NICOL, S. AND KAWAGUCHI, S. (2011). The use of patent databases to detect trends in the krill fishery. CCAMLR Science 18, 135-144.

LYNCH, H.J., WHITE, R., NAVEEN, R., BLACK, A., MEIXLER, M.S. AND FAGAN, W.F., 2016. In stark contrast to widespread declines along the Scotia Arc, a survey of the South Sandwich Islands finds a robust seabird community. Polar Biology, 1-11.

HEWITT, R. P., WATKINS, J., NAGANOBU, M., SUSHIN, V., BRIERLEY, A. S., DEMER, D., KASATKINA, S. YOSHIMI TAKAO, Y. GOSS, C., MALYSHKO, A., BRANDON, M. , KAWAGUCHI, S., SIEGEL, V., TRATHAN, P., EMERY, J., EVERSON, I. & MILLER, D. 2004. Biomass of Antarctic krill in the Scotia Sea in January/February 2000 and its use in revising an estimate of precautionary yield. Deep Sea Research II, 51(12), 1215-1236.

HEYWOOD, R. B., I. EVERSON, AND J. PRIDDLE. 1985. The absence of krill from the South Georgia zone, winter 1983. Deep Sea Research Part A. Oceanographic Research Papers 32, no. 3: 369-378.

NICOL, S. (2006) Krill, currents and sea ice; the life cycle of Euphausia superba in relation to its changing environment. Bioscience 56(2), 111-120. NICOL, S., Foster, J. (2016) The Fishery for Antarctic Krill: Its Current Status and Management Regime. In: Biology and Ecology of Antarctic Krill 2016, 387-421. V. Seigel ed. Springer International Publishing.

NICOL, S. & BRIERLEY, A. 2010. Through a glass less darkly - new approaches for the study of distribution, abundance and biology of krill. Deep-Sea Research II. 57, 496-507.

SOUTHWELL, C., EMMERSON, L., MCKINLAY, J., NEWBERY, K., TAKAHASHI, A., KATO, A., BARBRAUD, C., DELORD, K. AND WEIMERSKIRCH, H., 2015. Spatially extensive standardized surveys reveal widespread, multi-decadal increase in East Antarctic Adélie penguin populations. PloS one, 10(10), p.e0139877.

TRIVELPIECE, W. Z., HINKE, J. T., MILLER, A. K., REISS, C. S., TRIVELPIECE, S. G., & WATTERS, G. M. 2011. Variability in krill biomass links harvesting and climate warming to penguin population changes in Antarctica. Proceedings of the National Academy of Sciences, 108(18), 7625-7628.

REISS, C.S., COSSIO, A.M., LOEB, V. AND DEMER, D.A., 2008. Variations in the biomass of Antarctic krill (Euphausia superba) around the South Shetland Islands, 1996–2006. ICES Journal of Marine Science: Journal du Conseil, 65(4), 497-508.

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