# PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN

## I. INTRODUCTORY NOTES AND THE PLANKTON OF AKKESHI BAY, HANASAKI INLET AND NEMURO HARBOUR*

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*With 14 Text-figures*

### I. Introductory Notes

With a purpose to establish plankton community-types of bays and inlets along the coast of Japan in relation to their hydrological conditions, the writer has engaged these several years in collecting plankton samples whenever he had a chance to join the oceanographical surveys planned mostly by Prof. D. MIYADI, to whom the writer is indebted for facilities and useful advices.

The writer is also indebted to Dr. T. TOKIOKA for the help in identifying species and in preparing the manuscript, to Mr. T. HABE, Mr. K. MOTOZIMA and many other friends in the Zoological Institute of Kyoto University for much assistance during the works on the sea and for admitting him, to quote their hydrological data in this paper. This investigation was carried out by the aid from the Ministry of Education.

*Method of collecting the material*: In the quantitative investigation of plankton, there may be three sources of errors: (1) in locating the stations, (2) in sampling and (3) in counting and measuring the samples. As our laboratory equipments are not sufficient for an accurate measurement of plankton, I preferred the way to find out general tendencies prevailing in bay waters by examining as many samples as I could collect in the field. The samples were collected in the following two ways: (1) vertical hauls by HENSEN's net whose diameter of the mouth was 20 cm, that of the largest part 50 cm and spread with No. 13 silk gauze (14641 meshes per square inch), (2) 10 liters of the surface water was drawn up by a backet to be filtered in a small net which was spread with No. 20 silk gauze, and provided with a small reservoir having a cock at its bottom.

*Quantitative method of examining the material*: The volume of each sample excluding larger animal plankters, such as medusae, salpae, etc., was read by a

*Contributions from the Seto Marine Biological Laboratory, No. 145.

measuring cylinder after the settling of 24 hours. The settled plankton was then diluted with water of 10 cc, 20 cc, or 30 cc, etc. respectively, according to the volume of plankton. 1 cc of this diluted sample was poured into a chamber with a brass frame of 40 mm long×25 mm wide×1 mm thick on the slide glass sectioned into 1 mm squares. To avoid too much efforts of seeing throughout the whole slide the counts were made in several transverse rows of squares.

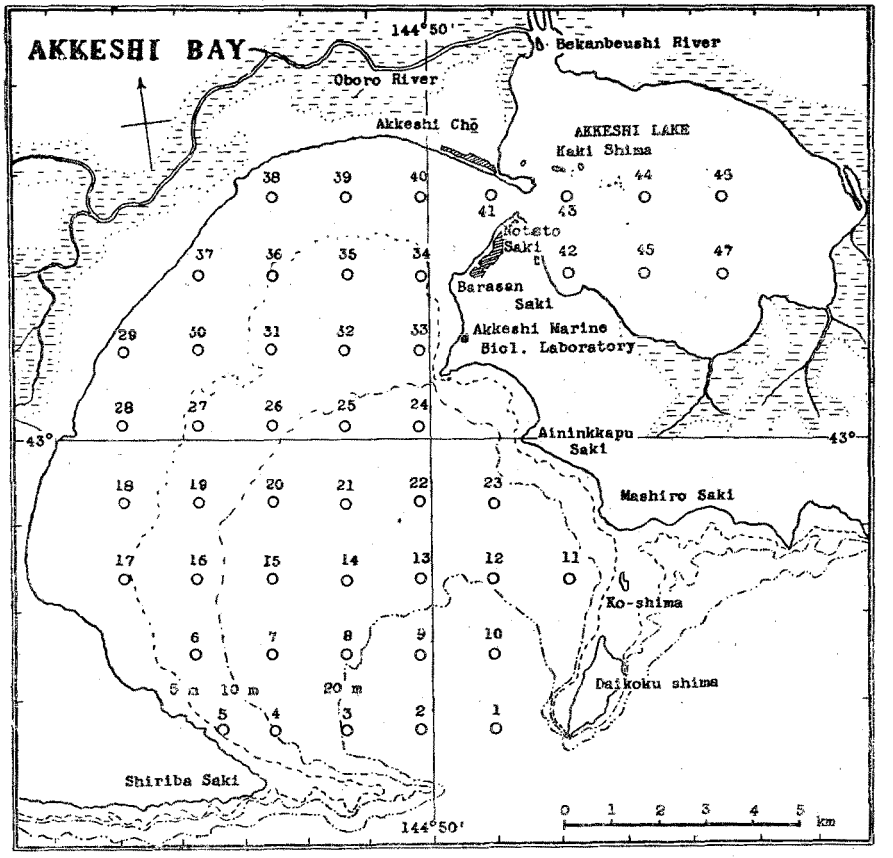


**Fig. 1. Map of Akkeshi Bay and Akkeshi Lake showing stations and isobaths.**

*Hydrological observations*: The water temperature was measured by a reversing thermometer, the water color by FOREL's scale and the transparency by SECCHI's disc with 30 cm diameter. The salinity was calculated from chlorinity determined by titration degree being computed from FOX's table. Phosphates ($P_2O_5$) were estimated by ATKINS' modification of DENIGÈS' method,[1] silicates ($SiO_2$) by ATKINS' modifica-

[1] ATKINS, W. R. G. 1923. The phosphate content of fresh and salt waters in its relationship to the growth of the algal plankton. Journ. Marine Biol. Assoc. vol. 13, pp. 119–150.

tion of DIÉNERT and WANDENBULCKE's method[1] and the hydrogen-ion concentration was determined colorimetrically using thymolblue as the indicator.

## II. Plankton of Akkeshi Bay in August, 1948

A series of hydrological, planktological and benthological surveys were carried out by Mr. T. HABE and the writer along the southern coast of Hokkaido during the period from the 26th of August to the 5th of September, 1948. The followings are the planktological results obtained by us in the Akkeshi Bay and the Akkeshi Lake, where the survey was performed in some detail. Before going further, we wish to express our hearty thanks to the members of the Akkeshi Marine Biological Station for their kind help offered us during our works.

Akkeshi Bay lies on the southeastern coast of Hokkaido and has roughly a round shape. It is separated from the Pacific Ocean southwestwards by the cape of Shiriba-saki and southeastwards by reef with two islets, Daikoku-shima and Koshima, on it. It is connected at its northern end with a shallow lagoon named Akkeshi Lake by a narrow, about 700 m wide, channel. The bay is the deepest at its mouth, where it measures ca. 30 m (Fig. 1). The lake is less than 2 m deep, and the bottom with less depth than 1 m is covered densely with *Zostera marina* L., while the region adjacent to the narrow mouth forms a remarkable bed of *Ostrea gigas* THUNBERG. Two rivers, Bekanbeushi and Oboro, which drain the marsh and moorland along the coast, supply humous water to the lake at its northwestern end. For the hydrological conditions of this lake, the readers are referred to INUKAI and NISHIO (1937).[2]

Owing to the inflow of humous water the lake water had yellowish brown color, small transparency, low salinity, lower values of pH and saturation degree of dissolved oxygen and higher values of phosphates and silicates. The influent waters flows out of the bay along its southwestern coast as shown clearly in the hydrological data (Tables 1 & 2, Figs. 2–4). The surface water temperature of the bay ranged from 18.5° to 21.5°C, the lowest record of 18.5°C was observed at the mouth part, and records higher than 21.0°C were found along the northwestern coast (Fig. 3).

### A. Quantitative Analysis of Plankton

The settling volume of plankton (Fig. 5) was much larger in the southeastern part of the bay than in the northwestern part, and smallest in the lake.

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[1] ATKINS, W. R. G. 1923. The silica content of some natural waters and of culture media. Journ. Marine Biol. Assoc. vol. 13, pp. 151–159.

[2] INUKAI, T. and NISHIO, S. 1937. A limnological study of Akkeshi Lake with special reference to the propagation of the oyster. Jour. Fac. Agr., Hokkaido Imp. Univ., Sapporo, Vol. 40, pp. 1–33.

Table 1. Hydrological condition of Akkeshi Bay.

| Station Numbers | Date | Air temp. (°C) | Water temp. (°C) | Mud temp. (°C) | Depth (m) | Trans-parency (m) | Water Color | pH (surface) | Settling volume of plankton (cc/10L) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 26. 9.40 | 24.0 | 19.0 | — | 30 | 5.5 | 8 | 8.3 | 0.27 |
| 2 | 10.10 | — | — | — | 20 | 7.3 | 9 | — | 0.25 |
| 3 | 10.20 | — | 19.3 | — | 18 | 6.0 | 9 | 8.3 | 0.17 |
| 4 | 10.30 | — | 20.3 | — | 17 | 5.0 | 9 | 8.4 | 0.09 |
| 5 | 10.35 | — | 20.6 | — | 9 | 3.9 | 10 | 8.3 | 0.10 |
| 6 | 10.50 | — | 21.3 | — | 11 | 3.5 | 10 | 8.3 | 0.03 |
| 7 | 11.00 | — | 21.4 | — | 15 | 4.5 | 10 | 8.3 | 0.02 |
| 8 | 11.15 | — | 19.4 | — | 20 | 5.0 | 10 | 8.3 | 0.05 |
| 9 | 11.25 | — | 19.7 | — | 23 | 6.0 | 9 | 8.4 | 0.29 |
| 10 | 11.41 | — | 19.3 | — | 25 | 8.0 | 8 | 8.4 | 0.36 |
| 11 | 13.20 | 26.0 | 18.6 | — | 20 | 5.0 | 9 | 8.3 | 0.27 |
| 12 | 13.30 | 26.0 | 18.6 | — | 23 | 7.0 | 9 | 8.3 | 0.62 |
| 13 | 13.45 | 23.0 | 19.4 | — | 21 | 7.0 | 9 | 8.3 | 0.91 |
| 14 | 14.05 | — | 20.9 | — | 19 | 6.5 | 9 | 8.3 | 0.27 |
| 15 | 14.17 | — | 20.4 | — | 19 | 4.0 | 9 | 8.3 | 0.24 |
| 16 | 14.30 | 24.0 | 21.1 | — | 14 | 3.0 | 11 | 8.35 | 0.05 |
| 17 | 14.40 | — | 21.8 | — | 11 | 3.5 | 11 | 8.4 | 0.07 |
| 18 | 14.50 | 25.8 | 21.8 | — | 12 | 3.0 | 10 | 8.4 | 0.03 |
| 19 | 15.00 | 24.8 | 21.6 | — | 12 | 3.0 | 11 | 8.35 | 0.04 |
| 20 | 15.07 | — | 21.2 | — | 15 | 2.5 | 11 | 8.3 | 0.02 |
| 21 | 15.20 | 24.8 | 20.5 | — | 16 | 4.0 | 10 | 8.3 | 0.13 |
| 22 | 15.30 | 23.0 | 20.2 | 16.3 | 17 | 5.0 | 10 | 8.35 | 0.34 |
| 23 | 15.40 | 23.5 | 19.7 | 16.5 | 15 | 6.5 | 9 | 8.35 | 0.26 |
| 24 | 15.55 | 23.8 | 19.7 | 16.2 | 14 | 7.0 | 9 | 8.3 | 0.21 |
| 25 | 27. 8.50 | 22.5 | 19.8 | 15.8 | 12 | 5.0 | 9 | 8.3 | 0.15 |
| 26 | 9.05 | 22.5 | 19.8 | 15.8 | 13 | 3.5 | 9 | 8.3 | 0.07 |
| 27 | 9.20 | 22.5 | 20.0 | 15.9 | 12 | 2.5 | 9 | 8.3 | 0.05 |
| 28 | 9.40 | 23.0 | 21.0 | — | 6 | 3.5 | 9 | 8.3 | 0.04 |
| 29 | 9.50 | 25.8 | 20.7 | 16.0 | 5 | 1.8 | 10 | 8.3 | 0.05 |
| 30 | 10.05 | 22.5 | 20.7 | 16.0 | 6 | 2.5 | 10 | 8.25 | 0.12 |
| 31 | 10.20 | 25.0 | 21.0 | 16.0 | 11 | 2.0 | 9 | 8.4 | 0.04 |
| 32 | 10.30 | 23.5 | 20.5 | 15.8 | 11 | 3.0 | 9 | 8.3 | 0.02 |
| 33 | 10.45 | 24.5 | 20.5 | 15.8 | 12 | 5.0 | 9 | 8.3 | 0.17 |
| 34 | 11.00 | 24.0 | 20.7 | 16.6 | 1 | 2.5 | 9 | 8.3 | 0.07 |
| 35 | 11.15 | 22.5 | 20.7 | 16.6 | 8 | 2.5 | 9 | 8.3 | 0.17 |
| 36 | 11.44 | 27.0 | 20.1 | 16.3 | 8 | 2.0 | 9 | 8.2 | 0.08 |
| 37 | 11.55 | 25.0 | 20.9 | 18.2 | 5 | 2.0 | 9 | 8.3 | 0.10 |
| 38 | 12.15 | 25.0 | 20.5 | 17.5 | 5 | 1.5 | 9 | 8.4 | 0.21 |
| 39 | 12.30 | 24.3 | 20.7 | 17.3 | 6 | 2.0 | 9 | 8.35 | 0.23 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 40 | 27.12.45 | 24.0 | 20.6 | 16.8 | 6 | 2.0 | 9 | 8.35 | 0.12 |
| 41 | 30. 9.45 | — | 21.5 | 20.5 | 3 | 1.5 | 9 | 8.2 | 0.04 |
| 42 | 10.05 | 22.5 | 17.5 | 18.5 | 1.5 | 1.5 | 10 | 8.1 | 0.05 |
| 43 | 10.45 | — | 17.2 | 18.0 | — | — | 10 | 8.1 | 0.05 |
| 44 | 11.45 | — | 17.6 | 18.0 | 2 | — | 10 | 8.2 | 0.02 |
| 45 | 11.00 | — | 17.3 | 18.0 | 3 | 1.2 | 10 | 8.1 | 0.04 |
| 46 | 11.15 | — | 17.5 | 18.0 | 2 | 1.0 | 10 | 8.1 | 0.04 |
| 47 | 11.30 | — | 17.2 | 18.0 | 2.5 | 1.0 | 10 | 8.1 | 0.04 |

Table 2. Chemical analysis of the water of Akkeshi Bay.

| Station Numbers | Depth (m) | Water temp. (°C) | Salinity (‰) | Oxygen (cc/L) | Oxygen (%) | pH | $P_2O_5$ mg/m³ | $SiO_2$ mg/m³ |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 19.0 | 32.578 | 5.59 | 103.1 | 8.3 | 18.0 | 2100 |
| | 10 | 16.1 | 32.773 | 5.94 | 104.0 | 8.3 | — | — |
| | 20 | 15.6 | 33.080 | 5.81 | 101.0 | 8.3 | — | — |
| | 30 | 15.4 | 33.188 | 5.67 | 99.4 | 8.3 | — | — |
| 7 | 0 | 21.4 | 31.293 | 5.13 | 95.7 | 8.3 | — | — |
| | 10 | 15.9 | 32.846 | 5.61 | 97.7 | 8.3 | — | — |
| 13 | 0 | 18.6 | 32.538 | 5.99 | 109.7 | 8.3 | 17.10 | 1600 |
| | 10 | 16.3 | 32.080 | 5.98 | 103.0 | 8.3 | — | — |
| | 20 | 15.2 | 33.134 | 4.67 | 79.4 | 8.3 | — | — |
| 22 | 0 | 20.2 | 32.051 | 6.04 | 111.0 | 8.35 | 24.0 | 2650 |
| 25 | 0 | 19.8 | 31.636 | 5.79 | 103.7 | 8.3 | — | — |
| | 10 | 15.8 | 32.773 | 4.28 | 73.2 | 8.3 | — | — |
| | 12 | 15.6 | 32.809 | 3.51 | 59.8 | 8.3 | — | — |
| 28 | 0 | 21.0 | 31.293 | 5.51 | 102.2 | 8.3 | — | — |
| 30 | 0 | 20.7 | 31.076 | 5.61 | 103.5 | 8.25 | — | — |
| | 6 | 16.0 | 32.231 | — | — | 8.1 | — | — |
| 32 | 0 | 20.0 | 32.051 | 6.05 | 110.8 | 8.3 | — | — |
| 35 | 0 | 20.7 | 31.112 | 5.72 | 105.5 | 8.3 | 31.7 | 3150 |
| | 8 | 16.1 | 32.628 | — | — | — | — | — |
| 41 (1) | 0 | 21.5 | 30.318 | 5.43 | 101.3 | 8.3 | 44.7 | 3940 |
| (2) | 0 | 17.3 | 28.838 | 4.31 | 73.6 | 8.2 | — | — |
| 42 | 0 | 17.5 | 26.925 | 4.63 | 79.6 | 8.1 | — | — |
| 43 | 0 | 17.2 | 30.625 | 4.54 | 79.9 | 8.1 | — | — |
| 44 | 0 | 17.6 | 30.115 | 5.57 | 98.8 | 8.2 | 59.6 | 4720 |
| 45 | 0 | 17.3 | 28.513 | 4.88 | 84.8 | 8.1 | — | — |
| 46 | 0 | 17.5 | 28.369 | 4.65 | 82.1 | 8.1 | — | — |
| 47 | 0 | 17.2 | 28.369 | 4.95 | 86.9 | 8.1 | — | — |

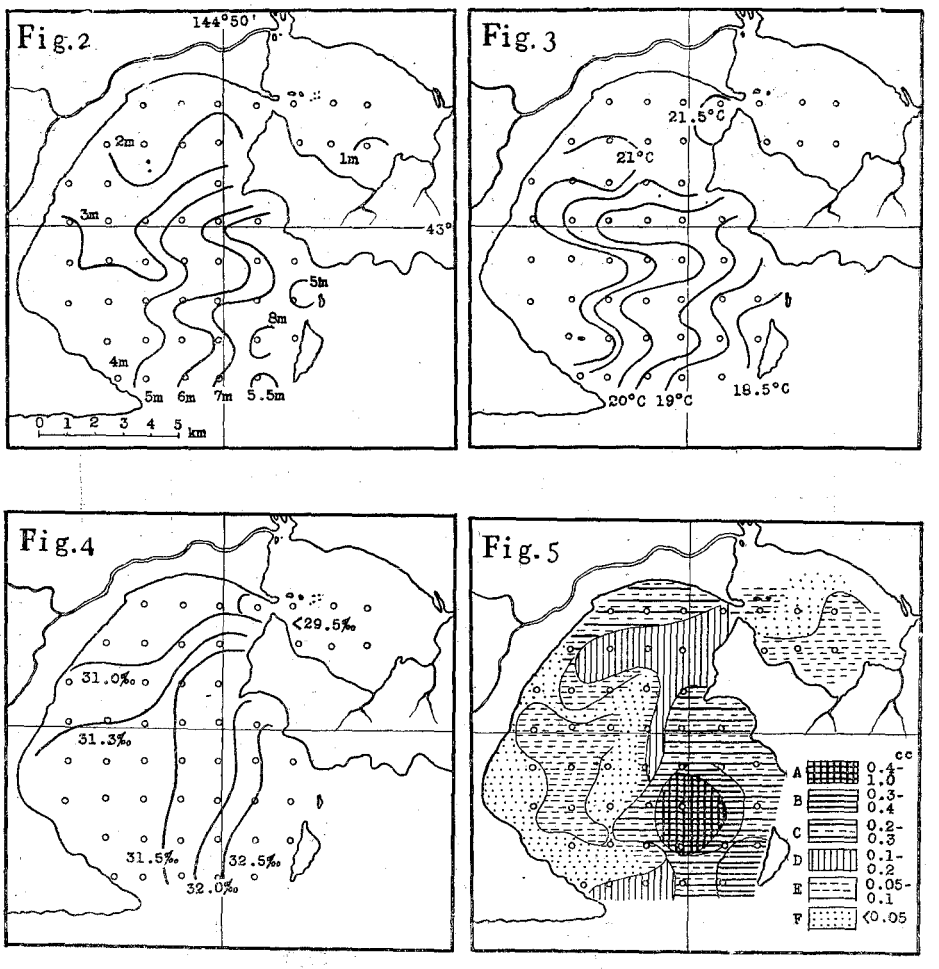


Fig. 2 Distribution of transparency during the survey.
Fig. 3. Isotherms of the surface water.
Fig. 4. Isohalines of the superficial layer.
Fig. 5. Distribution of the settling volume of plankton per 10 liters.

The population density of zooplankton was not parallel to the settling volume. Its denset population was found in the central and innermost part of the bay as well as in Akkeshi Lake, where the number of zooplankton reached 200–500 per 10 liters. The population was much smaller in other parts measuring only 25–50 per 10 liters as shown in Table 3 and Fig. 6. The numerical percentage of zooplankton in the total plankton ($Z/N \times 100$) is shown in Table 3 and Fig. 7, where Z is the number of zooplankton and N is that of the whole plankton. The value of Z/N was very small, less than 1%, in the southeastern part of the bay, where the settling volume was the largest but it increased gradually (ca. 2%) towards the inner parts of the bay and attained the maximum in the lake (about 20%).

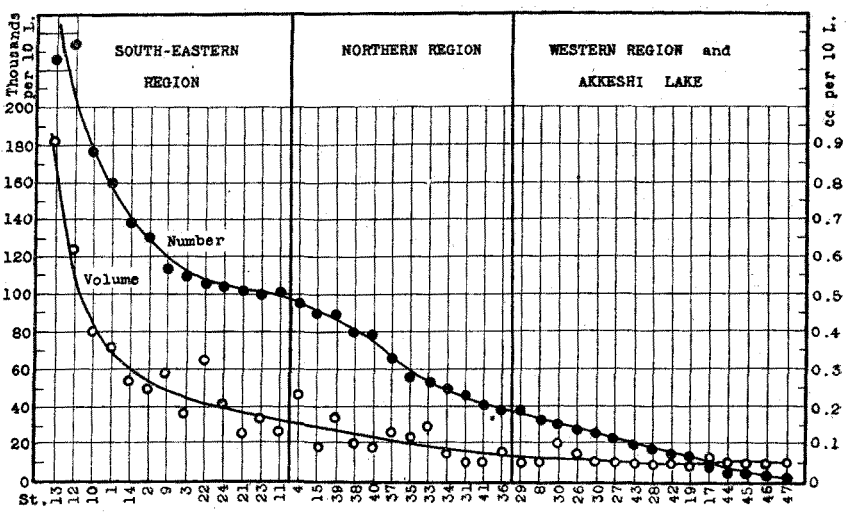


Fig. 6. The relation between the settling volume (cc) of plankton and the number of individuals, cells or colonies (each per 10 liters).

The phytoplankton population was found densest at the southeastern and northern parts of the bay, where 10–24 thousands of cells or colonies were counted in 10 liters. Its distribution became thinner in the western part and was the thinnest in the lake. The percentage of phytoplankton (P/N×100) was greatest in the southeastern part of the bay and decreased towards the inner parts to reach the minimum in the lake. The area around Stations 12 and 13 seemed to be the centre of the phytoplankton vegetation in these days (Table 3 and Fig. 7).

When both settling volume (V=cc/10 L) and number (N=n/10 L) of plankton are projected on a graph, two lines should be parallel, if its composition is the same at all stations. In the present case (Fig. 6), V and N lines were nearly parallel in the southeastern and the northern parts of the bay, but they lost the parallelism in the western part and the lake. This fact teaches us the presence of the remarkable variation in the plankton composition in different parts of the bay, namely the uneven distribution of phyto- and zooplanktons.

## B. Qualitative Analysis of Plankton

1. *Zooplankton*: As are shown in Table 3 and Fig. 8, zooplankton ratio in the whole plankton was far greater in the lake and the western half of the bay (Z/N×100 = 0.6–19.4%) than in the eastern half (Z/N×100 = 0.04–10.09%). The percentage composition of the main zooplankton groups (Figs. 9 and 10) was as follows: Copepoda (74%), Protozoa (22%), Rotifera (3%) and Copelata (1%). The copepods and protozoans were found in some prominent patches in the northeastern part as

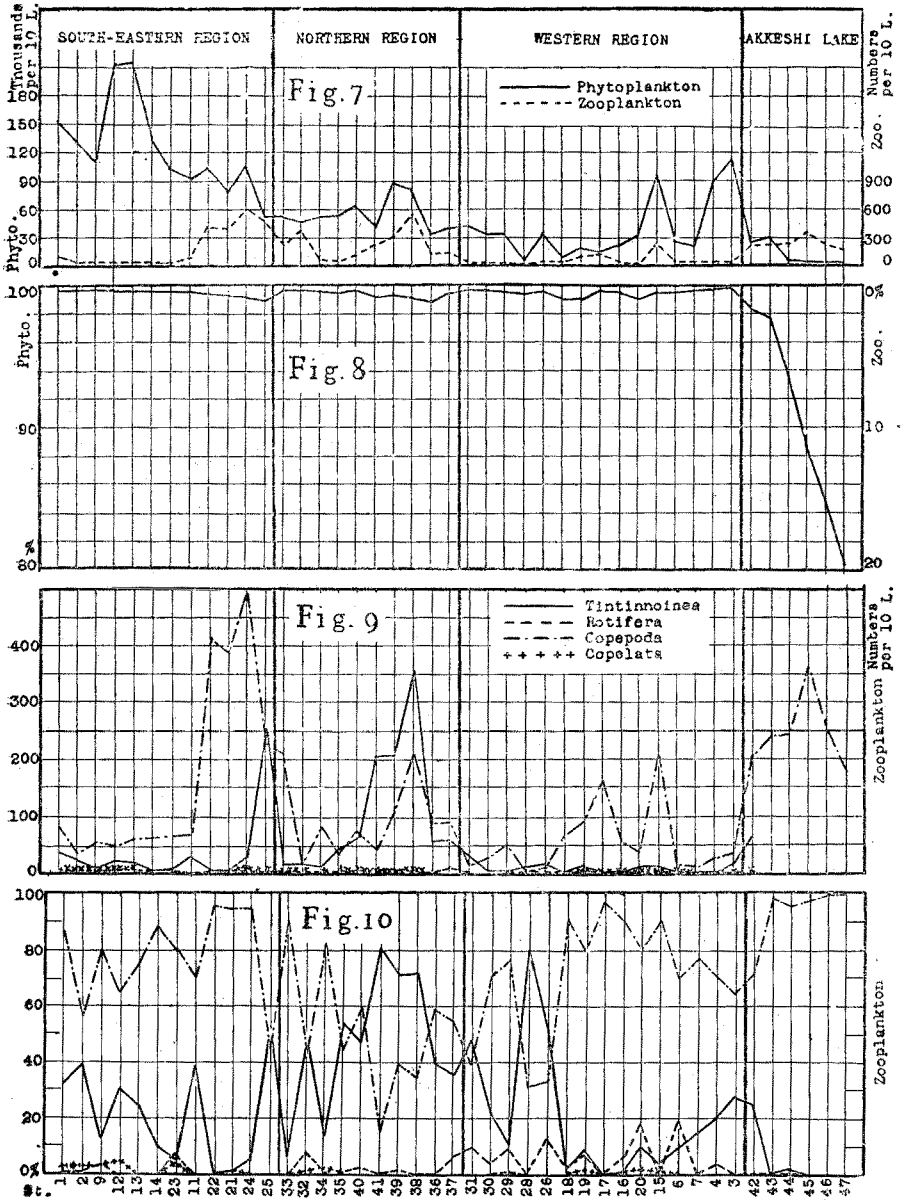


Fig. 7. Relative abundance of zoo- and phytoplanktons.
Fig. 8. Ratio between the zoo- and phytoplanktons.
Fig. 9. Population of some zooplanktons.
Fig. 10. Percentage composition of zooplankton.

shown clearly in Fig. 9. Main part of the zooplankton was occupied by the copepods, which were distributed most abundantly in the northeastern part as well as in the lake, but avoided the area of dense population of phytoplankton. The Copepoda population consisted chiefly of juveniles of *Oithona nana*, which were found

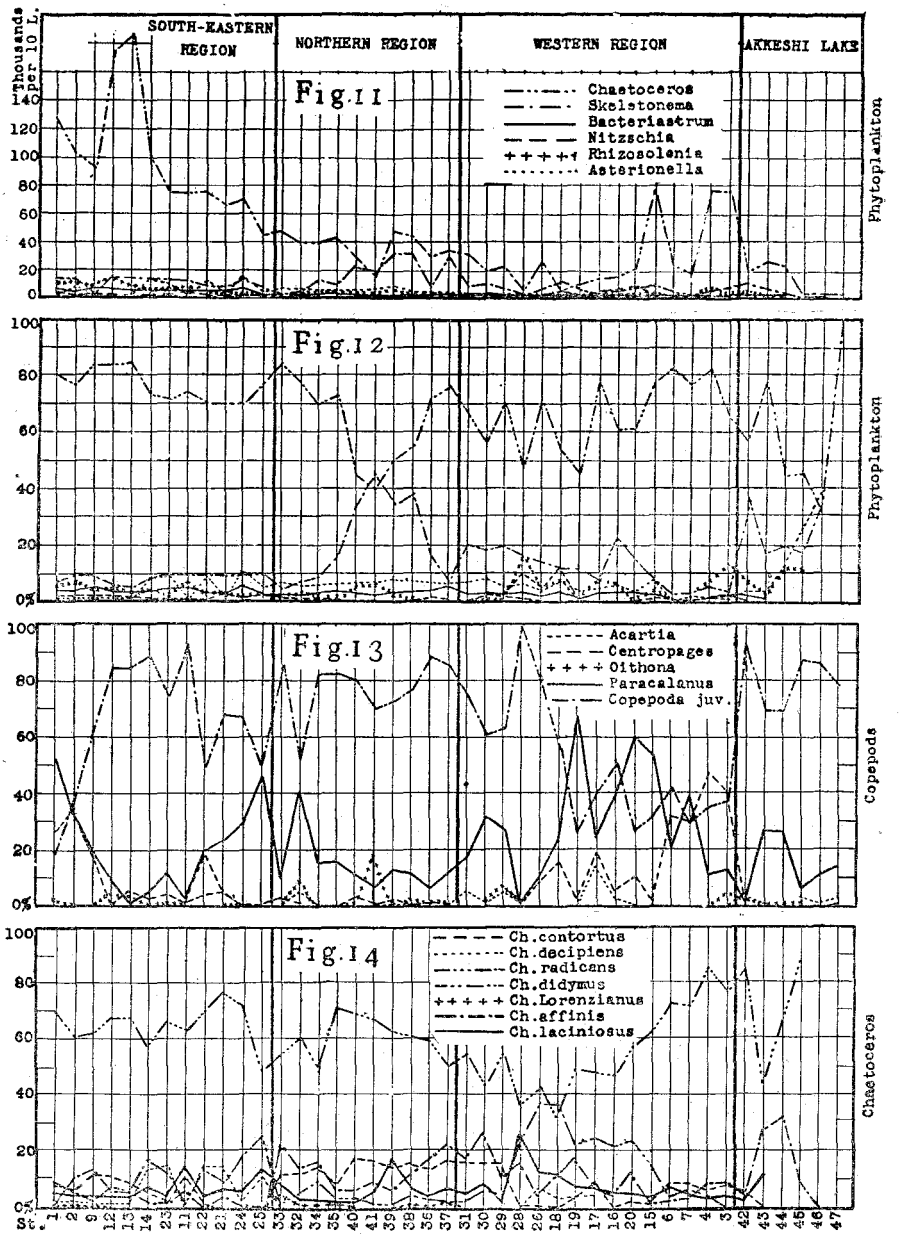


Fig. 11. Cell or colony number of some diatom groups in the phytoplankton.

Fig. 12. Percentage composition of some diatom groups in the phytoplankton.
Fig. 13. Percentage composition of the copepod community.
Fig. 14. Percentage composition of *Chaetoceros*.

Table 3. Population and composition of plankton.
Z·····number of zooplankton, P·····number of phytoplankton, N=Z + P.

| Region | Total number N/10 L. | Zooplankton | | Phytoplankton* | |
|---|---|---|---|---|---|
| | | Z/10 L. | Z/N×100 | P/10 L. | P/N× 100 |
| Southeastern | 147,720 | 100 | 0.07 | 147,620 | 99.93 |
| Middle | 98,160 | 490 | 0.50 | 97,670 | 99.50 |
| Northern | 62,060 | 240 | 0.39 | 61,850 | 99.76 |
| Western | 39,060 | 90 | 0.42 | 38,970 | 99.76 |
| Akkeshi Lake | 6,400 | 270 | 4.21 | 6,180 | 95.76 |

*The number of colony was counted in colony-forming species.

at most of the stations, although the adults were very sparse and distributed in a manner differing from that of the juveniles. *Paracalanus parvus*, the next prominent copepod, was found usually in adult form and distributed widely from the inner parts to the outer parts of the bay. No oceanic copepod was observed during this survey. Protozoans were represented by some species of Tintinnoinea, of which *Helicostomella fusiformis, Favella ehrenbergi, Favella taraikaensis and Tintinnopsis radix* were the dominant components. Among rotifers were *Notholca bifurca* and *Synchaeta* sp., and Copelata was represented by *Oikopleura dioica*. Other zooplankters found in the material were as follows:

| Species | Akkeshi Bay | | | Akkeshi Lake |
|---|---|---|---|---|
| | Southeastern | Northern | Western | |
| Tintinnoinea | | | | |
| *Tiarina fusus* | | + | | |
| *Tintinnopsis beroidea* | | + | + | |
| *Tintinnopsis radix* | + | + | + | |
| *Coxliella ampla* | | + | | |
| *Helicostomella fusiformis* | + | + | + | |
| *Favella ehrenbergi* | + | + | + | + |
| *Favella taraikaensis* | + | + | + | + |
| *Parafavella gigantea* | + | | | |
| *Tintinnus rectus* | + | + | + | + |
| *Tintinnus turris* | + | + | + | |
| *Undulla californiensis* | | + | + | |
| Copepoda | | | | |
| *Microsetella norvegica* | + | + | + | |
| *Euterope acutifrons* | | + | + | |

| | | | | |
|---|---|---|---|---|
| Cladocera | | | | |
| *Evadne nordmanni* | + | + | + | |
| *Podon leuckarti* | + | | | |
| Larvae | | | | |
| Polychaeta larva | | + | + | + |
| Pelecypoda larva | + | + | + | + |
| Gastropoda larva | + | + | + | + |
| Bipinnaria larva | + | + | + | + |
| Echinopluteus larva | + | | | |

2. *Phytoplankton*: In contrast to the zooplankton, the phytoplankton ratio was the largest in the southeastern part of the bay (Table 3 and Fig. 8). Throughout the whole stations percentage composition of diatoms was as follows: *Chaetoceros* occupied 75.6%, *Skeletonema* 11.5%, *Rhizosolenia* 4.5%, *Asterionella* 3.8%, *Bacteriastrum* 3.3% and *Nitzschia* 1.7% (Figs. 11 and 12).

The composition of phytoplankton varied slightly according to stations and some slight patch formations were noticed as in zooplankton (Table 4 and Figs. 12 and 14). *Chaetoceros*, as a whole, was abundant in the eastern half of the bay. While the distribution of *Ch. didymus, Ch. radicans* and *Ch. Lorenzianus* was chiefly restricted to the eastern region and was thinly populated in the western half, that of *Ch. compressus, Ch. affinis, Ch. laciniosus* and *Bacteriastrum delicatulum* was rather even, although they were very sparse. *Rhizosolenia Faeröensis, Asterionella japonica* and *Nitzschia longissima* were also widely distributed, but were more densely in the mouth part than in the inner part. *Skeletonema costatum* occurred most abund-

| Species | Akkeshi Bay | | | Akkeshi Lake |
|---|---|---|---|---|
| | Southeastern | Northern | Western | |
| Dinoflagellata | | | | |
| *Prorocentrum micans* | + | + | + | + |
| *Dinophysis ovum* | | + | + | |
| *Goniaulax polygramma* | + | + | + | + |
| *Pyrophax horologicum* | + | | | |
| *Ceratium fusus* | + | + | + | + |
| *Ceratium furca* | + | | + | |
| *Peridinium crassipes* | + | + | + | |
| *P. pellucidum* | + | + | + | + |
| *P. oceanicum* var. *oblongum* | + | | + | |

| | | | | |
|---|---|---|---|---|
| Diatoms | | | | |
| *Melosira Borreri* | + | + | + | |
| *Paralia sulcata* | + | | | |
| *Stephanopyxis nipponica* | + | + | + | |
| *Thallassiosira hyalina* | + | | + | |
| *Dactyliosolen mediterraneus* | + | | | |
| *Coscinodiscus Asteromphalus* | + | + | + | |
| *Arachnoidisus ornatus* | + | | + | |
| *Chaetoceros decipiens* | + | + | + | + |
| *Chaetoceros criophilus* | + | + | + | |
| *Bacteriastrum hyalinum* | + | + | + | + |
| *Corethron hystrix* | + | + | + | |
| *Biddulphia reticulata* var. | + | + | | + |
| *Bid. aurita* | + | + | + | |
| *Triceratium* sp. | | + | | |
| *Hemiaulus Hauckii* | + | + | + | + |
| *Ditylum Brightwellii* | + | + | + | + |
| *Climacodiam biconcavum* | + | | | |
| *Cerataulina* sp. | | + | + | |
| *Rhizosolenia setigera* | + | | + | |
| *Rh. hebetata* forma *semispina* | + | + | + | |
| *Rh. alata* forma *genuina* | + | + | + | + |
| *Rhabdonema adriaticum* | | + | | + |
| *Thalassiothrix Frauenfeldii* | + | + | + | + |
| *Thalassionema Nitzschioides* | | + | + | + |
| *Cocconeis Scutellum* | | + | + | + |
| *Pleurosigma intermedia* | + | + | + | |
| *Pleurosigma* sp. | + | | + | |
| *Nitzschia seriata* | + | + | + | + |
| *Nit. longissima* var. *Reversa* | + | + | + | + |
| *Surirella* sp. | | + | | + |
| *Amphora* sp. | | + | | + |

antly in the innermost part of the bay.

Among dinoflagellates, habitat segregation was noticed between *Ceratium fusus* and *C. furca* which were sparsely distributed in the mouth part, and *Peridinium pellucidum* and *P. crassipes* which were the inhabitants of the northern half of the bay. Other phytoplankters found in the material are listed above (pp. 103–104).

3. *Number of species*: Table 4 shows the number of species at each station. Most of the species are of pelagic life, although a few littoral diatoms and animals are counted as tychoplankton. The number of species was greatest in the southeastern region, and decreasing gradually towards the inner part of the bay reached the least value in Akkeshi Lake. The western region is less in population.

Table 4. Number of species occurring at each station.

| Station / Species number | Southeastern Region | | | | | | | | | | | | Northern Region | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 9 | 12 | 13 | 14 | 23 | 11 | 22 | 21 | 24 | 25 | 33 | 32 | 34 | 35 | 40 | 41 | 39 |
| (Z) | 19 | 20 | 15 | 18 | 19 | 16 | 14 | 20 | 14 | 19 | 19 | 18 | 15 | 14 | 12 | 14 | 13 | 12 | 15 |
| (P) | 27 | 28 | 24 | 24 | 26 | 19 | 24 | 25 | 21 | 27 | 18 | 16 | 18 | 15 | 18 | 18 | 18 | 24 | 17 |
| Total | 46 | 48 | 39 | 42 | 45 | 35 | 38 | 45 | 35 | 46 | 37 | 34 | 33 | 29 | 30 | 32 | 31 | 36 | 32 |
| Mean | | | | | | 41 | | | | | | | | | | 31 | | | |
| Total species throughout the stations | | | | | | (83) | | | | | | | | | | (61) | | | |

| Western Region | | | | | | | | | | | | | | | Akkeshi Lake | | | | | | Total species |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | 36 | 37 | 31 | 30 | 29 | 28 | 26 | 18 | 19 | 17 | 16 | 20 | 15 | 6 | 7 | 4 | 3 | 42 | 43 | 44 | 45 | 46 | 47 | |
| 16 | 12 | 11 | 11 | 14 | 15 | 9 | 14 | 19 | 15 | 15 | 16 | 16 | 14 | 13 | 11 | 13 | 19 | 8 | 10 | 9 | 8 | 6 | 9 | 30 |
| 18 | 15 | 14 | 14 | 15 | 12 | 11 | 18 | 8 | 8 | 7 | 18 | 14 | 15 | 14 | 21 | 27 | 28 | 16 | 18 | 14 | 16 | 14 | 12 | 49 |
| 34 | 27 | 25 | 25 | 29 | 27 | 20 | 32 | 16 | 23 | 32 | 34 | 30 | 29 | 27 | 32 | 40 | 47 | 24 | 28 | 23 | 24 | 20 | 21 | 79 |
| | | | | | | | | | | 30 | | | | | | | | | | 23 | | | | |
| | | | | | | | | | | (74) | | | | | | | | | | (42) | | | | |

## C. General Considerations

As is obvious from the hydrological observations previously mentioned, the humous water characterized by low salinity and small transparency is shed out of Akkeshi Lake into the bay and flows southwards along the western coast. Contrarily, the oceanic water of lower temperature flows from the mouth towards the northwestern part of the bay. The diatoms, which constituted the main part of the phytoplankton in the present material, seemed to be drifted into the bay with the oceanic water flourish prodigiously in the mingling area of both the oceanic and humous waters.

The presence of *Rhizosolenia Faeröensis* may be taken as a proof that the cold current "Oyashio" is affecting considerably the water climate of the bay. *Nitzschia longissima* is a littoral tychoplanktonic diatom rarely to be found in the pure oceanic water.

The animal plankters, on the other hand, seemed to propagate in the contaminated water and are drifted away into the oceanic water. The more important zooplankters are *Oithona nana* juveniles *Notholca bifurca, Synchaeta* sp., *Peridinium pellucidum* and several Tintinnoinea ciliates.

## III. Plankton of Hanasaki Inlet in August, 1948

Hanasaki Inlet lies to the east of Akkeshi Bay on the southeastern coast of Hokkaido. It is a small anchorage for fishing-boats and has a pier near its mouth. The field work of this inlet was carried out on the 29th of August.

### A. Qualitative Analysis of Plankton

The settling volume and the population of both phyto- and zooplankton (Table 1) were considerably larger in the inmost part than in the pier region. The zooplankton population in the inmost part was about 750 per 10 liters in contrast to about 500 in the mouth part. The numerical percentage of zooplankton in the total plankton ($Z/N\times100$) were very small, being less than 0.5% in all stations. The phytoplankton occupied somewhat larger percentage in the interior region than in the pier region. As a natural result of the similarity of plankton composition at all stations, the settling volume (V=cc/10 L) and the number (N=n/10 L) varied in parallel relation.

Table 1. Population and composition of plankton. Z ..... number of zooplankton, P.....number of phytoplankton, N = Z+P.

| Region | Total number | Zooplankton | | Phytoplankton* | | Settling volume of plankton cc/10 L. |
|---|---|---|---|---|---|---|
| | | Z/10 L. | Z/N×100 | P/10 L. | P/N×100 | |
| Pier region | 100,107 | 494 | 0.49 | 99,613 | 99.51 | 0.75 |
| Inmost region | 137,764 | 751 | 0.55 | 137,013 | 99.45 | 0.82 |

*The number of colony was counted in colony-forming species.

In comparison to Akkeshi Bay, where the most prodigious development of phytoplankton occurred in its central region and the percentage composition of zooplankton grew larger towards the interior, the phytoplankton percentage in Hanasaki Inlet was the largest in the inmost region. This fact may be correlated to the smallness of Hanasaki Inlet where the influence of the open sea water reaches its inmost region. In my opinion the phytoplankton development is stimulated at the mingling zone of both bay and open sea waters.

Table 2. Number per ten liters and percentage composition of zooplankton.

| Species | Pier region | | Inmost region | |
|---|---|---|---|---|
| | N | % | N | % |
| Protozoa | 239 | 48.39 | 119 | 15.86 |
| *Favella ehrenbergi* | 10 | 4.18 | 4 | 3.36 |
| *F. taraikaensis* | 225 | 94.14 | 106 | 89.08 |
| *Tintinus tubulosus* | 3 | 1.25 | 7 | 5.88 |
| *Parafavella denticulata* | 1 | 0.41 | 2 | 1.68 |
| Rotifera | 8 | 1.62 | 28 | 3.72 |
| *Synchaeta* sp. | 8 | 100.00 | 28 | 100.00 |
| Copepoda | 216 | 43.73 | 540 | 71.92 |
| *Acartia clausi* | 4 | 1.85 | — | — |
| *Oithona nana* | 10 | 4.62 | 78 | 14.44 |
| *Paracalanus parvus* | 21 | 9.74 | 4 | 0.44 |
| Copepoda juv. | 181 | 83.79 | 458 | 84.82 |
| Cladocera | 14 | 2.83 | 48 | 6.39 |
| *Evadne nordmanni* | 14 | 100.00 | 48 | 100.00 |
| Copelata | 3 | 0.60 | 3 | 0.39 |
| *Oikopleura dioica* | 3 | 100.00 | 3 | 100.00 |
| Larva | 5 | 1.01 | 11 | 1.46 |
| Polychaeta larva | 3 | 60.00 | 9 | 81.82 |
| Gastropoda larva | 2 | 40.00 | 2 | 18.18 |
| Coelenterata | 9 | 1.82 | 2 | 0.26 |
| *Bougainvillia* sp. | 9 | 100.00 | 2 | 100.00 |

## B. Qualitative Analysis of Plankton

The more important species among zooplankters were Copepoda (60.4%), Protozoa (28.7%), Cladocera (5.0%), Copelata (0.5%) and others (2.2%). The adults of copepods were distributed in the more interior part of the inlet than their juveniles. The population of *Oithona nana* grew larger toward the interior in contrast to *Paracalanus parvus* which was more abundant in the pier region. *Acartia clausi* was restricted to the pier region. Protozoans were represented as in Akkeshi Bay by Tintinnoinea, among which were *Favella taraikaensis*, *F. ehrenbergi* and some other species, Rotifera by *Synchaeta* sp. which was also found in the Akkeshi Bay, and Copelata by *Oikopleura dioica* (Table 2).

Other zooplankters found in the samples are listed as follows:

| Species | Pier region | Inmost region |
|---|---|---|
| *Tintinnus rectus* | + | + |
| *Tin. tubulosus* | + | + |
| *Parafavella gigantea* | + | + |
| Pelecypoda larva | + | + |
| Echinopluteus larva | + | |

The phytoplankton ratio was larger in the interior region than in the mouth part (Table 3). Among phytoplankters, *Chaetoceros* and *Bacteriastrum* were abundant in the interior region, though both of them appeared at all stations. Other diatoms,

Table 3. Cell or colony number per ten liters and percentage composition of phytoplankton.

| Species | Pier region | | Inmost region | |
|---|---|---|---|---|
| | N | % | N | % |
| Dinoflagellata | 77 | 0.07 | 120 | 0.08 |
| *Dinophysis intermedia* | 2 | 2.59 | 4 | 3.33 |
| *Peridinium crassipes* | 8 | 10.35 | 25 | 20.83 |
| *P. pellucidum* | 58 | 75.32 | 79 | 65.84 |
| *P. oceanicum* var. *oblongum* | 9 | 11.68 | 12 | 10.00 |
| *Skeletonema costatum* | 20,196 | 20.27 | 3,942 | 2.68 |
| *Bacteriastrum delicatulum* | 3,445 | 3.46 | 5,825 | 3.96 |
| *Chaetoceros* | 69,145 | 67.43 | 117,240 | 79.74 |
| *Ch. compressus* | 11,325 | 16.37 | 17,182 | 14.65 |
| *Ch. radians* | 35,860 | 51.86 | 65,202 | 55.61 |
| *Ch. didymus* | 2,315 | 3.35 | 5,499 | 4.69 |
| *Ch. affinis* | 8,365 | 12.09 | 16,566 | 14.13 |
| *Ch. laciniosus* | 11,280 | 16.33 | 12,791 | 10.92 |
| *Coscinodiscus Asteromphalus* | 748 | 0.76 | 1,490 | 1.02 |
| *Nitzschia longissima* var. *Reversa* | 488 | 0.48 | 311 | 0.21 |
| *Nitz. seriata* | 188 | 0.18 | 211 | 0.14 |
| *Asterionella japonica* | 5,326 | 5.35 | 17,910 | 12.17 |

except *Skeletonema*, and dinoflagellates, such as *Peridinium pellucidum*, occurred rather widely in the inner region.

Following is the list of other phytoplankters :

| Species | Pier region | Inmost region |
|---|---|---|
| *Prorocentrum micans* | + | + |
| *Pyrophax horologicum* | | + |
| *Goniaulax polygramma* | + | |
| *Paralia sulcata* | + | |
| *Thallassiosira hyalina* | | + |
| *Coscinodiscus Janischi* | + | |
| *Chaetoceros decipiens* | + | + |
| *Biddulphia reticulata* | + | |
| *Hemiaulus Hauckii* | + | + |
| *Ditylum Brightwellii* | + | |
| *Triceratium americanum* | | + |
| *Rhizosolenia setigera* | + | |
| *Rh. Faeröensis* | + | + |
| *Rh. alata* forma *genuina* | + | + |
| *Rhabdonema adriaticum* | | + |
| *Pleurosigma* sp. | | + |
| *Thalassionema Nitzschioides* | + | + |

The species composition of the plankton at all stations was less than that of the mouth part of Akkeshi Bay (Tab. 4).

Table 4. Number of species occurring at each station.

| Species number | Pier region | Inmost region | Total species |
|---|---|---|---|
| (Z) | 19 | 16 | 21 |
| (P) | 26 | 24 | 30 |
| Total | 45 | 40 | 51 |

## IV. Plankton of Nemuro Harbour in August, 1948

Nemuro Harbour is situated at the southeastern end of Hokkaido, being placed not far from Hanasaki Inlet. This harbour is also a small indentation and protected from the open sea by breakwaters. The field study was made on the 28th of August. The hydrological conditions of the harbour are shown in Table 1. The surface water temperature was about 18.2°C at the mouth. The temperature records at all strata were slightly higher in the interior region than in the mouth part. The salinity was usually above 32.37‰. The saturation degree of oxygen was 92.8% in the mouth part and 73.9—86.5% in the interior. The results on the observation

of water color, transparency and pH are shown in Table 1. The contents of phosphate and silicate were higher in the inner region than in the mouth part.

Table 1. Hydrological condition of Nemuro Bay.

| Station | Air temp. °C | Water temp. °C | Transparency m | Water color | pH | Salinity ‰ | Oxygen cc/L. | Oxygen % | $P_2O_5$ mg/m³ | $SiO_2$ mg/m³ |
|---|---|---|---|---|---|---|---|---|---|---|
| mouth part | 16.5 | 18.2 | 6.2 | 7 | 8.2 | 32.61 | 5.20 | 92.8 | 15.0 | 2800 |
| middle part | 16.6 | 18.5 | 5.4 | 7 | 8.2 | 32.48 | 4.35 | 77.9 | — | — |
| inmost part 1 | 16.6 | 18.5 | 4.0 | 8 | 8.2 | 32.43 | 4.11 | 73.9 | 27.3 | 2400 |
| 〃 2 | 16.6 | 18.5 | 4.0 | 8 | 8.2 | 32.37 | 4.81 | 86.5 | — | — |

## A. Quantitative Analysis of Plankton

The settling volume of plankton was much larger in the mouth part than in the interior. The zooplankton population was the largest in the inmost part, being about 600 per 10 liters. The percentage composition of zooplankton is shown in Table 2. It was very small, less than 0.2% in the middle part, and increased slightly towards both the mouth of the harbour and the inmost region. The phytoplankton was the densest in the middle part and decreased towards the mouth part as well as the interior. The values of P/N×100 were larger than 99% at all stations, being slightly larger in the central region.

The settling volume and the population of plankton varied in nearly parallel relation at most of the stations except the central region (Table 2).

Table 2. Population and composition of plankton. Z …… number of zooplankton, P……number of phytoplankton, N = Z + P.

| Station | Total number | Zooplankton Z/10 L. | Zooplankton Z/N×100 | Phytoplankton* P/10 L. | Phytoplankton* P/N×100 | Settling volume cc/10 L. |
|---|---|---|---|---|---|---|
| mouth part | 68,209 | 277 | 0.41 | 67,932 | 99.59 | 0.44 |
| middle part | 263,394 | 332 | 0.13 | 263,062 | 99.87 | 0.85 |
| inmost part 1 | 81,537 | 589 | 0.72 | 80,948 | 99.28 | 0.47 |
| 〃 2 | 68,308 | 523 | 0.77 | 67,785 | 99.23 | 0.40 |

*The number of colony was counted in colony-forming species.

## B. Qualitative Analysis of Plankton

The important constituents among zooplankters were Copepoda (65–85%) and Protozoa (12–31%), of which the former had a wide distribution, but exhibited a tendency to increase towards the interior as we have noticed in Hanasaki Inlet (Table 3).

Table 3. Number per ten liters and percentage composition of zooplankton.

| Species | Mouth part | | Middle part | | Inmost part 1 | | 〃 2 | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| Protozoa | 36 | 12.99 | 97 | 29.23 | 183 | 31.08 | 80 | 15.31 |
| *Favella ehrenbergi* | 6 | 16.69 | 8 | 8.25 | 20 | 10.92 | 21 | 26.25 |
| *F. taraikaensis* | 25 | 69.44 | 85 | 87.62 | 157 | 85.79 | 48 | 60.00 |
| *Tintinnopsis radix* | 5 | 13.88 | 4 | 4.13 | 6 | 3.29 | 11 | 13.75 |
| Copepoda | 235 | 84.85 | 224 | 67.47 | 393 | 66.73 | 433 | 82.79 |
| *Paracalanus parvus* | 13 | 5.53 | 18 | 8.05 | 30 | 7.64 | 55 | 12.70 |
| *Acartia clausi* | 6 | 2.54 | 2 | 0.89 | 3 | 0.76 | 3 | 0.69 |
| *Oithona nana* | 22 | 9.36 | 40 | 17.86 | 86 | 21.87 | 21 | 4.84 |
| *Oithona similis* | 6 | 2.54 | 2 | 0.86 | — | — | — | — |
| *Centropages abdominalis* | 8 | 3.41 | 5 | 2.23 | 8 | 2.04 | 2 | 0.46 |
| Copepods juveniles | 180 | 76.59 | 157 | 70.08 | 266 | 67.69 | 353 | 81.31 |
| Copelata | 2 | 0.72 | 4 | 1.20 | 3 | 0.50 | 3 | 0.57 |
| *Oikopleura dioica* | 2 | 100.00 | 4 | 100.00 | 3 | 100.00 | 3 | 100.00 |
| Larva | 4 | 1.44 | 7 | 2.10 | 10 | 1.69 | 7 | 1.33 |
| Polychaeta larva | 4 | 100.00 | 7 | 100.00 | 10 | 100.00 | 7 | 100.00 |

The population of adult Copepoda, such as *Paracalanus parvus* and *Oithona nana* and their juveniles, chiefly of *O. nana*, was quite large in the interior region. Contrarily, *Acartia clausi* and *Centropages abdominalis* were very thinly distributed, though with an increasing tendency towards the mouth of the harbour. *Oithona similis* was less numerous and found from the central and mouth regions. Among Tintinnoinea, *Favella taraikaensis* was the most prominent, being found mainly in the central and interior region, and *F. ehrenbergi* and *Tintinnopsis radix* were also quite

| Species | Mouth part | Middle part | Inmost part |
|---|---|---|---|
| *Helicostomella fusiformis* | + | + | + |
| *Coxliella ampula* | + | + | |
| *Tintinnus rectus* | + | | |
| *Tin. turris* | + | + | + |
| *Undulla californiensis* | + | + | + |
| *Microsetella norvegica* | + | + | + |
| Echinopluteus larva | + | | |
| Pelecypoda larva | + | + | + |
| Gastropoda larva | + | + | + |

numerous in the interior region but decreasing towards the mouth. Copelata, which was represented only by *Oikopleura dioica*, and the larvae of polychaetes and gastropods were sparsely distributed all over the sea. No Chaetognatha, Rotifera and oceanic species were observed. Other species found in the samples are listed in the bottom of p. 111.

The percentages of phytoplankton composition were *Chaetoceros* 86,6%, *Bacteriastrum* 4.8%, *Skeletonema* 3.3%, *Coscinodiscus* 3.3%, *Asterionella* 1.5% and Dinoflagellata less than 0.3%. The diatoms, as a while, had their center of production at the central region and became less numerous towards the mouth and inmost region. A similar segregation of habitat as in copepods was observed in dinoflagellates between *Ceratium fusus* and *C. furca*, which ranged from the central to mouth region on the one hand, and *Peridinium pellucidum* and *P. crassipes* ranging from the central to inmost region on the other. The same phenomenon was noticed in the survey of Akkeshi Bay (Table 4).

Table 4. Cell or colony number per ten liters and percentage composition of phytoplankton.

| Species | Mouth part | | Middle part | | Inmost part 1 | | 〃 2 | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| Dinotlagellata | 161 | 0.24 | 1,055 | 0.41 | 411 | 0.55 | 347 | 0.52 |
| *Dinophysis ovum* | 2 | 1.24 | 3 | 0.22 | 2 | 0.45 | 2 | 0.57 |
| *Ceratium fusus* | 25 | 15.53 | 23 | 2.18 | 13 | 2.94 | 15 | 4.33 |
| *C. furca* | 4 | 2.48 | 7 | 0.50 | 3 | 0.71 | 9 | 2.59 |
| *Peridinium crassipes* | 25 | 15.53 | 93 | 8.83 | 32 | 7.25 | 23 | 6.62 |
| *P. pellucidum* | 99 | 61.49 | 835 | 79.34 | 368 | 83.44 | 287 | 82.72 |
| *P. oceanicum* var. *oblongum* | 6 | 3.73 | 94 | 8.93 | 23 | 5.21 | 11 | 3.17 |
| *Skeletonema costatum* | 2,992 | 4.40 | 16,564 | 6.29 | 3,740 | 4.62 | 2,240 | 3.30 |
| *Bacteriastrum delicatulum* | 2,349 | 3.46 | 6,730 | 2.55 | 3,890 | 4.80 | 3,230 | 4.76 |
| *Chaetoceros* | 60,349 | 88.84 | 235,171 | 89.37 | 70,069 | 86.57 | 59,259 | 86.61 |
| *Ch. compressus* | 8,910 | 14.96 | 88,020 | 37.40 | 35,650 | 50.87 | 15,215 | 25.67 |
| *Ch. radicans* | 14,900 | 24.68 | 48,752 | 20.43 | 15,699 | 22.40 | 20,935 | 35.32 |
| *Ch. didymus* | 1,590 | 2.66 | 2,985 | 1.26 | 2,310 | 3.29 | 1,432 | 2.41 |
| *Ch. affinis* | 31,250 | 51.78 | 86,499 | 36.80 | 12,755 | 18.22 | 15,690 | 26.47 |
| *Ch. laciniosus* | 3,699 | 6.12 | 8,915 | 3.79 | 3,655 | 5.22 | 5,987 | 10.13 |
| *Coscinodiscus Asteromphalus* | 996 | 1.46 | 1,992 | 0.75 | 1,244 | 1.33 | 1,668 | 3.28 |
| *Nitzschia longissima* var. *Reversa* | 42 | 0.06 | 35 | 0.01 | 25 | 0.03 | 21 | 0.03 |
| *Asterionella japonica* | 1,048 | 1.54 | 1,586 | 0.62 | 1,539 | 1.90 | 1,020 | 1.50 |

Other species found in the samples are listed as follows:

| Species | Mouth part | Middle part | Inmost part |
|---|---|---|---|
| *Prorocentrum micans* | + | + | + |
| *Goniaulax polygramma* | + | + | |
| *Coscinodiscus gigas* | | + | + |
| *Chaetoceros decipiens* | + | + | + |
| *Biddulphia aurita* | | + | + |
| *Bid. reticulata* | + | + | + |
| *Bererochea malleus* | | + | |
| *Rhizosolenia alata* forma *genuina* | + | + | |
| *Rh. setigera* | + | | |
| *Rh. Faeröensis* | + | + | + |
| *Pleurosigma* sp. | + | + | + |
| *Nitzschia seriata* | + | + | + |

The number of species was greater in the middle and mouth parts than in the inmost part of the harbour (Table 5).

Table 5. Number of species occurring at each part.

| Species number | Mouth part | Middle part | Inmost part | Total species |
|---|---|---|---|---|
| (Z) | 18 | 17 | 16 | 22 |
| (P) | 24 | 26 | 20 | 30 |
| Total | 42 | 43 | 36 | 52 |