

Exploration & Exploitation of Antarctic Krill Resources

A.H. Parulekar & S.G. Prabhu Matondkar

Ecobiological Features

The euphausiids (eucarid - malacostraca - crustacea - Arthropods) are small shrimp like organisms, collectively called as Krill. They are characterized by small size (excepting Euphausia superba - the Antarctic Krill which averages about 5 cm length, when matured), frilly gills (easily seen from lateral or side view) and photophores or light-producing organs. Pigments distributed in variable patterns within the transparent body are used as a macroscopic character for the identification of krill in the field. The krill is limited to waters, where the salinity is greater than 28 parts per thousand.

The 11 species of krill inhabiting Antarctic waters have a circumpolar but asymmetrical range occupying an area of roughly 15 to 20 x 10⁶ km² year round and approximately 42 to 56 percent of the ocean south of the Polar Frontal Zone, which ranges from 50°s in the Southern Atlantic and Indian Ocean to 62°s in the Southern Pacific.

The krill form dense apparently monospecific aggregations, referred to as swarms. The sizes and shapes of swarms are estimated, based on visual observations, echo sounding records and acoustic scanning techniques. Krill may remain in the same area throughout its life, though actively swimming against prevailing currents or through passive transport via eddy currents that hold them in an area for a prolonged period. They may also be transported over large areas, returning to a specific area at certain time/season of the year.

The largest concentration of krill is generally found in the East Wind

Drift Zone : the Weddell, Ross, Amundsen and Bellinghausen Seas; north and east of South Georgia Island; the Scotia Sea north of the Orkney Island; around the South Shetland Island and West of the South Sandwich Islands.

The location of krill spawning area are still being investigated. The maintenance of krill population within specific geographical region is a relatively unknown factor. After spawning, fertilization of the eggs occur externally and the eggs which are denser than the water, sink. The developing krill ascend to the surface layer where they congregate in the top 100 meters, most often in the top 10 meters and exhibit diurnal vertical migrations. Krill growth rates vary geographically, since oceanographic conditions and phytoplankton concentrations (source of nourishment) are different throughout the distribution range of krill. Euphausia superba - a commercially important species - may live upto 4 years.

Chemical Composition & Food Value

Krill are a potentially valuable, high quality food rich in proteins, oils and contain many important minerals as well as significant quantities of, at least, two vitamins, B12 and A. An overview of the general chemical composition, as compiled from various published reports, is presented in Table 1, 2 & 3.

The chemical composition can vary inter-specifically, although the exact cause is not known. With an increase in body weight, there is a relative increase in the proportion of lipids and a corresponding increase in proteins and carbohydrates with increase in size. For example, in smaller krill, the protein fraction is generally the largest whereas in large specimens, proteins and lipids are approximately equal. The cholesterol content has been estimated to be 0.3% of wet weight. A considerable loss in free amino acid in cooked krill meat has been reported.

Table 1: Chemical Composition of Krill (Percent net weight)

	Water	Ash	Crude Fat	Crude Protein
Whole	76.0-89.3		1.5	1.2-4.6
Edible part	76.6		1.5	2.7
Other	79.8		3.3	2.1
Whole (male)	77.9		-	1.7
Whole (female)	75.3		-	4.3
Whole (raw frozen)	78.7		3.4	4.2
Whole (precooked frozen)	80.0		3.9	3.8

Source : Nemoto & Nasu, 1975

Table 2 : Elemental Composition of Krill (mg/100 g dry weight)

Element	Content
U	15-30
Na	1000-2000
Mg	3000-5000
Al	15-40
Si	10-20
P	10000
Ca	>7000 - >10000
Ti	1-3
Cr	2-5
Mn	1-10
Fe	100-300
Co	< 1
Ni	10-50
Cu	10-100
Zn	800-1500
Sr	400-500
Ag	0.5-0.1
K	(1076-1400)

Source : *Chenard et. al., 1976*

Table 3 : Amino Acid Composition Of Krill

Amino Acid	Percent of Total protein
Lysine	7.7
Histidine	2.1
Arginine	6.0
Aspartic Acid	10.9
Threonine	4.7
Serine	3.5
Glutamic Acid	10.5
Proline	4.4
Glycine	4.0
Alanine	4.9
Cysteine	1.1
Valine	6.8
Methionine	1.7
Isoleucine	7.6
Leucine	9.6
Tyrosine	4.4
Phenylalanine	5.3
Gultamine	12
Tryptophan	-
Asparagine	-

Source : *Chenard et. al., 1976*

Flourides in high concentrations (133-240 mg/100 g fat free dry weight) have been reported in krill. These are mainly localized in the shell whereas the muscle tissue possesses concentrations of 55-75 mg/100 g fat free dry weight. Consequently, krill peeled or otherwise, does not comply with the requirements for human consumption.

Resources & Harvesting

The standing stock assessment of krill (Table 4) range from 44.5 to 2573.6 x 10⁶ metric tons live weight and annual production (assessed from predation) from 200 to 330 x 10⁶ metric tons. The estimated total annual predation of krill does not corresponds well with the estimated total annual production of krill.

Various methods are used for estimation of krill stocks. Krill abundance and spatial pattern (aggregation) can be estimated with modern acoustic instruments coupled with net catch. Nets can be of various mesh sizes for selective krill catch. Indirect methods like catch to efforts ratio, egg numbers, P/B ratio of predators and age structure of krill population are commonly used as the indicators of krill abundance.

The remotely operated nets fitted with cameras are also useful for locating and estimating krill swarms in productive regions.

Experiments have been performed with several type of gears, including surface side trawl and frame nets; single and twin midwater trawls and purse seines. In more recent explorations, the single-boat armed midwater trawl has been used, however the relative performance and efficiency of all the gears used, so far, is far from well known.

The catch rates reported by the 1975-1976 West German expedition averaged 8 to 12 tons per hour of towing time, with a maximum haul of 35 tons in 8 minutes. It is difficult to assess catch rates, as full-scale commercial type fishing operations have not been reported.

The economics of establishing a krill fishery are largely unknown, as commercial scale operations have not yet occurred and experimental harvesting costs are not being released by participating countries like Poland, USSR, West Germany, Norway, Argentina, Canada, Japan, South Korea and Taiwan.

Since 1970, many countries are involved in experimental krill fishing. Interest in krill resources greatly expanded during 1976-1977 because of improvements in harvesting performance and the need to redeploy long distance fishing fleet affected by the implementation of 200 mile exclusive economic zone. The available data (Table 5 & 6) reveal that the krill fishing

Table 4: Krill Stock Estimates

Author		Stocks (million tons)
Lubimova et. al.	(1979)	800 - 5000
Marr	(1962)	44.5
Everson	(1977)	521
Gulland	(1970)	750
Doil et. al.	(1979)	1200
Voronina	(1983)	60 - 100
Kalinowaski	(1983)	100 - 400
Parulekar et. al.	(1987)	1718 - 2573.6

**Table 5 : Total Commercial Catch of Krill (all areas):
Share of Indian Ocean Sector**

Year	*	**			
	Total	Area 58.4	58.5	58.6	58.7
1973	59	-	-	-	-
1974	19785	446	-	-	-
1975	44029	2677	-	-	-
1976	5635	4750	-	-	-
1977	91516	12801	-	-	-
1978	132349	52855	-	-	-
1979	333128	63732	-	-	-
1980	477003	116864	-	-	-
1981	448132	155030	-	-	-
1982	528201	147978	-	-	-
1983	228643	79645	-	-	-
1984	130875	25554	-	-	-
1985	191460	5932	-	-	-
1986	445673	15910	-	-	-
1987	376456	29557	-	-	-
1988	370663	6490	-	-	-
1989	395470	207	-	-	-

* Chile, Japan, Poland, Soviet Union, etc (19 Countries)

** France, Japan, Soviet Union (3 Countries)

(Source: Report of VIIIth meeting of Scientific Committee of Commission For The Conservation of Antarctic Marine Living Resources (CCAMLR), Nov. 1989.

Table 6: National Krill Landings (In tonnes)

Country	1983	1984	1985	1986	1987	1988	1989
Chile	3752	1649	2598	3264	4063	5938	5394
GDR			50				
Japan	42282	49531	38274	61074	78360	73112	78928
Republic of Korea	1959	2657			1527	1505	1779
Poland	360			2065	1726	5215	7871
Spain					379		
USSR	180290	74381	150358	379270	290401	284873	301498
Total	228643	12848	191460	445673	376456	370663	395470

Source: Report of VIIIth Meeting of Scientific Committee of Commission For Conservation Of Antarctic Marine Living Resources (CCAMLR) Nov. 1989.

**Table : 7
Chemical Composition of Krill Mince Products**

	Dry	Crude Protein	Lipids	Ash	Shell
Cogulated Paste Mince	26.3	15.6	6.3	2.8	--
Precipitate	25.2	14.2	8.7	--	0.39
	26.6-28.8	18.1-19.7	4.5-7.0	--	0.02-0.07

Ref: FAO report 268 (1985)

in the Indian Ocean sector is almost negligible as compared to other sectors.

Processing

The krill processing like krill harvesting, involves many uncertainties. The processing of some products, like meat can be accomplished using present technology, but most technologies require substantial development.

The choice of processing system whether shore-based or aboard ship will depend on factors, such as location of krill swarms and the length of time, krill can be stored on vessel, prior to processing.

The larger share of water soluble proteins in krill muscles poses certain problems in processing. However, the major difficulty is due to active system of proteolytic enzymes. During cold storage, proteolytic activity increases due to the diffusion of enzymes from the intestine to the muscular tissue, thus making krill rather unfit for processing into food products. Active lipase in the digestive tract of krill is reported to cause the decomposition of phospholipids and consequent increase in free fatty acids.

Various krill products, such as, whole meats, coagulated paste, protein concentrate, dried products and meals have been produced on an experimental basis. The development of markets for krill products will however require further consumer research and product development (Table 7)

Other Products and By-Products

About 0.8% chitin is available in krill. Deacytlation of chitin will give chitosan. Chitin/Chitosan can be used in waste water treatment hemostatic agent and base material for drug, nutrients and in agriculture chemicals.

The enzymes found in digestive tract of krill can be used in industries like

food, animal feed, tanning, pharmaceuticals etc.

Similarly krill oil contains high phospholipids and fatty acids and can be used as raw material in oil, cosmetic and pharmaceutical industry.

Output of Krill Fishing

A vessel of B-414 type (90 m L & 15 m B, 1500 t, 80 days endurance) will be needed for krill fishing operations. The estimated krill landing for 106 fishing days with 55 t krill per day, is no loss no gain basis operation. The cost of product (2.5-2.9 US \$ per kg) is slightly lower than the cost of Indian shrimp product of 3.75-4.0 \$ per kg and US - Japan shrimp product of 4.0-5.2 per kg in market.

India's Contributions to Antarctic Krill Research

Since 1981-82 around 100 stations data are repeatedly collected from a part of the Indian Ocean Sector region. The rate of primary production, zooplankton biomass and krill biomass is studied. The ecological assays, an indirect method, are used for consumption of krill biomass. The krill data used are collected by bongo nets or as a part of biological productivity studies. So far, no data have been collected on experimental and/or commercial krill fishing haul by haul. Such data will be needed in future, for calibration and confirmation of acoustic survey of krill resources and thereby, to arrive at a realistic estimate of potential krill resources.

Advantages & Constraints

There are both incentives and disadvantages in establishing krill fishery in the Southern Ocean. Among factors conducive for establishing such a fishery are:

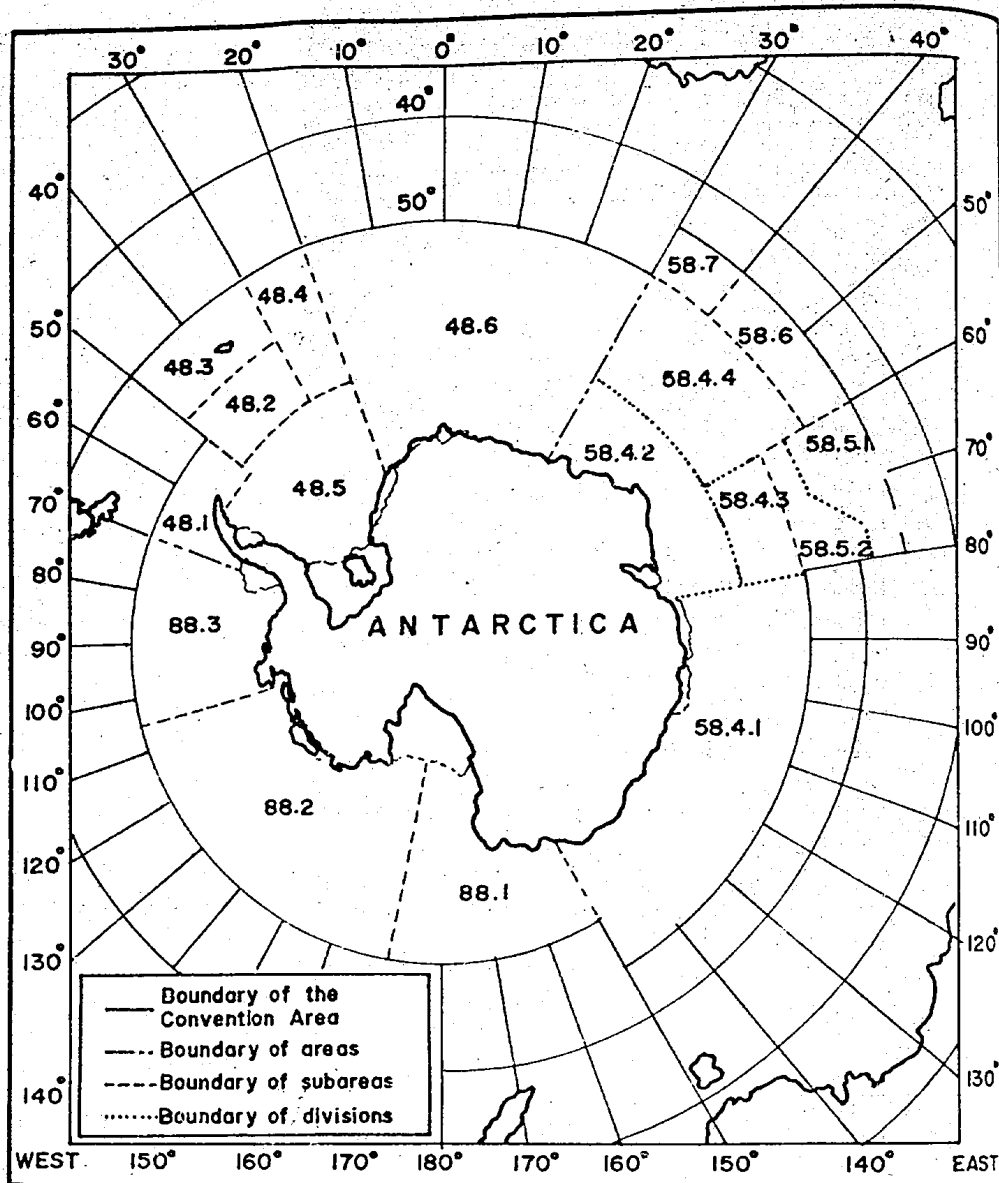


Fig. 1

INDIAN OCEAN ANTARCTICA AREA	58
ENDERBY-WILKES SUBAREA	58.4
ENDERBY-WILKES DIVISION I	58.4.1
ENDERBY-WILKES DIVISION II	58.4.2
ENDERBY-WILKES DIVISION III	58.4.3
ENDERBY-WILKES DIVISION IV	58.4.4
KERGUELEN SUBAREA	58.5
KERGUELEN DIVISION	58.5.1
HEARD-MCDONALD DIVISION	58.5.2
CROZET SUBAREA	58.6
MARIN-EDWARD SUBAREA	58.7

presence of a large, renewable and unexploited resource, not within the EEZ of any nation.

requirements of an expanding human population for new and abundant protein source.

The most information gaps appear to be:

- i) relationship between currents, eddies, gyres and krill distribution.
- ii) the biology of all Antarctic krill species : feeding habits, in relation to swarming and the abundance of phytoplankton; the exact location of krill swarming grounds; the causes and maintenance of swarming; longevity and mortality of krill; the rates of predation on krill and the role of krill in Antarctic food chain.
- iii) accurate information on standing stocks and sustainable yield and, hence, overexploitation would cause severe environmental imbalance.
- iv) harvesting and processing technologies have not yet been fully developed.
- v) commercial scale costs cannot be determined from the experimental operations, so far, undertaken.
- vi) the potential stability of krill products is also not known and, hence, potential revenues cannot be estimated.

Since krill dominate the Southern Ocean ecosystems, management and conservation of the krill resources will become important as harvesting increases. Because of the lack of information on important aspects of krill biology, the exploitation of such resources should be well planned and monitored. To achieve it, the existing data gaps must be filled.

What Needs to be Done

Fig. 1 depicts the areas in the Indian Ocean or northern sector of the southern Ocean, as demarcated by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). Very little information on potential and harvestable krill resources, is available for No. 58 area from Indian

Ocean region which is the most accessible region of the Southern Ocean, for exploration and exploitation of krill resources by India. A full fledged survey on krill resources and oceanographic features over a period of 5 years, on a grid sampling basis as shown in Fig. 2, is a pre-requisite. Besides this, general survey of other contiguous region is also planned (Fig.2) for next 5 years (from starting year) covering all the sectors of the Southern Ocean.

With the support from the Department of Ocean Development and with the participation of oceanography and fishery research institutes of CSIR and ICAR, a full fledged and detailed exploration on the ecology, biology hydrography, resource potential, processing and consumer preference, can be undertaken and successfully be completed within a period of five years.

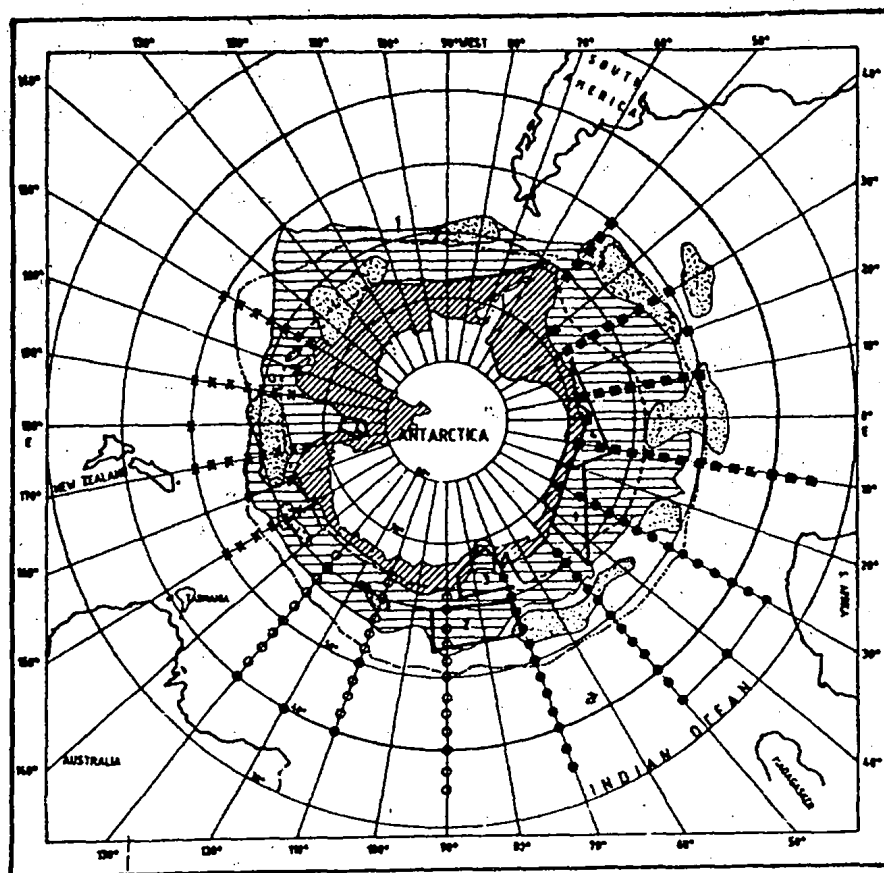


FIGURE-2

PROPOSED TRACKS / AREAS FOR CRUISES

TRACKS	—			
STATIONS	○	●	■	×
YEAR	1	2	3	4
AREAS	1	2	3	4
YEAR	1	2	3	4

(Subjected to ice conditions)

CONVERGENCE ———
 DIVERGENCE - - - - -
 (After Knox 1984)

PACK ICE SUMMER (March)
 WINTER (September)
 (After Tranter 1982)

KRILL (After Lubinova & Shitsov 1980)