PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN

V. THE PLANKTON OF HIROSIMA BAY IN THE SETO-NAIKAI (INLAND SEA)*

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With 7 Text-figures

Hirosima Bay, which is remembered as a base of the former Japanese Navy, is also famous for its oyster farming, but no detailed oceanographical survey has ever been made. The present paper deals with the results of a preliminary survey made on October 12, 1951, and forms a part of my planktological investigations of Japanese inlet waters. Owing to the lack of time, however, the field work was confined to the northwest small area of the bay lying just southwest of the city of Hirosima.

For general oceanographical conditions of the southern part of this bay, the reader is referred to the reports published by the Kōbe Marine Observatory (SUDA et al 1930; OKADA et al 1936) and Fisheries Experimental Stations (UDA & WATANABE, 1933). For methods of investigation refer to my preceding papers of this series.

Hydrological Conditions

Hirosima Bay represents one of the most significant bays in the Seto-naikai or Inland Sea, forming a large indentation of about 50 km long in the N-S direction and 40 km wide in the E-W direction. Its coast line is curved evenly with slight arms or inlets, but is studded with many islets of various sizes. The tidal range of the bay is great, more than 3 meters in extent, and the current is very strong during inflow or outflow, especially between islets.

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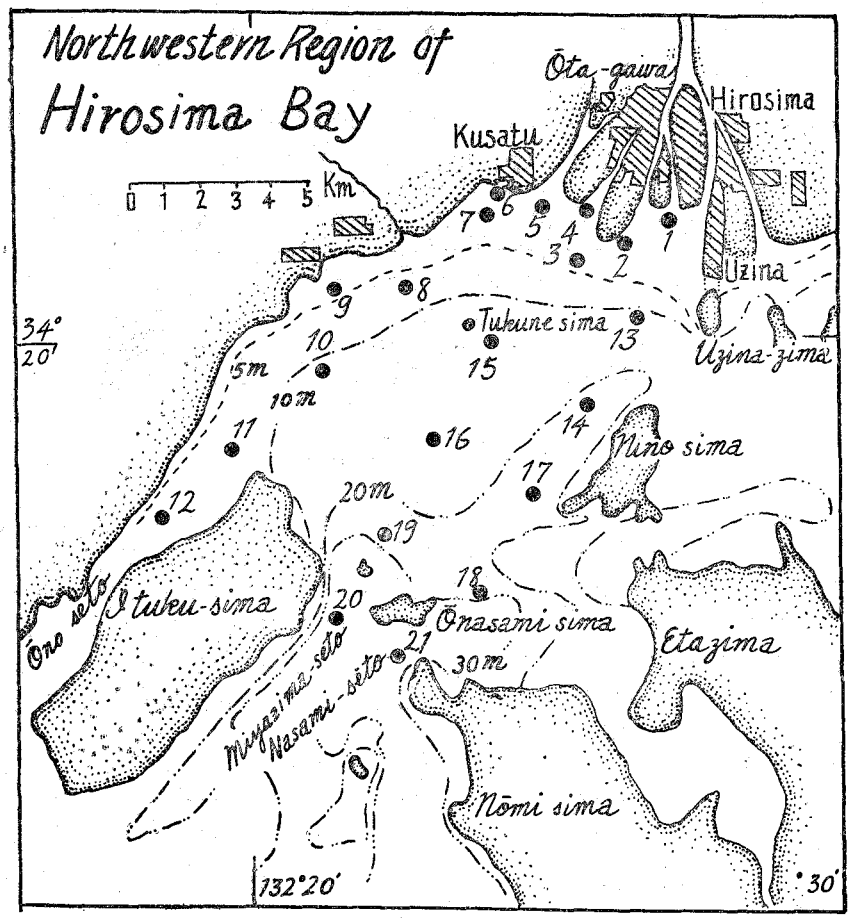

Fig. 1. Map of the northwestern region of Hirosima Bay showing stations and isobaths.

The surveyed area (Fig. 1), which is the northwest part of the head of the bay, is surrounded by the southern coast of Tyūgoku Region on the north and west, and connects the main region of the bay with a wide channel of about 3.5 km between two large islands Ituku-sima and Nōmi-sima on the south, and communicates on the east with Uzina-wan, which is the northeast part of the head of the bay.

Main part of the surveyed area is relatively shallow, ranging from 9 m to 13 m. Only southwards the 20 m isobath line runs from the northern end of Ituku-sima to the northern end of Nino-sima. The greatest depth is found at the central part of two channels of the southern entrance (Miyazima-seto and Nasami-seto), measuring about 58 m and 54 m respectively.

Hirosima Bay receives many rivers especially at its head and on the west coast, and a large delta or alluvial bank is formed near the mouth of Ōta-gawa, which passes through the city of Hirosima. This is only an influent which empties into the surveyed area. The shallow basin near its estuary is

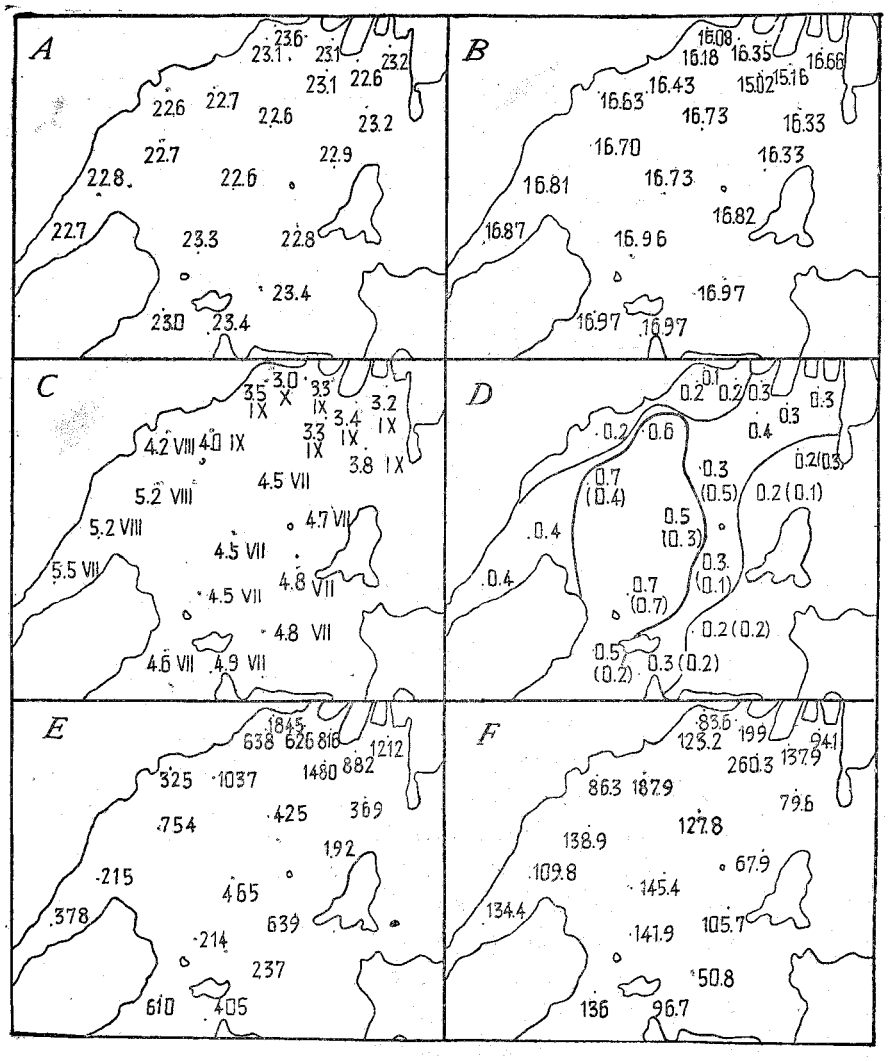

Fig. 2. A. Water temperature (°C) of the superficial layer.
B. Chlorinity (Cl ‰) of the surface water.
C. Distribution of water color (no.) and transparency (m.).
D. Settling volume (cc) of plankton per one meter haul (about 10 liters of water) between surface and 5 m depth.
E. Number of zooplankton (individuals) per one meter haul.
F. Number of phytoplankton (thousands) per one meter haul.

largely occupied by the oyster farm with spat-collecting bamboos in wide areas, they are set so thickly that it is difficult for a boat to pass.

Although the bay is thus well protected from the open sea, the water circulation seems to be rather good by strong tidal current. But the influences of rivers are conspicuous.

So far as my field work concerns, the surface temperature of the surveyed area ranged from 22.6°C to 23.4°C, being lower in the central area than in the northern and southern areas (Fig. 2, A). The chlorinity of the surface water was generally uniform and relatively small, being from 15 to 17 Cl ‰ (Fig. 2, B). Such low chlorinity is largely due to the dilution by spread of river waters.

The water was more yellowish brown and less transparent in the innermost part near the mouth of Ōta-gawa (nos. 9–10 of FOREL'S scale and 3–4 m of the SECCHI'S disc) than near the western (nos. 7–8 and 4–5.2 m) and southern entrances (no. 7 and 4.5–5 m); the most turbid water (no. 10) was found at St. 6 at the mouth of Ōta-gawa (Fig. 2, C). Other items were not observed whatever.

Plankton

A. Quantitative Analysis of Plankton

The plankton samples were collected at 21 stations. The settling volume of plankton (Fig. 2, D) was larger in the central part than in the eastern and western parts. The smallest volume was found near the northern coast.

The plankton was relatively rich throughout all stations. The largest number of individuals, cells or colonies per 10 liters was 290 thousands at St. 3 and the smallest was 50 thousands at St. 18. More than 200 thousands were counted at 3 stations, 190 thousands at one station, 100–150 thousands at 10 stations and less than 100 thousands at 7 stations.

The relation between the settling volume and the population density is generally parallel to each other in the eastern part, but irregular in the western and central parts, where the plankton was relatively small in density (Fig. 3). This may be due to the richness of small-sized diatoms such as *Skeletonema costatum*.

The largest number of zooplankton was found at St. 1–4 near the northern coast, where it attained 700–1800 per 10 liters. The smallest was in the eastern half, measuring only 400 per 10 liters as shown in Fig. 2, E. The population of phytoplankton was also very large throughout all stations. It was found densest at St. 3 near the northern coast, whence the number ob-

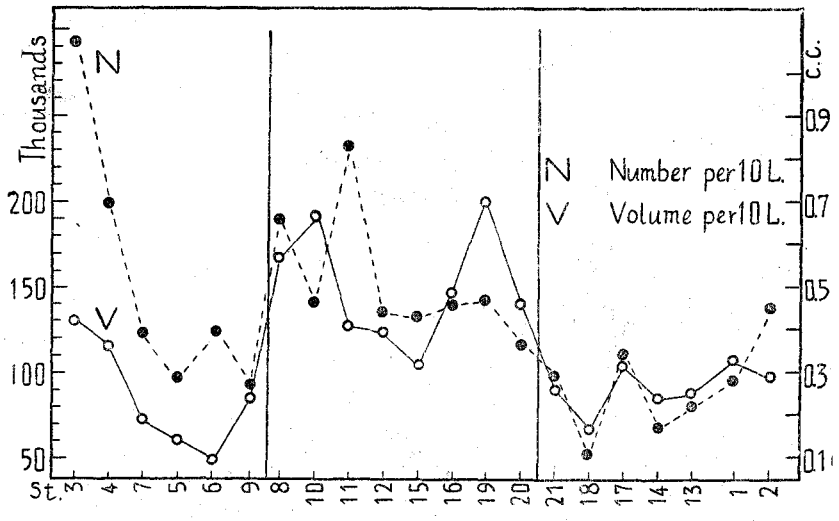

Fig. 3. Relation between the settling volume (cc) of plankton and the number of individuals, cells or colonies (each per 10 liters).

tained was 260 thousands per 10 liters. The smallest was found at St. 18, 13 and 14 in the eastern part, measuring only 50–80 thousands (Fig. 2, F).

The numerical percentage of phytoplankton in the total plankton (P/N× 100) was very large, more than 99 %, with a single exception of St. 6 (off Kusatu port) where it was less than 97.8 %.

B. Qualitative Analysis of Plankton

Zooplankton: The important component of zooplankton (Fig. 4) was copepods (20–70 %). Next came the other animals, such as Protozoa, medusae, Copelata, Chaetognatha, Cladocera, etc., all of which were represented by about 5–35 % in totals. Larval forms of animals, such as polychaetes, molluscs, copepods and cirripeds, were represented by 20–50 % in the total zooplankton. As shown in Fig. 4, these composition varied from station to station. Among copepods the following 11 species were discriminated at each station: *Paracalanus parvus* (20–73 %), *Oithona nana* (5–50 %), *Oithona similis* (1–40 %), *Acartia clausi* (0–45 %), *Microsetella norvegica* (0–43 %), *Oncaea venusta* (0–15 %), *Euterpe acutifrons*, (+) *Corycaeus crassiusculus* (0–1 %), and *Eucalanus attenuatus* (+) *Calanus pauper* (0–0.5 %). Of these, only the last-named two are offshore species, and the rest inshore forms. The surveyed area was predominated by *Paracalanus parvus* which was abundant in the inner region and smallest near Kusatu Port (St. 6) (Fig. 5). It increased gradually southwards. *Oithona nana,*

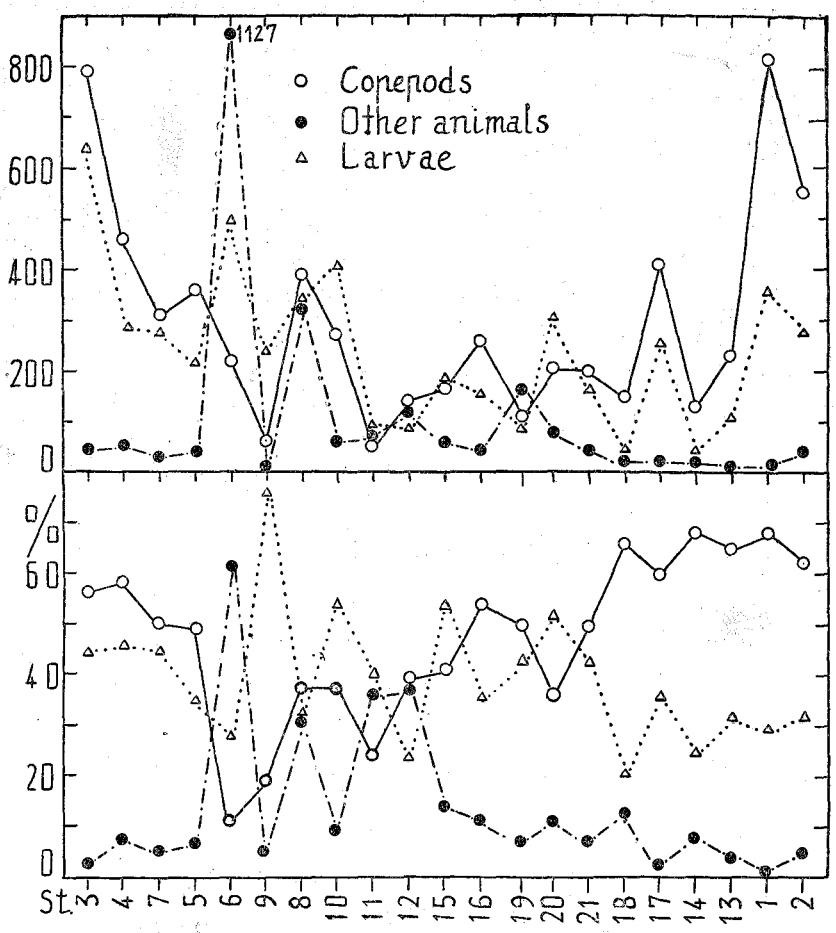

Fig. 4. Population density (above) and percentage composition (below) of zooplankton (each per 10 liters).

which was the next important species among zooplankters, was only found in abundance in the northern area and decreased towards the southern channel in contrast with the case of *Paracalanus parvus*. The population of *Acartia clausi* was restricted to the innermost area near Kusatu Port. *Oithona similis* was found rather abundantly in the offshore area towards the eastern and southern channels, but scantily in the inshore area. *Microsetella norvegica*, *Corycaeus crassiusculus* and *Oncaea venusta* were also found in the eastern half of the central area. Calanoids such as *Eucalanus attenuatus* and *Calanus pauper* occurred scarcely in the offshore area.

Sagitta crassa f. *naikaiensis* (Chaetognatha) and *Oikopleura dioica* (Copelata) which are considered as typical indicators of inland water (TOKIOKA,

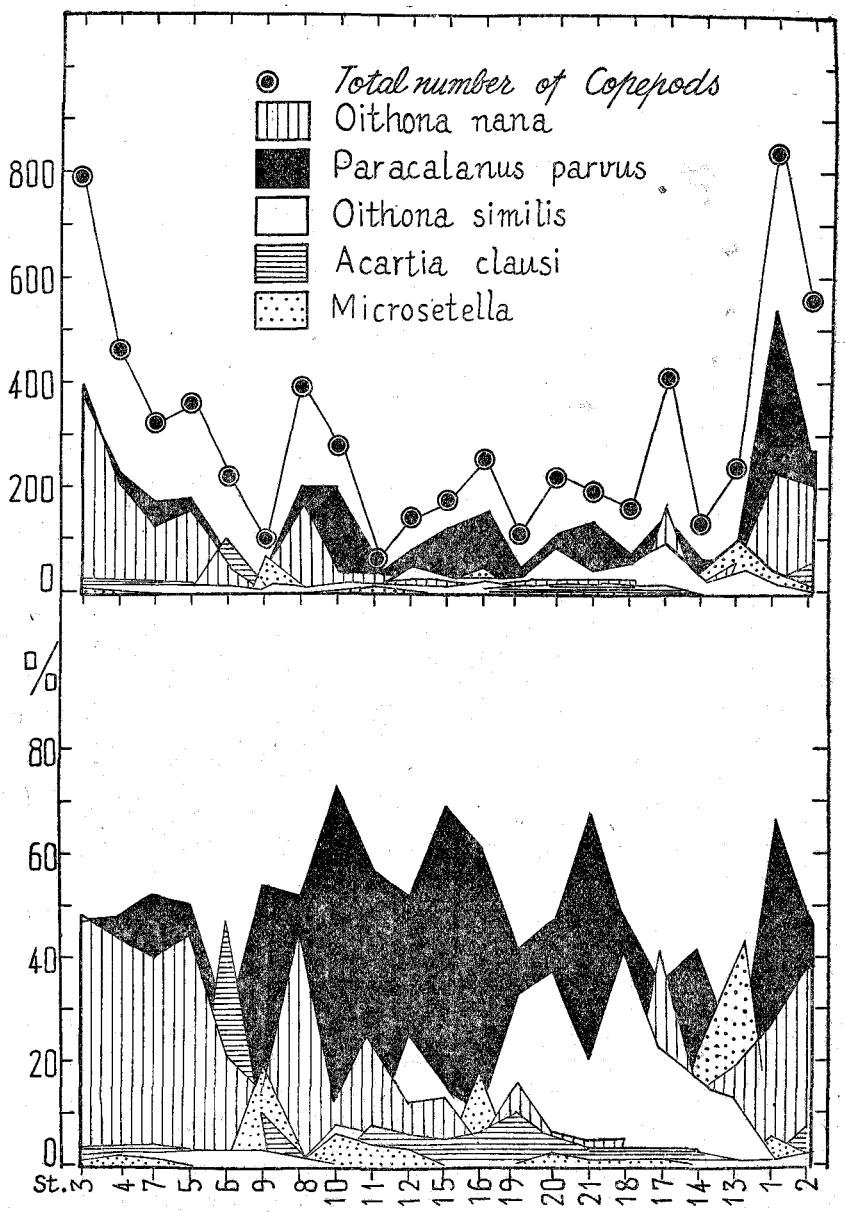

Fig. 5. Individual number (above) and percentage composition (below) of important copepods caught per one meter haul (10 liters of water) between surface and 5 m depth.

1939), and *Evadne nordmanni* and *Penilia schmackeri* (Cladocera) were widely distributed. Among protozoans, *Favella campanula, Tintinnopsis radix, Tin. cylindrica, Tin, nordquisti* etc., were found sparsely in the inner region and *Favella campanula* only was abundantly in the innermost area near Kusatu Port. At

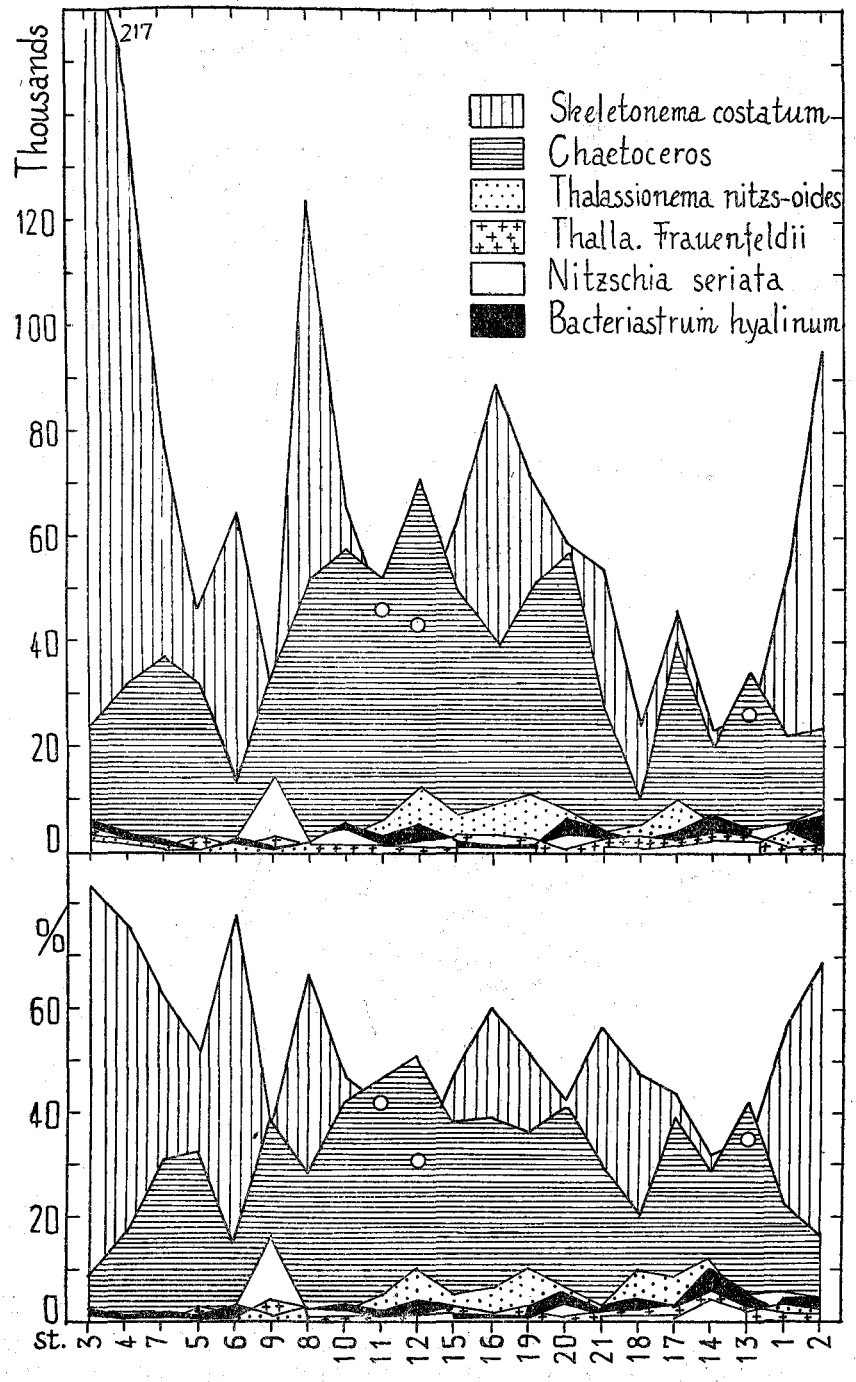

Fig. 6. Cell or colony number (above) and percentage compositions (below) of important diatom groups.

the center of the surveyed area there were found some offshore forms, such as *Muggiaea atlantica, Sticolonche zanclea* and *Sagitta enflata.* The larval forms were mainly represented by nauplii of copepods in the inshore region. The cirripedian nauplii and molluscan veligers were also frequent.

Phytoplankton: Diatoms showed almost the same composition at all stations, although varying in frequency of occurrence (Fig. 6). *Skeletonema costatum* and *Chaetoceros* spp. were dominant throughout the whole stations. *Skeletonema* occurred considerably in abundance along the northern coast and decreased southwards. On the other hand, *Chaetoceros* such as *Ch. coarctatus, Ch. peruvianus, Ch. denticulatus, Ch. tetrastichon, Ch. didymus, Ch. decipiens, Ch. Lorenzianus, Ch. laevis,* etc., were very abundant mainly in the central area towards the southern channel, and similarly decreased in the northern and eastern areas. *Thalassionema nitzschioides, Thalassiothrix Frauenfeldii, Nitzschia seriata* and *Bacteriastrum hyalinum* were also frequent as important components.

The distribution of dinoflagellates (including 7 species) was rather uneven. Among them *Ceratium fusus* and *C. furca* were most frequent at St. 20 near the southern channel, and the smallest in the central area. *C. tripos,* however, rather evenly occurred in the whole area.

It is thus clear that a remarkable dissimilarity exists in the composition and distribution of plankton of Hirosima Bay and those of Imari and Nagasaki Bay where have hitherto been surveyed (YAMAZI, 1952 a, b).

Many offshore forms were found also in this bay. It seems that these immigrant species were brought into this area by the strong tidal currents and southerly winds. They are listed as follows:

Zooplankton; *Calanus pauper, Eucalanus attenuatus, Acanthometron pellucida, Sticholonche zanclea,* Radiolaria spp. *Muggiaea atlantica, Sagitta enflata.*

Phytoplankton; *Chaetoceros coarctatus, Ch. peruvianus, Ch. denticulatus, Ch. tetrastichon, Rhizosolenia setigera, Rh. imbricata, Rh. alata* forma *indica* and *Guinardia flaccida.*

General Consideration on Regional Distribution

The local difference in topographical and hydrological features in the inner region of Hirosima Bay are generally inconspicuous. But as the tidal current is relatively strong, the infuence of the open sea water is appreciably recognized. The salinity of surface water shows a considerable decrease towards the mouth of Ōta-gawa, where the water is yellowish brown and

less transparent. The following three areas (Fig. 7) may be recognized according to the distribution of dominant zooplankters.

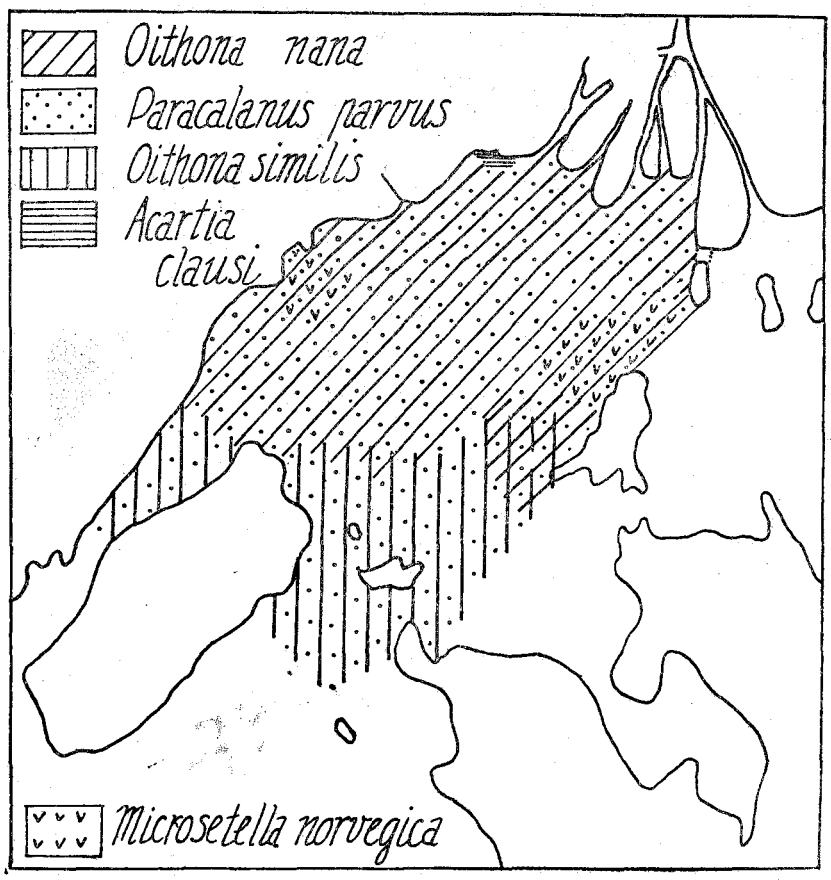

Fig. 7. Distribution of dominant copepods in the northwestern region of Hirosima Bay.

1. *Acartia clausi* area.

This area, which is dominated by the strictly inshore species *Acartia clausi*, is restricted only to the pier of Kusatu. This species was widespread over the bay in small numbers. It was also very abundant in the innermost part of Ago Bay (TOKIOKA and YAMAZI, 1950; TOKIOKA, YAMAZI and HUSE, 1951). According to BIGELOW (1926) and BIGELOW and SEARS (1839), this copepod is restricted to the neritic region of the Gulf of Maine. GURNEY (1928–1929) reported it as a littoral and brackish form, and DEEVEY (1948) found it in the Tisbury Great Pond in abundance from winter to late spring, and said that it is "fairly euryhaline and eurythermal species surviving unfavor-

able conditions either as resting stages or in small numbers". The water, where it was abundant, showed yellowish color and low transparency, but the salinity was almost similar to that of the neighbouring area.

2. *Paracalanus parvus—Oithona nana* area.

In the inner region, *Paracalanus parvus* and *Oithona nana*, commonly occurring in most bay or inlets, were distributed densely. The percentage composition of the former species in the total plankton was greater in the northern region than that of the latter, while in the southern region it was the reverse. They were associated with a copepod, *Microsetella norvegica*, diatoms (*Skeletonema costatum* and *Chaetoceros* spp.) and several species of dinoflagellates.

3. *Paracalanus parvus—Oithona similis* area.

In the southern region, however, *Paracalanus parvus* and *Oithona similis* were predominant. The composition in this area was similar to that of the preceding area, but the population density was smaller. Such diatoms as *Chaetoceros* and *Thalassionema nitzschioides* were more abundant as associates.

In contrast with the cases of Imari Bay and Nagasaki Bay it is remarkable that the plankton community of Hirosima Bay consists largely of the ecotone of *Paracalanus parvus*, associated with *Oithona nana* and *O. similis*, and lacks the *Oithona nana* sociation; that is, the *Oithona nana* area, as usual in Imari Bay and Nagasaki Bay, was weakly developed in this bay, at least in the surveyed area. In addition, offshore forms brought into by the tidal current and southerly winds were relatively abundant. This may probably be interpreted as due to influence of the open sea water inflowing through the course of Hōyo Strait—Iyo-nada, where is the widest area of the western part of the Inland Sea.

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