PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN

XVII. SEASONAL SUCCESSION OF ZOOPLANKTON IN THE INNER AREA OF TANABE BAY FROM JUNE TO OCTOBER, 1954[1)]

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With 9 Text-figures

This paper deals mainly with the seasonal variation in the quantitative and qualitative distribution of zooplankton in the innermost area of Tanabe Bay during the period from June to the end of October, 1954. The plankton and water samples were collected off the coast of Tunasirazu where is located at the southern inlet in Tanabe Bay every other day or occasionally every three days. The towing was made vertically from the bottom (5 m in depth) to the surface with a KITAHARA's quantitative silk tow net. After macroplankton such as larger medusae were removed, the total volume and number of other plankton organisms were measured separately. The volume of the samples was measured by the settling method. The counting was made to obtain percentage composition and estimated the individual number of various species per one meter haul. Although there were no sufficient data about the occurrence of microplankton, the 200 cc of water sample was taken in every towing.

In connection with this survey in Tanabe Bay, a routine observation on zoo- and phytoplankton in Taizi Bay and the Moriura inlet of Katuura Bay during the same period (YAMAZI and HORIBATA, 1955) has been made simultaneously by Mr. HORIBATA as a co-worker and this survey is now still in progress. The present report may be of some interest in view of the fact that (1) the plankton samples were obtained every other day and at the same time the hydrological and meteorological data of the environment were available for comparison. (2) During the same period, a similar observation was made in two different bays, Tanabe and Katuura Bay, both situated on the opposite side of Kii Peninsula. By analyzing and separating these data it may be possible to deduce the influence of environmental factors on the plankton communities.

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Brief Summary on Periodical Changes from Summer to Autumn

June 1st–20th: Surface water temperature gradually rose from 20°C to 24°C (Fig. 1). There was considerable fluctuation in the chlorinity from 17 to 18‰, due to a small rainfall and drainage (Fig. 2). Phosphate values (P_2O_5) were relatively small, being about 10 mg per m^3. Silicate contents (SiO_2) varied between 900–1,500 mg per m^3. The catalytic activity of sea water was relatively high but showed an irregularity (Fig. 3). During the early days total plankton volume and total zooplankton number were very small, but became gradually larger (Fig. 4).

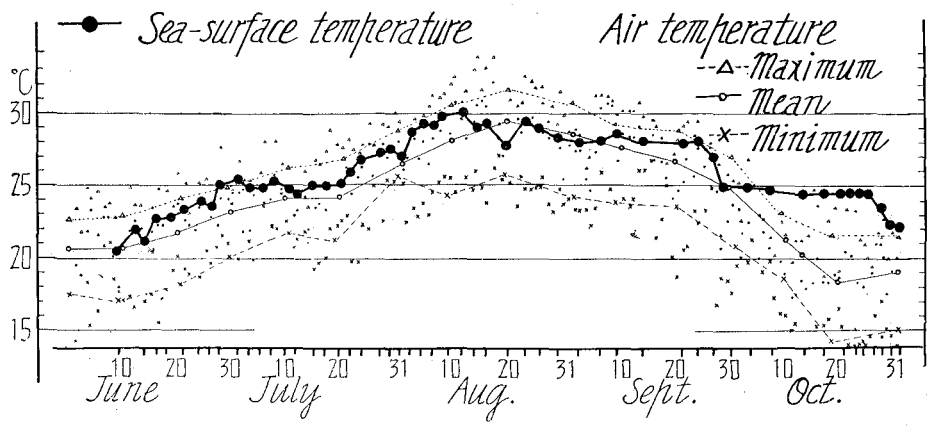

Fig. 1. Seasonal changes in air and sea-surface temperature in Tanabe Bay from June to October inclusive, 1954.

June 21st–30th: The water temperature slightly rose from 23°C to 25°C, but the chlorinity suddenly fell to 13‰ because of a heavy rainfall. Silicate contents showed a sharp rise from 1,000 to 2,000 mg per m^3. Catalytic activity of sea water and phosphate contents showed a smaller fall respectively. The total plankton volume considerably increased, though zooplankton numbers increased slightly.

July 1st–10th: The chlorinity suddenly increased from 13‰ to more than 17‰. Phosphate and silicate contents as well as catalytic activity of sea water showed a gradual fall. The total plankton volume was relatively small but zooplankton number prominently decreased except for one case when the number was very small.

July 11th–20th: The number of total plankton was relatively the same as in the early decade, but a gradual increase was found later. The number of zooplankton reached the maximum throughout the whole summer period. The temperature was

almost the same as in the early decade. The chlorinity showed more than 17‰, and the phosphate and silicate contents were small. The catalytic activity of sea water was quite irregular.

July 21st–31st: The volume of total plankton, especially of *Chaetoceros*, then increased to a maximum abundance throughout the whole period and then actually decreased at the end of July. The number of zooplankton was uniformly rich with 2–3 thousands per one m haul. The phosphate reduced from 7 to 9 mg per m^3 and silicate gradually fell. The chlorinity gradually increased and reached from 17 to

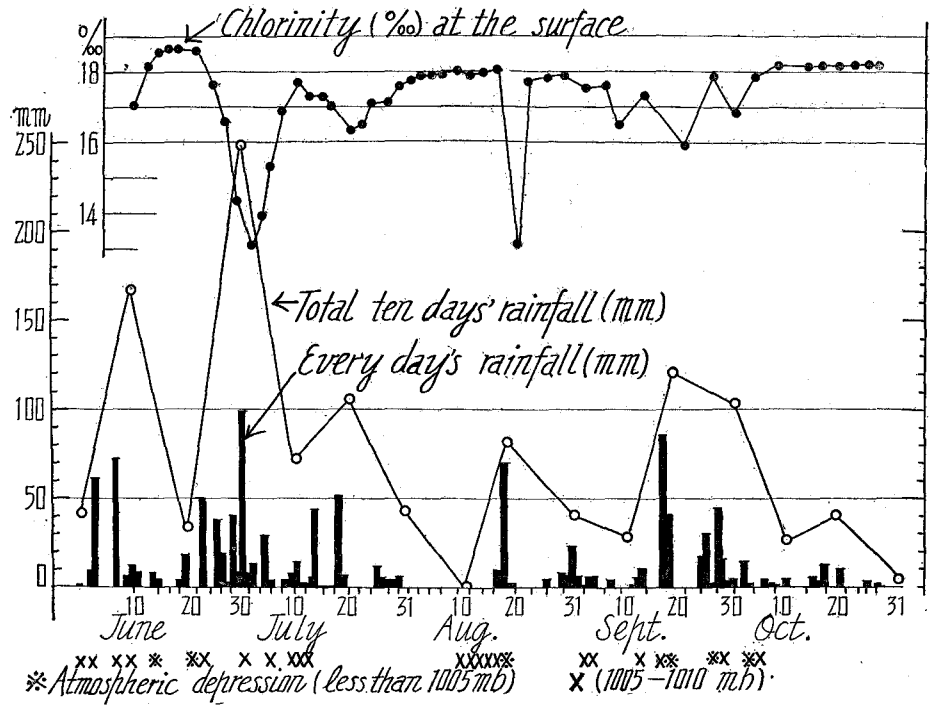

Fig. 2. Variations of surface chlorinity (above), total ten days' and every day's rainfall (middle) and main atmospheric depression (below) from June to October, 1954.

18‰. A considerable fluctuation in the catalytic activity of sea water was observed at the surface layer, varying from 5 to 30 $K_{30°C} \cdot 10^3$ as before.

August 1st–20th: The volume of total plankton gradually fell and was very scarce till August 10–20th, when there was a minimum of 0.02 cc per one m haul. Diatoms were negligible in relative abundance. The astonishing fall occurred also in both Taizi Bay (YAMAZI and HORIBATA, 1955) and Uranouti (UEDA, 1949), suggesting that it is not a local phenomenon. The temperature reached its maximum 30°C for the year on August 10th, and thereafter began to fall gradually. The

chlorinity was uniformly higher (18‰) except only on August 21st (13‰), when a typhoon (No. 12) came across. Low values were observed for the phosphate contents (5–10 mg per m^3), the silicate contents (1,000–1,500 mg per m^3) and the catalytic activity of sea water (10–20 $K_{30°C} \cdot 10^3$).

August 21st–September 30th: During the last decade of August to the beginning of September there was a very small increase in the volume of total plankton and the number of zooplankton, but not in the middle decade of September. But in the

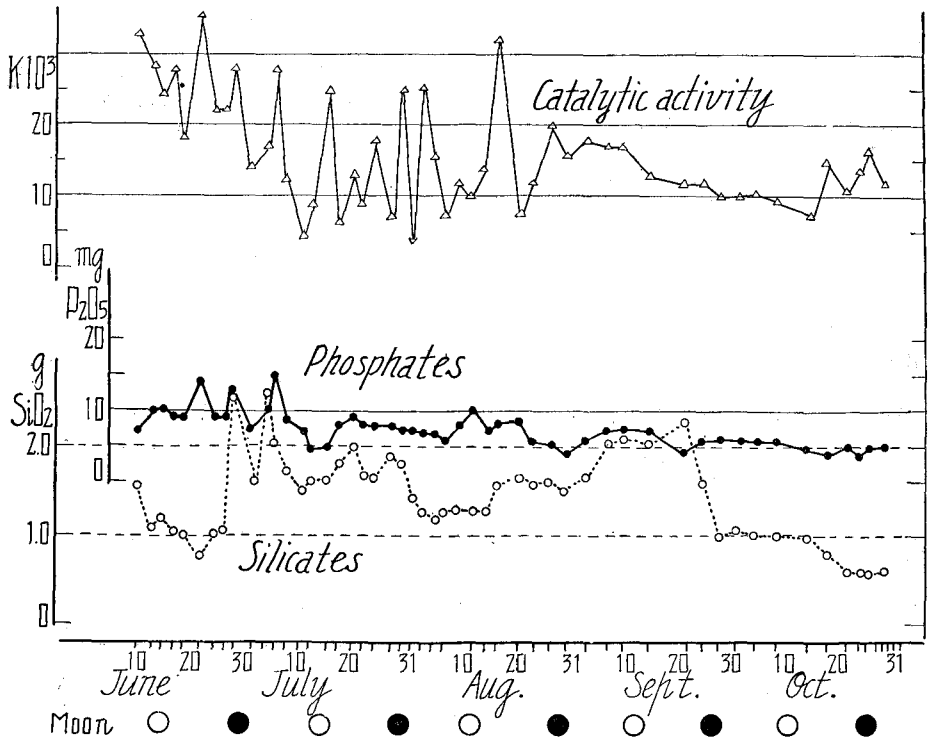

Fig. 3. Variations of catalytic activity of surface water ($K_{30°C} \cdot 10^3$) (above), phosphates (P_2O_5, mg/m^3) (middle), silicates (SiO_2, mg/m^3) (below) at the innermost station of Tanabe Bay and the age of the moon during the period from June to October, 1954.

last decade of September the volume and number gradually increased. The water temperature decreased slightly from 29°C to 27°C and fell sharply from September 30th when it was about 25°C. These were considerable fluctuations in the chlorinity from 10 to 18‰, becoming gradually lower, and also a small fall in phosphate contents and a rise in silicate contents.

The data given above show that the quantity of plankton is closely correlated with the hydrological conditions in early summer. The plankton volume decreases with the fall of the chlorinity, when the latter is considerably influenced by rainfall.

This may be due to the decrease of diatoms or to the sinking down to the bottom from the hauled layers. On the other hand the population of zooplankton was continually increasing in number coincided with low salinity and a gradual fall of temperature. In the highest temperature and salinity as in the late summer, both zoo- and phytoplankton were not abundant. Occasionally a great variation in volume

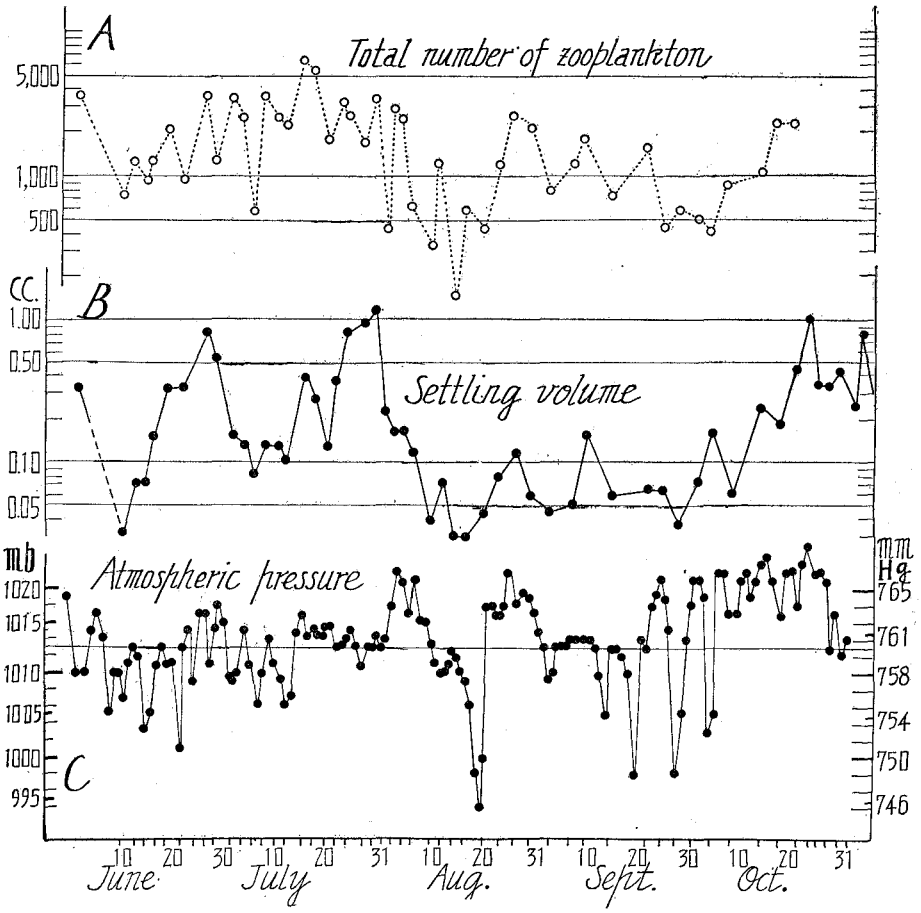

Fig. 4. Variations of total number of zooplankton per one meter haul (A), settling volume (B) and every day's atmospheric pressure during the period from June to October, 1954.

of total plankton and in number of zooplankton occurred at intervals of a few days, these figures being obtained in routine observations. The hydrological conditions, especially water movement caused by atmospheric pressure, wind and tide may be of great importance, as the plankton samples showed the differences in composition of the species.

Seasonal Variations of Zooplankton

The abundance of zooplankton is rather irregular in this inner region of the bay as in other bays. The plankton occurs in swarms or in different water masses. The most important zooplankton in the inner area of Tanabe Bay is as usual copepods (Fig. 5), followed by the larval forms. Protozoans and the other animals are not important in number. Copepods were most numerous, but showed relatively large fluctuations. On the whole they were not abundant in early June and gradually increased, and attained the maximum at the end of July. Although almost disappeared

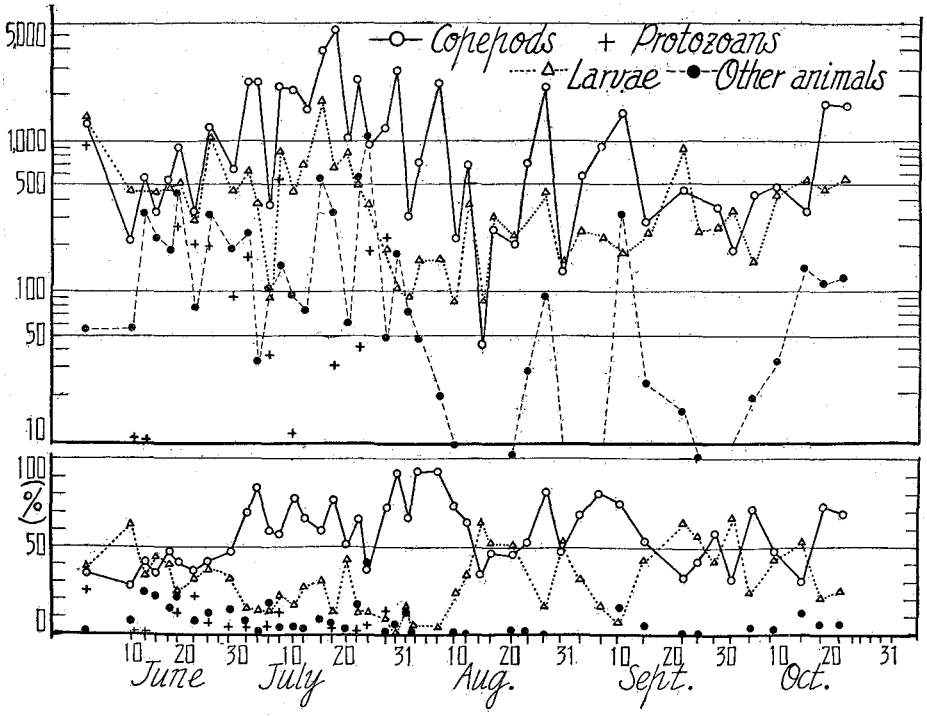

Fig. 5. Variations of total number of zooplankton per one meter haul (above) and their percentage composition (below).

there in the middle of August, they gradually increased during the end of August to September. The larval forms and other animals showed a considerable fluctuation in occurrence, but were mostly abundant during early June to the end of July. In August and September they were not encountered or very scarce.

All the copepods such as *Oithona nana, Paracalanus parvus, Acartia clausi, Acartia spinicauda, Oithona similis, Oncaea media, Microsetella rosea, Microsetella norvegica, Oithona rigida, Centropages* sp., *Oncaea venusta* and *Corycaeus* sp. occurred there as important components. The seasonal change of these copepods in number and percentage composition is given graphically in Figs. 6 and 7. As shown in the

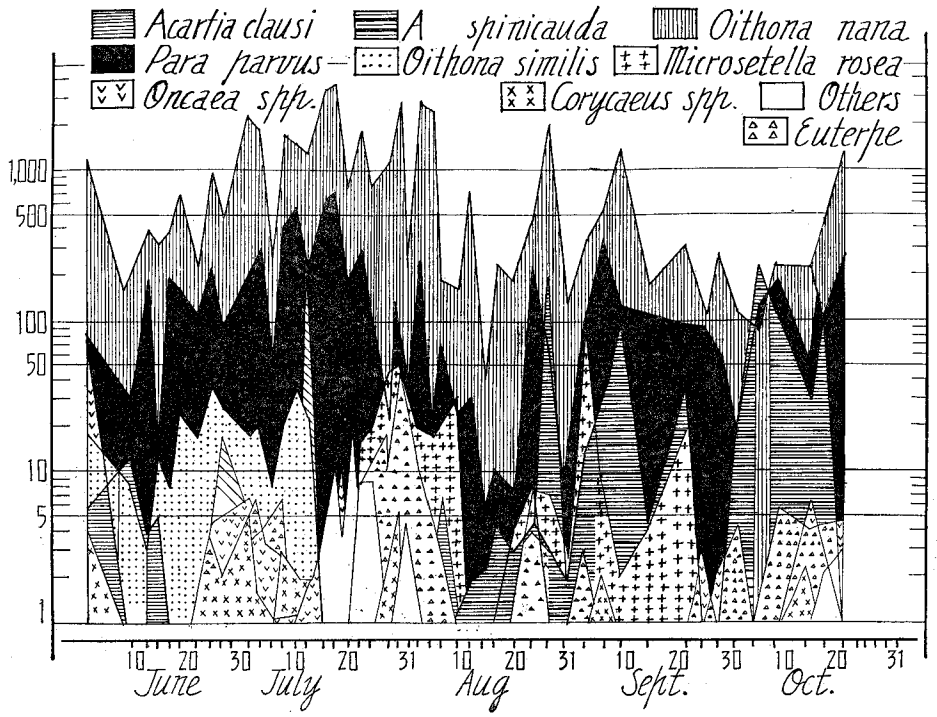

Fig. 6. Variations of total number of important copepods per one meter haul.

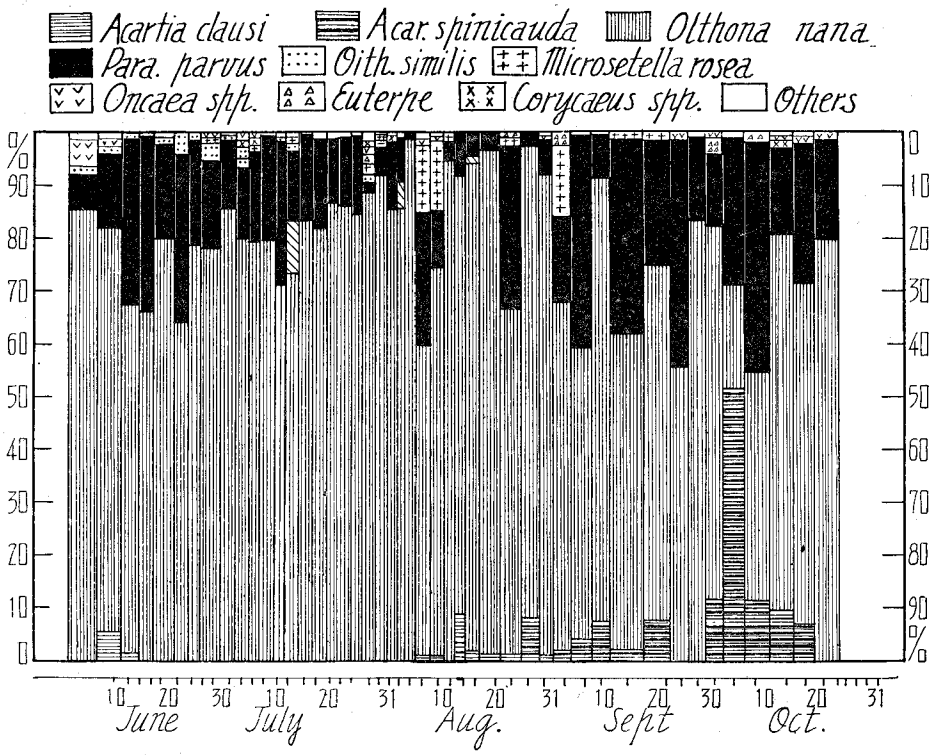

Fig. 7. Variations of percentage composition of important copepods per one meter haul.

two figures, the most abundant copepod was *Oithona nana* though the number was rather irregular. Generally it was very common in early summer but relatively less abundant in late summer and in early autumn. Its percentage reached 60-90% of the total copepods throughout this period except for two cases in autumn. *Paracalanus parvus* which was a subdominant copepod, occurred in the same manner of flactuation as in *Oithona nana*. Its percentage was from 5 to 45% of the total copepods. *Acartia clausi* was very small in number and percentage composition in this period. It did not appear after the end of June. On the other hand, *Acartia spinicauda* at first appeared scarcely after the beginning of August and became commoner till the

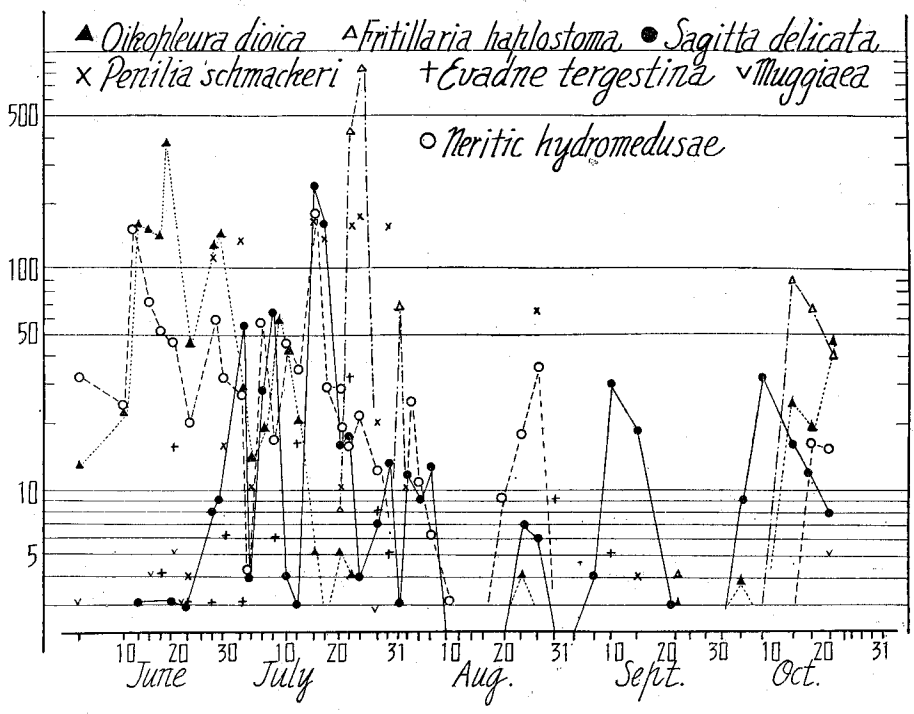

Fig. 8. Variations of total number of important zooplankton per one meter haul.

end of October. *Oithona similis* occurred till the middle of July but so far disappeared. *Microsetella rosea* was found during August and September. *Oncaea* appeared from the end of July to the end of October. These two species were only in very small numbers. Several individuals of *Oithona rigida* were found only at the end of June.

The Cladocera 'such as *Penilia schmackeri* and *Evadne tergestina* also appeared in swarms, the former being common in July and in early September (Fig. 8). After the end of September it disappeared. The chaetognath *Sagitta delicata* (Fig. 8) appeared always in large numbers in early summer. After the end of August three peaks were found, although their number was smaller than in July. Among tunicates,

Oikopleura dioica was the commonest. It occurred abundantly in early summer and after midsummer. The oceanic tunicate *Fritillaria haplostoma*, on the other hand, occurred in swarms in the middle of July, even when *Oikopleura dioika* scarcely appeared. In midsummer the inlet forms such as *Oikopleura dioica*, larval forms were very small in number, while the oceanic forms such as *Fritillaria*, *Muggiaea*, copepods and chaetognaths were relatively rich. This suggests that the influx of oceanic water is stronger than in the other period. These oceanic forms appeared in small numbers in late summer and autumn, but later disappeared suddenly.

Although the various benthic animals have different breeding period, their larvae

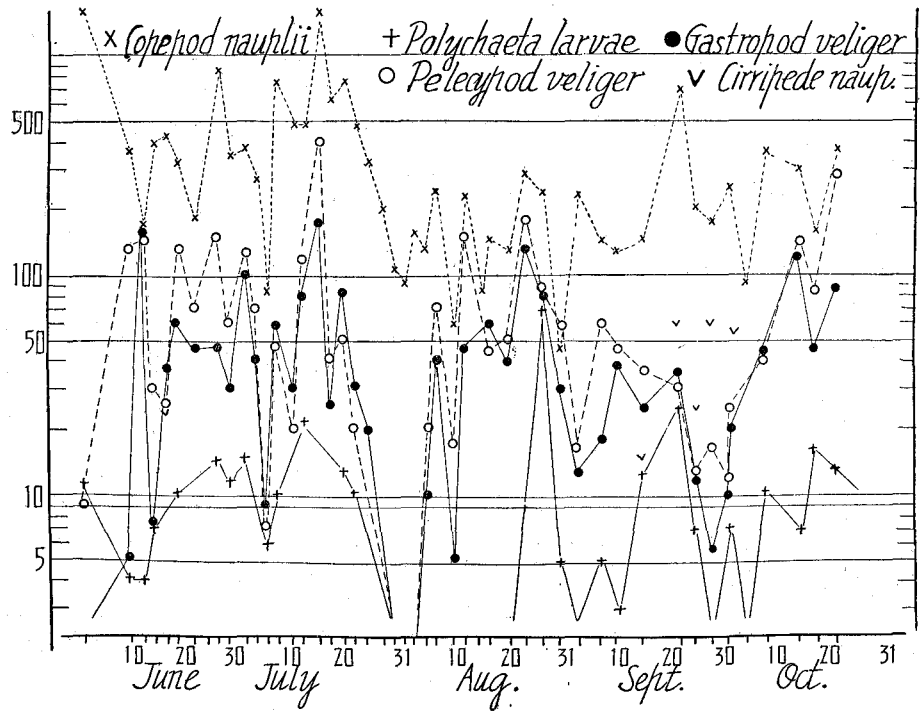

Fig. 9. Variations of abundance of important larval forms per one meter haul.

are numerous in early summer (Fig. 9). The larval plankton was represented mainly by copepod nauplii, larvae of polychaetes, veligers of pelecypods and gastropods and cirripede nauplii. The proper identification of most larval forms was very difficult except for some species of copepods and a few benthic animals. Copepod nauplii were always found in greater numbers than the other larval forms, with two peaks in July and September. They were more abundant in early summer than in autumn, and decreased in midsummer. Cirripede nauplii were also found in June and September, but were most abundant during the last decade of September. Polychaete larvae occurred throughout the period, except in midsummer. They were most

abundant in July and September. Both pelecypod and gastropod veligers were found with three major peaks in the middle of July, the end of August and the beginning of October. Besides, a number of different larval forms were found but it was unable to me to identify them with certainty.

The phytoplankton was most plentiful from June to July, with a maximum number in the middle of the period. Large numbers were also found in late October. An analysis of the seasonal change of phytoplankton will be discussed later in another paper.

Discussion

In the innermost area of Tanabe Bay, zooplankton community was characterized by the predominance of an inlet form *Oithona nana* and its associates during the period from June to october, 1954. The main associates are inlet forms *Paracalanus parvus, Penilia schmackeri, Evadne tergestina, Acartia spinicauda, Sagitta delicata, Oikopleura dioica,* larvae of benthic animals, and so on. However, a small periodical variation occasionally occurred. When the population of local plankton was poor, the open sea forms were relatively plentiful. During this period, the chlorinity at the surface showed a wide range from 13‰ to 18.7‰. At the end of June the chlorinity showed suddenly a considerable fall and rise, but after the middle of July it has been recovered to keep a mean value of 18‰ till the end of October, though a slight fluctuation occurred in September. These fluctuations of chlorinity have been reflected by the abundance of plankton population, although it cannot be explained if the chlorinity influenced directly upon the abundance of plankton or not.

During the days of low atmospheric pressure and strong southerly wind the neritic and oceanic forms such as *Oithona similis, Microsetella rosea, Oncaea* spp., *Corycaeus* spp., *Euterpe acutifrons, Fritillaria* sp., *Sagitta enflata,* etc. were generally found in larger numbers and the population of plankton was poorer than in other days. Although in the slight stabilization for waters from June to July the maximum of plankton was found, the late summer minimum from the late of August to the early of September which was a minimum in stabilization, and prevented rich development of plankton. This fact suggests that the open sea water deeply penetrated into this area. It is thus concluded that a strong inflow of open sea water penetrated into the innermost area of the bay having a wide mouth occasionally disturbs the abundance of inlet plankton communities localizing there.

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