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A Time to Krill

Features of Antarctic Krill

"Antarctic krill are tiny shrimp-like crustaceans." This phrase has been repeated so often that many people are surprised when they actually see them for the first time. At six centimetres adult length and over a gram in weight, most people comment on how big krill actually are. The constant underestimation of the size of krill is probably the result of a general lack of public awareness about them and their importance in the Antarctic ecosystem. The animals most commonly depicted in books and articles about the Antarctic are the whales, seals and penguins but seldom is much space given to the animals that are their prime food source. This is unfortunate because Antarctic krill (*Euphausia superba*) is one of the most abundant and successful animal species on the planet. Most pictures of krill are either drawn or photographed from dead or dying specimens. Krill are difficult to keep in aquariums so most biologists have to be content with studying them pickled. Dead krill are opaque and their bodies are usually curled up. When they are alive, however, they present a much prettier picture. They are mostly transparent, although their shell is tinged a bright red by small pigment spots. They have large black eyes and a digestive system that is often vivid green from the pigments of the microscopic plants they have eaten. Their overall appearance is quite beautiful and very different to the evil-smelling specimens preserved in formalin in laboratory jars.

Krill is a general term used to describe about 85 species of open-ocean crustaceans known as euphausiids. They look like smaller versions of more familiar crustaceans such as prawns or lobsters, and range in size from small tropical species less than a centimetre in length to little-known deep-sea giants that can reach lengths of 14 centimetres. All species of krill have a recognisably crustacean shape; that is, they have an elongated head-trunk region (cephalothorax) and a muscular, segmented tail (abdomen) to which are attached five pairs of paddle-like swimming legs. The head region houses up to thirteen pairs of modified limbs that gather food, manipulate it, grind and ingest it. Six of the pairs of `thoracic' limbs form a specialised `food basket', with the fine bristles that project from them forming a net-like structure. During feeding, these limbs are thrown down and outwards enclosing a parcel of water, and the water is squeezed out through small flap valves in the `basket' leaving particles trapped on the inside from where they are passed to the mouth. Antarctic krill are mainly herbivorous feeding on the phytoplankton (microscopic suspended plants) of the Southern Ocean but planktonic animals (zooplankton) may also form a part of their diet. In summer, female Antarctic krill lay up to 10,000 eggs at a time sometimes several times a season, into the surface waters of the Southern Ocean. The eggs are thought to sink to a depth of 2000 metres before hatching. They then begin their long (up to ten days) `developmental ascent', during which the newly hatched larvae journey up towards the sunlit waters to feed. Once krill have surmounted their first hurdle and have reached the surface waters, they begin to grow and change, becoming more like the adult as time progresses. Antarctic krill larvae face a second great hurdle of their life with their first long, dark, ice-bound winter. No-one is quite sure how krill, young or old, survive the Antarctic winter. They do not seem to build up large fat reserves, so must either use some food available under the ice such as the algae which grows on the underside of the pack ice, detritus on the sea-floor or the other animals in the water or utilise some internal store other than fat. Evidence for the latter comes from laboratory studies in which Antarctic krill were found to be able to withstand long periods (up to 200 days) of starvation. They do this by shrinking, using up the very material of their body to meet their metabolic needs. Krill, like all crustaceans grow by moulting; that is, they cast off the old confining shell and expand in size while the new one is still soft. What seems to be unique in krill is the ability to use this process in reverse (in other words, to shrink) when food is absent. It certainly tends to confuse ecologists when the individuals emerging from under the ice in spring are noticeably smaller than the ones that went in the previous autumn!

As krill come to resemble adults they begin to aggregate into huge schools or swarms, sometimes stretching for kilometres in every direction, with many thousands of krill packed into each cubic metre of water turning the water red or orange. The first seamen who ventured into the waters round Antarctica were confused by discoloured patches on the surface of the water. Captain Cook may even have mistaken one of these patches for shallow water and leading him to suspect he was near land. Surface swarms of krill, however, are not a common sight. Most of the time schools remain unseen, at depth during daylight hours and only rise to the surface at night. This diurnal vertical migration is a behaviour adopted by a variety of aquatic animals but is perhaps exhibited in its most spectacular guise by Antarctic krill. Just why krill occasionally break the rules and arrive at the water's surface during broad daylight is still unknown. In some species it is linked to reproduction but in others there seems to be no rhyme nor reason to it. One thing is certain, though, and that is, when they reach the surface, they immediately become prey for myriads of surface feeding predators such as seabirds, squid, fish or whales. It is the aggregating nature of krill that has enabled the baleen whales to evolve their feeding habits; if krill were any less dense, great whales would not be able to filter enough water to strain out sufficient prey, and their great size attests to the abundance of krill.

The obvious abundance of krill has not gone unnoticed by fishing fleets searching for new species as traditional ones are fished out. One small species of krill has been harvested off the coast of Japan for the last 40 years and is used mainly as food for farmed fish. Since the 1960s, however, attention has been turned to Antarctic krill, mainly because of its huge range (around 35 million square kilometres or four and a half times the area of Australia) and colossal abundance. Estimates of krill abundance made in the 1960s, based on the amount of krill freed up by the removal of the baleen whales from the Southern Ocean, suggested that a huge sustainable krill harvest of might be possible. More recent estimates based of echosounder surveys are more modest and indicate that figures around 150 million tonnes may be more representative of the total krill population size. Right from their first scientific discovery, there has been speculation about using Antarctic krill for food. In the reports of the German South Polar Expedition of 1901–1903, Von Drygalski noted catching "huge quantities of shrimps [krill] " close to the ice "in such quantities that we were able to eat them too; they tasted quite good, but they were rather small and tiresome to peel..." In this they anticipated some of the problems later faced by the commercial fishery.

Map - Distribution of Antarctic krill and krill fishing limits

Commercial krill fishing began in the early 1970s and has continued unabated ever since. The current catch is just over 100,000 tonnes a year which although down on the peak years of the early 1980s, is still by far the largest catch in Antarctic waters. Krill are caught by large freezer trawlers and processed on board into products for human consumption, and farmed fish, and a surprising amount of krill is now used for bait in recreational fisheries.

There have been a number of problems associated with the krill industry. For a start, Antarctic krill are found in a remote location that is expensive to get to and operate in. And there are a number of biological obstacles too. They have extremely powerful digestive enzymes that tend to spoil the catch by breaking down the krill's body tissue soon after death. Krill shells are also rich in fluoride so they have to be removed before the meat is fit for human consumption. These processing problems all add to the cost of production and so the fishery has failed to grow as fast as some had initially predicted. Currently fishing vessels from only four nations are actively involved in the fishery: South Korea, Poland, Japan, and the Ukraine, but indications are that the number of operators in the fishery will increase.

Graph - Catches of Antarctic krill and national catches in 1999/2000

The slow growth of the krill fishery has come as a relief to those concerned about the impact of krill harvesting on the Antarctic ecosystem. Most of the larger Antarctic animals, the seals, whales and seabirds as well as the less well known fish and squid, depend directly or indirectly on Antarctic krill. We have little idea what impact the removal of large quantities of krill from the ecosystem might have, although it is fairly safe to say that it is unlikely to be benign. To be sure, there is room for a large harvest of krill, especially if the areas fished are spread around the Southern Ocean to lessen the local impact, but the rate at which the fishery can grow and the maximal catches that are permissible should be determined in advance. The prospect of a free-for-all fishery for Antarctic krill led to the signing of a unique fishing treaty in 1981. This is the Convention on the Conservation of Antarctic Marine Living Resources, designed to protect the Antarctic ecosystem from the consequences of a rapidly expanding krill fishery and to aid recovery of the great whales and some of the overexploited species of fish. The first steps towards management of the krill fishery came in 1991 at the tenth meeting of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the body set up to oversee the implementation of the Convention. The Commission has now set limits on the krill fishery in most of the area where krill has been caught and the total precautionary catch limit around the Antarctic is 4.8 million tonnes (see map of CCAMLR area with catch limits).

This catch limits is much higher than the current fishing levels but this is a reflection of the huge size of the resource and of the pre-emptive approach to management that CCAMLR was designed to take.

Scientific management of the krill fishery requires that we know about critical aspects of the life history of krill. To date it has proved extremely difficult to study these oceanic animals since they will not adapt well to laboratory conditions. In the early 1980s a major international scientific program called BIOMASS (Biological Investigations of Marine Antarctic Systems and Stocks) began studying the role of krill in the Antarctic ecosystem. Up until the 1970s almost everything known about Antarctic krill came from studying krill pickled at sea and studied on shore, but many of the pressing questions about their biology could only be answered by studying live animals. As part of the program, techniques had to be developed for keeping krill alive for experimental purposes. These were pioneered in Australia, first at the Australian Institute of Marine Science in Townsville and then at the Australian Antarctic Division in Kingston where a supply of live krill has been kept continuously since 1982. Experimental studies on krill made possible by the existence of captive populations led to an explosion of knowledge about their life processes: their growth rates, longevity, physiology and behaviour. There are, however, many aspects of the biology of krill that are still difficult to study and for which information is urgently needed for the management of the fishery. We need to be able to accurately assess krill abundance; this is a pressing problem as current estimates vary widely. It is still uncertain whether krill populations drift with the currents or whether they are able to maintain self-sustaining populations in particular areas, and one of the major question marks hanging over their life history is what they do over winter. We still don't know how long krill live for. While early estimates suggested two years, recent studies have shown they can survive in the laboratory for are at least 11. Determining the age of krill is related to the problem of winter shrinkage. Crustacean age is usually measured by size, but if krill are growing and shrinking in response to a fluctuating food supply, it is unlikely there will be any simple relationship between size and age. This is a problem for fisheries management as estimates of production are based on how long we think the animals live for and the natural levels of mortality.

Of course, understanding the biology of krill is only part of the problem when utilising an ecosystem approach to management of the marine ecosystem. Knowing how the physical and biological elements in the ecosystem interact is critical for being able to predict the effects of harvesting and also the effect of other changes such as those that might be the result of global warming. It is now well documented that elements of the physical environment such as the extent of winter sea ice can vary considerably between seasons and that there are associated changes that occur in the ecosystem. Understanding the mechanisms underlying these interactions is critical if we are to take into account potential changes when developing management strategies for the Antarctic region.

The Antarctic ecosystem is far from pristine; the marine living resources of the region have been exploited for nearly 200 years. The emergence of a krill fishery posed the greatest threat to the integrity of the Antarctic ecosystem but the fishery has operated far below its potential despite its early rapid growth. If the fishery continues to expand only slowly, it gives scientists time to carry out the research necessary to answer critical questions concerning the biology of krill and their interactions with other species in the Antarctic ecosystem. This knowledge will, in turn, be fed back into the management process to provide further safeguards. Although the fishery for Antarctic krill is not turning out to be the cornucopia that many had imagined, it is also not turning out to be the environmental scourge that it had the potential to be; in fact, it may end up being the agent for the restoration of the Antarctic ecosystem. Without the krill fishery there would have been no CCAMLR and it is likely that CCAMLR will be the forum within which the major decisions will be made to manage the whole Antarctic ecosystem, restoring the populations of depleted species as well as maintaining a sustainable harvest of krill.

Reading list

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