PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN

IX. THE PLANKTON OF ONAGAWA BAY ON THE EASTERN COAST OF TÔHOKU DISTRICT[1)]

ISAMU YAMAZI
Seto Marine Biological Laboratory, Sirahama

With 10 Text-figures and 1 Table

On the eastern rias coast of the Tôhoku District, there are numerous indentations of different forms. For planktological investigation in these bays, my special attention was paid on the plankton communities in relation to the topographical conditions characterizing the rias coast and then the hydrological conditions in different bays. As a first step I surveyed Onagawa Bay, one of the remarkable bays on that coast, on August 28, 1951 on board the boat of the Onagawa Fisheries Laboratory, Tôhoku University.

The plankton samples were vertically collected from the 5 meter layer to the surface and from the bottom to the 5 meter layer by a KITAHARA's quantitative silk tow net in a small scale. The diameters of the mouth and largest part of the net are 11.25 cm and 25 cm respectively and the length is about 50 cm. Therefore, the net passes through the water of approximately 50 liters in every towing. The mesh of the MÜLLER's gauze is No. XX–13. Other methods of observations and examinations are referred to my previous papers in this series.

I am indebted to the staff members of the Onagawa Fisheries Laboratory and, in particular, Dr. C. MATSUDAIRA of Tôhoku University for his kind advice and aid on the determination of chlorinity and catalytic activity of sea water. Thanks are also due to Prof. D. MIYADI, Dr. H. UTINOMI and Dr. T. TOKIOKA for suggestion and advice. The investigation was partially supported by a grant from the Ministry of Education for scientific researches.

1) Contributions from the Seto Marine Biological Laboratory, No. 216.

Hydrological Conditions

Onagawa Bay (Fig. 1) lies on the base of Ozika Peninsula, forming a deep indentation of about 6.5 km long in the east and west direction. It communicates with the Pacific Ocean by a rather wide mouth of about 4 km, between the island of Izusima and the cape of Haya-saki. The coastal line is indented westwards to form two main inlets, Onagawa and Nonohama, and generally fringed with fantastic rock and stone, and sandy beaches are hardly developed. The basin is relatively deep. The greatest depth is found near the entrance, being about 4.5 km, and the 30 m isobath line runs deeply into both inlets along the coast line. Only a very small river pours into the head of the Onagawa inlet.

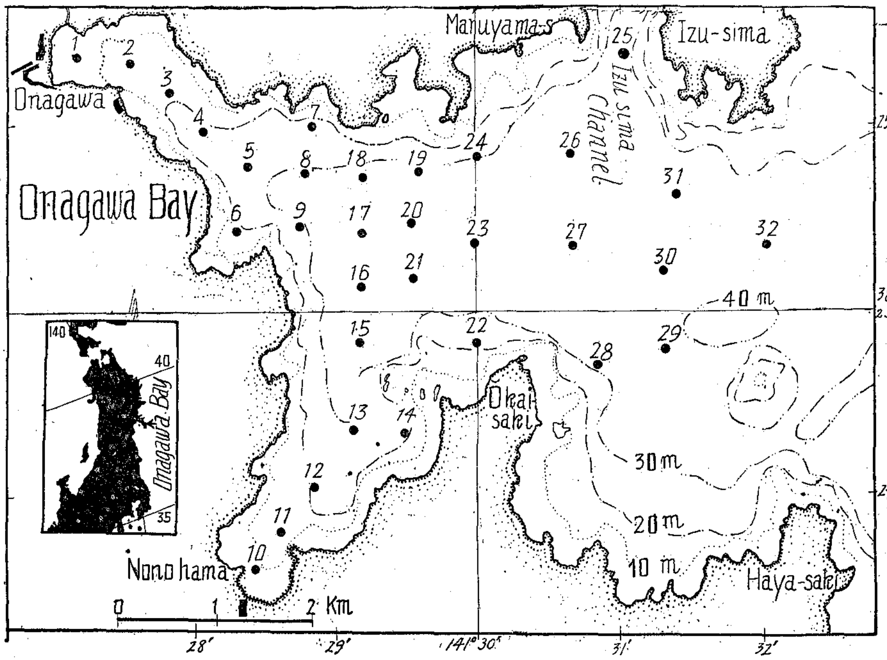

Fig. 1. Chart of Onagawa Bay showing stations and bathymetric contours.

The hydrological data from the analyses of surface samples are shown in Fig. 2.

Water temperature (Fig. 2, A): The water temperature at the superficial layer reaches its highest in the central area (about 25–25.3°C), and lowest in the innermost part of the Onagawa inlet (about 24–25°C).

Chlorinity (Fig. 2, C): Chlorinities at the surface were generally high. Lowest chlorinities were found at stations of the Onagawa inlet (about 18–18.5 Cl ‰), where pours a little fresh water from drainage. The Nonohama inlet showed the least changes in chlorinity (about 18.5–18.7 Cl ‰), probably because of no drainage and the horizontal and vertical exchange with open sea water. In this area a patch of higher chlorinity than that of the outer region was found.

Transparency (Fig. 2, B): The transparency of water was the smallest in the Onagawa inlet and northern area of the central region (about 4–6 m). The water of the Nonohama inlet was more transparent (about 7–8.5 m) than that of the northern area of the bay. The highest area was found towards the eastern entrance. The

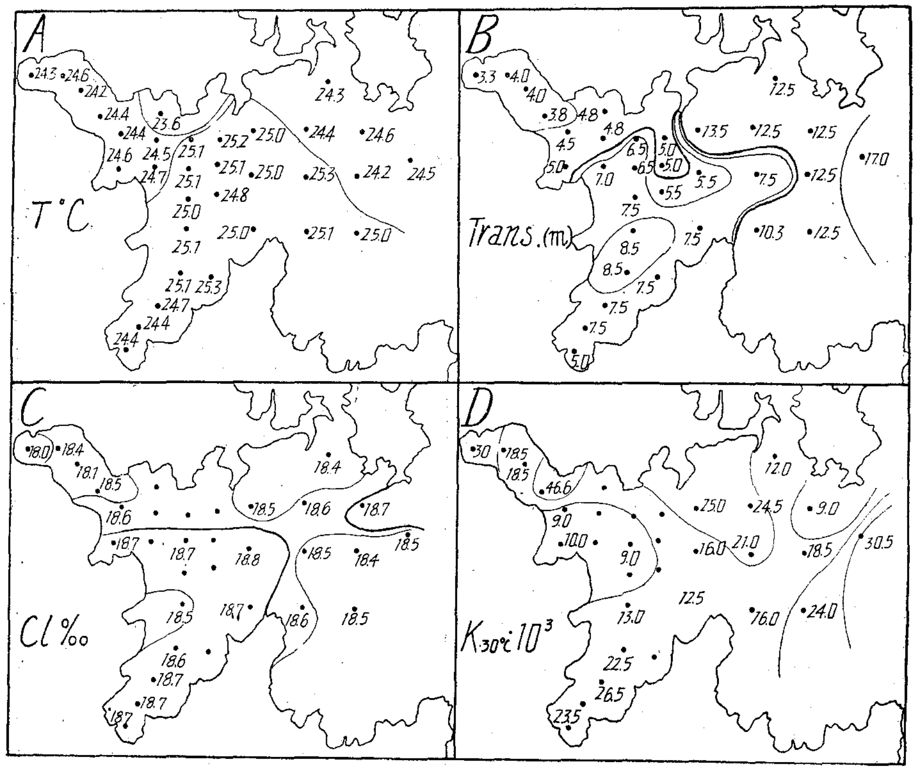

Fig. 2. Hydrological conditions during the survey (August 28, 1951).
A. Distribution of surface temperature in °C.
B. Distribution of transparency in M.
C. Distribution of chlorinity in ‰ of the superficial layer.
D. Catalytic activity of sea water in $K_{30°C} \cdot 10^3$ of the superficial layer.

highest area was found towards the eastern entrance of the bay, measuring about 17 m near the south of Izusima.

Catalytic activity of sea water (Fig. 2, D): The highest value of the catalytic activity of sea water (MATSUDAIRA, 1950; YAMAZI, 1953) was found at the entrance of the bay and the Nonohama inlet (about 22–30 $K_{30°C} \cdot 10^3$). The lowest value as found at the mouth of the Onagawa inlet. At St. 1 and 4 in the Onagawa inlet, however, it showed locally high values (about 30 and 46 $K_{30^{\circ}C} \cdot 10^3$).

Plankton

A. Quantitative Analysis of Plankton

The plankton samples were hauled at 32 stations (Fig. 1). As shown in Fig. 3, A, the settling volume of total plankton was relatively small throughout all stations. It was largest in the outer half of the bay, and smallest in two inlets, Onagawa and Nonohama. The total number (Fig. 3, B) was also very small throughout all stations,

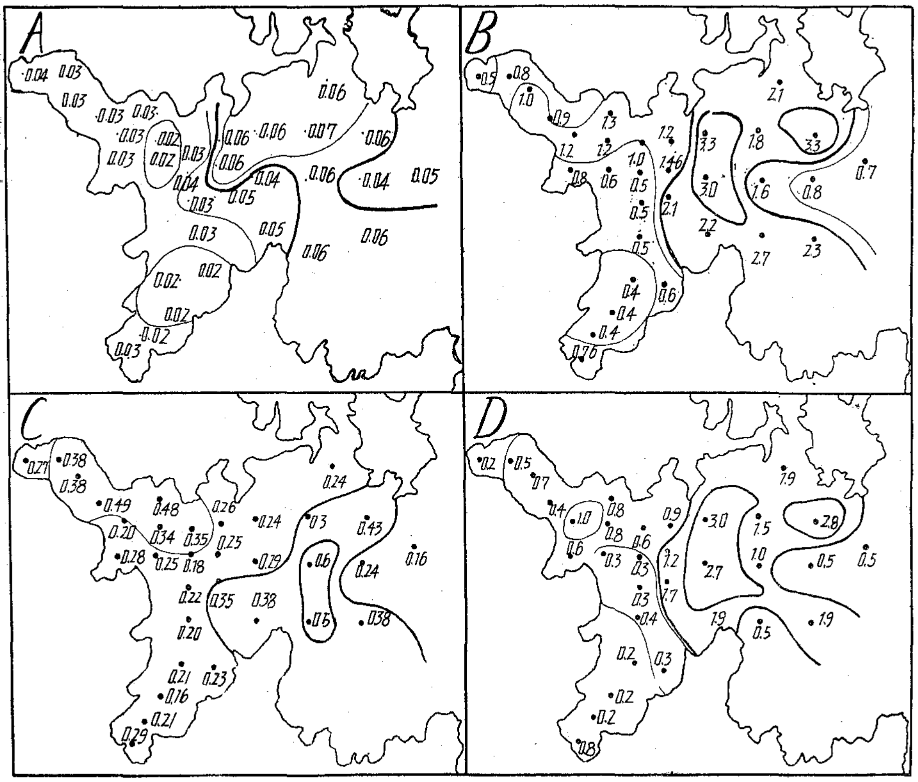

Fig. 3. Distribution of plankton in Onagawa Bay (August 28, 1951).

A. Distribution of settling volume (cc) per one m haul from the 5 m depth to the surface.

B. Distribution of total number of plankton (unit of number is thousand).

C. Distribution of total number of zooplankton per one m haul (unit of number is thousand).

D. Distribution of total number of phytoplankton in cells or colonies per one m haul (unit of number is thousand).

proportionally to the settling volume. The largest number of individuals, cells or colonies measured at the northeastern area was only 3–3.3 thousands per one m haul, and the smallest number was about 0.4 thousands per one m haul in the inlet of Nonohama.

The relation between the settling volume and number (Fig. 4) is generally parallel in the inner part of the bay. In the outer part of the bay, however, it is not the

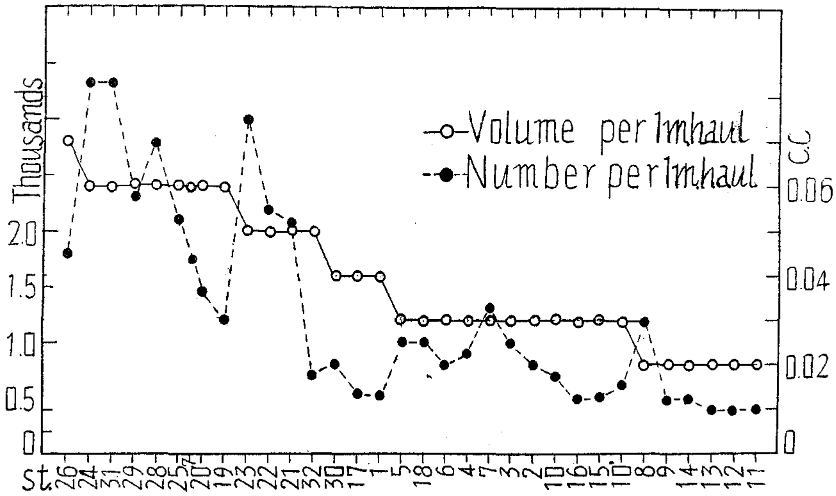

Fig. 4. Relation between settling volume (cc) and total number of individuals, cells or colonies of plankton at each station (each per one m haul).

case, since their composition varies at different stations. At St. 24, 31, 23 and 28 the number was very large because of unusual richness of diatoms.

As shown in Fig. 3, C, the population of zooplankton was relatively poor through-

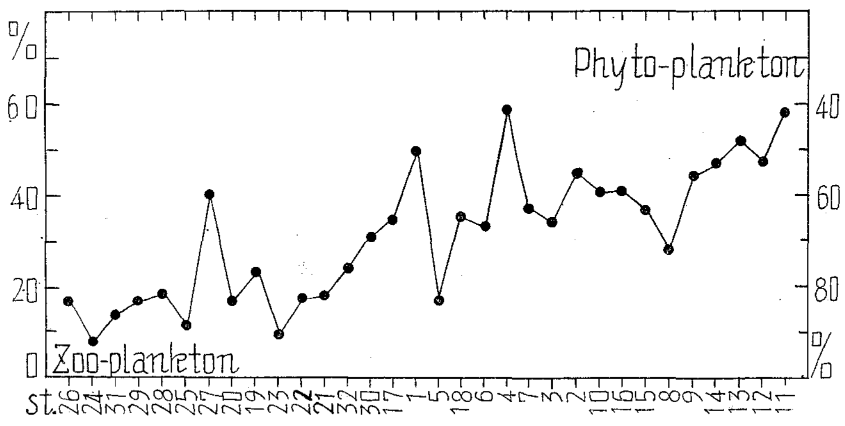

Fig. 5. Percentage composition between total number of zoo- and phyto-plankton per one m haul.

out all stations, but it was found densest in the mouth, and smallest in the central and the inlet of Nonohama. The numerical percentage of zooplankton in the total plankton (Z/N×100) was very large, more than 10–20% in the mouth and 30–60% in both inlets (Fig. 5).

The population of phytoplankton was the densest in the outer half of the bay, where the number was only less than 3.3 thousands cells or colonies per one m haul. It was the thinnest in the inner part of both inlets as in the case of zooplankton. The numerical percentage of phytoplankton in total plankton (P/N×100) was relatively

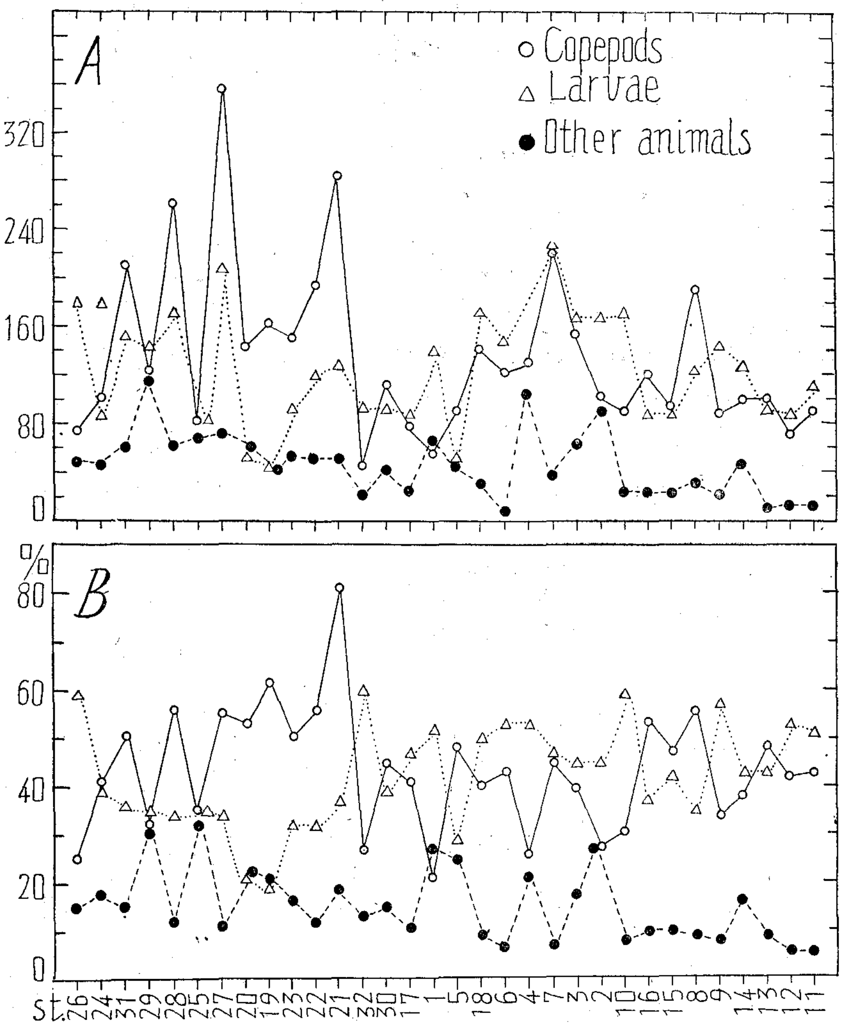

Fig. 6. Population of zooplankton groups per one m haul (above), and their percentage composition (below).

small as compared with all the bays I formerly surveyed. The value was large in the mouth (about 80–90%) and decreased towards the inner region and attained the minimum in the Nonohama inlet (about 50–60%).

B. Qualitative Analysis of Plankton

ZOOPLANKTON

As shown in Fig. 6, the most important component of zooplankton was copepods (30–60%). The next was larval forms of various animals, such as polychaetes, molluscs, copepods and ascidians, all of which were represented by 20–60% in total zooplankton. The other animals such as protozoans, medusae, rotifers, chaetognaths, tunicates and cladocerans, etc. were represented by 5–30%.

The copepods, which are relatively large in size, form the most important population in this bay. The main components of copepods of the bay were almost similar at all stations, but they varied in the population density and its percentage composition. Among copepods the following 15 species were remarkable: *Acartia clausi* (1–75%),

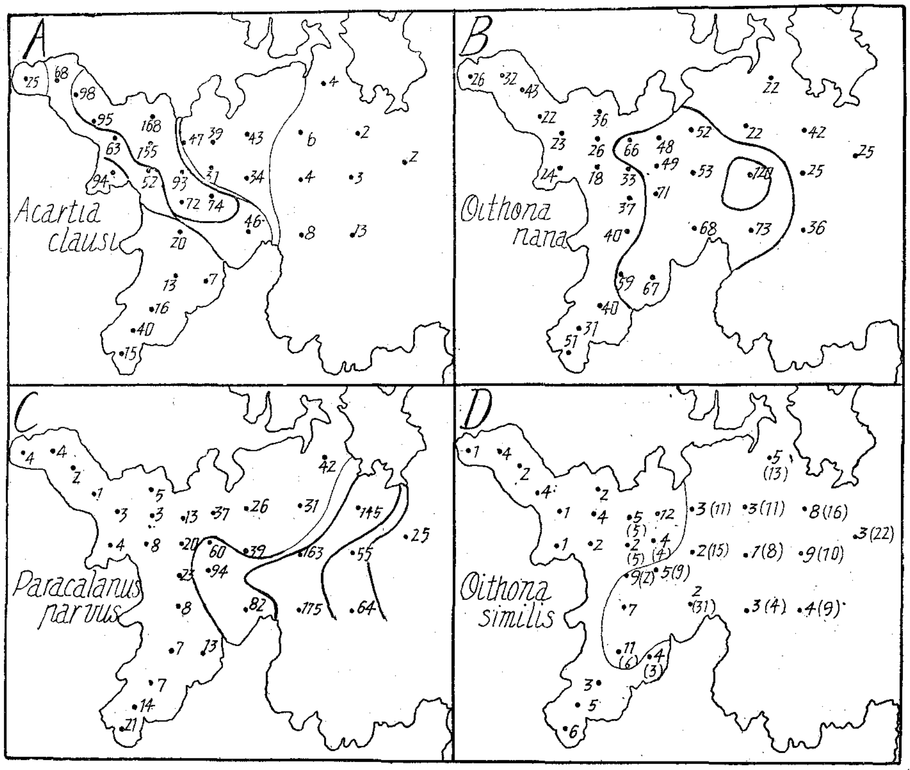

Fig. 7. Distribution of important copepods from the 5 m layer to the surface. The number in parentheses shows the average number of individuals from the bottom to the 5 m depth per one m haul.

Oithona nana (4–63%), *Paracalanus parvus* (1–70%), *Oithona similis* (0–15%), *Microsetella norvegica* (0–8%), *Oncaea media* (0–55%), *Oncaea venusta* (0–12%), *Euterpe acutifrons* (0–4%), *Oithona rigida* (0–5%), *Oithona plumifera, Calanus minor, Cal. pauper, Cal. darwinii, Calocalanus pavo, Copilia longistylis* (each less than 1%), etc. Of these species the last six are of the offshore origin, and they occurred scarcely in the outer part of the bay. *Acartia clausi* (Fig. 7, A and Fig. 9) predominated and occurred mainly in the Onagawa inlet, where it attained about 50–160 individuals (20–80%) per one m haul. *Euterpe acutifrons* was also restricted to the Onagawa inlet. *Oithona nana* (Fig. 7, B and Fig. 9) was evenly distributed in the bay, although the individual number was observed most abundantly in the central region (50–120 individuals) and decreased towards the Nonohama and Onagawa inlets as well as towards the mouth. Its percentage reached 50–65% of the total copepods in the central region and Nonohama inlet and decreased towards the inner part, in contrast with the case of *Acartia clausi*. *Paracalanus parvus* (Fig. 7, C and Fig. 9) predominated in the mouth (about 50–170 individuals and 50–70% in its percentage composition) and decreased towards the inner part (10–40 indivibuals) and smallest in the Onagawa inlet, where *Acartia* was numerous. *Oithona similis* was widely distributed, but it was very sparsely found in the samples from the surface to the 5 m depth, while in the samples from the 5 m depth to the bottom it was relatively numerous (10–20 individuals per one m haul) in the outer half of the bay. *Microsetella norvegica* plus *M. rosea* were widely distributed but very sparsely. *Oncaea media* plus *Oncaea venusta* (this species was very few in number) were rather evenly found from the mouth to the Nonohama inlet, but the former was abundant in the patch at the central region. From the Onagawa inlet *Oncaea* was not obtained.

The cladocerans such as *Penilia schmackeri, Evadne tergestina* and *Podon leuckarti* were widely distributed, though small in number, and they decreased towards the inner part of the Onagawa inlet. Among chaetognaths, an oceanic form *S. enflata* was only found at the outer stations very sparsely. A neritic form *Sagitta delicata*, on the other hand, was widely distributed throughout all stations (Fig. 8, D). *Oikopleura dioica* and *O. longicauda* were also found, though the latter species was more abundant than the former (Fig. 8, C). The other tunicates *Fritillaria haplostoma*, and *Doliolum nationalis* were distributed in the outer region. *Favella campanula, Tintinnus lusus-undae* and a rotifer *Encentrum* sp. were restricted to the inner region. Radiolarians, *Noctiluca scintillans* and *Stycholonche zanclaea* were only sparsely distributed. The larval forms, copepod nauplii (Fig. 8, D) occurred widely in the bay.

PHYTOPLANKTON

Diatoms: Diatoms were important in the outer half of the bay. They were characterized by the dominance especially of the species of *Chaetoceros* and *Rhizosolenia*, and to a less degree of dinoflagellates in number. The *Chaetoceros* such as *Ch. affinis*, *Ch. didymus*, *Ch. laciniosus* and *Ch. subsecundus* were relatively abundant throughout all stations except the Onagawa inlet where diatoms were very poor. *Rhizosolenia calcar-avis*, *Rh. alata* forma *gracillima*, *Rh. styliformis* and *Rh. hebetata* forma *semispina* were also important in the occurrence. The first two were relatively abundant at all stations, but the latter two were found chiefly at the outer stations. *Thalassiothrix Frauenfeldii*, on the contrary, was richer in the Onagawa inlet than in the outer half of the bay, though not found in the Nonohama inlet. Oceanic warm

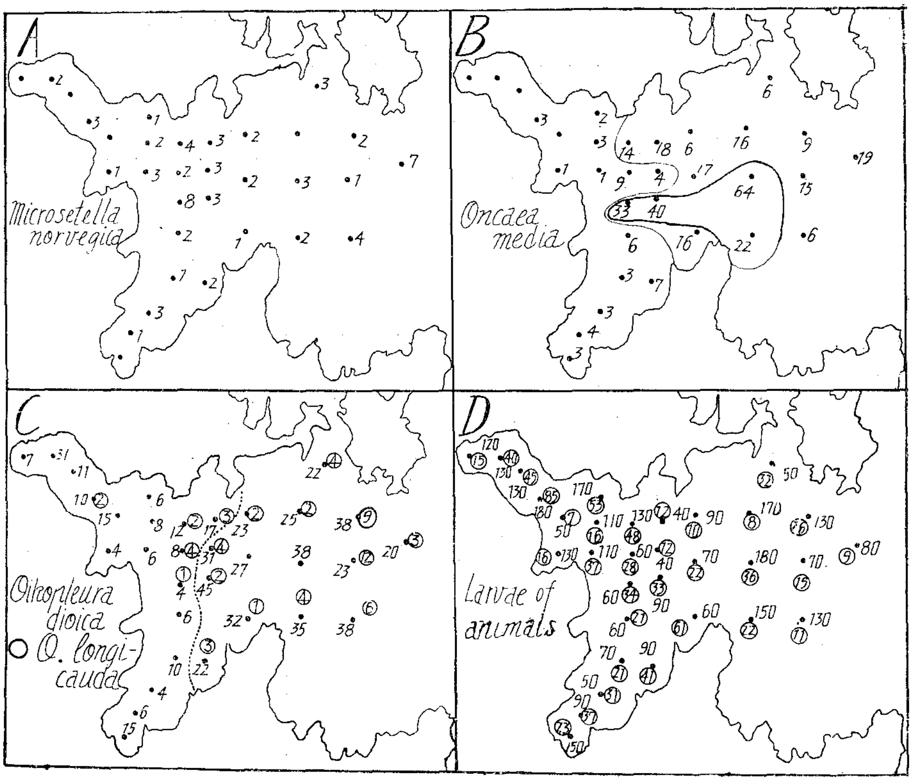

Fig. 8. Distribution of important copepods (A, B), tunicates (C) and larvae of animal groups (D). The number in the circle in D shows the individual number of animal groups except copepod nauplii.

water forms such as *Ch. coarctatus*, *Ch. peruvianus*, *Rh. Bergonii*, *Climacodium Frauenfeldianum*, *Ch. biconcavum* appeared also, though only in very small numbers in the outer part of the bay.

Dinoflagellates: The dinoflagellates were subdominant in abundance and 13 species were recognized in the sample. Of these, *Pyrocystis noctiluca*, *Ceratium candelabrum*, *C. smatoranum*, *C. macroceros*, and *C. trichoceros* were moderately abundant

Table 1. Individual number per 1 m haul of each species obtained by the vertical haul.

Station number	5 (Inner part of the bay)								32 (Outer part of the bay)				
Hauled depth (m)	0-1	1-3	3-5	5-10	10-15	15-20	20-25	25-30	0-5	5-10	10-20	20-30	30-43
Copepods (total)	148	270	256	57	48	14	20	23	53	71	65	11	34
Paracalanus parvus	4	37	35	16	1	1	—	—	18	25	12	2	8
Acartia clausi	130	153	156	37	30	6	9	8	2	1	—	1	2
Oithona similis	1	4	3	4	4	5	1	—	3	2	22	13	3
Oithona nana	5	66	60	9	9	3	3	2	18	40	8	2	7
Oithona rigida	2	1	—	—	—	—	—	—	—	—	—	—	—
Microsetella norvegica	2	—	—	—	—	—	—	—	—	—	—	—	—
Euterpe acutifrons	2	—	1	—	3	1	1	—	—	—	—	—	—
Oncaea venusta	2	—	—	—	—	—	—	13	1	1	4	1	1
Oncaea media	2	9	1	1	1	2	6	13	10	2	19	2	13
Other animals (total)	44	53	42	4	7	1	2		18	17	32	4	19
Penilia schmackeri	2	9	6	1	1	—	—	—	—	—	6	1	6
Evadne tergestina	3	14	8	2	1	—	—	—	3	2	—	—	2
Podon sp.	3	2	2	1	—	—	—	—	—	—	—	—	—
Sagitta delicata	4	11	2	—	1	—	1	—	—	—	4	—	—
Oikopleura longicauda	—	—	—	—	—	—	—	—	3	6	2	1	1
Oikopleura dioica	28	17	24	—	4	1	1	—	12	9	20	2	12
Encentrum marinum	4	—	—	—	—	—	—	—	—	—	—	—	—
Larvae of animals (total)	56	99	105	40	80	65	68	29	94	52	36	8	52
Polychaeta larva	3	—	—	—	—	—	—	—	2	—	—	1	—
Pelecypoda veliger	—	—	—	—	—	—	—	—	6	—	—	—	—
Gastropoda veliger	3	12	2	—	—	—	—	—	1	—	—	—	10
Copepoda juv. and nauplii	50	85	103	40	80	65	68	29	85	52	36	7	42
Total number	248	422	403	101	135	80	90	52	165	140	133	23	105

in the outer part of the bay, although they were widely distributed. *Peridinium grande*, *Per. Oceanicum* var. *oblongum*, *C. fusus*, *C. furca* and *C. deflexum* appeared very sparsely in the inner part of the bay.

C. Observations on the Vertical Distribution of Zooplankton

The vertical distribution of zooplankton was observed in detail at the mouth (St. 32) and inner part of the bay (St. 5), measuring about 43 m and 30 m in depth respectively. As shown in Table 1, plankton were hauled with the similar closing

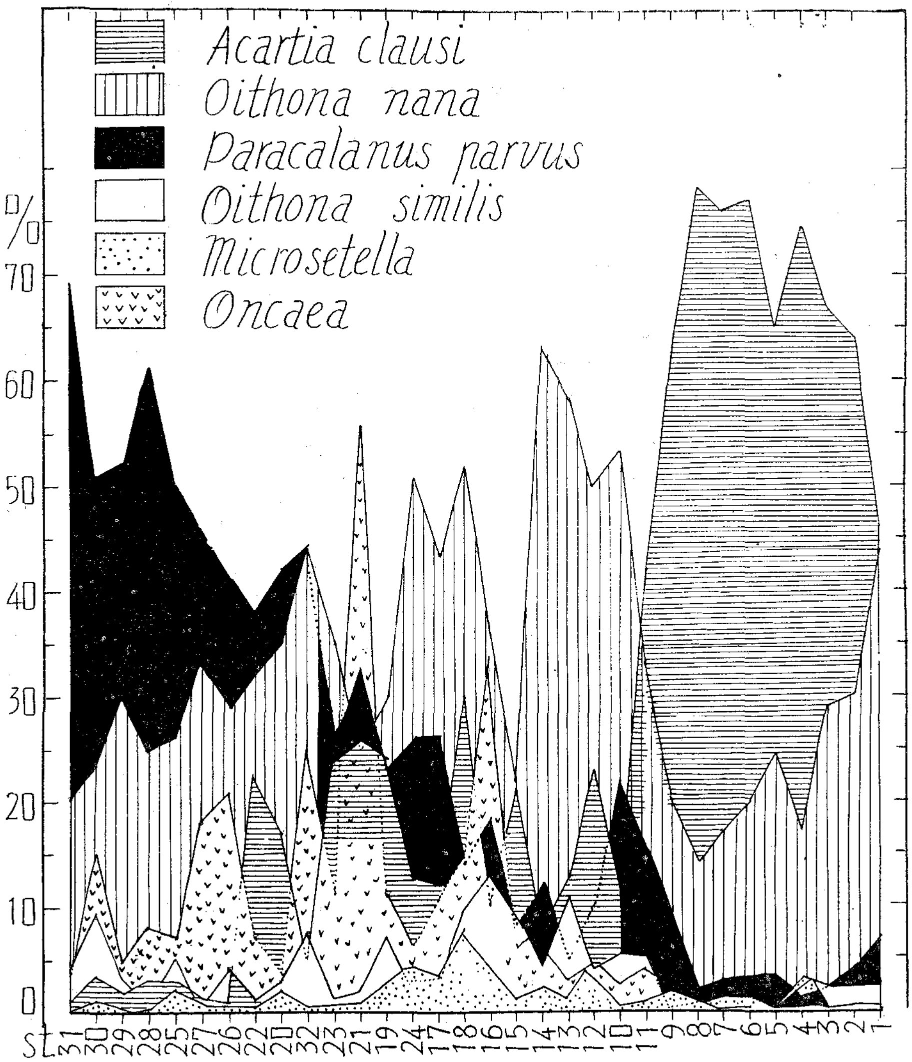

Fig. 9. Percentage composition of important copepods per one m haul between surface and 5 m depth.

net at different depths. The result showed that some species were distributed more fairly in the upper layers at the inner station than at the mouth station. *Oithona similis* was found more abundantly in the lower layer than in the upper layer. On the other hand, the inshore forms were found in the upper layers, in a range of 1–10 meters at St. 5 and 5–20 meters at St. 32.

Consideration on Regional Distribution

As clear from the data described above, plankton communities in Onagawa Bay consist of various components. It is reasonable that they are directly or indirectly

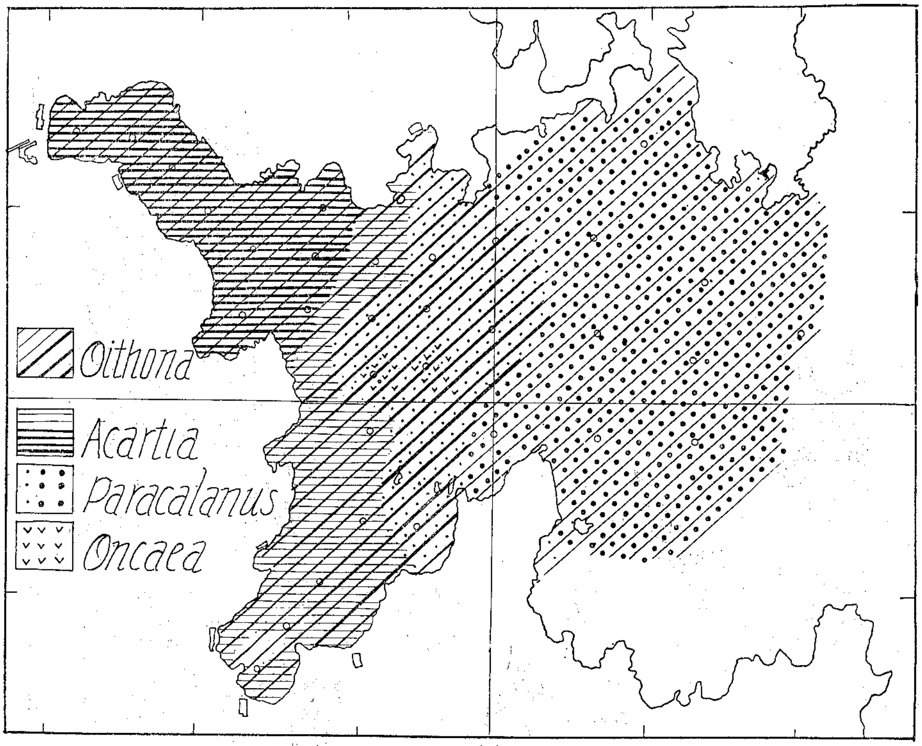

Fig. 10. Distribution of dominant copepods in Onagawa Bay.

influenced by the peculiar topographical and hydrological character of the bay, since the bay is a deep rias inlet opened directly to the ocean with a rather wide mouth.

According to the distribution of the dominant copepods and their relative abundance, the following three communities and three faciations may be recognized (Fig. 9 and Fig. 10).

1. *Acartia clausi*—*Oithona nana* community.

The area of the Onagawa inlet was abundantly occupied by *Acartia clausi* community, associated with many of *Oithona nana* and their nauplii. The other associates were *Paracalanus parvus*, *Euterpe acutifrons*, *Oithona similis*, *Microsetella norvegica*, *Oikopleura dioica*, *Sagitta delicata*, *Favella campanula*, *Encentrum* sp. and larval forms such as pelecypod, gastropod veligers and polychaete larvae. Associated diatoms were, for example, *Chaetoceros affinis*, *Ch. laciniosus*, *Rhizosolenia hebetata* forma *semispina*, *Rh. calcar-avis* and *Rh. alata* forma *gracillima.*

The animal productivity was relatively large, although the vegetatives were of lesser importance than in the outer areas.

The water of this area was highly stagnant and yellowish brown in color with small transparency in the surface layer. The surface water showed a tendency of relatively low salinity, and it tends to be, as a whole, colder in winter and hotter in summer than in the other areas of the bay.

2. *Oithona nana* community.

The Nonohama inlet and the central part of the bay were densely occupied by a small copepod *Oithona nana.* It was associated with *Paracalanus parvus*, *Acartia clausi*, *Oithona similis*, *Oncaea venusta*, *Penilia*, *Evadne*, *Oikopleura dioica*, *Sagitta delicata*, copepod nauplii, molluscs veligers. As diatoms, *Ch. affinis*, *Ch. didymus*, *Ch. subsecundus*, *Rh. hebetata* f. *semispina*, *Rh. calcar-avis* and *Bacteriastrum hyalinum* were found. Dinoflagellates such as *Ceratium macroceros*, *C. trichoceros*, *C. tripos* forma *atlantica*, *Pyrophacus horologicum* and *Pyrocystis noctiluca* occurred there.

The population density represented by this community was much larger than that in the preceding community in the Onagawa inlet. In this area the association sometimes showed marked local variations, and the following three faciations were observed.

(a) *Oithona nana*—*Acartia clausi* community.

In the inward area of the central region and Nonohama inlet, *Oithona nana* occurred together with large number of *Acartia clausi.* The productivity of this area was relatively small.

(b) *Oithona nana*—*Oncaea* community.

In the central region, *Oithona nana* occurred together with large number of *Oncaea media* and small number of *Oncaea venusta.* The productivity was larger than that of the preceding area.

(c) *Oithona nana*—*Paracalanus parvus* community.

The northern area of the central region was predominated by *Paracalanus parvus*, besides *Oithona nana.* The productivity was very large.

3. *Paracalanus parvus*—*Oithona nana* community.

Paracalanus parvus was a predominant component of the plankton near the mouth of the bay as usual in other bays. Besides, there were found the neritic copepods such as *Oithona similis*, *Microsetella*, *Oncaea venusta* and *O. media*, and the oceanic forms such as *Calanus darwinii*, *Cal. pauper*, *Eucalanus attenuatus*, *Sagitta enflata*, *Oikopleura longicauda*, *Fritillaria*, *Doliolum nationalis*, *Pyrocystis noctiluca*, *Pyrophacus horologicum*, *Ceratium candelabrum*, *Cer. trichoceros*, *Cer. deflexum* and *C. smatoranum*, and diatoms such as *Chaetoceros coarctatus*, *Ch. peruvianus*, *Rh. hebetata* f. *semispina and Rh. calcar-avis.*

This area is relatively deep and the water shows higher transparency and lower water color and higher salinity than in other inner areas. There are numerous indications of intrusion of oceanic influence into the bay.

Among these communities there were marked differences in composition and abundance. For instance, *Acartia* is the most abundant in the inner area but sparse in the outer. The warm-water oceanic species, such as *S. enflata*, calanoid copepods and dinoflagellates and diatoms, were found numerously in the outer area. The appearance of these species can be regarded as an indicator of water mass exchange.

Generaly speaking, the plankton community of Onagawa Bay is largely occupied by the *Oithona nana* and *Paracalanus parvus* communities. The *Acartia* community is rather restricted to the Onagawa inlet. The offshore forms brought from the mouth into the central region of the bay where is the area largely occupied by *Oithona nana*—*Oncaea* community relatively abundant. And it is also remarkable in this bay that the plankton productivity is very small in this survey, as is the case with the outer region of Imari Bay, Kyusyu (YAMAZI, 1952 a).

Summary

1. The qualitative and quantitative survey of the plankton of Onagawa Bay was made in August of 1951.

2. The densest population of zoo- and phytoplankton was found in the central region of the bay, but as a whole the plankton community of the bay was poor, apparently as a result influenced by a direct oceanic influx.

3. In Onagawa Bay, three plankton communities and three faciations in relation to the distribution and abundance of important copepods and their associates were distinguished, that is (1) *Acartia clausi*, (2) *Oithona nana*, (2a) *Oithona* associated with *Acartia* (2b) *Oithona* associated with *Oncaea* (2c) *Oithona* associated with *Paracalanus*, and (3) *Paracalanus parvus* and *Oithona nana* communities.

LITERATURE

MATSUDAIRA, T. 1950. The catalytic activity of sea water. I. Method of determination and some physical and chemical characteristics. Tôhoku Jour. Agric. Res. vol. 1, no. 2.

——— 1951. On the vertical distribution of catalytic activity in Tōhoku sea area with the consideration of water mass. Jour. Ocean. Soc. Japan., vol. 6, no. 4 (In Japanese with English synopsis).

YAMAZI, I. 1950, 1951 and 1952 a, b, c. Plankton investigation in inlet waters along the coast of Japan. I, II, III, IV, V. Publ. Seto Mar. Biol. Lab. vol. 1, no. 3 & 4; vol. 2, no. 2.

——— 1952, d. Idem. VI. Special Publ. Japan Sea Reg. Fish. Res. Leb. on the 3rd Anniv. of its Founding. Nanao.

——— 1953. Idem. VII. Publ. Seto. Mar. Biol. Lab. vol. 3, no. 1.