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TWO SERIES OF MACROZOOPLANKTON CATCHES WITH THE N70V NET IN THE INDIAN SECTOR OF THE ANTARCTIC OCEAN

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Abstract: Two series of macrozooplankton catches using the Discovery pattern N70V net were studied as a supplement to the previous report by the present author. These samples revealed that both standing crops and individual numbers of three copepod species, *Calanus propinquus*, *Calanoides acutus* and *Rhincalanus gigas*, were extremely poor in comparison with any other comparable data. The results again make us confirm a possible change of major herbivorous copepod populations in the sizes and/or community structures. These changes are perhaps a phenomenon related to gradual changes in quantitative relationships of relative biomass size between *Euphausia superba* and their predators, especially through the intense exploitation of rorqual whales during the past several decades, which resulted in a 'surplus' in krill population. A possible intensified competition for food between herbivorous copepods and *E. superba* is discussed as the subject of feeding strategies.

1. Introduction

In my previous report (KAWAMURA, 1986), the past and present abundances of macrozooplankton collected with the Discovery pattern N70V net during the BIOMASS SIBEX II (1983/84) were compared. There were no notable differences in the total standing crops of macrozooplankton, whereas a possible decrease was indicated with the magnitudes about 1/10 to 1/100 to the past records in the individual number of three major herbivorous copepods, *Calanus propinquus*, *Calanoides acutus* and *Rhincalanus gigas*. Although the above-mentioned results are still tentative, KAWAMURA (1986) deduced those evidences to be a phenomenon reflecting some changes in the marine Antarctic ecosystems, especially in interspecific dynamics between *Euphausia superba* and their major predators, the rorqual whales.

During the austral summer of 1983/84 zooplankton sampling using the reconstructed N70V net was conducted at two stations in the Indian Sector of the Antarctic Ocean on the icebreaker SHIRASE during her commission for the 25th Japanese Antarctic Research Expedition (JARE-25). This is to report briefly the results from the SHIRASE samples along with further considerations to supplement the previous report (KAWAMURA, 1986).

2. Materials and Methods

The whole sampling procedures in the field such as the speed of net tows, depth

Table 1. Sampling data on N70V net tows on the icebreaker SHIRASE, JARE-25, 1983/84.

	Stn. 1	Stn. 3
Date	14 Dec. 1983	15 Dec. 1983
Local time	1040–1158	0950–1045
Position	63°42.2′S	64°13.4′S
	44°54.4′E	43°54.5′E
Depth of net tows (m)	44.2–0	50–0
	100.1–46.4	99.9–50
	249.5–89.1	250–99.6
	499.7–216.5	499.4–241.5

of water columns fished, and laboratory treatments were similar to those in the previous study (KAWAMURA, 1986). Data on zooplankton samplings are given in Table 1. The two sampling stations are closely dated and positioned. Since the depth layers actually fished were slightly different from the planned sampling depth ranges, *i.e.*, 0–50, 50–100, 100–250 and 250–500 m, the biomass and individual numbers of three copepod species were converted to approximate to planned depth ranges. Filtering efficiency of the reconstructed Discovery pattern N70V net was measured using two flow-meters in the towing tank. At the mouthring, the top part of the net, it was 89.7% whereas it was 86.1% at the part of choak line where actual filtering cone begins. If we take 86.1% as an actual performance of the net, then the volume of water filtered by the net per unit length of water column is 0.33 m^3 per meter, or 16.6 m^3 per each 50-m tow. The number of copepods was, however, expressed as the number per haul so as to compare the results directly with the Discovery's data by FOXTON (1956). Also, *Metridia gerlachei* was excluded from Table 5 since no past comparable data are available for this species.

3. Results

The total wet weight biomass of macrozooplankton throughout all sampling depth ranges was 0.17–0.53 g/haul (Table 2). The samples generally contained 1–275 individuals of chaetognaths of various body sizes with diatoms predominated by *Thalassiothrix antarctica* and *Chaetoceros convolutus*, especially the trend was clear at Stn. 3 for the diatoms. In comparison with the data obtained by the R. V. HAKUHO MARU (KAWAMURA, 1986) in the Australian quadrant and by the DISCOVERY II (FOXTON, 1956) in the Indian Ocean sector, catches of plankton by the SHIRASE are considerably small.

Table 2. Biomass of macrozooplankton collected with the N70V net (g/haul).*

Depth of net tows (m)	Stn. 1	Stn. 3
50–0	0.31**	0.17
100–50	0.38	0.31
250–100	0.33	0.19
500–250	0.41	0.53**
Total	1.43	1.20

* Wet weight of plankton was converted to approximate to planned sampling depth ranges.

** Unusual large salps were removed before weighing.

In the existing Discovery's data on individual numbers of copepods collected with the N70V net, four most important herbivorous copepod species are included, *i.e.*, *Calanus propinquus*, *C. simillimus*, *Calanoides acutus* and *Rhincalanus gigas*. Of these *C. simillimus* did not occur in the present samples. The individual numbers of the major copepod species mentioned above are given in Table 3. Among four species compared, *Calanoides acutus* was most abundant, but the density of this species through 500–0 m column at Stns. 1 and 3 was 0.72 and 0.42 individuals per m^3, respectively, very small values for the noted copepod species in the Southern Ocean.

Table 3. Individual number of major copepod species collected with the N70V net during JARE-25, 1983/84 (BIOMASS SIBEX II) (number/haul).

Species	*C. propinquus*		*C. acutus*		*R. gigas*		*M. gerlachei*	
Station	1	3	1	3	1	3	1	3
50–0 m	2.27	—	22.73	11.00	—	—	—	—
100–50 m	2.78	2.83	61.12	18.86	28.71	8.49	2.78	0.94
250–100 m	0.93	—	13.06	10.73	21.43	9.44	12.12	9.43
500–250 m	—	—	22.07	29.00	22.96	45.00	8.83	10.00
Total	5.98	2.83	118.98	69.23	73.10	62.93	23.73	20.37

4. Discussion

Both biomass and individual numbers of major copepod species found in the SHIRASE samples were very small on the whole compared with any of the previous data obtained by the N70V net catches. Generally, it is not easy to compare the abundance of plankton catches collected at different times and places, and/or with different sampling gears due to many factors that directly or indirectly influence the catch amounts. MOTODA (1957) found a sampling bias with the magnitudes of 20–495% through 12 sets of the Norpac net catches being comprised of 36 samples that were collected at the same sampling station. However, with some amount of samples a comparison may be possible to some extent when sampling methods, gears and data processing are taken into consideration under a reasonable coincidence with each other as it was shown by HOPKINS (1971). The sampling schemes on both the R. V. HAKUHO MARU and SHIRASE were the same in gears and treatment of samples, and these may roughly provide one of baselines for comparing the present data with those by the Discovery Investigations. By selecting six data sets by the DISCOVERY II in the Indian Ocean sector (FOXTON, 1956, Tables IIa–f), the average total biomass of macrozooplankton was compared (Table 4). On the whole, the biomass given in Table 2 is considerably small when it is compared with any of the previous data; about 77.5% less than the Discovery catches for 0–500 m column. The catches of the N70V net, especially, in the upper 100 m sometimes contained a large quantity of diatoms. After excluding the catch data for this layer, *i.e.* 100–500 m, KAWAMURA (1986) found no notable differences between the data during the 1930's (FOXTON, 1956) and those of BIOMASS SIBEX II by the R. V. HAKUHO MARU. The data from the SHIRASE samples, on the other hand, are considerably smaller than those of two previous investigations, but it is needed to accumulate the catch record with the N70V net for the further

Table 4. Average biomass of macrozooplankton collected with the N70V net (g/haul).

Authority	FOXTON (1956)	KAWAMURA (1986)			
Region	Antarctic*	Ant. Conv.	Pack ice	Antarctic	
Station	2517 1220–1224	AC-I-C	4, 5 & PI-2	3B,	6
Date	11xii38 13–16xii33	28xii83	23xii, 16 & 19i84	25xii83	21i84
50–0 m	0.67**	0.85	3.96**	10.92**	
100–50 m	1.50**	0.85	1.59**	6.37**	
250–100 m	1.70	0.66	0.79	1.21	
500–250 m	1.97	2.84	2.50	1.42	
Total	5.84	5.20	8.84	19.92	

* Selected DISCOVERY stations that were close at position and date to the present study.
** Some samples were rich in phytoplankton.

examination. As KAWAMURA (1986) suggested, behavior of salp population is considered very important in total zooplankton biomass. Especially, very small aggregated zooids which are difficult to be sorted out from the samples sometimes cause a large biomass of zooplankton catches. Recent findings in South Georgian waters by MACAULAY *et al.* (1984) suggest a rapid response of salps to the changes in environments to show an erratic annual variation in their concentrations. This may also suggest a possible increase in population size of salps over the wide range of the Southern Ocean during the past several decades as one of responses to a possible change in the marine Antarctic ecosystems (*e.g.* LAWS, 1977).

To compare the individual numbers of three major copepod species, Table 5 was constructed from KAWAMURA (1986, Table 8). The values for the present data were smallest among all compared. This may again make us confirm the previous findings, which may be deduced to a possible decrease in population sizes of major herbivorous copepods as a results of changes in trophodynamic relationships between *Euphausia superba vs.* rorqual whales and *E. superba vs.* herbivorous copepods during the past decades.

These considerations largely rest on the results on feeding strategies of both *Euphausia superba* and herbivorous copepods. Under a limited feeding environment, such as the low food density and biassed food particle size, the copepods may respond to them by postponed or greatly reduced rates in their growth or developments as found in the North Sea *Calanus finmarchicus* and *C. helgolandicus* (DIEL and KLEIN BRETELER, 1986). Another finding is that the population of *Calanoides carinatus* under unfavorable food conditions is maintained by high mortality rate in younger

Table 5. Comparison of the present and past abundances in average number of three major copepod species collected with the N70V net in the upper 500 m column.

Authority	*C. propinquus*	*C. acutus*	*R. gigas*
KAWAMURA (Present study)*	4.4	94.1	68.0
KAWAMURA (1986)	32.3	175	119.3
HARDY and GUNTHER (1935)	278.5	884.6	228.2
MACKINTOSH (1937)	2.1	934.6	949.6
ANDREWS (1966)	—	338	—

* Average for two catches at Stns. 1 and 3.

stages (BORCHERS and HUTCHINGS, 1986). All these above-mentioned may finally lead to lessen the population size of the species. Generally, the herbivorous copepods have some optimum particle size ranges for food (RAYMONT, 1983). The four copepod species under consideration are the typical herbivores in the Antarctic Ocean (*e.g.* ANDREWS, 1966), and are also known as non-swarming species (KAWAMURA, 1974, 1986). The krill, *E. superba*, undoubtedly competes for their food with herbivorous copepods. This euphausiid species has been known to form a dense swarm of varying spatial scales. ANTEZANA and RAY (1984) considered that swarming krill through their mass feeding may leave food particles of strongly biassed size fractions caused by their selective feeding. The size composition of possible food particles left for the copepods after skimming of *E. superba* may sometimes become a larger fraction (QUETIN and ROSS, 1985) or very small one (BOYD *et al.*, 1984; MORRIS, 1984; WEBER and EL-SAYED, 1985). Krill also undertakes 'compression feeding' (HAMNER *et al.*, 1983) using 'basket' formed by the thoracic appendages, and even gnaws upon food particles (MCWHINNIE and DENYS, 1978). *E. superba* is probably able to switch its feeding scheme from one to another, and such characteristics undoubtedly function as beneficial strategies than the case in copepods under a natural feeding environment.

At present we do not know the quantitative and qualitative relationships between the primary production and its consumption by grazing. The bloom of *Biddulphia sinensis* in the Subantarctic waters is probably less important for smaller herbivores (BALECH, 1970), and the same is true for *Thalassiothrix antarctica* in the Antarctic Ocean. It is needed to examine this kind of aspects more quantitatively. However, there is one viewpoint that food condition around the Antarctic herbivores, especially for copepods, is in a state of considerable competition (HOPKINS, 1971). A considerably smaller number of individuals in four major copepod species in recent catches is perhaps a results related to a possible growing competition for food with *E. superba* whose population has became larger in relative abundance among zooplankton community in the Antarctic Ocean.

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