PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN

XII. THE PLANKTON OF MIYAKO BAY ON THE EASTERN COAST OF TÔHOKU DISTRICT[1]

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With 16 Text-figures

A plankton investigation of Miyako Bay on the eastern coast of the Tôhoku District, about 40 km north of Kamaisi Bay, was made on October 18, 1952, by the same methods as already employed in Onagawa and Kamaisi Bay (YAMAZI, 1953). The samples were collected at a superficial layer and near the bottom. The 26 stations where samples were collected are shown in Fig. 1. The survey was made possible with the help of Mr. E. YAMADA, of Miyako Fisheries High School and his colleagues whose kindnesses and cooperation are heartily acknowledged.

Hydrological Conditions

Miyako Bay is a wedge-shaped inlet, approximately 9 km long and 3 km wide at the mouth. The coast line around the bay is monotonous, only with a small cape Tatega-saki near the mouth on the west coast. The interior of the bay is not so deep as in Onagawa and Kamaisi Bay, mostly less than 20 meters, except near the mouth where it is about 60-80 m deep. The basin near the mouth of the bay has steep wall on the west and east coasts, but the remaining interior becomes gradually shallower inwards and westwards. Two small rivers pour into the inlet, the Miyako midway on the west coast and the Tugaruisi at the head of the bay. The discharge of freshwater and sewage from Miyako River is relatively large.

Water temperature (Fig. 2, A and B): The water temperature is affected by air temperature and total hour of sunshine. The surface water temperature reached its minimum from the mouth to the middle part along the eastern coast and then increased towards the inner part and western coast. It varied from 16.4°C near the

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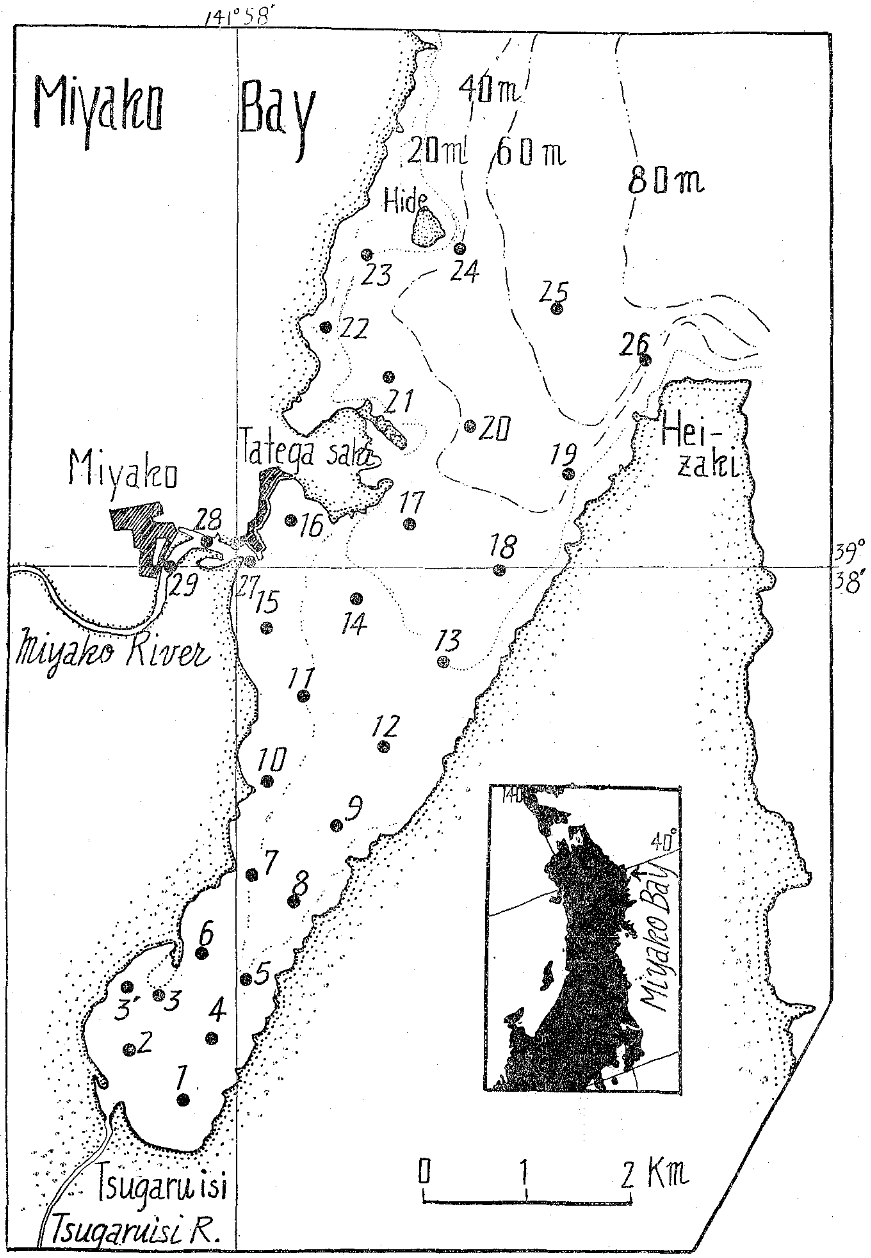

Fig. 1. Chart of Miyako Bay showing stations and bathymetric contours (October 18, 1952).

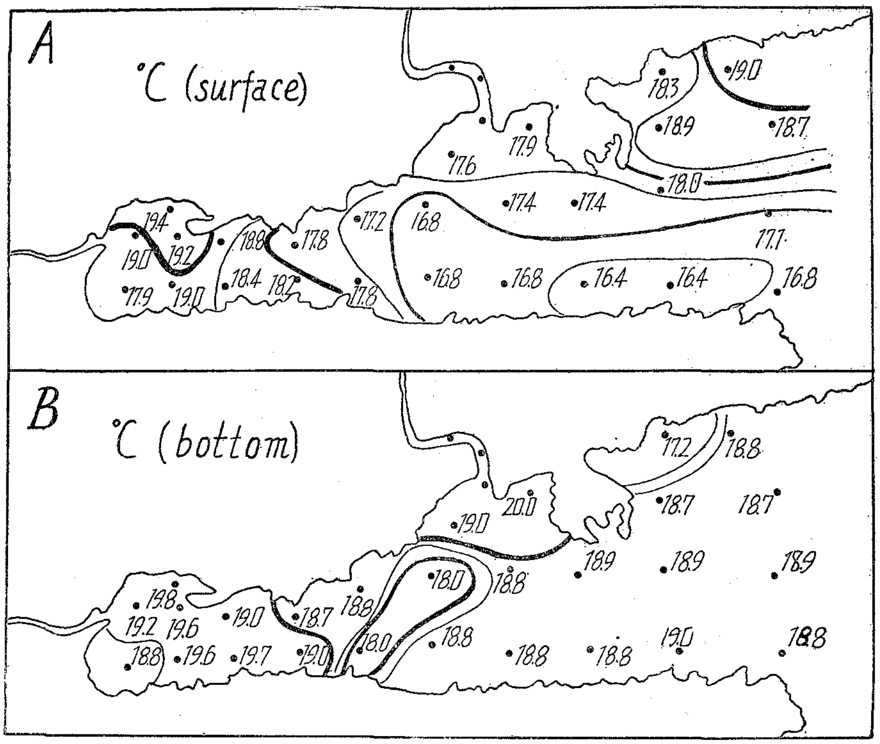

Fig. 2. Distribution of water temperature (°C) at the surface (A) and the bottom (B).

mouth to 19.4°C in the head with a range of 3°C. The bottom water was warmer than the surface. It ranged from 18°C to 20°C, lower in the mouth than in the inner and western part, as in the surface. Such small range of water temperature is a characteristic feature in hydrological conditions of the bay which reflects the direct influence of oceanic influx, due to the topographical simplicity.

Chlorinity (Fig. 3, A and B): The chlorinity of the sea water showed the expected correlation with freshwater discharge. The lowest chlorinity at the surface was found near the estuary of Miyako River, where the discharge pours into the bay and extends widely. The low chlorinity was also found at the innermost part, where a small river pours into. The bottom chlorinity was uniform ranging from 18.5 to 18.6 ‰ except in the narrow area of the innermost part, where the value showed from 16 to 17 ‰.

Transparency and water color (Fig. 4, A and B): The transparency of water was 8-11 m from the mouth to the middle part along the eastern coast. It was very small between the innermost and the estuary of Miyako River, about 2-4 m, and the water was also discolored (No. 7 FOREL's scale).

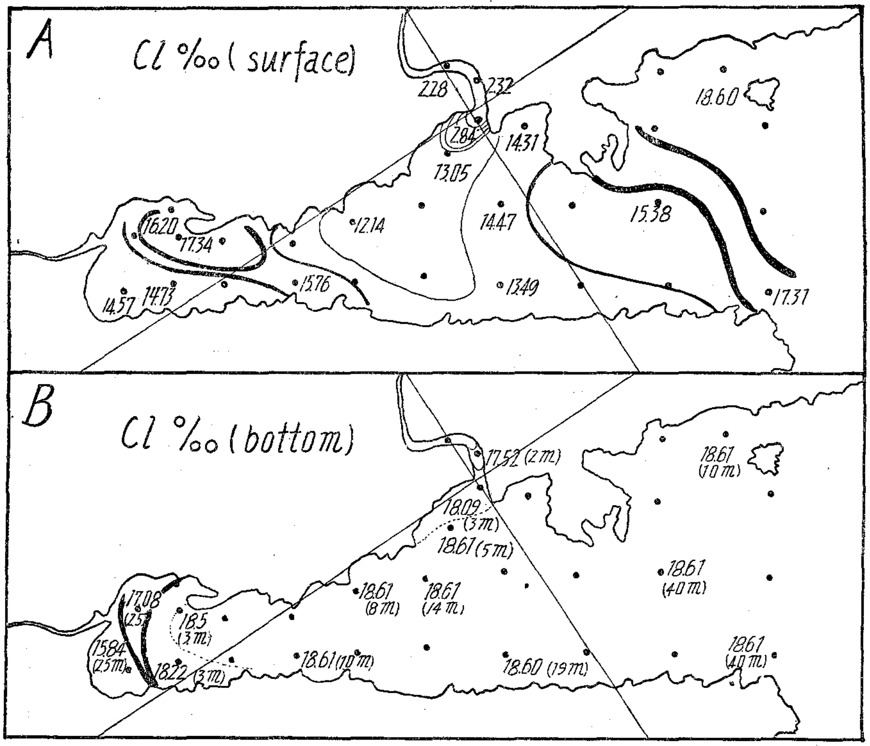

Fig. 3. Distribution of chlorinity in ‰ at the surface (A) and the bottom (B).

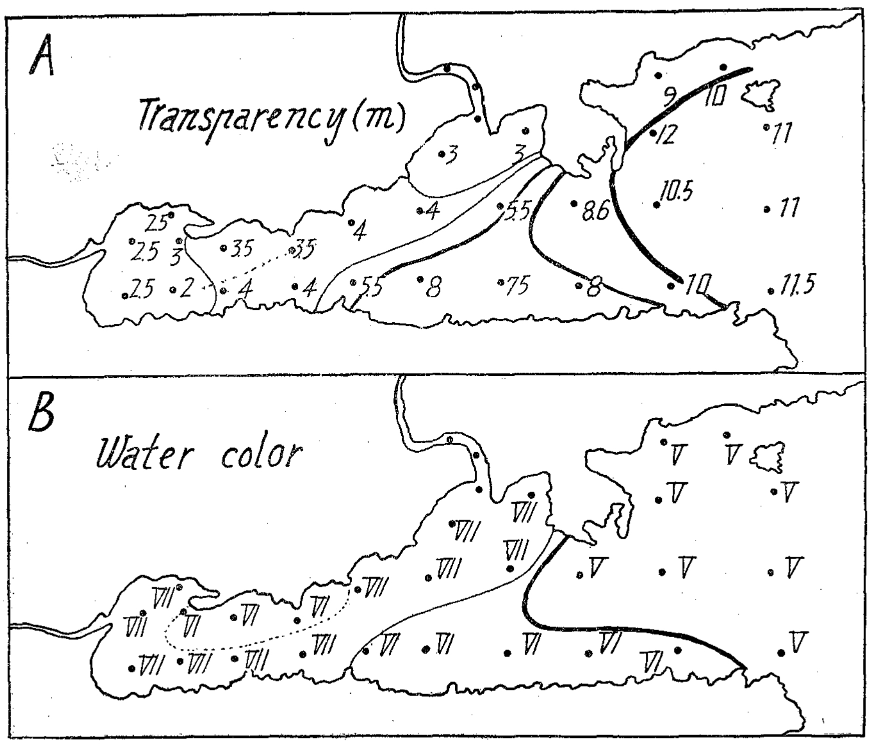

Fig. 4. Distribution of transparency in meter (A) and water color in FOREL's scale (B).

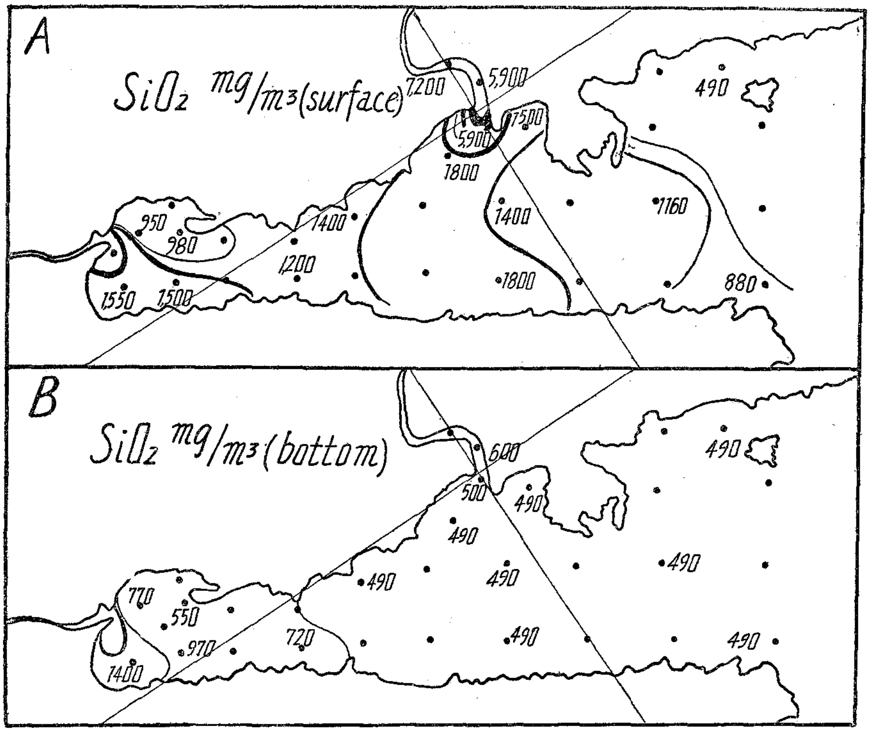

Fig. 5. Distribution of silicate content (SiO_2) in mg per m^3 at the surface (A) and the bottom (B).

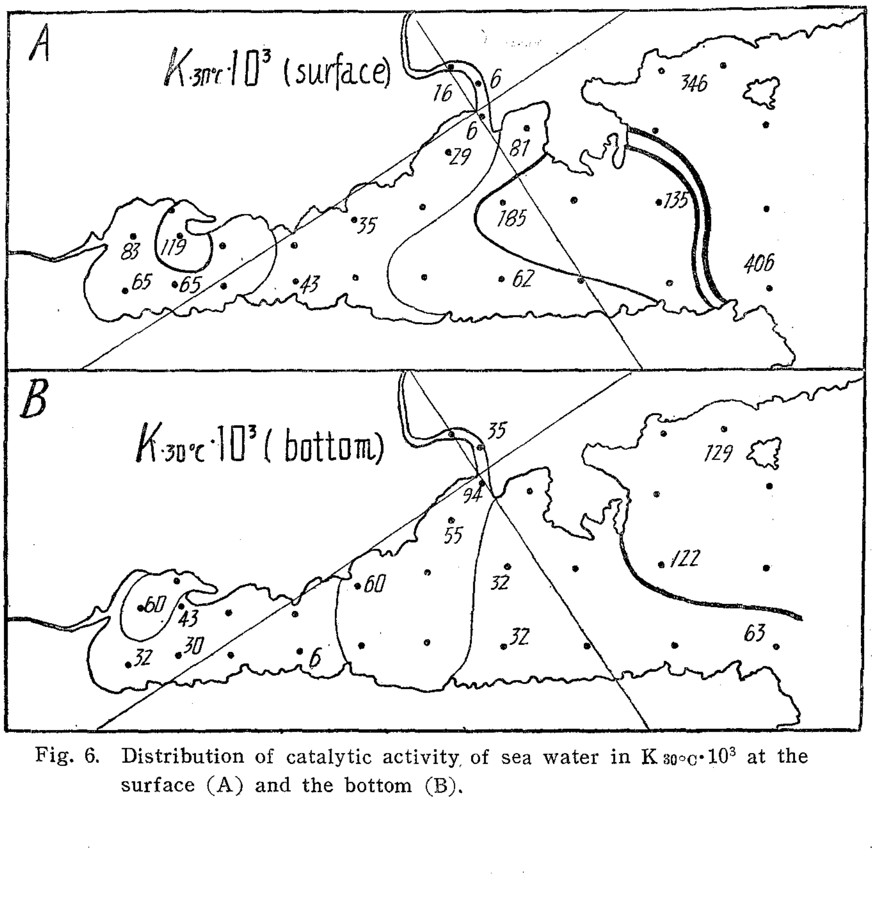

Fig. 6. Distribution of catalytic activity of sea water in $K_{30°C} \cdot 10^3$ at the surface (A) and the bottom (B).

Silicate contents (SiO_2) (Fig. 5, A and B): Silicates (SiO_2 mg/m^3) is a convenient hydrological property for indicating the extent of freshwater discharge and the mixing rate of sea water in correlation with chlorinity distribution. In the surface layer it was generally much larger than that of the subsurface layers except at the shallow basin of the innermost part. The highest silicate content was found near the estuary of Miyako River and next near the estuary of Tugaruisi River. Lower silicates were found in the mouth of the bay.

Catalytic activity of sea water (Fig. 6, A and B): At the surface the catalytic activity of sea water ($K_{30°C} \cdot 10^3$) was higher in the mouth than in the inner part. The lower values were found near the estuaries.

Plankton

A. Quantitative Analysis of Plankton

The plankton samples were vertically hauled from the bottom to the surface. The settling volume and total number are shown in the value per one meter haul in Fig. 7, A and B. These were much larger than those of Onagawa and Kamaisi bays. The value ranged from 0.01 to 0.17 cc and from 15 to 133 thousands of individuals, cells or colonies per one meter haul, respectively. The largest volume and number (about 70–130 thousands) found in the bay were in the middle region (Sts. 7, 9 and 13), and decreased towards the mouth and innermost area (15–20 thousands). The higher number of the inner region is probably due to nutrients plentiful around the estuaries.

The correlation between the settling volume and total number of individuals, cells or colonies is shown in Fig. 9. It is evident that the variability of volume and number are relatively parallel. When the number is small, the volume is generally small too, but there is no decisive correlation thoughout all stations. The irregularities at the mouth (Sts. 19, 21, 25 and 26) are largely due to the poorness of plankton number and the variation of composition.

The total number of zooplankton at each station (Fig. 8, A) was the largest in the inner region, where the number reached 500–1,000 individuals. The population decreased towards the western part of the middle region and attained the minimum in the mouth, where occurred 100–200 individuals. The distribution of phytoplankton population was also similar. The numerical percentage of zooplankton (Fig. 9) in the total plankton was very small, less than 2%. It generally decreased from the central western region to the inner and the outer region of the bay.

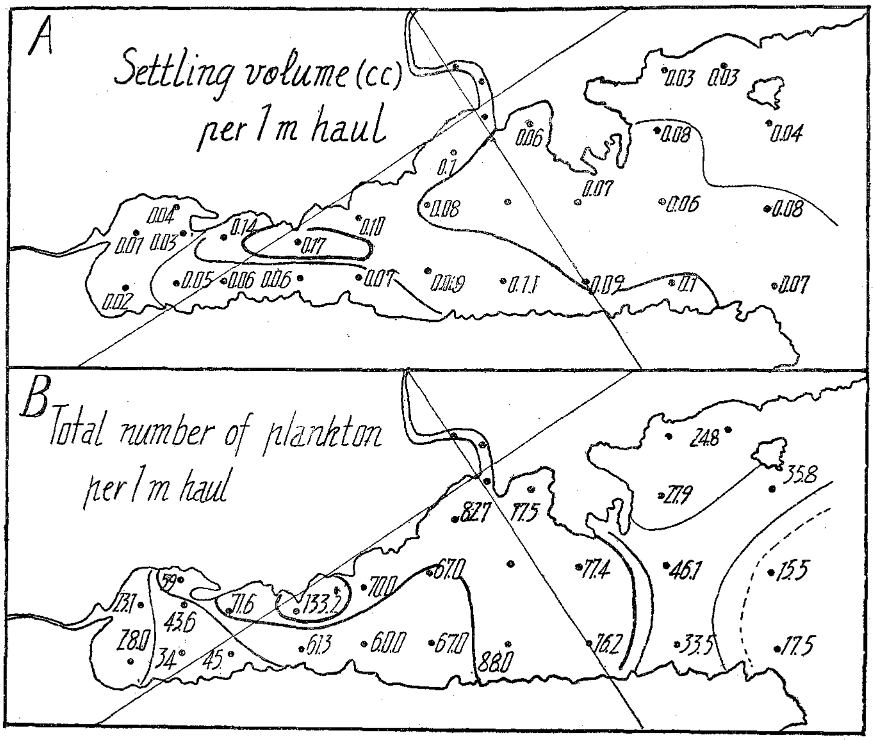

Fig. 7. Settling volume in cc (A) and total number of plankton per one meter haul from the bottom to the surface (Unit of number is thousand).

B. Qualitative Analysis of Plankton

ZOOPLANKTON

As shown in Figs. 8, 10 and 15, the main components of zooplankton were larval forms (25–65 %), protozoans (1–35 %), copepods (5–70 %) and other animals (1–30 %). The distribution of these populations and their percentage composition varied at each station, but they were densest in the inner region and gradually decreased towards the outer region. The number of species was smaller than that of Kamaisi Bay. The higher number of species was found in the outer region than in the inner.

The highest number of copepods occurred in the inner region, but its percentage composition was lower than that in the outer region (Figs. 8, C and 10). The main components of copepods are shown in Figs. 11 and 12. Of these species, *Acartia clausi* was dominant in the inner region. *Oithona nana* and *Euterpe acutifrons* were rather widely distributed from the middle to the inner region but they were sparse in the mouth. *Paracalanus parvus* and *Oithona similis* occurred widely, but relatively rich in the middle region. *Oncaea media* and *Oncaea venusta*, together with *Microsetella norvegica* and *M. rosea*, were restricted to the mouth.

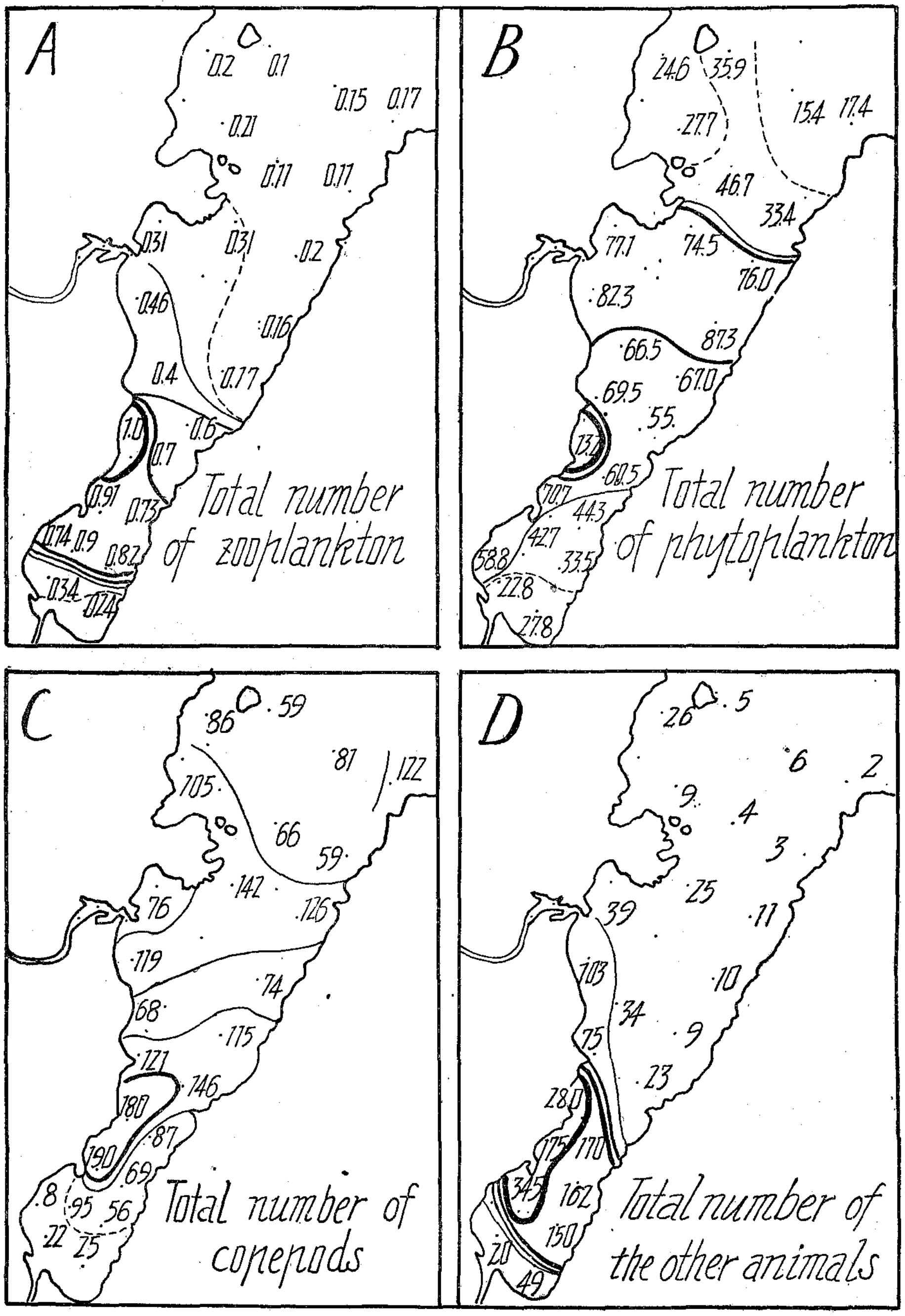

Fig. 8. Distribution of plankton in Miyako Bay.
A. Total number of zooplankton at each station (Unit of number is thousand).
B. Total number of phytoplankton (Unit of number is thousand).
C. Total number of copepods.
D. Total number of other animals than copepods.

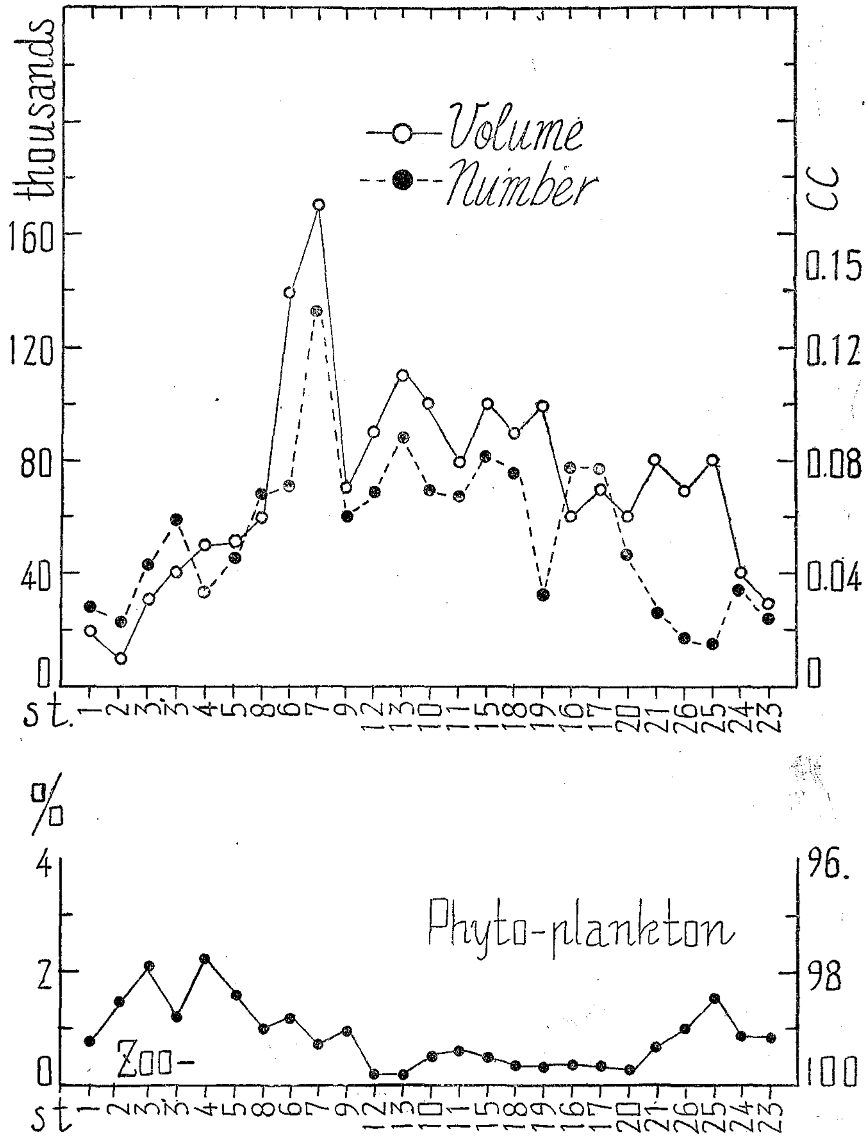

Fig. 9. Correlation between settling volume and total number (top) and percentage composition of zoo- and phytoplankton (bottom).

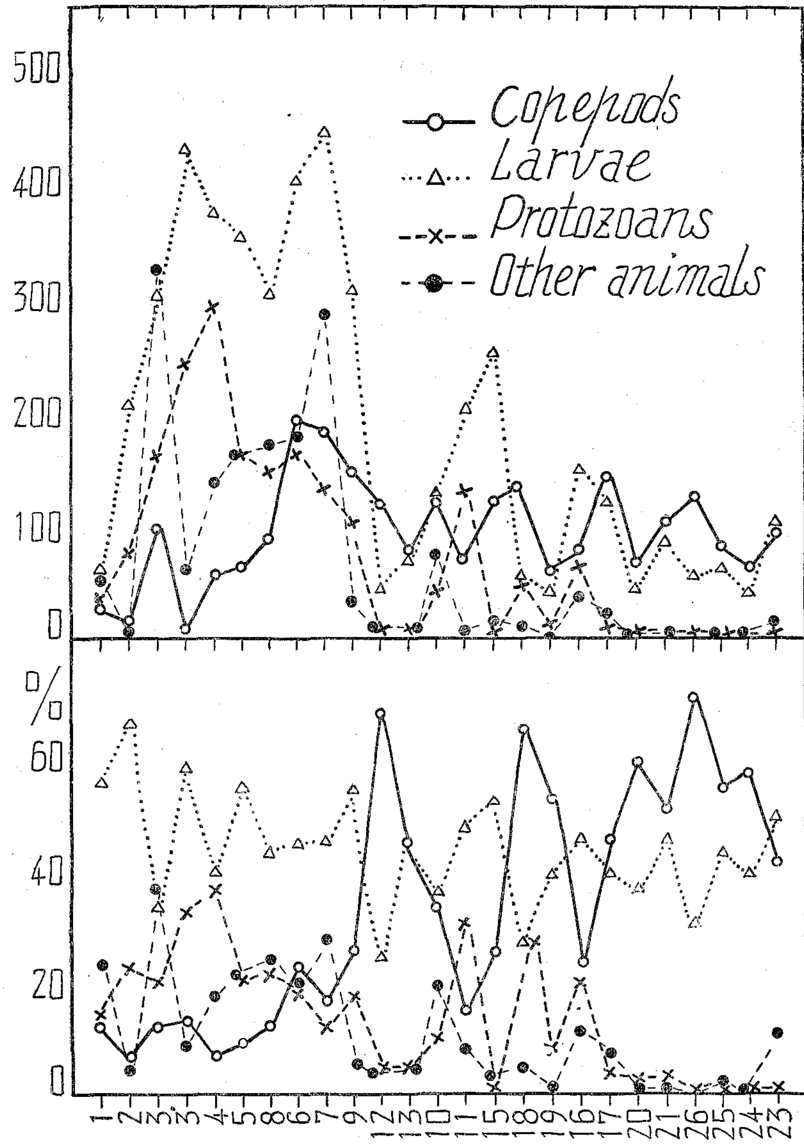

Fig. 10. Number of zooplankton groups per one meter haul (top) and their percentage composition (bottom).

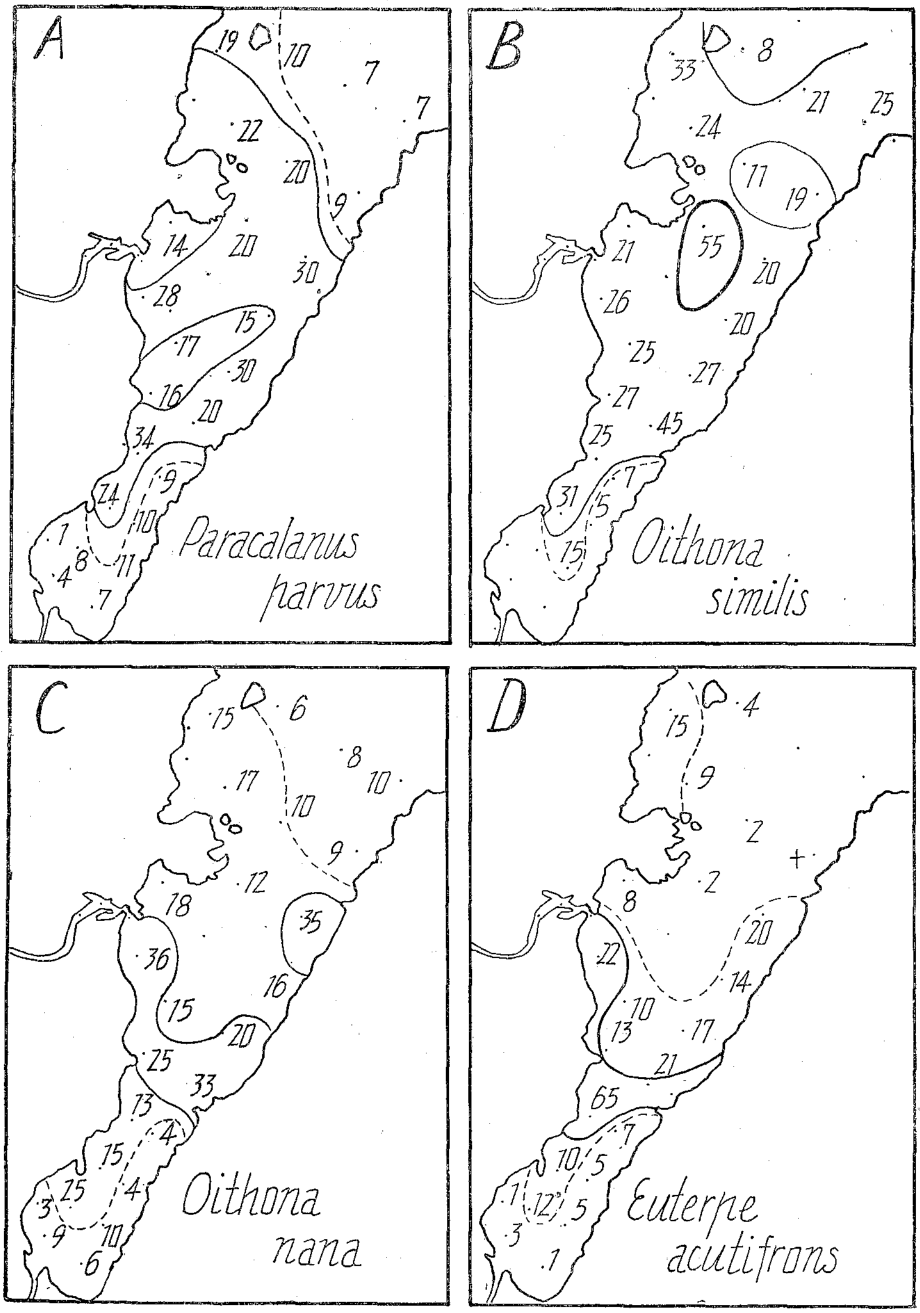

Fig. 11. Distribution of important copepods per one meter haul.

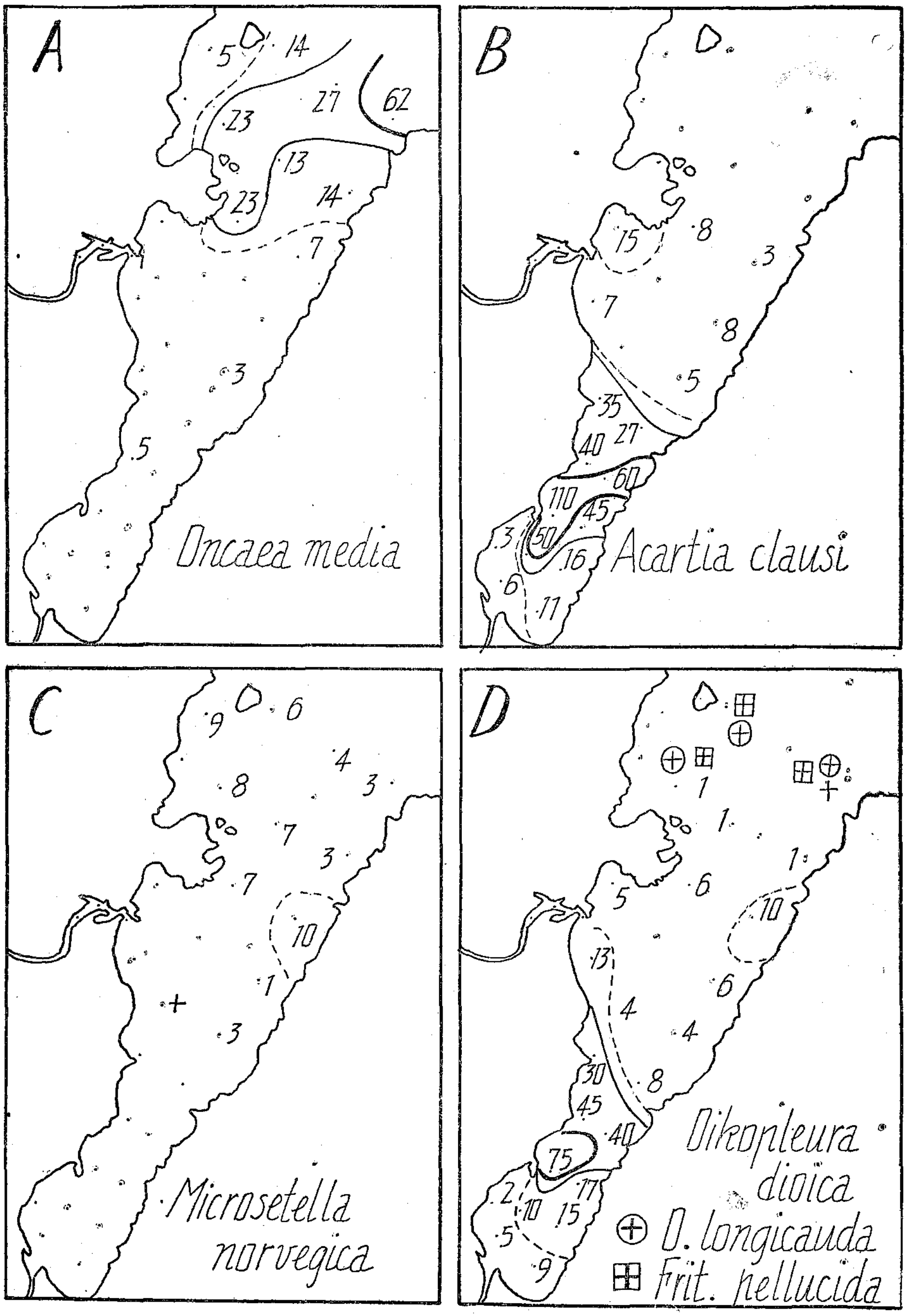

Fig. 12. Distribution of important copepods and tunicates per one meter haul.

As shown in Fig. 13, the percentage composition of these species varies at all stations. In the inner region, *Acartia clausi* was the highest, next *Oithona nana* and the others were much lower. In the middle region, *Oithona nana*, *Paracalanus parvus*, *Oithona similis* and *Euterpe acutifrons* were all of similar values, but *Acartia clausi* was much low. In the outer region, *Oithona similis*, *Oncaea media*, *Oncaea venusta* and *Paracalanus parvus* showed larger percentages than *Oithona nana* and *Euterpe*, and *Acartia* was not found at all. The offshore copepods, such as *Calanus darwinii*, *Cal. minor*, *Cal. tenuicornis*, *Cal. helgolandicus*, *Pseudocalanus elongatus*, *Centropages bradyi*, *Temora stylifera*, *Oithona plumifera* and *Corycaeus* sp. were found widely, but very sparsely.

Oceanic chaetognaths *Sagitta minima* and *S. enflata* and oceanic tunicates *Oikopleura longicauda*, *Fritillaria haplostoma* and *F. pellucida* were found together occasionally in the outer region (Fig. 12, D). Inshore chaetognath *S. delicata* was sparsely found in wide areas. Neritic tunicate *Oikopleura dioica* was found chiefly in the inner region, while very scarce in the mouth (Fig. 12, D). The true inlet rotifer *Encentrum* sp. occurred very abundantly, mainly in the inner region and decreased towards the western part of the middle region (Fig. 15 A).

Among protozoans, tintinnoids were important. *Tintinnopsis radix*, *Tin. mortensenii*, *Tintinnus lectus* and *Favella taraikaensis* were predominant in the inner region of the bay. They were not found in the outer region except the first one (Fig. 14).

Copepod nauplii were usually the most abundant of all zooplankton thoughout all stations, mostly in the inner region of the bay (Fig. 15, B). The other larvae, such as those of polychaetes, gastropods and pelecypods, were very scarce everywhere.

PHYTOPLANKTON

Diatoms: The diatoms were very rich in the inner region of the bay. They were characterized by the dominance especially of *Skeletonema costatum* and to a lesser degree, *Chaetoceros* spp. Dominant diatoms in the middle region were different from those in the inner region. The predominant diatoms in the middle region were *Chaetoceros* spp. and to a lesser degree, *Skeletonema costatum*, *Bacteriastrum hyalinum*, *Thalassiothrix Frauenfeldii*, *Thalassionema nitzschioides* and *Coscinodiscus* spp. Among Chaetoceros, *Ch. peruvianus*, *Ch. decipiens*, *Ch. Lorenzianus*, *Ch. didymus*, *Ch. affinis*, *Ch. laciniosus*, *Ch. curvisetus* and *Ch. radicans* were abundant. Small number of *Rhizosolenia* was found in the outer region, but it was fewer in the inner region than in the outer. Oceanic forms, such as *Ch. coarctatus*, *Ch. densus*, *Rh. robusta*, *Rh. calcar avis*, *Rh. setigera*, *Rh. alata* f. *indica*, *Guinardia flaccida*, *Climacodium biconcavum*, *Ditylum sol* and *Corethron hystrix* occurred very sparsely in the middle and outer regions of the bay.

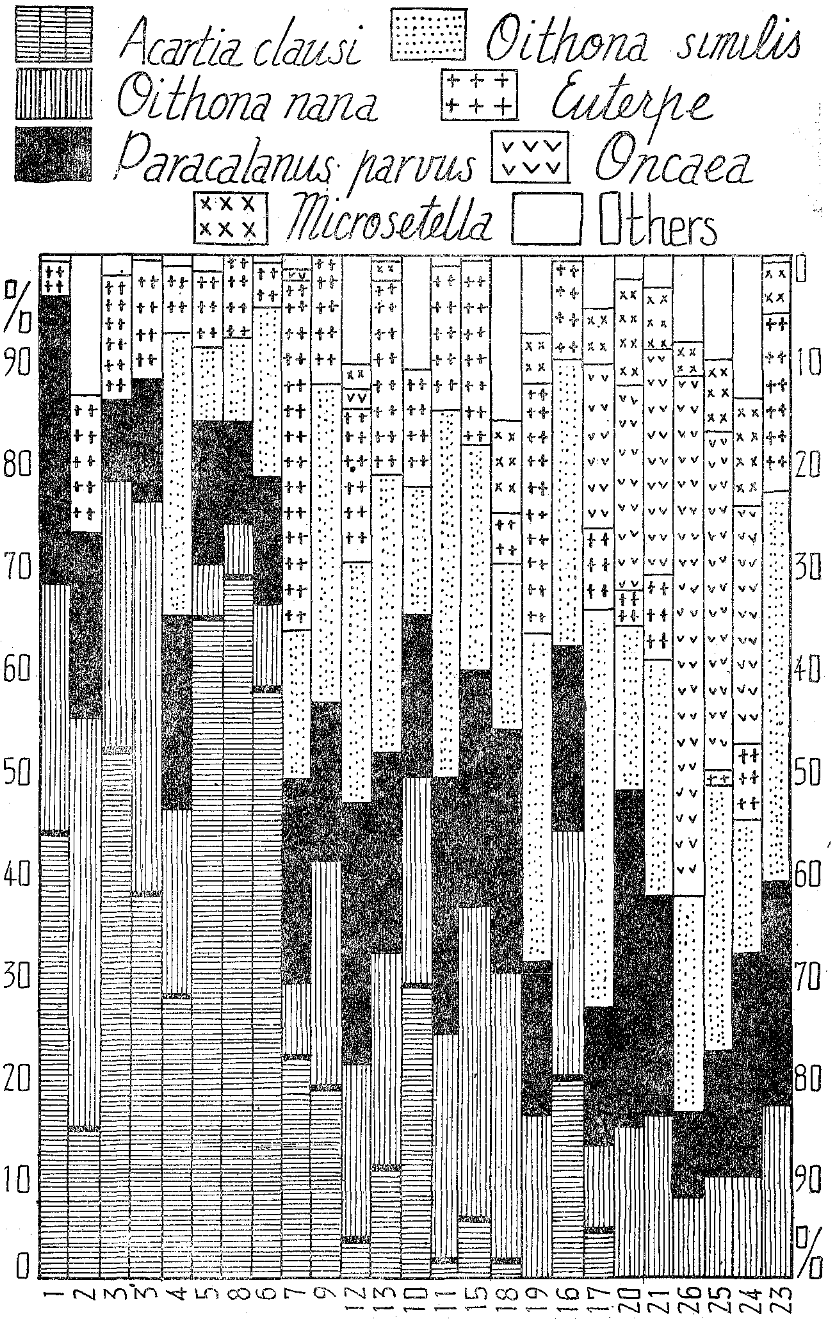

Fig. 13. Percentage composition of important copepods per one meter haul at each station.

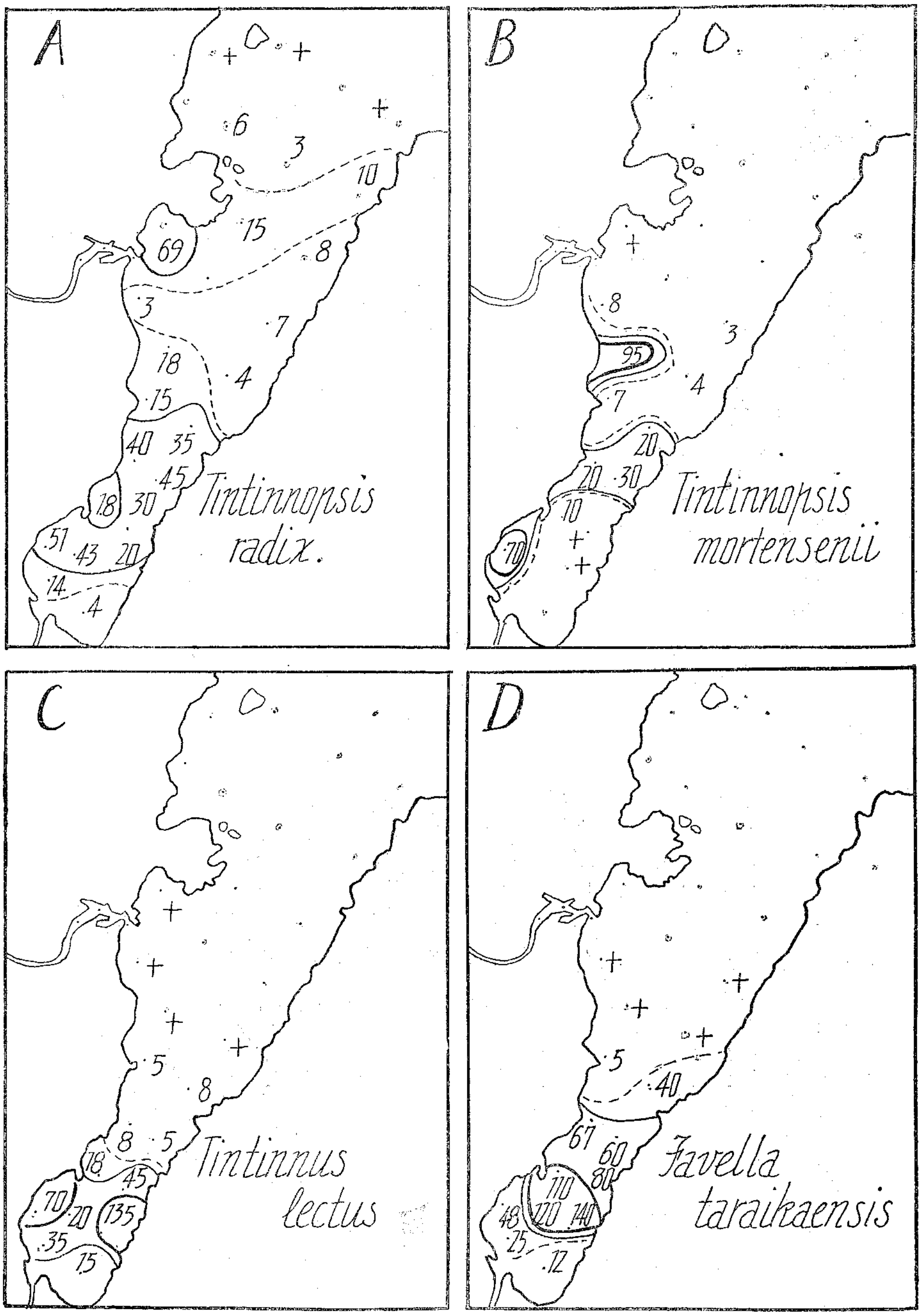

Fig. 14. Distribution of important tintinnoids at each station per one meter haul.

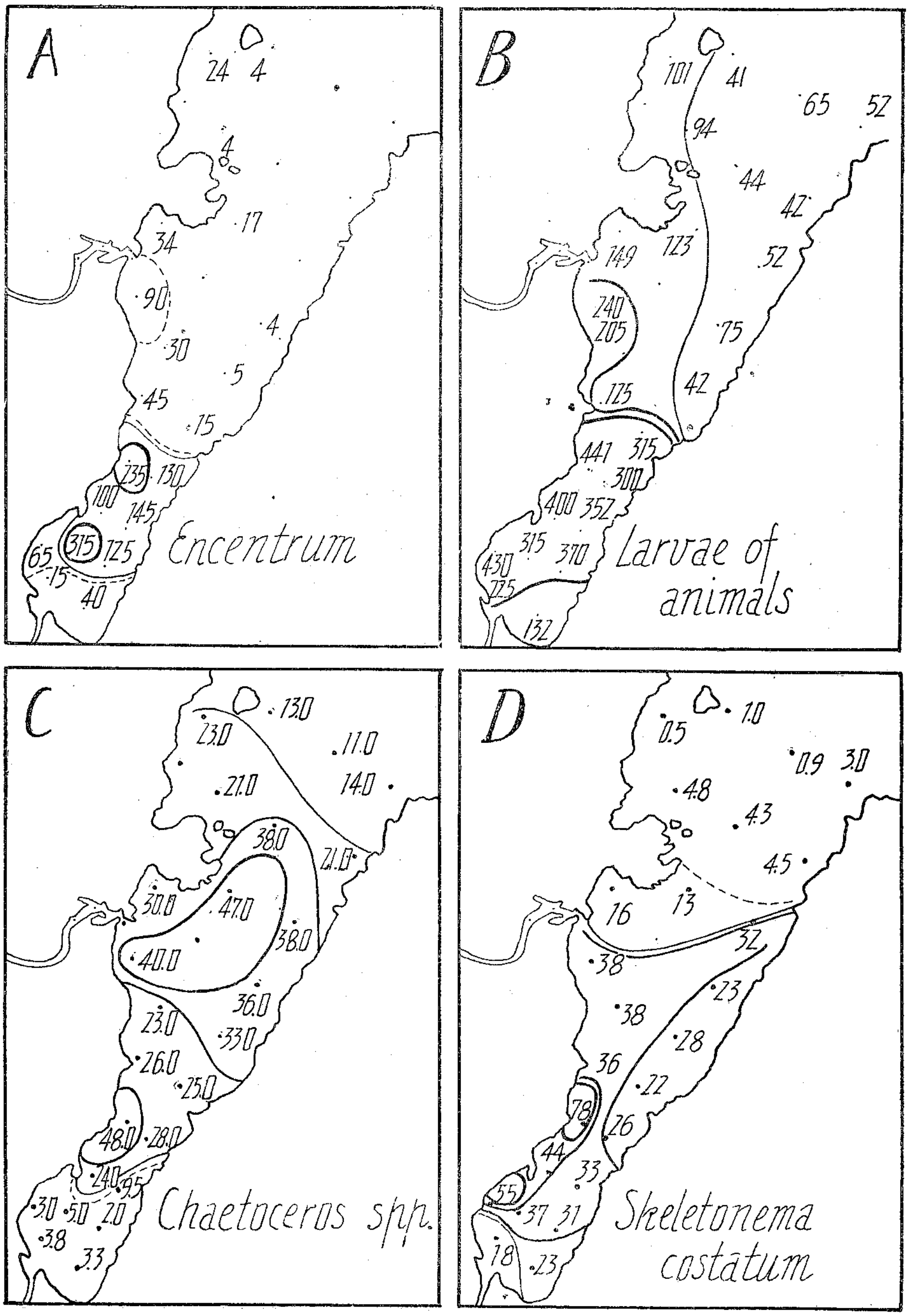

Fig. 15. Distribution of important zoo- and phytoplankton groups at each station. (Unit of number in C and D is thousand).

Dinoflagellates: The dinoflagellates were very scarce in number, although oceanic species occurred in the middle and outer regions. They were *Dinophysis candata, Pyrocystis noctiluca, Ceratocorys horrida, Ceratium tripos* f. *atlanticum, C. candelabrum, C. smatoranum, C. macroceros, C. trichoceros, Cer. molle, C. deflexum, C. masciliense,* etc. However, some species such as *Per. oceanicum* var. *oblongum, Per. conicum, Ceratium fusus* and *Cer. furca* occurred very sparsely in the inner region of the bay.

Consideration and Conclusion

Miyako Bay is a long funnel-like embayment of rias coast characterized by a very deep basin in the mouth which gradually becomes shallower and narrower towards the interior of the bay. The salinity at the surface is low in the inner and western half of the middle region, and at the subsurface layer it is high and relatively uniform except in the inner shallow area at the head. The productivity of the plankton is higher in the inner region than in the outer region. The bay may be divided for convenience' sake into three main regions, the inner, middle and outer, when the distribution of dominant copepods and their associates is taken into consideration (Fig. 16), excepting those of widespread forms showing a rather uniform density of occurrence from the mouth of the bay to the head.

The inner region and the western areas of the middle region are characterized by the abundance of inshore copepods *Acartia clausi* and *Oithona nana,* together with copepod nauplii, *Encentrum* sp., *Oikopleura dioica, Tintinnopsis radix, Tintinnus lectus* and *Favella taraikaensis.* Diatoms such as *Skeletonema costatum* and *Chaetoceros* spp. are also abundant.

The outer region of the bay is characterized by the dominance of *Oncaea media, Oithona similis, Microsetella* and oceanic copepods. The population density of zoo- and phytoplankton is relatively small in the outer region, but the number of species exceeds that in the inner region.

The middle region is intermediate between the inner and outer regions in plankton productivity. *Oithona nana, Paracalanus parvus, Oithona similis* and *Euterpe acutifrons* show almost the same percentage composition respectively. On the other hand, *Chaetoceros* is the most abundant there.

Generally speaking, Miyako Bay as well as the bays of Kamaisi and Onagawa is directly influenced by the open sea water. As the contour of the bay and the bottom condition are comparatively monotonous, the arrangement of plankton communities within the bay seems to be rather typical. All these bays, especially the innermost regions, are more or less different from one another in the topographical, hydrological and planktological conditions. The components of plankton population

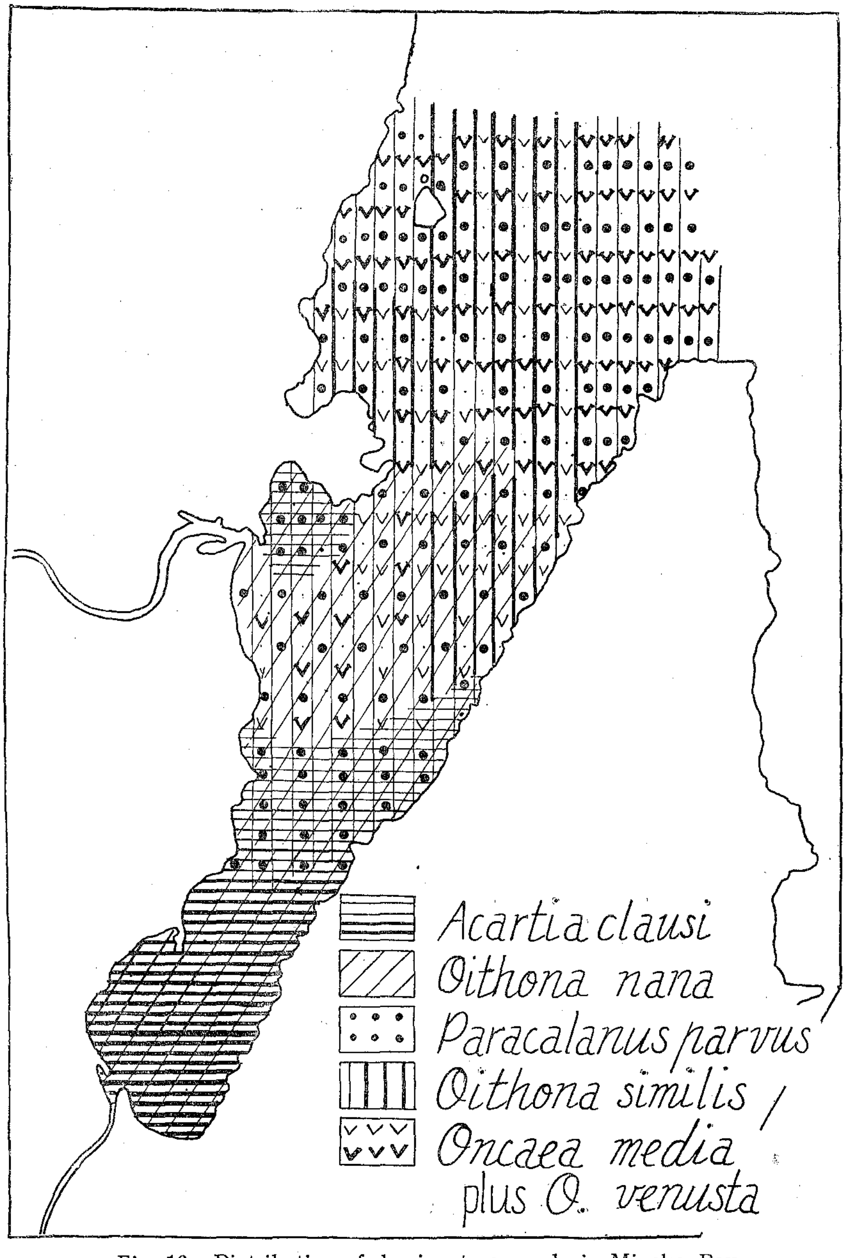

Fig. 16. Distribution of dominant copepods in Miyako Bay.

are almost similar, but their numerical abundance and distributional range are not quite similar. The plankton communities of Miyako Bay are rather more allied to those of Onagawa Bay than of Kamaisi Bay, although the differences may be due in part to seasonal variation. For instance, 1) the typical inshore form *Acartia clausi* occurs abundantly in the bays of Miyako and Onagawa, but very sparse in the bay of Kamaisi, and 2) total number of species and offshore forms is fewer in Miyako and Onagawa than in Kamaisi Bay. This may be reasonable since Kamaisi Bay is a comparatively small embayment shorter and wider in extent, and thus better exposed to the influence of the open sea. However, the productivity of diatoms in Miyako and Kamaisi bays is larger than in Onagawa Bay.

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