Bull. Fac. Fish. Hokkaido Univ.
45(2), 39-47. 1994.

Microzooplankton Biomass in the Western North Pacific Ocean in Spring, 1985*

Tsuneo ODATE**,*** and Yoshiaki MAITA**

Abstract

Biomass of microzooplankton (copepod nauplii, tintinnids, naked ciliates, and others) was investigated in the western North Pacific Ocean during the spring of 1985. Surface water survey showed that the total microzooplankton biomass was one order of magnitude higher in the subarctic than in the subtropical water. Vertical observation, however, revealed that the microzooplankton biomass was high in the top 50 m in the northern sea area while the biomass maximum layer occurred bolow depth of 50 m in the southern sea area. Using the relationship between the surface and the integrated biomass throughout the 0-200 m water column, the microzooplankton biomass in the surface was converted to the integrated biomass. The mean biomass in the water column was 1.2-fold higher in the transitional water (1.83 g m^{-2}) and 1.7-to 3.4-fold higher in the subarctic water (2.68 and 5.40 g m^{-2}, respectively) than in the subtropical water (1.59 g m^{-2}). Since macrozooplankton biomasses in the transitional (15.8 g m^{-2}) and the subarctic waters (41.7 g m^{-2}) are 1.7- and 4.6-fold larger than the subtropical water (9.07 g m^{-2}), respectively, it seems that relative abundance of microzooplankton to macrozooplankton is low in the subarctic and high in the subtropical water.

Introduction

Net towing is one of conventional methods to collect macrozooplankton, and has been conducted by many oceanographers. As a result the abundance and distribution of macrozooplankton have been revealed from various sea areas and seasons (e.g. Odate, 1986).

Recent studies have shown that the size of major primary producers in the ocean, especially in the oligotrophic open water, is smaller than 2 μm, so are called picophytoplankton (Sieburth et al., 1978) [see Chisholm (1992) and references therein]. Macrozooplankton can not graze upon picophytoplankton directly (Marshall and Orr, 1956; Rassoulzadegan and Etienne, 1981; Laybourn-Parry, 1992). Hence, microzooplankton, which easily escape from the mesh aperture of a conventional net, must play an important role in picophytoplankton dominant ecosystems. That is, microzooplankton appear to be a link by which picophytoplankton carbon is transformed to higher trophic levels (Sherr and Sherr, 1988; Stoecker and

* *Contribution No. 274 from the Research Institute of North Pacific Fisheries, Faculty of Fisheries, Hokkaido University*
(北海道大学水産学部北洋水産研究施設業積第 274 号)
** *Division of Marine Biochemical Science, Research Institute of North Pacific Fisheries, Faculty of Fisheries, Hokkaido University*
(北海道大学水産学部北洋水産研究施設海洋生産学部門)
*** *Present : Laboratory of Biological Oceanography, Faculty of Bioresources, Mie University, 1515 Kamihama-cho, Tsu 514, Japan*
(現所属：三重大学生物資源学部水圏環境学講座)

Capuzzo, 1990).

It is considered that relative abundance of microzooplankton to macrozooplankton is high in the subtropical water where picophytoplankton predominates, while it is low in the subarctic water where large cell-sized phytoplankton is abundant (Taniguchi, 1984, 1985). The present study aims to show biomass of microzooplankton in the western North Pacific Ocean, where a large number of data on macrozooplankton biomass has been collected (e.g. Odate, 1986). And then, the relative abundance of microzooplankton to macrozooplankton will be discussed.

Materials and Methods

Samplings were carried ont during the cruise of the R/V Hakuho Maru (KH-85-2), from April 12 to May 15, 1985 in the western North Pacific Ocean (Fig. 1).

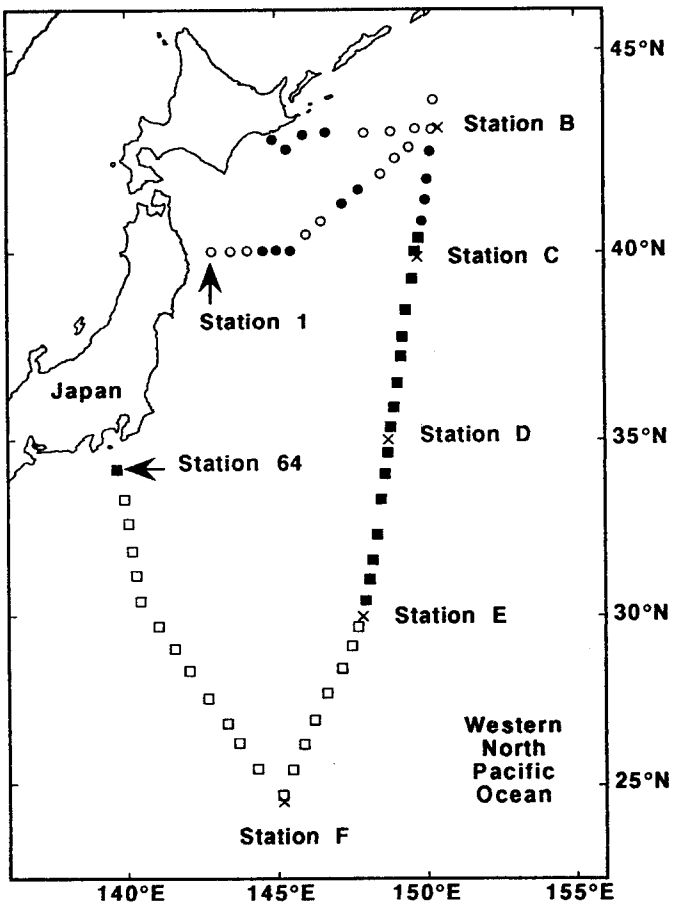

Fig. 1. Sampling stations in the western North Pacific Ocean. At Stations 1-64 the surface water sample was collected; closed and open circles, the bloom and non-bloom water in the subarctic, respectively; closed squares, the transitional water; open squares, the subtropical water. At Station B-F (cross signs) vertical samplings were conducted.

Discrimination of water masses in the occupied sea area has been conducted in the earlier paper (Odate and Maita, 1988/1989) based on the surface water temperature and the satellite image (Hattori and Nakai, 1986), i.e., the subarctic water (the surface water temperature was less than 10°C ; open and closed circles in Fig. 1), the transitional water (10–20°C, closed squares), and the subtropical water (>20°C, open squares). Moreover, the subarctic water was divided into two types, i.e., the bloom water, where surface chlorophyll *a* was more than 1.0 μg l^{-1} (closed circles), and the non-bloom water, where surface chlorophyll *a* was less than 1.0 μg l^{-1} (open circles) (Odate and Maita, 1988/1989).

At Stations B-F (cross signs in Fig. 1), seawater samples from ten different depths between the surface and 200 m were taken using a Van Dorn sampler, while only surface water samples were collected at Stations 1–64. Seawater (20 l) were filtered using a screen (mesh aperture, 40 μm) to concentrate larger animals and one liter of the filtrate was prepared to examine smaller ones. The samples were fixed with Lugol's solution (3%, v/v) and concentrated by settling in the land laboratory. Biomass of microzooplankton was estimated following the methods described by Odate and Maita (1988) based on a light microscopic observation of 1/2 to 1/20 subsamples.

Results and Discussion

The microzooplankton assembly consisted of ciliates, radiolarians, foraminiferans, appendicularians, copepods, and others. Among them, tintinnids, naked ciliates, and copepod nauplii were commonly observed over the sampling area and were dominant components. Copepods (copepodite stage and adult) also occurred in the samples and their biomass was not negligible. We, however, eliminated them from microzooplankton, since they were too few to quantify in the subsamples, which are equivalent to 1–10 l of seawater, as mentioned by Endo et al. (1983).

In the subarctic surface water, the total microzooplankton biomass was high (Fig. 2). In particular, biomasses of higher than 100×10^{-3} mm^3 l^{-1} were observed in the bloom water. The microzooplankton community in the bloom water was predominated by copepod nauplii. Percent contribution of naked ciliates was high at Stations 7–8 and 11–18 of the non-bloom water. In the transitional water, the total microzooplankton biomass decreased from north to south. Most of the microzooplankton community were predominated by copepod nauplii. At Stations 31, 32, and 34 the community was characterized by naked ciliates, while tintinnids dominated at Station 41 and other microzooplankton (e.g. radiolarians, foraminiferans, and appendicularians) prevailed at Station 43. The total microzooplankton biomass was very low in the surface of the subtropical water, where tintinnids and other microzooplankton predominated, although at Stations 61–63 copepod nauplii was abundant.

From the surface observations, it has been shown that the microzooplankton biomass was high in the northern sea area, being consistent with earlier studies (Endo et al., 1983 ; Taniguchi, 1984). Mean biomasses of copepod nauplii, tintinnids, naked ciliates, and the total microzooplankton in the surface water are shown in Fig. 3. The mean biomasses of the former two groups (81.8 and 19.0×10^{-3} mm^3 l^{-1}, respectively) were 23.6- and 10.5-fold higher in the bloom water than in the

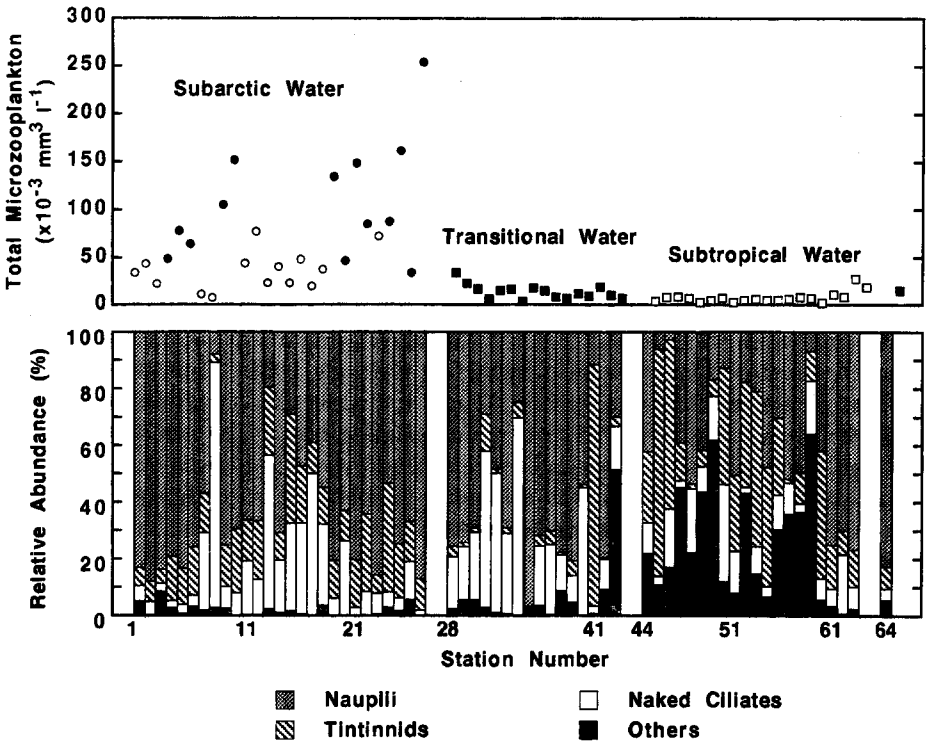

Fig. 2. Biomass of total microzooplankton and relative abundance of dominant components in the surface water. Symbols are the same as in Fig. 1.

subtropical water (3.47 and 1.80×10^{-3} mm^3 l^{-1}, respectively). And, they were 3.5 and 3.8 times higher in the bloom than in the non-bloom (23.4 and 5.06×10^{-3} mm^3 l^{-1}, respectively). The mean biomass of nauplii in the transitional water (9.07×10^{-3} mm^3 l^{-1}) was 2.6 times higher than that in the subtropical water (3.47×10^{-3} mm^3 l^{-1}), although the difference of tintinnids was not evident between the two sea areas (1.36 and 1.80×10^{-3} mm^3 l^{-1}, respectively). Biomass of naked ciliates was almost the same level in both the bloom (6.17×10^{-3} mm^3 l^{-1}) and non-bloom waters (7.25×10^{-3} mm^3 l^{-1}) in the subarctic. Total microzooplankton including others was one order of magnitude higher in the bloom water (107.9×10^{-3} mm^3 l^{-1}) than in the subtropical water (7.50×10^{-3} mm^3 l^{-1}). The total microzooplankton biomass was 2.6 times higher in the transitional water (36.3×10^{-3} mm^3 l^{-1}) than in the subtropical water (13.9×10^{-3} mm^3 l^{-1}). The variation in the total microzooplankton biomass resulted from abundance of nauplii as shown by Endo et al. (1983).

Vertical distributions of the biomass of the dominant components of the microzooplankton community (copepod nauplii, tintinnids, and naked ciliates) are shown in Fig. 4. As shown in Fig. 2, their biomasses in the surface water were high in the northern sea area (Stations B and C) and low in the southern sea area (Stations D, E, and F). At the former two stations, the biomasses were high in the top 50 m, while at the latter three stations, large biomass occurred below the depth of ca. 50 m. Considering the vertical distribution, the microzooplakton biomass in

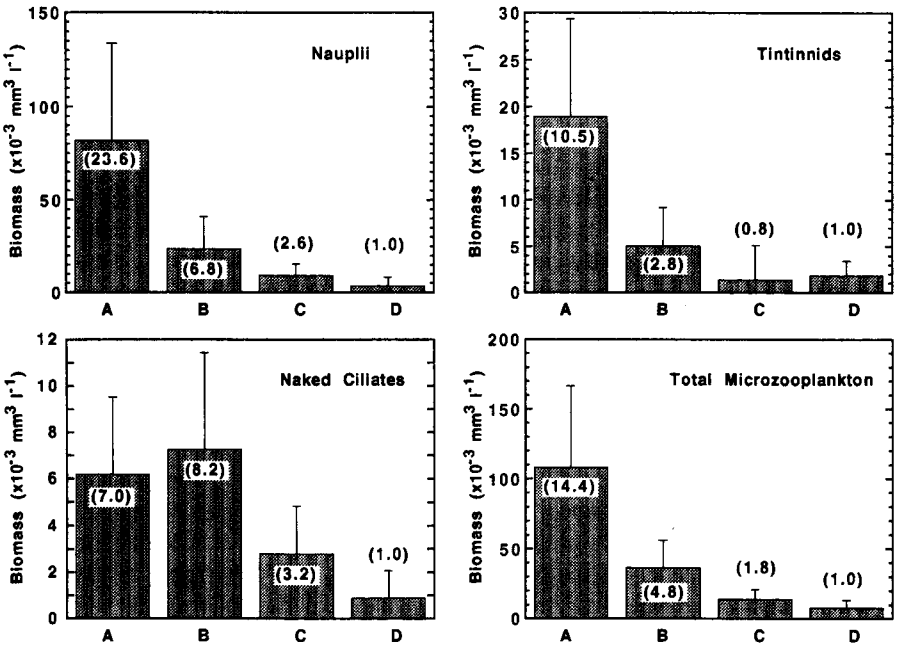

Fig. 3. Mean biomasses in four water types. Bars indicate one standard deviation. A, the bloom water in the subarctic ; B, the non-bloom water in the subarctic ; C, the transitional water ; D, the subtropical water.

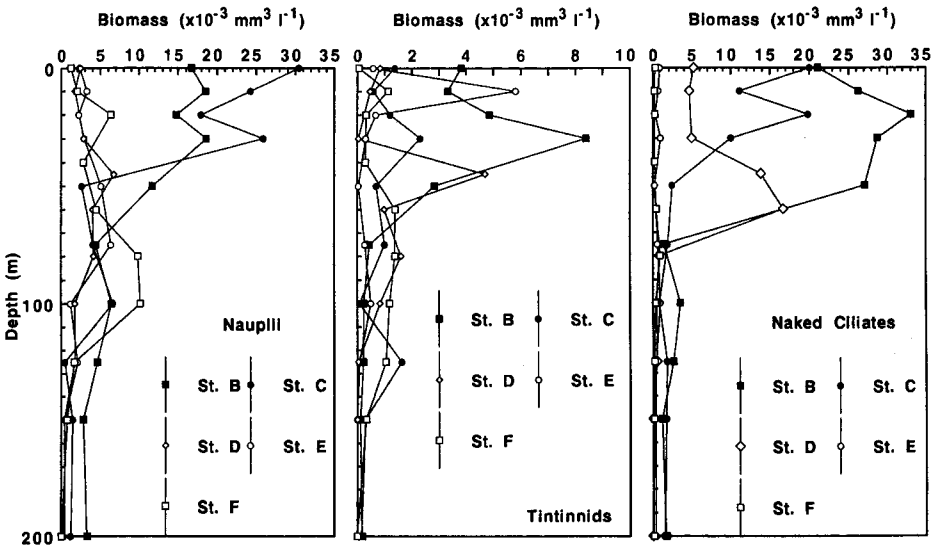

Fig. 4. Vertical distributions of biomass of copepod nauplii, tintinnids, and naked ciliates at Stations B-F.

the water column can not be evaluated based on the surface biomass only, although we have shown that microzooplankton biomass was one order of magnitude higher in the northern sea area than in the southern one based on surface observations (Fig. 3).

The relationship between the surface and the integrated biomasses (0-200 m) of the total microzooplankton is demonstrated in Fig. 5. In this figure, our unpublished results, which were collected in the North Pacific Ocean during early summer, are also shown. The relationship was a significant positive ($p<0.001$) with a positive intercept. Using this equation, the microzooplankton biomass in the surface water (Fig. 2) was converted into the integrated biomass, assuming specific gravity of 1.0 (Fig. 6). Because of the positive slope, the integrated biomass was still high in the subarctic water, as shown by the surface microzooplankton biomass. However, biomass ratio of the subarctic water to the subtropical water became small. This is due to the relatively large intercept, which is equivalent to 82% and 24% of the mean biomass in the subtropical water and the subarctic bloom water, respectively. The large intercept may imply that contribution of microzooplankton biomass in the subsurface layer is more essential in the subtropical water than in the subarctic water. The mean biomass of microzooplankton was 1.2-fold higher in the transitional water (1.83 g wet weight m^{-2}) and 1.7-to 3.4-fold higher in the subarctic (2.68 and 5.40 g wet weight m^{-2}, respectively) than in the subtropical water (1.59 g wet weight m^{-2}) (Fig. 7).

Endo et al. (1983) reported than the total microzooplankton biomass in the western subtropical North Pacific Ocean was 0.84-1.80 g wet weight m^{-2}, which is

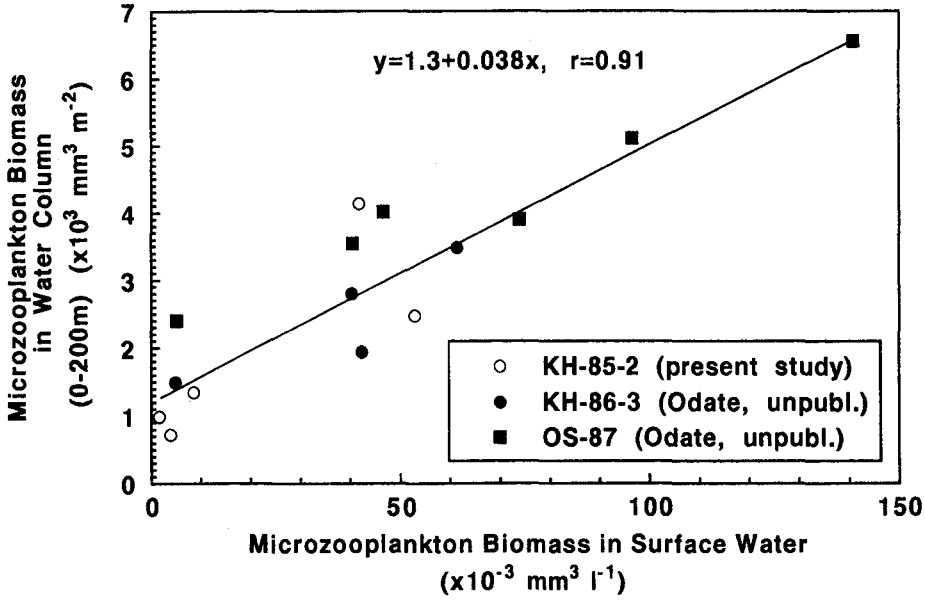

Fig. 5. Relationship between total microzooplankton biomasses in the surface water and in the water column (0-200 m). Data collected in the North Pacific Ocean (Odate, unpublished results) are also included.

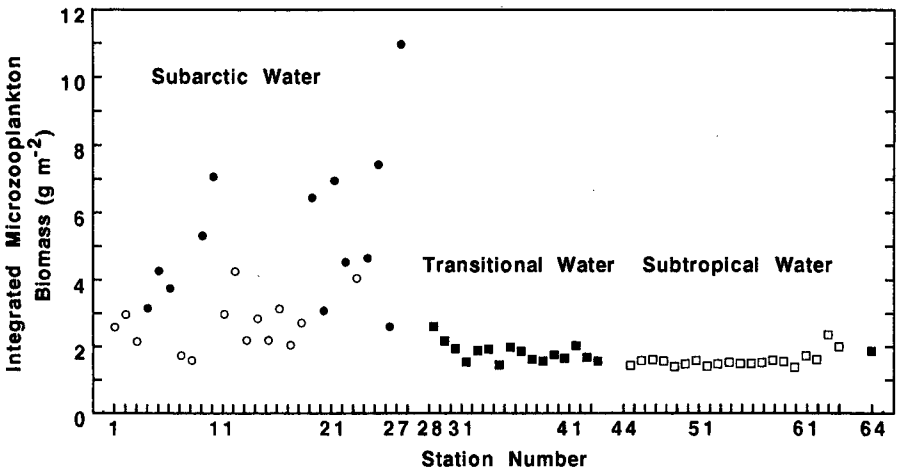

Fig. 6. Biomass of total microzooplankton estimated using the equation in Fig. 5. Symbols are the same as in Fig. 1.

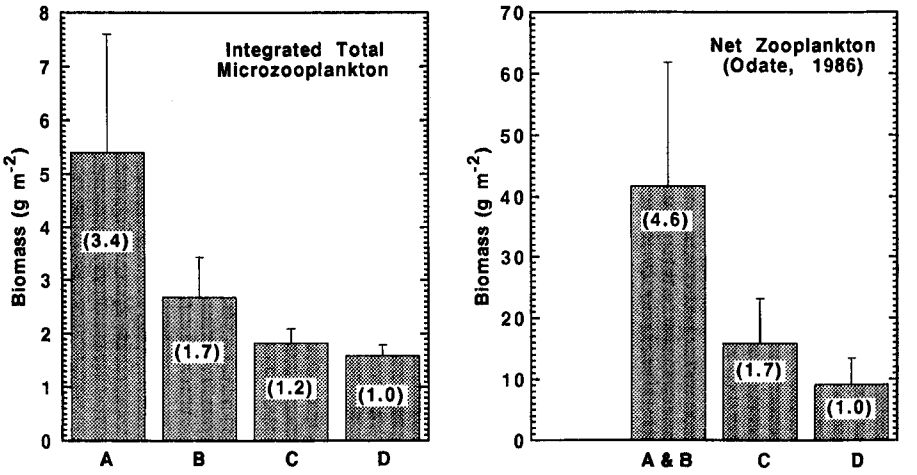

Fig. 7. Mean biomasses of microzooplankton, which are estimated using the equation in Fig. 5, in the four types of water columns. Bars indicate one standard deviation. Water types are the same as in Fig. 3. Mean biomasses of macrozooplankton (Odate, 1986) are also shown.

comparable to our estimated microzooplankton biomass in the subtropical water. On the other hand, Taniguchi (1984) reported the microzooplankton biomass in the oceanic cold water off the Sanriku Coast to be 4.80 g wet weight m^{-2}, which is in the range of our two estimations conducted in the bloom and non-bloom water of the subarctic water. Our estimation of the integrated biomass of the total microzooplankton seems to be appropriate.

It is generally thought that relative abundance of microzooplankton biomass to

macrozooplankton biomass is high in the subtropical water, since picophytoplankton dominate in this sea area (Endo et al., 1983; Taniguchi, 1984, 1985). Regional mean biomass of macrozooplankton collected in the western North Pacific Ocean during May (Odate, 1986) is shown in Fig. 7, where the subarctic water mass is not divided into two sub-areas. The macrozooplankton biomasses in the transitional (15.8 g m^{-2}) and the subarctic waters (41.7 g m^{-2}) are 1.7- and 4.6-fold larger than the subtropical water (9.07 g m^{-2}), respectively. The regional difference in macrozooplankton is larger than that in microzooplankton. Consequently, the relative abundance of microzooplankton to macrozooplankton is likely to be high in the subtropical water. Indeed, using the data in Fig. 7, the relative abundance is calculated as 17% in the subtropical water, 11% in the transitional water, and 6% in the non-bloom water. A relatively high percentage of 13% obtained in the bloom water was still lower than that in the subtropical water.

As shown in Fig. 3, copepod nauplii and tintinnids biomasses were 3.5 and 3.8 times higher in bloom water than in non-bloom water, respectively. It is considered that microzooplankton biomass changes in accordance with phytoplankton abundance in the subarctic water. In this sea area, the maximum biomass of macrozooplankton in a year is observed after the spring phytoplankton bloom (Cushing, 1959; Heinrich, 1962; Odate, 1986; Odate and Maita, 1988). These temporally different variations in microzooplankton and macrozooplankton biomass affect the relative abundance of the former to the latter. That is, microzooplankton biomass is large and macrozooplankton biomass is small during the spring phytoplankton bloom, then the relative abundance becomes high, while macrozooplankton biomass increases and microzooplankton biomass decreases after the bloom, then the relative abundance becomes small.

It can be concluded that the relative abundance of microzooplankton to macrozooplankton will be smaller in the subarctic water than in the subtropical water, although considerable variations occur during spring. The change in the relative abundance is likely to result from the temporally and spatially larger variation in macrozooplankton biomass rather than microzooplankton.

Acknowledgments

We would like to thank the chief scientist, Dr. A. Hattori, and the scientists on board, captain, officers and crew of the R/V Hakuho Maru, the Ocean Research Institute, University of Tokyo for their help in sampling on the Cruise KH-85-2.

References

Chisholm, S.W. (1992). Phytoplankton size. p. 213-237, Falkowski, P.G. and Woodhead, A.D. (eds.) *Primary Productivity and Biochemical Cycles in the Sea*. Plenum Press, New York and London.

Cushing, D.H. (1959). The seasonal variation in oceanic production as a problem in population dynamics. *J. Cons. int. Explor. Mer*, **24**, 455-464.

Endo, Y., Hasumoto, H. and Taniguchi, A. (1983). Microzooplankton standing crop in the western subtropical Pacific off the Bonin Islands in winter, 1980. *J. oceanogr. Soc. Japan*, **39**, 185-191.

Hattori, A. and T. Nakai (eds.) (1986). *Preliminary Report of The Hakuho Maru Cruise KH-83-3*

and KH-85-2. Ocean Res. Inst. Univ. Tokyo, 117 pp.

Heinrich, A.K. (1962). The life histories of plankton animals and seasonal cycles of plankton communities in the ocean. *J. Cons. int. Explor. Mer*, **27**, 15-24.

Laybourn-Parry, J. (1992). *Protozoan Plankton Ecology*. Chapman & Hall, London, New York, Tokyo, Melbourne, Madras, 231 pp.

Marshall, S.M. and Orr, A.P. (1956). On the biology of *Calanus finmarchicus*. IX. Feeding and digestion in the young stage. *J. mar. biol. Ass. U.K.*, **35**, 587-603.

Odate, K. (1986). Automatic data processing for estimation of abundance of zooplankton in the waters off northeastern Honshu, Japan, 1951-1976. *Bull. Tohoku Reg. Fish. Res. Lab.*, No. 48, 31-47. (In Japanese with English abstact)

Odate, T. and Maita, Y. (1988). Seasonal changes in the biomass of zooplankton and their food requirement in Funka Bay. *J. oceanogr. Soc. Japan*, **44**, 228-234.

Odate, T. and Maita, Y. (1988/1989). Regional variation in the size composition of phytoplankton communities in the western North Pacific Ocean. *Biol. Oceanogr.*, **6**, 65-77.

Rassoulzadegan, F. and Etienne, M. (1981). Grazing rate of the tintinnid *Stenosemella ventricosa* (Clap. & Lachm) Jorg. on the spectrum of the naturally occurring particulate matter from a Mediterranean neritic area. *Limnol. Oceanogr.*, **26**, 258-270.

Sherr, E. and Sherr, B. (1988). Role of microbes in pelagic food webs : a revised concept. *Ibid.*, **33**, 1225-1227.

Sieburth, J.M., Smetacek, V. and Lenz, J. (1978). Pelagic ecosystem structure : heterotrophic compartments of the plankton and their relationship to plankton size fractions. *Ibid.*, **23**, 1256-1263.

Stoecker, D.K. and Capuzzo, J.M. (1990). Predation on Protozoa : its importance to zooplankton. *J. Plankton Res.*, **12**, 891-908.

Taniguchi, A. (1984). Microzooplankton biomass in the Arctic and subarctic Pacific Ocean in summer. *Mem. Nat. Inst. Polar Ras.*, Special Issue No. 32, 63-76.

Taniguchi, A. (1985). Plankton research in Japan with special reference to microzooplankton studies. *Bull. Mar. Sci.*, **37**, 411-413.