# Towards wise use of Antarctic krill

Antarctica: it conjures up pictures of heroic explorers enduring a freezing hell. It produces images of ruthless exploitation of living things in the surrounding seas — of whaling, and, from earlier this century, of the slaughter that nearly wiped out the fur seals.

Today, mankind seems poised to exploit another resource living in the antarctic seas — namely krill, a shrimp-like planktonic inhabitant of the Southern Ocean that occurs in astonishingly dense swarms near the ocean surface. Already Russia, Japan, Argentina, West Germany, and Poland have fisheries research vessels and trawlers fishing experimentally for krill in antarctic waters. Many experts feel that only the problem of processing krill into a form that will sell is preventing a large fishery from developing. Cracking that nut may not take long — indeed krill 'fingers' have already gone on sale in Chile for a trial period.

This time, the story of the use of an antarctic resource may be different. International and national agencies are trying to make sure that krill-fishing does not become yet another example of disastrous over-exploitation. With a bit of luck and continuing good will between nations, those who fish for krill will agree to limit their catches to levels that will allow the continued existence of a krill-fishery.

Krill is perhaps best known because it is the food of the five much-hunted antarctic baleen whales — the blue, fin, humpback, sei, and minke whales (see *Ecos* 19).

The prize to be plucked from the waters that surround Antarctica in the form of a fishery for krill is vast. Calculations to date have put the standing stock at values as different as 800 million and 5000 million tonnes. But fishing such quantities — even if we could use them — would

Antarctic krill living in these iceberg-infested waters forms the food of whales, seals, penguins, fish, and other birds and animals.

wipe out the krill. Fisheries biologists generally regard annual catch levels of 50–60 million tonnes as feasible — about the same order of size as the entire world fish catch at present.

### Other dependents

There is, however, a problem. Krill is not only the food of the now-diminished stocks of baleen whales. This thumb-sized crustacean is also the main food of two species of seals, several species of penguins, many types of fish, and probably also several species of deep-sea squid. Indirectly, krill also provides food for sperm whales (since they eat squid) and other predators that eat fish, like penguins and seals. So this prawn-like marine animal is the centre point of a web of other animals that depend on it. Establish a fishery for krill, and you may affect any or all of the dependent animals.

Before a massive fishery gets under way it would therefore be most desirable to get some idea of the effects that removing large quantities of krill will have on these other animals.

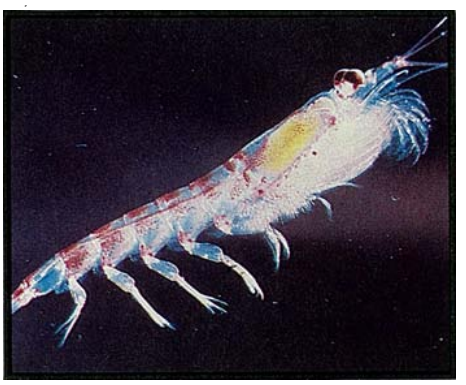
Two years ago a large international program began with the aim of gathering information to answer questions just such as this. Referred to as BIOMASS (standing for Biological Investigation of Marine Antarctic Systems and Stocks) it will go on for 10 years. It has two major aims:

- providing the information needed to permit conservation and wise management of the living resources of the Southern Ocean
- improving our understanding of the complex ecosystem on which the resources depend, and the flow of energy through that system

BIOMASS has been sponsored by SCAR and SCOR — the Scientific Committee on Antartic Research and the Scientific Committee on Oceanic Research (acronyms abound in international research). These committees are non-government bodies set up by the international scientific community under the general umbrella of the International Council of Scientific Unions.

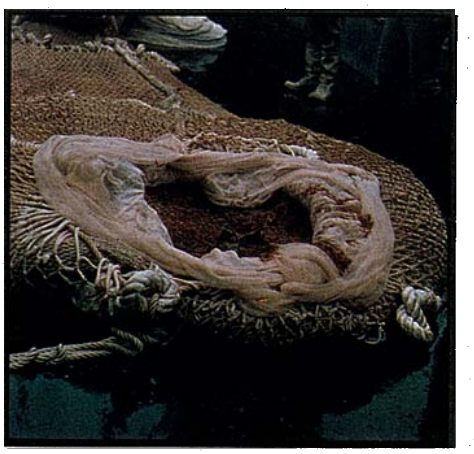
In spite of the fact that Australia has laid claims to about one-third of the Antarctic continent, it has made no commitment to participate in BIOMASS. Yet, if at some future date this country decided to extend its sovereignty over a 200-nautical-mile fishing zone around these claims, it would be appropriating a considerable segment of the Southern Ocean.

*International and national agencies are trying to make sure that krill-fishing does not become yet another example of disastrous over-exploitation.*



**Antarctic krill, the bountiful food of many creatures in the Southern Ocean.**

***Nella Dan* crashes through the waters of the Southern Ocean en route for one of Australia's antarctic bases. Fishing for krill in these rough and remote waters will present its own peculiar difficulties.**



**Trawl net full of krill hauled aboard the *Walther Herwig*.**

How much do we know about the ecosystem of the Southern Ocean now?

### State of knowledge

Let us begin with krill, the centre of the system. Antarctic krill (there are other krills at lower latitudes) comprise six species of prawn-like crustaceans, of which *Euphausia superba* is the largest and much the most abundant. Because of this, and because it is particularly amenable to fishing, *E. superba* and 'antarctic krill' are generally regarded as being synonymous.

Antarctic krill occurs only in the Southern Ocean. Biologists regard this ocean as being the 36 million sq. km of sea that surround Antarctica from the shore to as far north as the Antarctic Convergence. (At the Antarctic Convergence, which is located in the region of 55–60°S, cold antarctic water sinks beneath subantarctic water, with the result that the Convergence forms a natural barrier for plankton.) Krill probably occurs everywhere in the Southern Ocean, but its abundance varies very greatly.

The major concentrations seem to occur around the island of South Georgia, in the Scotia Sea, and in the East Wind and Weddell Drifts — two currents driven by the easterly winds that blow around the edge of the Antarctic continent (see the map on page 6). However, other concentrations have been found elsewhere.

It has been suggested that each con-

centration represents a self-maintaining population, but this may not be so since the water of the East Wind Drift moves anti-clockwise right around Antarctica, at the same time slowly spiralling outwards towards the north. Thus the krill may be being swept around the continent, merely becoming concentrated in particular regions. Obviously, it won't be possible to come up with management procedures for the krill resource until we know whether it is a single population, or several relatively isolated ones.

Within the regions where it is common, the krill forms into large numbers of extremely concentrated swarms. Each may contain as much as several kilograms of krill per cubic metre. The swarms vary in size from a few metres to several hundred metres across, and it is this swarm-forming habit that makes it relatively easy to trawl for krill. We don't know whether much of the krill population occurs in these swarms, and once again knowing the answer to this question is vital for managing the fishery properly.

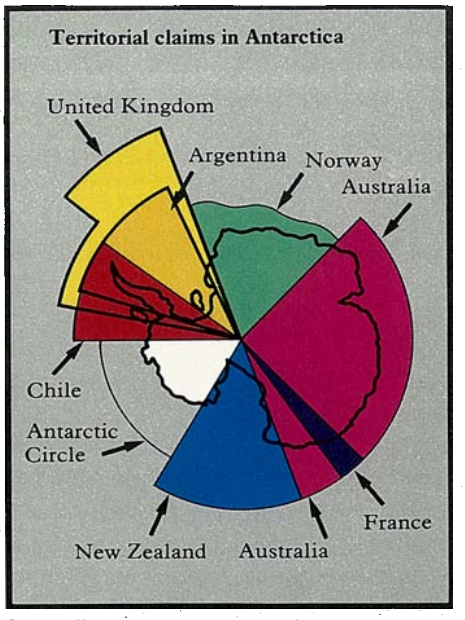
It used to be thought that the swarms all occurred on the surface. Nowadays it has been shown, using echo-sounding equipment and mid-water trawls, that the swarms may occur down to about 200 metres depth.

### Swarms explained?

Why do krill swarms form? Russian research indicates that they are a transient phenomenon, connected with the availability of food. Unlike the other five antarctic krill species, *E. superba* eats mainly diatoms and other phytoplankton, which live near the surface where there is enough light for photosynthesis. The Russian observations suggest that, when the phytoplankton is abundant, the individual krill animals spend part of the day actively foraging in the surface water. Once replete, they aggregate into swarms and sink.

Krill swarms appear to occur most where they have the most plentiful supplies of their phytoplankton food. In its turn this phytoplankton grows in the waters most richly endowed with nutrients. This relation raises the possibility of using a phenomenon known as fluorescence for detecting areas where krill is mostly likely to swarm.

The minute one-celled plants that make up the phytoplankton contain chlorophyll, which fixes energy from the sun for use by the cell. If you take the chlorophyll in those one-celled plants and, in a darkened room, shine blue light




**Australia claims about one-third of Antarctica. The claims of the United Kingdom, Argentina, and Chile conflict.**

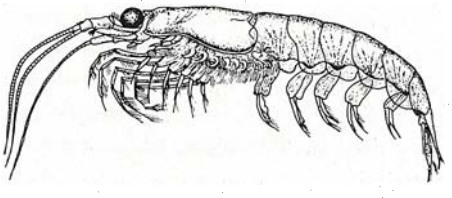
into the solution, it gives off a very dim red glow. This is fluorescence. The intensity of the fluorescence of the chlorophyll indicates how much phytoplankton is present.

The Southern Ocean is the world's most prolific producer of plankton, and parts of it are very rich in nutrients indeed. One may therefore expect to find the most phytoplankton — and hence the greatest concentrations of chlorophyll — in these parts, and samples taken from them should consequently give the brightest fluorescence. These are the waters where krill swarms may be expected to form.

Although Australia possesses no research ships capable of studying in antarctic waters, Mr David Tranter of the CSIRO Division of Fisheries and Oceanography was able to investigate fluorescence levels in the Southern Ocean's waters late last year as a guest aboard the *Walther Herwig*, a West German research ship. He found that, by and large, the relation between nutrients in the water, phytoplankton concentrations, fluorescence, and the availability of krill did indeed hold true.

### Life cycle

Krill's life cycle is thought to take between 2 and 4 years. The crustacean



**Antarctic krill, *Euphausia superba* — actual size.**

apparently spawns at the surface mainly between January and March. Its eggs then sink to a very considerable depth (possibly as deep as 3000 metres). During the weeks that follow, the eggs hatch and the tiny larvae climb again to the surface, passing through several life stages as they do so. Once at the surface they pass through a further six stages before becoming adults that reach their maximum size of 6 cm.

Unfortunately it has not yet been possible to work out how many eggs each female produces, and just how much krill is added to the population each year — vital pieces of information for rational

*Fisheries biologists generally regard annual catch levels of 50–60 million tonnes as feasible — about the same order of size as the entire world fish catch at present.*

***Walther Herwig*, the West German antarctic research vessel, off South Georgia.**

management. To date, most calculations of the annual addition to the population have been made by assuming that the total biomass remains constant, and calculating how much its various predators have creamed off.

Using this means, the most widely accepted calculations suggest that the amount consumed by whales, seals, penguins, and other predators totals around about 200 million tonnes each year. However, as a consequence of the great reduction of whale stocks during this century, the amount taken by each consumer has varied considerably.

### Can whales recover?

If more food has become available because of whaling, one may expect the

**Estimates of the amounts of krill eaten by predators annually**

| | (millions of tonnes) |
|---|---|
| whales | 43 |
| seals | 64 |
| birds | 15–20 |
| squid | 100 |
| fish | ? |
| total | more than 200 |

**Crab-eater seals apparently consume about 63 million tonnes of the krill eaten each year by seals — more than all the whales combined. The estimate for squid is very rough.**

krill-consumers that remain to respond in some way. In fact, there is evidence that some of the seals and smaller whales are maturing more quickly than they used to, presumably because of the greater krill supply available. Some penguin populations have also increased. This raises a disconcerting thought: if the smaller, faster-growing eaters of krill are the ones that are cashing in on the greater food supply, will the whale stocks be able to recover — regardless of whether large commercial fisheries develop as an additional competitor for krill?

The most reliable calculations of the amounts of krill that each predator eats have been presented by Dr R. M. Laws of the British Antarctic Survey. The main predators are whales, seals (mainly crab-eater seals), birds (mainly Adelie Penguins), squid, and fish. He estimates that whales currently consume about 43 million tonnes of krill each year, seals about

**Krill consumed by whales**

| | before whaling (millions of tonnes) | today (millions of tonnes) |
|---|---|---|
| fin | 81·5 | 16·4 |
| blue | 71·7 | 3·4 |
| minke | 19·8 | 19·8 |
| humpback | 11·0 | 0·3 |
| sei | 5·7 | 2·9 |
| | 189·7 | 42·8 |

**Dr Laws calculates that current consumption of krill by whales is less than one-quarter of that before whaling started.**

*Krill is perhaps best known because it is the food of the five much-hunted antarctic baleen whales.*

**Antarctic fur seal: once driven almost to extinction by sealers, but now recovering well.**

64 million tonnes, and birds between 15 and 20 million tonnes.

Calculating the amount eaten by squid is more difficult, since the estimates can only be made from our limited knowledge of the amount of squid that sperm whales eat, and then assuming the size of the squid population from this estimate. Dr Laws suggests that squid consume about 100 million tonnes of krill each year. He considers that not enough information is available to even guess how much fish consume.

Adding up the totals for whales, seals, birds, and squid gives an annual consumption of more than 200 million tonnes per year.

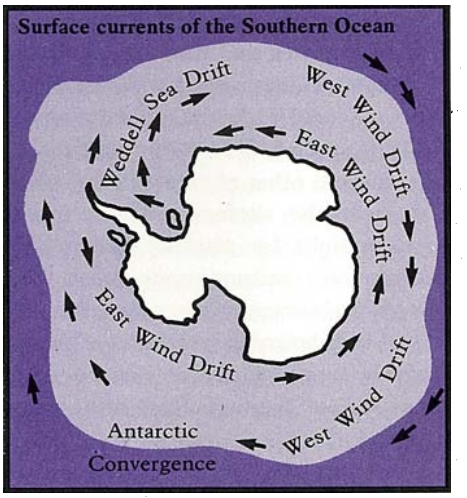
Dr Laws has also calculated that, before whaling commenced, the baleen whales were consuming no less than 190 million tonnes per year. Thus, as a consequence of whaling, whales have ceased to be the principal consumers of krill. Among the mammals and birds at least, the crab-eater seal — with an annual consumption of about 63 million tonnes — seems to have taken over.

### Sexual maturity earlier

As to the visible effects that depletion of whales has had on other krill predators, Dr Laws himself found that crab-eater seals now mature sexually earlier than they used to. Fur seals, whose numbers were reduced to a mere few thousand as a result of hunting early this century, have also increased faster than would have been expected — there are at least 300 000 today. These seals eat krill, but also fish and squid (both of which may be in more plentiful supply because of depletion of sperm whale stocks). Adelie and chinstrap penguins, and also the fish-eating king and gentoo penguins, have also increased.

Among the whales the pregnancy rate has risen in the blue, fin, and sei whales and, interestingly, in the case of the sei the rise happened before exploitation of this species began. In addition, the mean age at which sei and fin whales become sexually mature has dropped — from 11 years to 6 for the sei, and from 8 years to 3 in the case of the fin. In both whales the earlier sexual maturity seems to have been brought about by an increase in the rate of growth, which in turn resulted from increased food intakes.

*If the smaller, faster-growing eaters of krill are the ones that are cashing in on the greater food supply, will the whale stocks be able to recover?*




Quite what all this really means nobody is quite sure, other than it suggests that the various predators are reacting to changes in the food supply.

Crab-eater seals, for example, although now the main consumers of krill, may not compete directly with the baleen whales since they live the whole year round on the edge of the pack ice. But this edge spreads back and forth across the distribution range of krill as winter follows summer (in winter much of the krill will be under the ice.) The baleen whales, on the

'There appears no remaining problem that cannot be overcome in the next year or two, given the will and the resources . . . full-scale exploitation, at least at a modest level of annual catch, is not far off; it will probably have begun by the early 1980s.'

These statements come from a recent United Nations report entitled 'The Harvesting of Krill'. They imply that a fully operational krill fishery is just around the corner.

Perhaps the major factor that still holds would-be operators back is the need to find very large markets for the processed krill. Certainly this denizen of the Southern Ocean can be converted successfully into a high-protein powder for use as an animal feed, and, as mentioned in the main article, krill 'fingers' have already been on sale for a trial in Chile.

The problem is that setting up a fishery in a place as hostile or remote from much of the world's population as the Southern Ocean is very much a task for the specialist. In the long run, it will require enormous investment in the necessary equipment. Even so, once krill products can be made palatable for people, the world's major fishing nations could divert enough of their trawlers to the Southern Ocean for a fishery of several million tonnes to develop almost overnight.

Because fresh krill spoils quickly, it has been necessary to find ways of processing it into a usable food where it is caught. The other major problems have been finding reliable ways to locate krill swarms, and determining the best means of fishing them.

Judging by the experience of recent West German and Polish antarctic expeditions, it is no longer difficult to locate krill concentrations from which impressive catch rates can be achieved. However, perhaps only the Russians have actually tried sustained fishing, as if engaged in commercial operations.

Echo-sounders that transmit vertically downwards from the ship seem to provide the most effective means of detection. The echo-sounder needs to transmit at wavelengths between 100 and 200 kilohertz (kHz) — rather shorter than those normally used for commercial fishing. A problem with detecting krill in this way is that salps, another common inhabitant of the Southern Ocean's top layer, are similar in size. It is difficult, if not impossible, to tell the difference from an echo-sounder chart. For the time being, it does not seem that it will be necessary to develop such unconventional methods for detecting krill swarms as remote airborne sensing.

By the mid 1970s, or earlier, researchers realized that krill swarms can be found more frequently well below the surface than at or near the surface (as was previously thought). This means that fishermen will not have to worry too much about finding ways of extracting the crustacean from the usually rough surface waters of the Southern Ocean. Gathering it from below the surface presents a less difficult problem.

In their early trials the Russians and Japanese tried various methods of capture, including using purse seine nets. These nets are designed so that they can be placed around a shoal and then closed at the bottom ('pursed') to prevent fish escaping downwards. These trials have apparently been abandoned, and it now seems to be generally agreed that trawls that can be towed at a desired depth (mid-water trawls) are most likely to be the best, at least for the present.

The traditional trawl has needed redesigning for fishing for krill. The mouth of the net should be as large as possible. Also, the whole net must be made with a small enough mesh to prevent the krill from escaping once it has entered the mouth — traditionally only the net at the narrowest part (known as the 'cod end') has needed to be this small, since coarser net near the mouth shepherds the fish into the cod end.

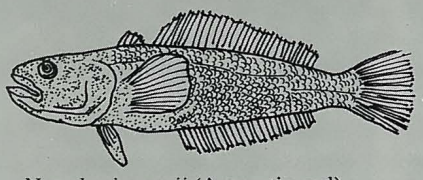
Making the mouth bigger and the mesh size smaller greatly increases the net's drag, and hence the amount of power needed to tow it. Usually, mid-water trawls are towed by one boat, but the Russians have tried using larger ones towed by two boats. An arrangement has even been proposed where two boats pull the trawl and a third one follows behind pumping out the krill from the cod end.

The idea of such a novel arrangement is to get around a major difficulty when fishing very dense swarms of krill as efficiently as possible. While the krill remains in the net in the water, it seems to suffer little damage. But once it is hauled on board it is easily crushed, and enzymes from ruptured stomachs quickly cause the catch to spoil. According to Russian research, krill should not be held for more than one hour before processing if the temperature is 10°C. Between 0° and 7°C this period may be extended by 2 or 3 hours, but the huge catches obtained when fishing krill swarms still have to be processed very quickly indeed.

The solution to this problem may well be a new breed of very large autonomous 'factory' trawlers designed especially for the Antarctic krill fishery. No such trawlers have yet been built.

'The Harvesting of Krill.' G. O. Eddie. (Food and Agriculture Organization of the United Nations and the United Nations Development Program: Rome 1977.)

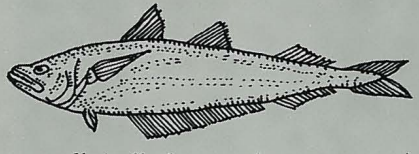
Krill hunt! P. Hjul. *Fishing News International*, 1978 (March), 22–3.



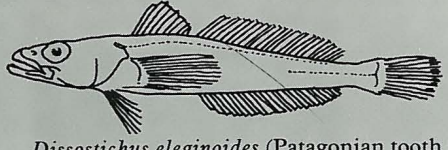
*Notothenia rossii* (Antarctic cod)

*Dissostichus mawsoni* (Antarctic tooth fish)

*Pleuragramma antarcticum* (herring)



*Micromesistius australis* (pollack or southern poutassou)



*Dissostichus eleginoides* (Patagonian tooth fish)

**Fish are another antarctic resource that is being investigated by several countries.**

other hand, migrate into the Southern Ocean only during summer, and leave for warmer seas during the winter. If all the krill of the Southern Ocean is a single population, then the seals may be reducing the amount available for the whales.

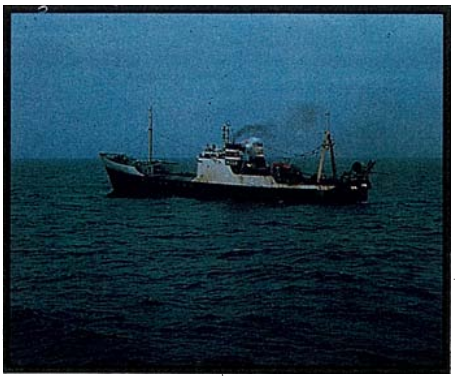
Again, the penguins must be limited in what they take by the distance they can travel from their rookeries. However, it's noteworthy that the best-documented increases in Adelie penguins and in fish-eating gentoo penguins have occurred in the South Atlantic Ocean, where there is the greatest overlap between whales and penguins.

Perhaps Dr Laws drew the wisest conclusion when he wrote that 'the baleen whales probably remain the most important vertebrate group in their effect on the antarctic ecosystem. Their stocks are likely to stabilize or slowly increase with realistic scientific management, but it is uncertain whether their original abundance will be regained even if commercial whaling ceases'. Only time and the sort of information to be gathered during such programs as BIOMASS will yield the answers.

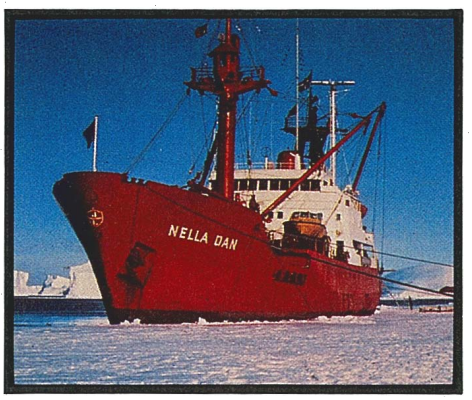
## Australian antarctic research

How could Australia contribute to BIOMASS? This country currently carries out a relatively small amount of scientific research in antarctic waters. Its most major biological project is being carried out by the Antarctic Division of the Department of Science and the Environment. This is a study of the ecosystems of fresh-water and saline lakes, and of the continent's soils.

Australia has no research vessels equipped for antarctic research; indeed it has no research trawlers of suitable size for studies around even its own coast.



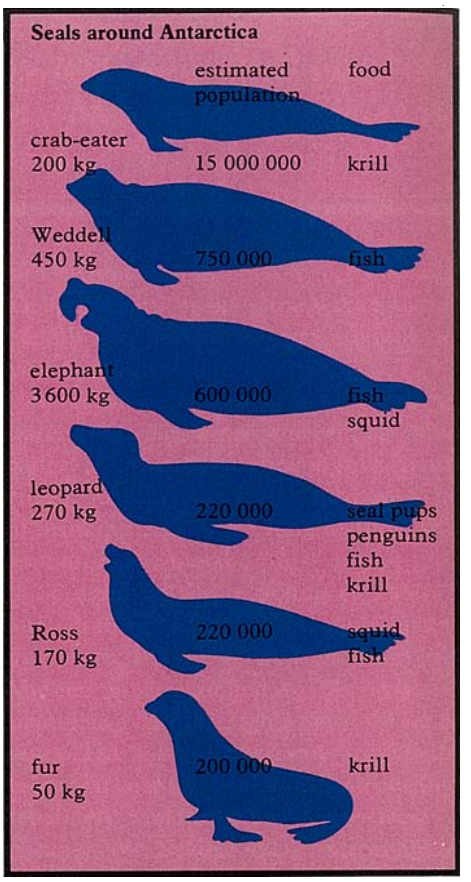
**Although nobody is yet fishing for krill as a commercial operation, trawlers like the West German *Julius Loch* (shown here) have taken large experimental catches.**

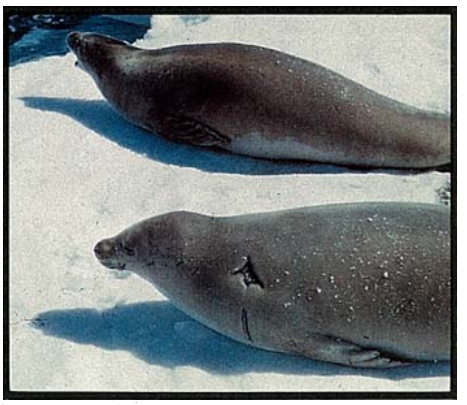



**Supply ships like the *Nella Dan* could gather important information about krill as they ply their way between Australia and Antarctica.**

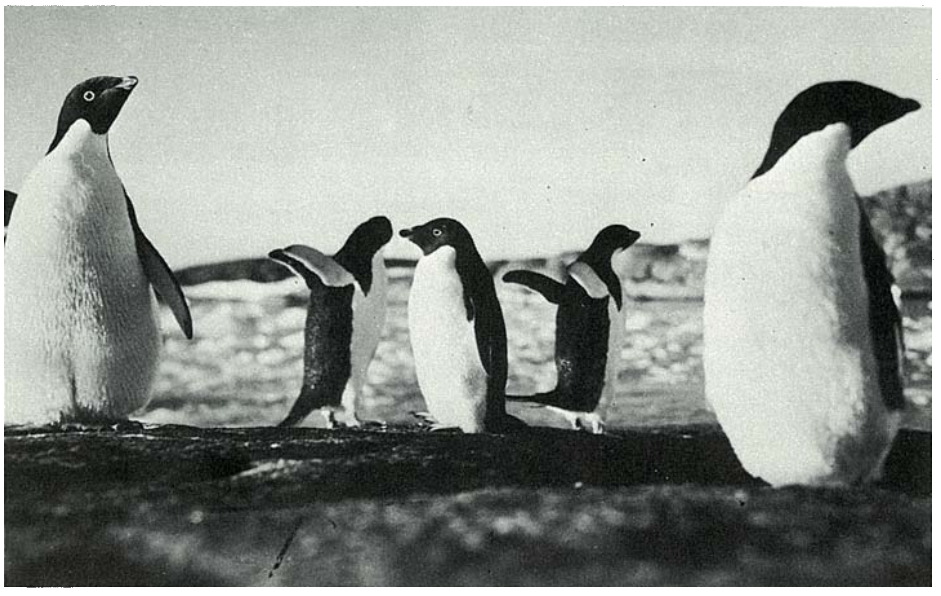
Thus we do not seem well placed to assist in the BIOMASS program.

Obviously, an Australian contribution will have to be selectively tailored to the facilities and opportunities available, which means that studies will have to be limited to what can be done from supply ships or laboratories on shore, and by remote sensing and by collaborating with institutes and other agencies abroad.



**Crab-eater seals now appear to consume more krill than all the remaining baleen whales.**



**Adelie penguins (left), which eat large quantities of krill, may have benefited from depletion of the baleen whale. Gentoo penguins (above) may also have benefited indirectly, since the fish they consume feed on krill.**

The Australian National Committee on Antarctic Research, a committee appointed by the Australian Academy of Science, recently considered what this country could do. It came up with a set of guidelines for research priorities.

### How can we contribute?

The Academy's committee suggested that we could make a useful contribution in three ways — by making broad-scale surveys of the most productive areas of the Southern Ocean, by investigating specific aspects of krill, and by studying selected predators of krill (such as crab-eater seals or Adelie penguins).

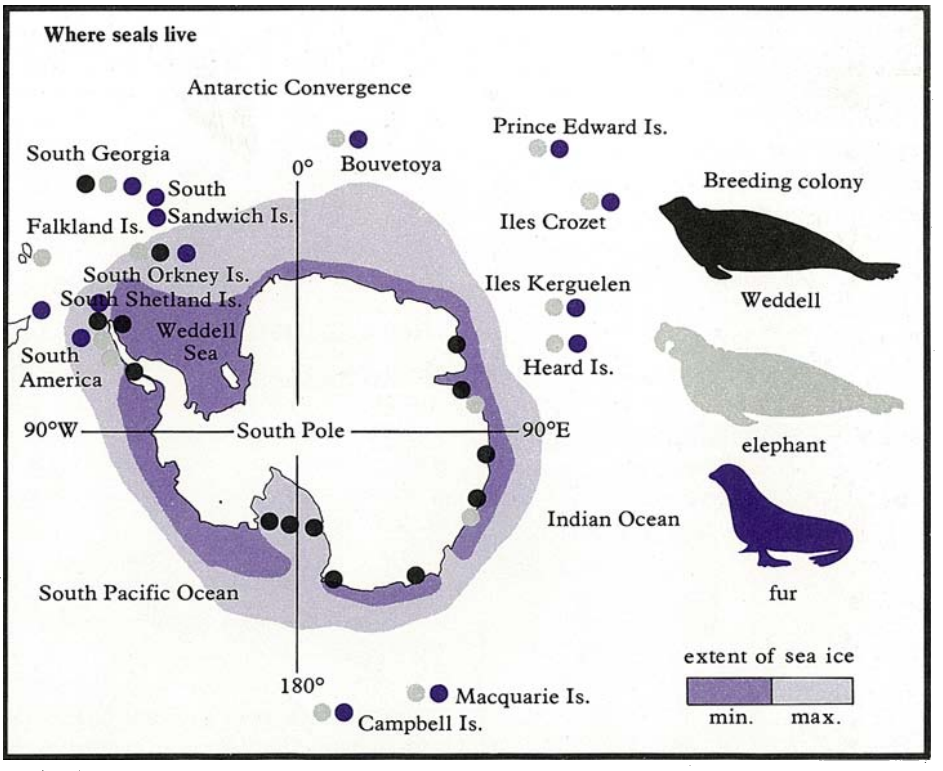
Broad-scale studies of the productivity of the Southern Ocean could be achieved using information on the ocean's colour and surface temperature that can be obtained from the NIMBUS satellite, which was launched late last year. In addition, the committee suggested, sea-water samples could be taken and analysed aboard supply ships as they steamed to and from Australia's antarctic bases. Suitably equipped with echo-sounders and sonar, these ships could also provide information on the abundance of krill.

*As a consequence of whaling . . . the crab-eater seal – with an annual consumption of about 63 million tonnes – seems to have taken over.*

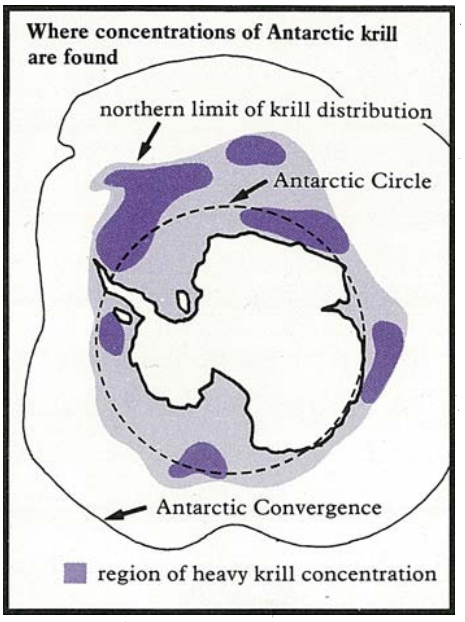
To make specific studies on krill, research ships would have to be provided. Such studies, the Academy's committee suggested, should include using trawls to verify echo-sounder records of krill, looking at the larvae, investigating any geographical variability that may occur in krill populations, and making underwater observations of krill's swarming behaviour.

Studies on the selected predators would include yearly censuses of particular colonies, investigation of their food consumption and energetics, and observations on their reproduction and mortality.

The BIOMASS program is now entering its third year, and it is about to move from the planning phase to one of technical preparation for the first of two international biological experiments. This will take place during the summer of 1980–81. A second is planned for 1983–84.




**Crab-eater, leopard, Ross, and Weddell seals generally live on the sea ice.**




**Krill concentrations are found almost exclusively south of the Antarctic Convergence.**

Even though the Commonwealth has made no public commitment to the BIOMASS program, several things have already been done. The Australian National Committee on Antarctic Research has, for example, nominated Dr Knowles Kerry of the Antarctic Division of the Department of Science and Environment as national coordinator. Also, some observations are now being made from supply ships plying their way between Australia and Antarctica. And, within the Antarctic Division itself, research programs are gradually being oriented somewhat towards the scientific problems that concern BIOMASS.

### More about the topic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