University of Canterbury

Graduate Certificate in Antarctic Studies

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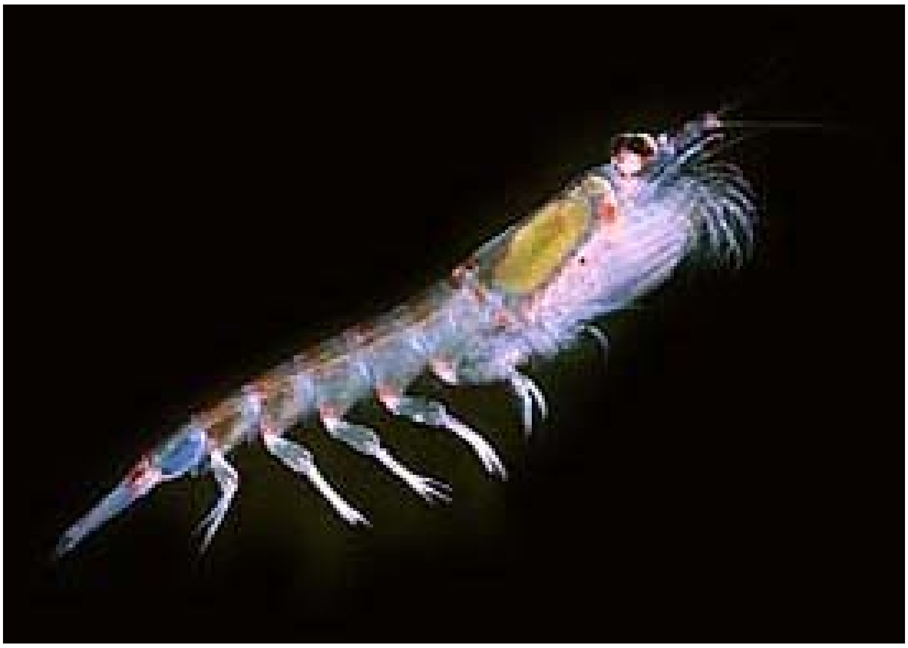
Review

Krill fisheries in the Southern Ocean



www.antarctica.org.nz/04-biology/images/krill.jpg, 10. Dec. 2006

3054 words

Maria Temminghoff

Student number: 69615346

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1 Description and behaviour

The word “krill” comes from the Norwegian language and means “whale food”.

There are over 80 known krill species. In this review I will concentrate on the most common one which is *Euphausia superba.* Krill in the Euphausiidae family are shrimp like crustaceans that swarm in dense shoals. Krill swarms may be as dense as 10,000 animals per cubic meter of water and can stretch for kilometres. Individuals range in length from 8-70 mm, weigh up to two grams and can live for up to six years. The krill species in the Euphausiidae family are bioluminescent which means that they can produce a strong blue-green light that is probably used for communication to help them congregate the spawn.

Like other crustaceans, krill have a hard calcified exoskeleton which is divided into three segments (see fig.1): the cephalon, thorax and abdomen. The head and thorax are fused into a cephalothorax. Generally the head has five segments, the thorax has eight and the tail has six. Usually each segment has a pair of appendages, but occasionally variations occur. **(Campbell, 2006)**

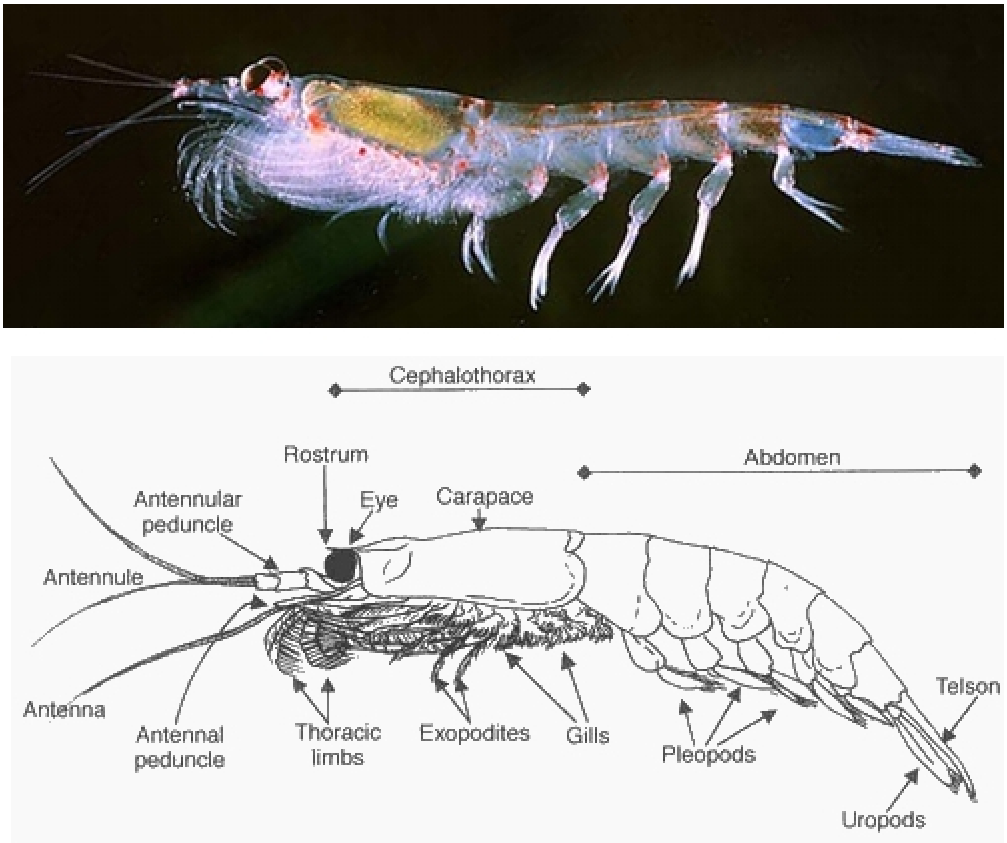


Fig.1: General view of Krill showing main morphological features

Source: http://www.lighthouse-foundation.org/index.php?id=177&L=1, 10.Dec.2006

The Antarctic krill feeds predominantly on phytoplankton. It eats very small diatoms (20 µm), which it filters from the water with a *feeding basket*.
The Antarctic krill manages to directly utilize the minute phytoplankton cells, which is accomplished through filter feeding. Therefore the krill uses it’s highly developed front legs, providing for en efficient filtering apparatus. (See fig.2 and 3)
(Kils, 1983)

Fig.2: Krill feeding under high
Phytoplankton concentration
http://en.wikipedia.org/wiki/Filter_feeder
10. Dec.2006

Fig.3: Filter setae
http://en.wikipedia.org/wiki/Filter_feeder
10. Dec.2006

2 Geographical distributions

The northern limit of the distribution of krill is defined by the Antarctic Convergence (the circumpolar front where the cold Antarctic surface water submerges below the warmer sub Antarctic waters. Especially high concentrations exist in the South Atlantic (Scotia Arc) (see fig.4). The total surface of the distribution of Antarctic krill is approximately 36 millions square kilometres, which represents for example four and a half times the area of Australia.
(Ambsdorf, 2006)

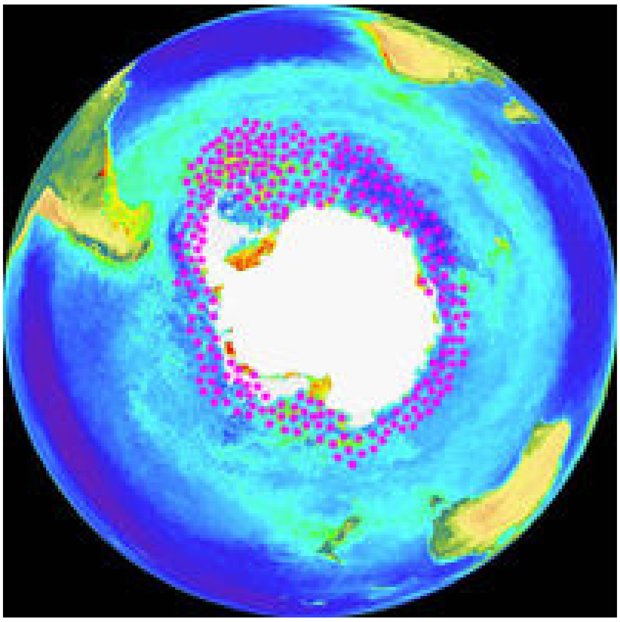


Fig.4: Krill distribution on a NASA SeaWIFS image
http://en.wikipedia.org/wiki/Antarctic_krill#_note-MH89, 10. Dec.2006

3 Position in the Antarctic ecosystem

The Antarctic krill is the keystone species in the Antarctic ecosystem. It ranges at the beginning of the food chain and provides an important food source for whales, seals, fish, penguins and seabirds. The diet of the crabeater seal for example consists to 98% of Euphausia superba. These seals have even developed special teeth that enable them to sieve krill from the water. These seals consume over 63 million tonnes of krill each year.

(Bonner, 1995)

All seals consume 63-130 million tonnes, all whales 34-43 million tonnes, birds 15-20 million tonnes, squid 30-100 million tonnes and fish 10-20 million tonnes, adding up to 152-313 million tonnes of krill consumption each year.

(Miller, Hampton, 1989)

4 History of krill fishery

Since the great abundance of Krill became apparent there has been speculation that it might form a suitable target for a fishery.

The first catches of Antarctic krill (up to 70 t) were made in 1961/62 by two Soviet research vessels. Throughout the 1960s ships from the Soviet Union continued to make sporadic small catches. The catches remained small until the Soviet Union set up a permanent fishery in the Southern Ocean in 1972. In the meantime suitable catching gear had been developed and scientists could now determine where the best concentrations lay.

One year later in 1973 7.5 thousand tonnes of krill were landed. By the mid 1970s full-scale commercial operations were underway. **(Mc Elroy 1984)**

The Japanese fishery began to develop in 1972 when a vessel from the Japan Marine Fishery Resource Research Centre caught just less than 60t in 59 days in the Indian Ocean sector. When commercial interests arrived in 1975 catches began to rise.

Other nations have also been involved in the krill fishery but compared to Japan and the Soviet Union (and later the Russian Federation and the Ukraine) they have always been minor players.

The catch of krill increased during the late 1970s as the fishery moved from its experimental phase and reached a peak in 1982 when 528 201t were landed, 93% of which was taken by the Soviet Union.

From 1986 to 1991 annual catches stabilised at around 350,000 to 400,000 tonnes. In the following season catches dropped due to the break-up of the Soviet Union, which forced this fleet to cease operations. Today about 120,000 t of krill are caught each year. (See fig.6)

(Ichii, 2000)

From 1993 to 2003 Japan and the Ukraine were the main krill fishing nations (see fig.5). The catch of Japan was around 60,000t per year and the Ukraine caught about 15,000t tonnes each year with a peak in the 1994/95 season where 59,150t were caught.

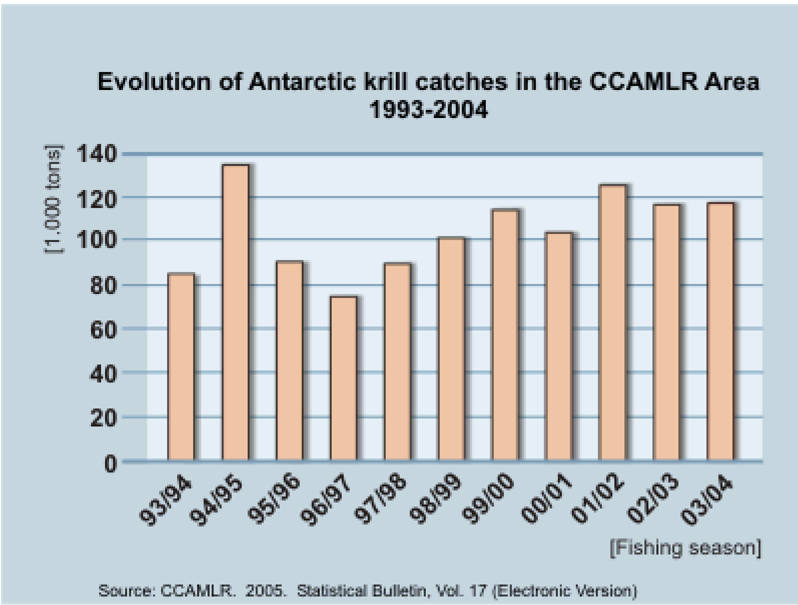
(SC-CCAMLR. 2003)

Antarctic krill catches (tonnes) in the CCAMLR Area (1993/94-2002/03), by country

	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03
Argentina	-	-	-	-	-	6.524	-	-	-	-
Chile	3.834	-	-	-	-	-	-	-	-	-
United Kingdom	-	-	-	308	634		-	-	-	-
India	-	-	6	-	-	-	-	-	-	-
Japan	61.097	63.377	58.769	60.937	67.481	66.076	80.602	67.377	51.079	59.682
Korea	-	-	-	-	2.849	27	7.233	7.525	14.353	21.276
Panama	-	637	-	-	-	-	-	-	-	-
Poland	7.997	12.521	22.104	14.408	19.133	19.167	20.049	13.696	16.365	8.905
Russia	-	-	-	-	-	-	-	-	-	-
Ukraine	12.613	59.150	10.277	-	-	6.719	-	14.023	32.015	17.715
Uruguay	-	-	-	-	-	3.444	6.477	-	-	-
USA	-	-	-	-	-	-	70	1.561	12.175	10.150
Vanuatu	-	-	-	-	-	-	-	-	-	-
South Africa	3	-	-	-	-	-	-	-	-	-
TOTAL	**85.544**	**135.686**	**91.156**	**75.653**	**90.098**	**101.957**	**114.430**	**104.182**	**125.987**	**117.728**

Source: CCAMLR. 2005. Statistical Bulletin, Vol. 17 (Electronic Version)

Fig.5: Antarctic krill catches (tonnes) in the CCAMLR Area (1993/94-2002/03), by country (Source: CCAMLR, 2005: Statistical Bulletin, Vol. 17 (Electronic Version). www.ccamlr.org) http://www.lighthouse-foundation.org/index.php?id=183&L=1, 10. Dec.2006



Source: CCAMLR. 2005. Statistical Bulletin, Vol. 17 (Electronic Version)

Fig.6: Evolution of Antarctic krill catches in the CCAMLR Area 1993-2004. Source: CCAMLR 2005. Statistical Bulletin, Bd. 17 (Electronic Version)

http://www.lighthouse-foundation.org/index.php?id=183&L=1, 10. Dec.2006

5 Present catching methods

In the following in is described which techniques are used to detect, catch and select the most valuable krill.

5.1 Detection of krill swarms

To detect krill concentrations, vessels utilize a range of information. The historical record of good harvesting areas is the most important indicator. Surface water temperatures are also monitored to identify oceanographic fronts, where krill tend to aggregate for prolonged periods.

In fishing grounds, sonar and echo-sounder are used to detect krill aggregations. An echo-sounder is especially suited to detect swarms at most depth immediately below the fishing vessel but has very limited horizontal range (normally no more than the vessel width). On the other hand the sonar has an effective horizontal detection range and a limited vertical range.

In general, krill trawlers target large and dense swarms. After being detected, the swarms are intercepted by trawlers, using sonar to make adjustments as to optimize the operation. Further adjustments to define the trawl depth are done following the swarm by using the echo-sounder and a net sounder. The net sounder indicates the net depth in relation to the surface, and also the quantity of krill that has entered the net. **(Ichii, 2000)**

5.2 Catching techniques

While the trawlers are fishing they usually travel at a speed of two knots. In most cases catch rates are not limited by the availability of krill but by processing on board and by the need to overcome quality concerns. When trawling, towing duration during hauls is generally adapted to reduce product deterioration. Krill catches in each haul is also limited to prevent the product from being crushed and to allow processing when the catch is still fresh (normally 2-3 hours). Towing and processing operations are continued throughout day and night. **(Ichii T. 2000)**

5.3 Catch selection

An important concern for Antarctic krill fisheries is quality and the commercial value of the catch. In general, Antarctic krill products are graded by body size and body colour. The term “green krill” is applied to individuals that have been feeding intensively on phytoplankton. Green krill are normally found in the early austral summer (December-January). When fresh frozen or boiled krill are produced, “green” krill are avoided because it lowers the quality of the product due to a dirtier appearance, a poor smell, and inferior taste. “White” krill is the term used for transparent krill that is of higher commercial value due to its firm and attractive appearance. “White krill is more frequent in the late austral summer.

Krill size is generally used as grading criteria: “LL” refers to krill that is larger than 45 mm, easier to peel and of higher value. It is used for human consumption and sport fishing. “L” is applied to individuals of 35-45 mm, and “M” is used for krill below 35 mm. These last two seizes are used for sport fishing aquaculture feed. **(Ichii T. 2000)**

6 Market for Antarctic krill products

Recent analysis of the fishery and the market for krill products show that an expansion of the Antarctic krill fishery might be about to happen. The main driving factor is an expected increase in the demand for krill products, particularly for aquaculture feeds but also for pharmaceutical uses. **(Sclabos, Toro, 2003)**

6.1 Human consumption of krill

The main krill product for human consumption is frozen krill tail meat, which consists of the cooked and peeled tail meat of krill, which is frozen at sea. It is marketed as a very nutritional organic seafood product with a mild taste, similar to lobster, rich in Omega 3 oils, vitamins, minerals and antioxidants. It can be used in pizzas, seafood salads, soups, and restaurant entrees. **(Sclabos, Toro, 2003)**

There have also been some reports on the marketing of “Antarctic Krill Concentrate” as health food supplement prepared from peeled, freeze-dried tail meat. **(Nicol, Forster, Spence, 2000)**

6.2 Chitin and Chitosan

There is a steady development of krill products for non-nutritional uses -such as pharmaceutical and industrial uses. Main applications are the production of chitin and chitosan from krill shells and krill enzymes for pharmaceutical and other purposes. Chitin and its substance-derived chitosan have a wide variety of current and potential uses, from loudspeakers membranes to cholesterol lowering products. Krill oils have also been described as an expanding market in the lucrative nutriceutical, cosmetic and pharmaceutical fields. **(Nicol, Foster, 2003)**

Krill’s powerful hydrolytic enzymes have a potential for pharmaceutical uses, such as the production of chemonucleolytic agents or debriding agents for the treatment of necrotic wounds. Research programs have succeeded in the identification of a single enzyme from krill, which may lay the basis for the development of drugs for the treatment of several types of infections. Moreover, krill enzymes may also be used in the restoration of art. **(Nicol, Forster, Spence, 2000)**

6.3 Krill for aquaculture feed

The use of krill for aquaculture feed seems to be the most important market for investments in krill harvesting. Aquaculture, especially salmon farming, lacks sufficient feed supply.

This lack of supply, along with increasing concerns over contaminants in aquaculture feeds, is leading the industry to seek feeding alternatives. Krill demand is likely to increase due to its excellent value as nutrient source for farmed fish and crustaceans (protein, energy, essential amino acids). Other properties of krill are its natural pigment content (particularly appropriate for salmon farming), its palatability, its low content of pollutants, and its likely improvement of larval fish survival. These attributes make krill a more attractive feed than potential competitors such as squid meal, clam meal, artemia soluble, and fish soluble. **(Sclabos 2003)**

In summary, the demand for high quality aquaculture feeds, and in particular as a protein source for salmon farms, might raise the profitability of krill fishing considerably. Furthermore, increasing restrictions to access to krill fisheries in the Northern Hemisphere is very likely to intensify pressure on Southern Ocean krill stocks. Antarctic waters are the most obvious source for krill. In light of these developments, an expansion of the Antarctic krill fishery seems inevitable. **(Nicol, Foster 2003)**

7 Management of Antarctic krill

In 1982 the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) came into force as part of the Antarctic Treaty System. The aim of this convention is to regulate the harvesting of marine species (except whales and seals) in the Southern Ocean. The major factor that prompted the negotiation of CCAMLR was the need to respond to the rapid expansion of the krill fishery in the 1970’s and the related concerns over the possible impacts that krill fishing might have on the Antarctic marine environment.

The key role of krill in the ecosystem was very important for the formulation of CCAMLR's basic principles. According to article II, the objective of the convention is the conservation of Antarctic marine living resources and their rational use. CCAMLR was the first international fisheries arrangement to incorporate the ecosystem and precautionary approaches as basic principles.

The ecosystem approach concentrates not only on harvested species but also takes into account the ecological inter-relationships between harvested and non-harvested species, in order to minimize fisheries impact on dependant and related species, and on the ecosystem as a whole.

CCAMLR has a decision-making body. Its 24 members take all management decisions on the basis of consensus.

The first challenge faced by CCAMLR at its entry into force, was to develop an effective system to accomplish the Convention's basic principles, at a time when a rapid expansion of krill fishing levels was anticipated. Right from the beginning it became clear that the traditional approaches to fisheries management were not appropriate for krill. Consequently, to consider the needs of krill dependant species more conservative reference points were adopted.

CCAMLR's scientific committee spent considerable effort in determining appropriate harvesting levels for krill using a simulation model, called KYM (Krill Yield Model).

(Croxall, Nicol, 2004)

8 CEMP: Ecosystem Monitoring Programme

An assessment of the impact of krill fishing on dependant species is one of the main tasks of CCAMLR's Ecosystem Monitoring Programme (CEMP). It is designed to detect and record significant changes in the critical components of the ecosystem. CEMP findings are integrated into long-term management procedures to be adjusted to new information on the Antarctic ecosystem.

Catch limits for krill in the South Atlantic (statistical area 48), where the current fishery primarily operates, have been set in 4 million tones, subdivided into four areas:

- 48.1: 1.008 million tones
- 48.2: 1.104 million tones
- 48.3: 1.056 million tones
- 48.4: 0.832 million tones

Although the current fishery is only taking a small proportion of this quota – around 100.000 – 160.000 tones are being harvested annually – it is important that catch limits for krill are established for large areas of the Southern Ocean, while the krill fishery are in fact taking place at much smaller scales. For example in the southwest Atlantic the fishery operates in les than 20% of the area. But in many areas fishing grounds overlap with feeding areas of krill predators. So if high krill quantities were removed locally here this could have an impact on the predators. It is therefore necessary to manage the krill fishery at much smaller scales and to develop a model that adequately takes into account the relations between predators and their prey.

In 2002 CCAMLR started this program by defining 15 “Small-scale Management Units” (SSMUs) for the management of the krill fishery in the South Atlantic. The current challenge is to set catch limits for each of these areas that adequately take into account the needs of krill-dependant species. **(Croxall, Nicol, 2004)**

9 Ecological concerns

The central role of krill in the Antarctic marine ecosystem makes it important to care about the potential impacts of krill harvesting on those species that have krill as an essential component of their diet. According to the information that is currently available, the Antarctic krill fishery occurs almost entirely within the rages of land-based krill predators such as penguins and seals. **(Croxall, Nicol, 2004)**

In some areas there is already competition for krill between fishing vessels and krill predators. This evidence is based on consumption rates in local areas and at particularly critical times of the year for predators.

(SC- CCAMLR, 2003)

Twenty years of long-term monitoring of seabirds and seals on South Georgia has shown an increase in the frequency of years when there is insufficient krill to feed seal pups and seabird chicks.

The impact of high krill catches that are taken in a small area, close to land-based predator colonies, also needs to be considered in relation to breeding times. Concentrated fishing may have its maximum impact on predator breeding success, when fishing takes place on the immediate foraging area and at the critical breeding time. For example, in the Antarctic Peninsula, the summer fishery takes place at the same time and in the same areas where penguins and seals are foraging to rear their young. **(British Antarctic Survey, 2000/01)**

10 Conclusion

In my opinion the krill fishery must be strictly controlled to keep the environmental impact as small as possible. Due to an increasing demand for krill products the krill fishery will expand in the next years. Especially aquacultures continue to grow because conventional fisheries decline due to over fishing. In some years krill will be more and more used as a food item for humans. The growing world population might make this necessary. Apart from that the need for krill as a source of biochemicals will increase.

Currently the Antarctic krill fishery is still controlled by economic and marketing factors but in the near future it might become economic to harvest krill commercially. This would cause huge ecological problems because of the important role of krill in the food web. So far there is little experience in managing fisheries on such a significant species.

Without strict and constant control the krill fisheries could cause unpredictable harm to the marine ecosystems.

From my point of view the precautionary approach that was adopted by CCAMLR seems to be a very effective way to manage the krill fisheries without forgetting the other animals that are dependant on krill.

So with a growing krill fishing industry there should be constant controls of the impacts on the environment and krill dependant predators. If any harm is caused it must be possible to enforce catch limits for certain areas. Apart from that I regard further research on krill and its role in the food chain as very important to assure an optimal protection of the whole ecosystem in the Southern Ocean.

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