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Author(s)	Yamazi, Isamu
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PLANKTON INVESTIGATION IN INLET WATERS ALONG THE COAST OF JAPAN

II. THE PLANKTON OF HAKODATE HARBOUR AND YOICHI INLET IN HOKKAIDO*

ISAMU YAMAZI

With 3 Text-figures and 4 Tables

The present paper deals with the result of surveys made in Hakodate Harbour on September 5, 1948 and in Yoichi Inlet on September 2. The methods of survey were the same with those described in my previous paper on three inlets of Hokkaido (Publ. Seto Mar. Biol. Lab., I (3) 1950).

During the field work I was helped by Mr. T. HABE and members of the Faculty of Fisheries of the Hokkaido University as well as the Hokkaido Fisheries Experimental Station. To all these gentlemen I wish to express my hearty thanks. I am also indebted to the Ministry of Education for some financial aid to this investigation.

I. Plankton of Hakodate Harbour

Hakodate Harbour occupies the eastern part of Hakodate Bay, being bounded by three breakwaters. The harbour is the deepest in its middle part measuring ca. 13 m. It reaches about 20 m on the outside of the breakwaters. The hydrological results of the survey are summarized in Table 1. As to a more comprehensive oceanographical conditions of this harbour, the readers are referred to a report published by the Hakodate Marine Observatory (1945),[1] and a study of its shellfish-field made by TANITA, KATO and OKUDA (1950)[2].

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*Contributions from the Seto Marine Biological Laboratory, No. 160.

1) Hakodate Marine Observatory. 1950. The report of the oceanographical observation in the Hakodate Harbour. Jour. Oceanogr. H. M. O. No. 2.

2) TANITA, S., KATO, K., & T. OKUDA. 1950. Studies on the environmental conditions of shellfish-fields. I. In the case of Hakodate Harbour. Bull. Fac. Fish., Hokkaido Univ. vol. 1, no. 1, pp. 1—10.

A. Quantitative Analysis of Plankton

The plankton was collected at 10 stations. It was much more abundant to the exterior of the harbour, especially in its northern part, than the inside,

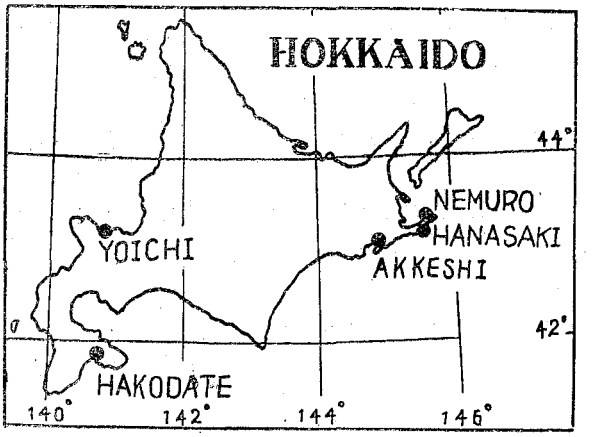

Fig. 1. Sketch map of Hokkaido, showing the Inlets which were surveyed.

Table 1. Hydrological conditions and some data on the plankton of Hakodate Harbour. N — total number of plankton per 10 L. For phytoplankton the unit is thousand.

	Inside of the harbour			Outside of the harbour	
	Southern	Central	Northern	Northern	Southern
Water temperature (°C, surface)	22 5	22.3	22.0	22.0	22.4
Water color (FOREL's scale)	X	X	IX	IX	IX
Transparency (m)	2.9	2.8	5.0	4.2	6.0
pH value (surface)	8.4	8 3	8.4	8.3	—
Salinity (‰, surface)	31.7	31.8	—	—	31.9
Oxygen (cc/L, surface)	4.5	5.4	—	—	6.3
Oxygen (%, surface)	86.4	103.2	—	—	119.0
P_2O_5 (mg/m)	28.3	19.8	17.6	—	14.4
SiO_2 (mg/m)	4100	3100	2800	—	1500
Settling volume (cc/10 L)	0.3	0.1	0.4	1.0	0.3
Number of zoopl. per 10 L. (Z)	302	227	364	554	108
Percentage of zoopl. (Z/N×100)	0.2	0.5	0 2	0.7	0.1
Number of phytopl. per 10 L.	133.1	46 2	199.5	211.5	89.2
Percentage of phytopl. (P/N×100)	99.8	99.5	99.8	99.3	99 9
Number of zooplankton species	16	15	17	17	16
Number of phytoplankton species	23	24	27	32	33

in the settling volume as well as the number of cells, individuals or colonies. As the phytoplankton formed the largest part of the plankton, the distribution of population density of the former and that of the settling volume of the total plankton had the same tendency, especially in the northern part of the area, where phytoplankton attained the maximum amount by about 200 thousands of cells or colonies per 10 L. The average cell or colony number throughout the whole area was 139 thousands per 10 L.

The zooplankton was more abundant in the northern half of both inside and outside of the breakwaters, where the count reached 30-500 individuals per 10 L. The southern part outside the harbour sustained the smallest amount. The size of zooplankton population was not parallel to the settling volume of the whole plankton. The numerical percentage of animals to the total plankton ($Z/N \times 100$) was less than 0.5; the largest value was found in the central part of the harbour, where the phytoplankton was relatively scarce.

B. Qualitative Analysis of Plankton

As shown in Table 2 and Fig. 2, the most important component of zooplankton was Copepoda (82.6%), being followed by Protozoa (5.2%) Cladocera (1.6%), Copelata (0.8%), and Polychaeta larvae (9.8%). Copepods were found most abundantly in the northern part outside the harbour and represented chiefly by juveniles. *Paracalanus parvus*, *Oithona nana*, *Centropages abdominalis* and *Microsetella norvegica* appeared sparsely, among which the first one occurred rather frequently in the northern part outside the harbour. No oceanic copepod was represented in the present material.

Protozoans were represented by Tintinnoinea, and among the five species of which listed in Table 2, *Undulla* appeared only in the inmost part of the harbour, and *Tintinnopsis beroidea* and *Amphorella quadrilineata* occurred in a small quantity. *Synchaeta* sp., *Sagitta delicata* and *Oikopleura dioica* seemed to be more abundant in the harbour than its outside. Polychaeta larvae occurred abundantly in the northern part of the surveyed area (about 159/10 L in the harbour and 50/10 L outside the harbour), but were very rare in the southern part.

The diatoms were practically the only components of the phytoplankton of this harbour. Among diatoms *Chaetoceros* (68%) and *Asterionella* (29%) were the most important genera being followed by *Thalassiosira* (1%), *Rhizosolenia* (0.2%), *Bacteriastrum* (0.2%) and *Nitzschia* (0.3%). Such diatom genera as *Thalassiothrix* and *Biddulphia*, and Dinoflagellata were very sparse. Among *Chaetoceros*, *Ch. compressus* and *Ch. laciniosus* were the dominants, but *Ch. cruvisetus*, *Rh. Stolterfothii* and *Thalassiothrix Frauenfeldii* were scarce,

Table 2. Composition of plankton in Hakodate Harbour. The number of colony was counted in colony-forming species. Unit of number in phytoplankton is thousand.

Region / Species	Inside of the harbour						Outside of the harbour			
	Southern part		Central part		Northern part		Northern part		Southern part	
	1	2	3	4	5	6	7	8	9	10
Protozoa	**15**	**19**	**11**	**11**	**12**	**18**	**14**	**18**	**14**	**5**
Helicostomella longa	2	2	4	3	8	13	6	4	6	2
Tintinnus tubulosus	3	3	2	2	1	1	2	4	—	—
Codonellopsis morchella	4	8	3	1	2	4	5	9	8	3
Tintinnopsis mortensenii	1	2	2	1	1	—	1	1	—	—
Undulla californiensis	3	4	—	—	—	—	—	—	—	—
Favella taraikaensis	—	—	—	4	—	—	—	—	—	—
Synchaeta sp.	4	8	8	16	12	4	6	6	5	—
Copepoda	275	169	264	182	141	286	493	269	158	103
Acartia clausi	7	1	—	—	3	6	12	8	8	1
Oithona nana	6	5	19	11	8	5	8	1	3	2
Paracalanus parvus	1	—	—	—	—	13	30	20	12	10
Microsetella norvegica	1	3	—	—	—	2	3	—	—	—
Copepoda juveniles	260	187	245	171	130	260	440	240	135	90
Oikopleura dioica	**2**	**2**	**2**	**4**	**3**	**6**	**3**	**3**	**2**	**1**
Polychaeta larvae	8	9	19	28	159	50	38	5	—	—
Sagitta delicata	—	—	—	—	—	—	—	—	2	1
Dinoflagellata	**33**	**192**	**363**	**356**	**263**	**489**	**399**	**249**	**118**	**27**
Prorocentrum micans	+	+	7	7	20	12	11	3	—	—
Peridinium crassipes	1	2	—	—	—	—	—	4	7	—
Per. pellucidum	30	180	350	340	233	452	382	190	103	25
Per. oceanicum var. *oblongum*	2	8	4	8	10	25	6	41	8	2
Chaetoceros	**62.6**	**71.3**	**43.1**	**25.8**	**34.7**	**119.1**	**183.5**	**136.7**	**121.1**	**60.9**
Ch. compressus	7.6	6.7	2.3	1.7	1.4	2.9	4.5	4.3	5.9	2.3
Ch. decipiens	0.2	0.1	0.1	+	+	0.2	0.2	0.2	0.2	0.4
Ch. radicans	1.9	1.2	1.3	1.5	1.2	1.1	0.9	0.7	0.6	1.2
Ch. didymus	0.9	0.9	1.1	1.3	1.2	2.0	1.9	0.7	0.9	1.8
Ch. Lorenzianus	+	+	+	+	+	0.3	1.8	0.2	0.1	0.2
Ch. affinis	3.2	3.2	3.4	1.5	1.5	8.4	13.9	2.4	4.5	5.1
Ch. laciniosus	48.7	58.9	35.3	19.5	29.1	103.9	159.8	127.9	109.3	49.7
Ch. coarctatus	+	0.1	+	+	+	+	0.1	+	+	0.1
Bacteriastrum hyalinum	**0.2**	**0.2**	**0.2**	**0.2**	**0.3**	**0.4**	**0.6**	**0.3**	**0.2**	**0.1**
Nitzschia seriata	**0.2**	**0.1**	**0.3**	**0.1**	**0.1**	**1.4**	**0.7**	**0.4**	**0.3**	**0.2**
Thalassiosira hyalina	**0.7**	**0.7**	**0.2**	**0.3**	**1.4**	**1.3**	**1.2**	**0.7**	**1.1**	**1.2**
Thalassionema nitzschioides	+	+	+	+	+	0.1	0.3	0.1	0.1	+
Asterionella japonica	**68.8**	**78.5**	**19.3**	**18.9**	**38.5**	**77.0**	**23.5**	**69.6**	**103.2**	**26.3**
Rhizosolenia	**0.4**	**0.1**	0.2	0.2	**0.1**	**0.3**	**1.1**	**0.3**	0.2	0.2
Rh. alata f. *genuina*	0.1	+	+	+	+	+	0.3	0.1	0.1	+
Rh. hebelata f. *semispina*	0.3	0.1	0.1	0.1	0.1	0.2	0.5	0.1	+	+
Rh. seligera	—	—	+	+	+	0.1	0.3	+	+	+
Rh. Stolterfothii	+	+	+	+	+	+	+	+	+	+

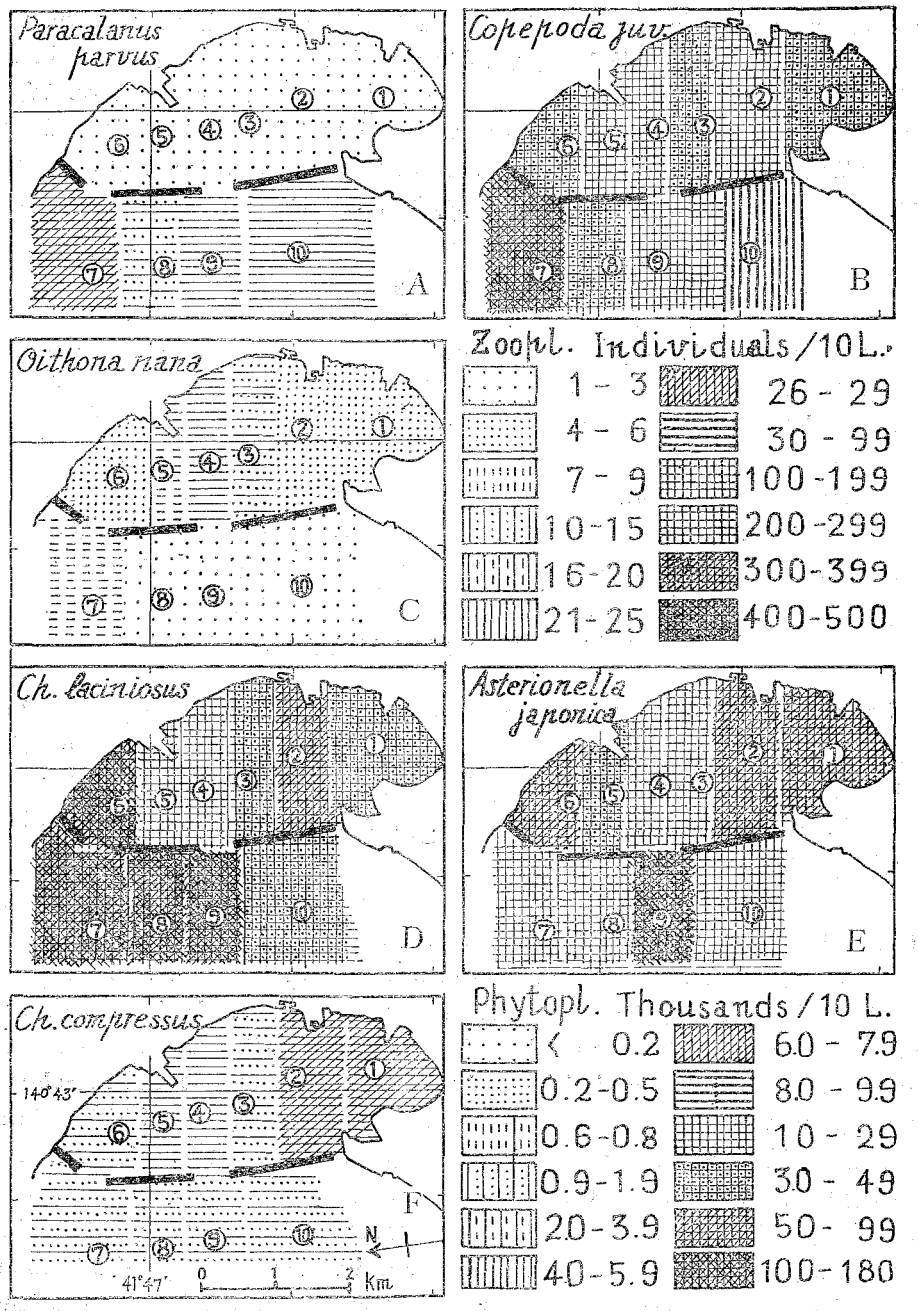

Fig. 2. Quantitative distribution of important species. A, B, C, Population of zooplankton (individuals/10 L). D, E, F, Population of diatoms (thousands/10 L.)

especially in the inmost part of the harbour. *Hemiaulus Hauckii, Hem. membranaceus, Rhizosolenia cylindrus* and *Leptocylindrus danicus* were found in very

small amounts only in the outside of the harbour. Dinoflagellates were represented chiefly by *Peridinium pellucidum*, which was more abundant in the harbour than the outside. Besides the species listed in Table 2, *Cer. tripos*, *Cer. trichoceros*, *Cer. fusus*, *Cer. furca*, *Cer. Kofoidii*, *Cer. Grande* and *Cer. intermedium* occurred very sparsely to the outside of the harbour, and some of these species were found in the open sea, too.

C. Remarks

From the data given above, it may be said that the surveyed area was filled with three kinds of water-masses at the time of our observation, although the demarcations among them were not clear. They are first the harbour water characterized by the scarceness of species, the richness of *Ch. compressus* and *Oithona* and the scantiness of *Paracalanus*, second the bay water with abundant diatoms and *Paracalanus*, and third the water of somewhat open-sea nature having rich species in spite of the small quantity of plankton.

II. Plankton of Yoichi Inlet

Yoichi Inlet lies on the southern coast of Otaru Bay, and is protected by a breakwater. The surface water temperature and the salinity were about 21°C and 33.49‰ respectively at the station near the pier and 22.6°C and 23.55‰ in the inner part, where a small river flows in. Ph-value was 8.2 at both stations.

The results of quantitative and qualitative analysis of the plankton collected at two stations are summarized in Table 3. By comparing this table with Table 2, the differences of plankton constitution between this inlet and Hakodate Harbour may become clear. The absence of *Helicostomella* (Tintinnoinea) which is an inhabitant of the inner part of inlet, and the occurrence of such species as *Oithona similis*, *Coricaeus* sp., *Oncaea venusta* and *Pseudocalanus elongatus* even at the inmost station are the characteristics of Yoichi Inlet. The water of Hakodate Harbour is much polluted by sewage from its surrounding city, although it maintains a moderately high salinity. Diatoms seem to be unable to keep their prosperity in this strongly polluted water, but attain a mass development along the margin of the turbid water outside of the harbour. In Yoichi Inlet the settling volume of plankton was slightly larger at the inner station than the pier station. This fact and the richness of species, including some species of the open water, seem to show the low degree of pollution and at the same time the strong influx of oceanic water into this inlet.

Table 3. Composition of plankton in Yoichi Harbour. N — total number of plankton per 10 L.
Unit of number in diatoms is thousand.

	Pier region		Inmost region	
Settling volume (cc/10 L)	0.82		0.88	
Number of zooplankton per 10 L (Z)	587		801	
Percentage of zooplankton (Z/N×100)	0.4		1.0	
Number of phytoplankton per 10 L (P)	159,062		73,380	
Percentage of phytopl. (P/N×100)	99.6		98.9	
Number of zoopl. species	26		24	
Number of phytopl. species	30		26	
Composition of zooplankton	**N**	**%**	**N**	**%**
Protozoa	**15**	**2.5**	**15**	**1.5**
Tintinnuis tubulosus	7	46.7	7	46.7
Codonellopsis morchella	4	26.7	3	20.0
Amphollela quadrineata	2	13.3	2	13.3
Undulla californiensis	2	13.3	3	20.0
Synchaeta sp.	**1**	**0.2**	**2**	**0.3**
Copepoda	**525**	**89.4**	**739**	**92.3**
Acartia clausi	5	1.0	6	0.8
Oithona similis	13	2.5	19	2.8
Oithona nana	8	1.5	15	2.2
Oncaea venusta	33	6.3	11	1.5
Paracalanus parvus	12	2.3	8	1.1
Pseudocalanus elongatus	4	0.8	2	0.4
Microsetella norvegica	4	0.8	—	—
Copepoda juv.	446	84.8	678	91.6
Sagitta delicata	**1**	**0.2**	**1**	**0.2**
Oikopleura dioica	**2**	**0.4**	**1**	**0.2**
Larvae	**43**	**7.3**	**44**	**5.1**
Polychaeta larva	6	14.0	18	41.9
Pelecypoda larva	2	4.6	8	18.6
Ophiopluteus larva	35	81.4	17	39.5

Composition of phytoplankton	Pier region		Inmost region	
	N	%	N	%
Dinoflagellata	**45**	**0.02**	**73**	**0.09**
Prorocentrum micans	2	4.4	4	5.4
Ceratium tripos	3	6.7	6	8.2
Cer. trichoceros	4	8.9	4	5.5
Cer. massiliense	7	15.6	5	6.8
Cer. fusus	2	4.4	4	5.4
Peridinium crassipes	2	4.4	3	4.2
Per. pellucidum	23	51.2	38	52.1
Per. oceanicum var. *oblongum*	2	4.4	9	12.3
Chaetoceros	**158.3**	**99.45**	**72.8**	**99.15**
Ch. compressus	18.8	12	11.3	15
Ch. radicans	56.4	36	12.4	17
Ch. didymus	10.5	7	11.0	15
Ch. affinis	3.3	2	4.6	6
Ch. criophilus	0.9	1	1.8	3
Ch. laciniosus	67.4	42	31.3	43
Ch. peruvianus	0.4	+	—	—
Ch. coarctatus	0.4	+	0.3	+
Bacteriastrum hyalinum	**0.2**	**0.1**	**0.2**	**0.1**
Biddulphia reticulata	+	+	+	+
Nitzschia seriata	+	+	+	+
Rhizosolenia	**0.5**	**0.34**	**0.3**	**0.48**
Rh. alta f. *genuina*	+	+	+	+
Rh. hebetata	0.4	85	0.3	6
Rh. Bergonii	0.03	6	0.03	6
Rh. setigera	0.04	7	+	+
Rn. Stolterfothii	+	+	+	+
Climacodium biconcavum	+	+	+	+
Skeletonema costatum	+	+	+	+
Dactyliosolen antarcticus	+	+	—	—
Hemiaulus membranaceus	+	+	—	—

III. General view on the planktons of 5 inlets in Hokkaido

The waters of Akkeshi, Hanasaki and Nemuro (YAMAZI, 1950) are affected by the cold Oyashio current flowing southwards along the Kurile Islands. Akkeshi Bay receives the inflow of many rivers draining the moorland, and its north-western part is filled with the water of yellowish brown colour, of small transparency and of low salinity. Inlets of Hanasaki and Nemuro face directly to the open sea and are not polluted in any high degree. The bays of Hakodate and Otaru are on the other hand affected by the warm Tsushima current which is a branch of the Kuroshio. Hakodate Harbour seems to maintain a relatively stagnant polluted water mass, whereas Yoichi Inlet is strongly influenced by the oceanic inflow. The dominant constituents of the plankton were somewhat similar in these five inlets despite of the differences in their oceanographical environments. For examples, *Chaetoceros laciniosus*, *Ch. com-*

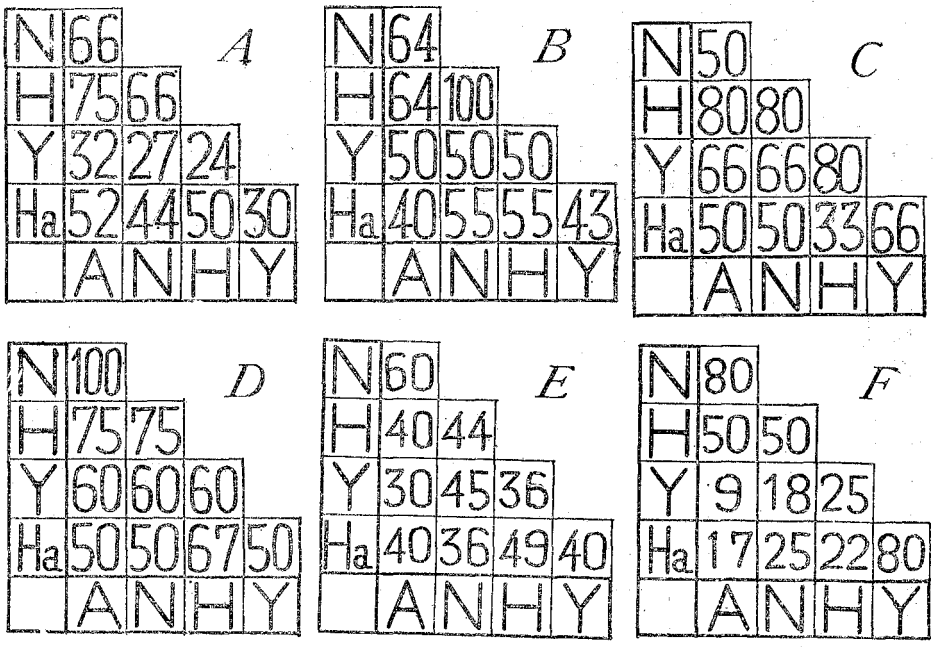

Fig. 3. Degree of similarity (S) in plankton compositions among five inlets.

$$S=\frac{c}{a+b+c}\times 100$$

a...number of species occurring only at St. A, b...number of species occurring only at St. B, c...number of species occurring at both Sts. A and B.

A. All diatoms. *B*. Diatoms occupying more than 1% of total plankton. *C*. Diatoms occupying more than 5% of total plankton. *D*. All Dinoflagellates. *E*. All zooplankton. *F*. All Tintinnoinea.

A……Akkeshi; N……Nemuro; H……Hanasaki; Y……Yoichi; Ha……Hakodate

pressus, Ch. radicans, Ch. didymus, Ch. alata f. *genuina, Rhizosolenia hebetata* f. *semispina, Rh. setigera* and *Bacteriastrum* occurred in all inlets. There were, however, differences in the manner of occurrence of some species as shown in Table 4. The most remarkable case is seen in *Asterionella japonica* which was very abundant in all inlets except Yoichi.

Table 4. Distribution of main diatom species in five inlets.

Species of diatoms	Nemuro	Hanasaki	Akkeshi	Hakodate	Yoichi
A. Cold water species					
Rhizosolenia Faeröensis	+	+	+	—	—
Chaetoceros decipiens	+	+	+	—	—
Thalassiosira hyalina	—	+	+	+	—
Biddulphia aurita	—	—	+	—	—
Coscinodiscus Janischii	+	—	—	—	—
B. Warm water species					
Asterionella japonica	+	+	+	+	—
Chaetoceros Lorenzianus	—	—	+	+	—
Ch. coarctatus	—	—	—	+	+
Ch. pervianus	—	—	—	—	+
Climacodium biconcavum	—	—	+	—	+
Hemiaulus Hauckii	—	+	+	—	—
Hem. membranaceus	—	—	—	—	+
Ditylum Brightwellii	—	+	+	—	—
Bererochea malleus	+	—	—	—	—
Rhizosolenia Bergonii	—	—	—	—	+
Rh. cylindrus	—	—	—	+	+
C. Ubiquitous species					
Skeletonema costatum	+	+	+	—	+
Dactyliosolen mediterraneus	—	—	+	—	—
Rhizosolenia Stolterfothii	—	—	—	+	+
Nitzschia seriata	—	+	+	+	+
Nitz. longissima	+	+	+	—	—
Thalassiothrix Frauenfeldii	—	—	+	+	—

An attempt to see the degree of similarity of the plankton communities of these five localities was made in Fig. 3, which shows the percentage of species in common to different inlets. Some notable facts deduced from this figure are: (1) Hakodate Harbour differs from other 4 inlets in the occurrence of diatom species, being more numerous in the former than in the latter, although they resemble those of Yoichi Inlet most closely. (2) Yoichi Inlet

differs from other inlets in that its diatoms are poor in population and of the open-sea origin. (3) Diatom as well as dinoflagellate florae of Nemuro, Hanasaki and Akkeshi Inlets resemble closely to one another (Fig. 3A, B, D). (4) As to the Tintinnoinean fauna, Hakodate Harbour is related to Yoichi Inlet most closely, and Nemuro, Hanasaki and Akkeshi Inlets have similar constitution (Fig. 3, F.) (5) From these facts, it may be said that the plankton composition as a whole has similarities among Nemuro, Hanasaki and Akkeshi Inlets on the one hand, and Hakodate Harbour and Yoichi Inlet on the other. But the similarities are closer among the former three inlets than between the latter two.

In general both the quantity and the species of plankton decrease toward the inner part of the inlet, where the water is polluted and highly stagnant. The vigorous propagation of plankton occurs in regions where the polluted or stagnant water mixes with open sea water. So far as my collections concern the chief inhabitants in the inner part of the inlets in Hokkaido were some tintinnoineans, rotifers such as *Synchaeta* sp. and *Notholca bifurca, Peridinium pellucidum, Oithona nana, Paracalanus parvus, Acartia clausi* and copepod juveniles.

ERRATUM

YAMAZI, I. 1950. Plankton investigation in inlet waters along the coast of Japan. I. (This journal, vol. 1, no. 3.)

Page 106: Line 9, *for* Qualitative *read* Quantitative.