

Zooplankton biomass and abundance of Antarctic krill *Euphausia superba* DANA in Indian ocean sector of the southern ocean

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Abstract. Zooplankton sampling was carried out during the first six Indian Scientific Expeditions to Antarctica (1981–1987) to estimate krill abundance in the Indian sector of the southern ocean (between 35° to 70° S and 10° to 52° E). This study aims to understand the distribution of biomass of zooplankton, especially the krill, using the data collected by net sampling techniques. Total zooplankton biomass for all the sampling stations ranged from 9 to 684 ml/1000 m³ (\bar{x} : 143.34 ± 138.61 SD; n = 150). Biomass data grouped by 5° latitude interval shows the presence of higher biomass (\bar{x} : 191 ml/1000 m³; n = 31) in the Antarctic divergence region (between 60° to 65° S). Euphausiid *Euphausia superba* DANA formed a considerable component of biomass and together with eggs and larvae represented over 60% (n = 39) of mean total zooplankton-biomass in the coastal ice region. The values for population density and biomass of adult-size krill varied between 0 to 4320 individuals and 6 to 305 ml/1000 m³, respectively.

The highest values were recorded between 62° to 69° S and between 16° to 30° E. A high density of krill larvae was encountered in the shelf region during January 1987 which was related to chlorophyll concentration. However, the values obtained during six consecutive summers showed that values of adult krill biomass at given location was highly variable and, hence, not comparable on inter-annual basis, during the sampling years.

Keywords. Distribution; zooplankton; Antarctic krill; biomass.

1. Introduction

The ocean south of the Antarctic convergence contains circumpolar community of plants and animals. Antarctic krill, *Euphausia superba* DANA, the protein rich species (Siebert *et al* 1980), plays a vital role in the Antarctic food chain and has been considered as a key organism of the Antarctic marine ecosystems (Hureau 1985). This is the most common species of Antarctic euphausiids and occurs in abundance in the Atlantic part of Antarctica (Storebakken 1988). The annual production of krill has been estimated to vary from 500 × 10⁶ to 1118 × 10⁶ tons (Gullard 1970; Parulekar and Prabhu Mathondkar 1987). Several attempts have been made by maritime nations to exploit the krill resources. However no clear picture of the distribution, seasonal and inter-annual variations in the biomass of this species has emerged. Presently the information available is restricted to only restricted areas and seasons (Everson 1985; Hampton 1985; Hoise *et al* 1988). The south-east sector of Antarctic ocean is for instance, one of the least studied regions (El-Sayed *et al* 1979; Hempel 1983).

A number of zooplankton studies covering the open water of the southern ocean have recently been published (Voronina *et al* 1980; El-Sayed, 1985; Hopkins 1985; Piatkowski 1987). In contrast only a few studies are available from the northern or the Indian ocean sector (El-Sayed *et al* 1979; Mauchline 1981; Goswami 1983;

Mathew 1986; Miller 1986). Most of the studies on krill biomass are based on the acoustic estimates (Hampton 1985; Makarov *et al* 1985; Shirakihara *et al* 1986) and barring the efforts of Miller (1986) and Endo *et al* (1986), no data on biomass by the more reliable net sampling technique are available.

The krill attracts the attention of scientists as a possible object of a commercial fishery. Keeping this view in mind the oceanographic data collected from first through sixth (1981-87) Indian Scientific Expedition to Antarctica (ISEXA) are compiled. The present investigation deals with the distribution of total zooplankton biomass and abundance of Antarctic krill in the relatively unexplored region of the southern ocean. The biomass values obtained are compared and discussed with those from other sectors of the southern ocean.

2. Materials and methods

The sampling area lies within the geographical coordinates 35° to 70° S and 10° to 52° E (figure 1). Zooplankton sampling on I, II, III, and V Indian Scientific Expedition to Antarctica (ISEXA) were executed during February-March on return voyage of the ship, whereas during IV and VI ISEXA, samples were collected throughout the austral summer, that is during December to March. All together 149 stations were covered. Sampling during ISEXA-I was carried out by vertical hauls from 100 m depth to the surface using the Indian Ocean Standard Net (IOSN, mesh size 300 μ m; Currie 1963). A Bongo net of 60 cm mouth diameter and mesh size

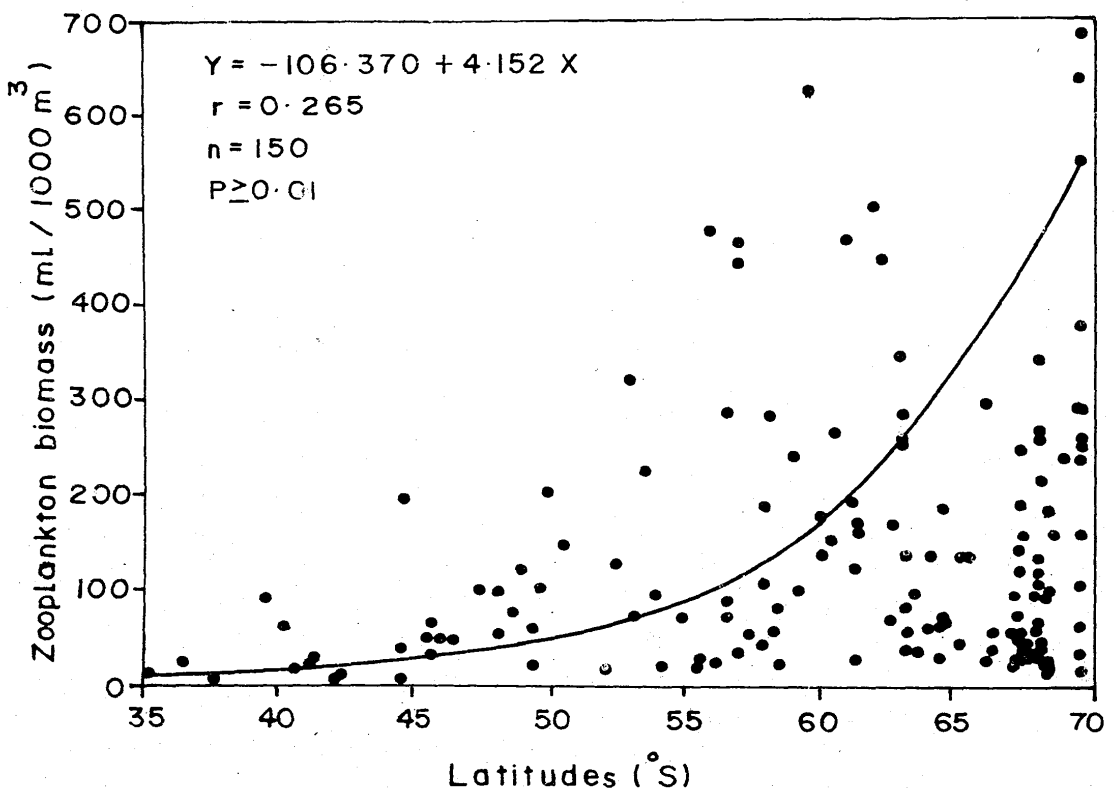


Figure 1. Quantum of zooplankton biomass at various geographical position (Latitudes) in the Indian ocean sector.

400 μm was used during ISEXA-II, III, IV and VI taking a vertical haul from 200 m depth to the surface (sampling on ISEXA-III was restricted to 150 m depth to surface). Horizontal surface tows were made during ISEXA-V using a Heron Tranter Net (mouth area 0.25 m², mesh size 300 μm) at a minimum towing speed of 1.5 knots. A TSK flowmeter was mounted at the mouth of the net to estimate the volume of water filtered. Sampling methods employed on each cruise, together with sampling dates have been summarized in table 1. Since the sampling was based on the availability of ship-time, consistency in sampling period could not be maintained during different cruises.

Table 1. A summary of the zooplankton sampling data in the Indian ocean sector of the southern ocean.

Expedition no.	Sampling details							
	Area		Depth (m)	Gear	Type of haul	No. of obser.	Zoopl. biomass (Mean \pm SD)	Duration
	Lat ($^{\circ}$ S)	Long ($^{\circ}$ E)						
ISEXA-I	39-70	11-45	1000	IOSN	V	16	107.4 \pm 153.1	3.1.82-2.2.82
ISEXA-II	46-68	10-38	200	BN	V	10	99.1 \pm 54.9	25.1.83-25.2.83
ISEXA-III*	36-68	14-52	150	BN	V	40	77.2 \pm 63.6	5.3.84-18.3.84
ISEXA-IV	35-70	10-52	200	BN	V	23	194.2 \pm 136.1	23.12.84-12.3.85
ISEXA-V	41-68	15-52	10	HT	ST	24	111.4 \pm 126.9	4.3.86-12.3.86
ISEXA-VI	38-70	11-38	200	BN	V	36	207.9 \pm 159.0	22.12.86-6.3.87

IOSN, Indian Ocean Standard Net; BN, Bongo net; HT, Heron Tranter net; V, vertical haul; ST, surface tow.

*Data from Mathew (1986).

Total zooplankton biomass was determined by the displacement method and values obtained were converted for per 1000 m³ of water volume.

3. Results and discussion

3.1 Biomass distribution

Zooplankton biomass, (vertical distribution) between sub-Antarctic and Antarctic waters varied between 9 and 684 ml/1000 m³ in the upper 200 m of the water column. Mean value for horizontal distribution was 365 ml/1000 m³. Biomass was richest in the waters south of the Antarctic convergence (40 $^{\circ}$ S). The latitudinal variations of total zooplankton biomass presented in figure 1, show that, the values increase gradually from Antarctic convergence zone (46 $^{\circ}$ S) to the south of the convergence zone. The poor correlation between zooplankton biomass and latitudes ($Y = -160.370 + 4.152X$, $r = 0.265$, $P \geq 0.01$; $n = 150$, figure 1) suggested a patchy distribution of zooplankton biomass, which might have resulted due to the swarming behaviour of *Euphausia superba* (Shirakihara *et al* 1986). It can be seen from figure 1 that, fluctuations in the mean value of zooplankton biomass for open waters was very high among the sampling years. The variations in biomass values were mainly due to the differences in the sampling season. Sampling during ISEXA-

IV was made in early summer *i.e.* on the 23 and 24 of December 1984, whereas during ISEXA-III in late summer *i.e.* from 2 to 5 March 1984. It has been reported by Verlencar *et al* (1990) that the ice-algae contribute to the biomass production in early summer and that reforming of plate-ice during the late summer may therefore result in a shift of zooplanktonic organisms towards the north.

3.2 Krill abundance

The euphausiids form a major constituent of the Antarctic zooplankton both in terms of number and weight. Among the euphausiid species, *E. superba* contributed substantially to the zooplankton fauna in the Indian ocean sector of the southern ocean. Adult krill were abundant between 62° and 69° S and 16 to 30° E. The density of krill also increased steadily between Antarctic convergence and divergence (65° S) zone. The biomass of adult krill in the upper 200 m water layer ranged between 6 to 305 ml/1000 m³ and on an average the krill accounted for 5% to 65% (\bar{x} : 35.71; n =121) of the total zooplankton biomass in the area south of Antarctic convergence. The density of *E. superba*, within the swarms was estimated by using aimed tows (ISEXA-V) and it varied from 0 to 4320 individuals/1000 m³ water. The maximum density was recorded at 62°·25' S; 28°·49' E. Such concentrations were also recorded at 59° and 63° S, but the body size composition of the specimens in the swarms were smaller than those collected at 62°·25' S.

To study the geographical (latitudinal) distribution of krill biomass in the total zooplankton, the data were pooled for 5° latitude interval and the results are summarized in figure 2. Zooplankton biomass was higher in the open waters, the

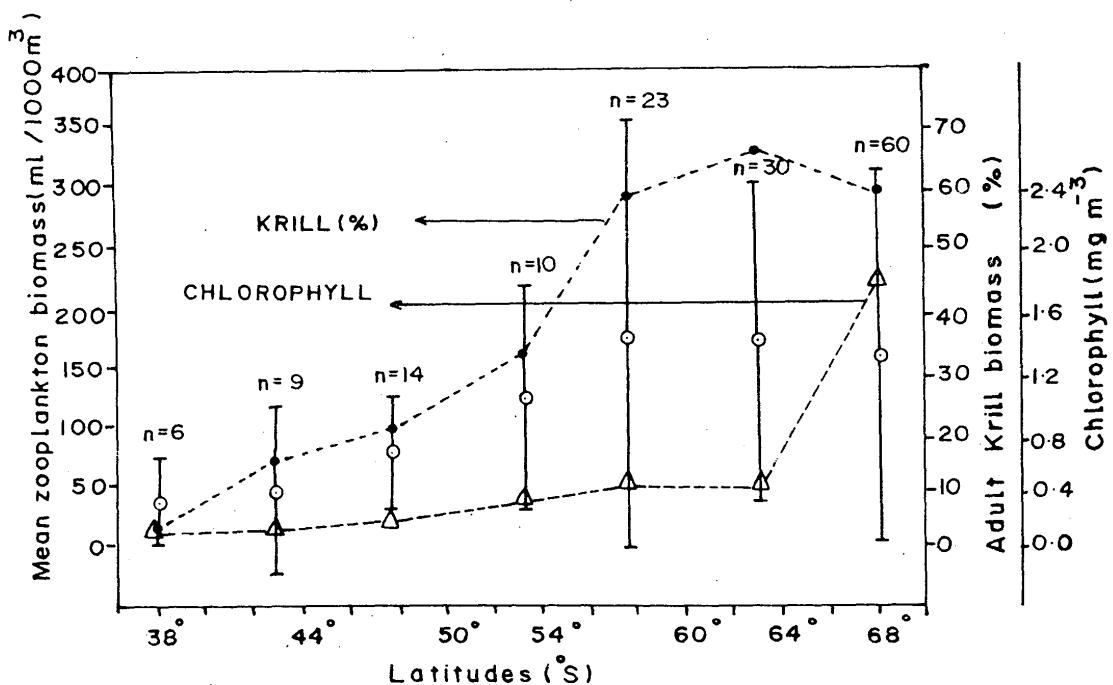


Figure 2. Variation in zooplankton biomass (data pooled for 5° latitudes) in the Indian ocean sector of the southern ocean.

maximum mean values (191 ml/1000 m³; $n=31$) being recorded in the Antarctic divergence region (between 60° to 65° S). The highest biomass of 684 ml/1000 m³ was recorded in the shelf region during January 1987, and was the result of large concentrations of euphausiid eggs, larvae and salp accumulations. Only on one occasion, however, biomass of such high magnitude was recorded.

The total zooplankton biomass, in the Antarctic waters, as discussed by Everson (1977), is considered to be mainly krill which contributes as much as 50% of the herbivorous zooplankton biomass. We also found high contribution (36%) of krill biomass in the present study. However, the values for total zooplankton biomass were lower than that recorded elsewhere (El-Sayed and Hampton 1980), which might be attributed to the coarse mesh and small opening area of the sampling gear, resulting in an under-estimation of both smaller and larger zooplankton.

3.3 Variation in zooplankton biomass in coastal waters of Queen Maud Land Region

The mean values for total zooplankton biomass fluctuated notably during the six sampling years (table 1) and the values were not consistent at particular location, especially in the shelf region. Krill contributed considerably to zooplankton biomass and together with eggs and larvae represented $\geq 60\%$ ($n=39$) of the total zooplankton biomass in the icy shelf region of Queen Maud Land. The fluctuations in zooplankton biomass were directly related to the algal peaks ($Y=418.578-88.439X$, $r=0.575$, $n=25$, $p\leq 0.001$, figure 3). Discussing the biological productivity of Antarctic coastal waters, El-Sayed and Taguchi (1981), and Pant (1986) suggested that the addition of phytoplankton, seeded from ice-algae helps in a steady build-up of zooplankton and krill biomass in the ice edge ecosystem.

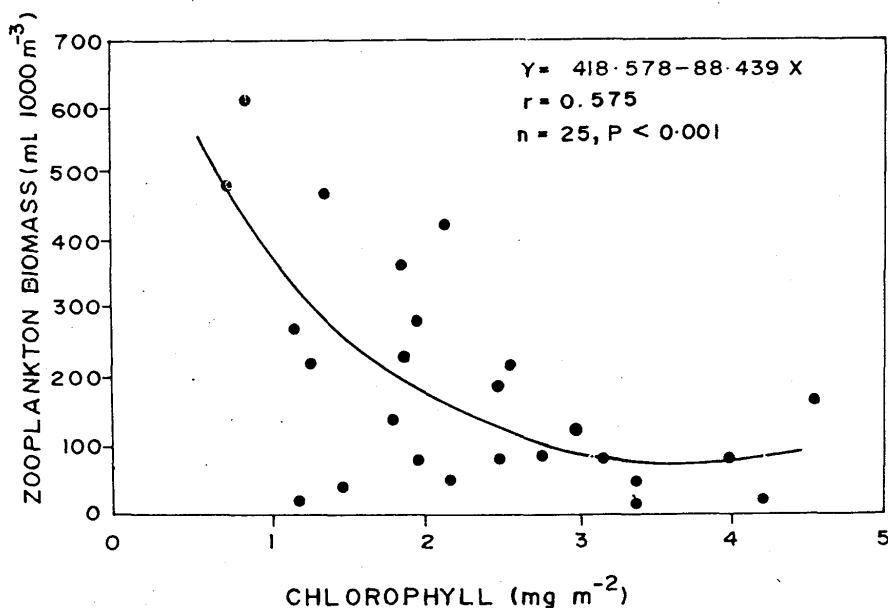


Figure 3. Relationship between the chlorophyll concentrations and zooplankton biomass.

The results of the close grid sampling, conducted to study the geographical distribution of krill indicates that, *E. superba* occurs in dense concentration between

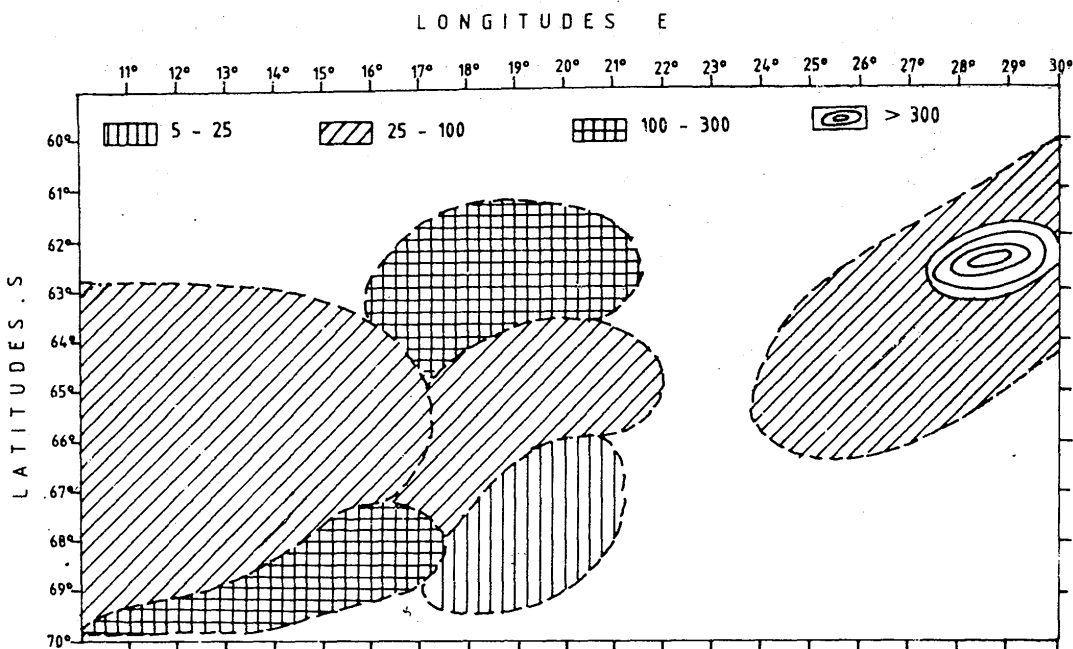


Figure 4. Area of highest krill biomass in Indian ocean sector.

62° to 65° S and 20° to 30° E (figure 4). Biomass of the adult-size krill (> 30 mm TL) was higher between 61° and 64° and between 67° and 70° S compared to other areas. Biomass of adult size krill was lower between the floating-ice and shelf region (65°–70° S) as compared to the open waters (figure 2), however, specimens were larger in size (length) at coastal stations and some of the females were bearing eggs. Occurrence of ovigerous or spent females in significant numbers at stations close to the ice-edge indicate the possibility of adult krill migration towards the south (Siegel *et al* 1990). The possible reason for krill migration could be the abundance of the ice-algae in the shelf region which serves as an attractive environment for breeding population (El-Sayed and Taguchi 1981).

Average density of krill in the Indian sector of Antarctic ocean vary between 1000 and 5000 adult individuals per 1000 m³ of water and there is a wide range of size and weight between the latitudes. In general, the krill biomass was relatively low in the study area as compared to the other regions such as Prydz Bay (Miller 1986; Hosie *et al* 1988; Higginbottom and Hosie 1989). The finding should provide a useful basis for comparison.

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