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Distribution of Recent Shallow Water Foraminifera of Matsushima Bay, Miyagi Prefecture, Northeast Japan

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ABSTRACT

The distribution of the Recent shallow water Foraminifera in Matsushima Bay on the Pacific coast of northern Japan was studied to analyse the fauna from the view point of taxonomic classification and environment. The foraminifers taken from the top part of the 47 sediment samples obtained by Phleger's bottom sampler, with one exception of a small pipe sampler, were used for the analyses. The living specimens were distinguished by the rose Bengal staining method.

Matsushima Bay measures one to three meters in depth except for a few narrow channels at the bay mouth. The larger part of the bay bottom consists of mud overgrown at places with *Zostera.* The sea water flows in and out of the bay through several narrow channels at the bay mouth area, and a river and two canals drain into the bay. Oceanographic observations, analyses of the bottom sediments, details of chlorinity, temperature and other features of the different areas in the bay and of the different seasons are described. Of the oceanographic data chlorinity seems to be most important with regard to the distribution of the Foraminifera. The approximate variation ranges of the chlorinity and temperature of the bottom water at each station as related with the distribution of the Foraminifera are described.

The distribution of the planktonic Foraminifera, number of species, and agglutinated Foraminifera show general correlation with chlorinity distribution, but the living benthonic population and calcareous procellaneous Foraminifera differ somewhat.

By the abundancy occurrences of benthonic Foraminifera, three facies and six subfacies are discriminated in the bay. Facies A (outer bay facies) is characterized by the abundant occurrences of *Pararotalia nipponica, P.? minuta, Elphidium subarcticum, "E". somaense, Ammonia japonica* and many other open shallow-sea species. Facies B (middle bay facies) comprises two subfacies and is a facies transitional between the outer bay and inner bay facies and characterized by a mixed assemblage. Facies C (inner bay facies) comprises four subfacies and is characterized by the abundant occurrences of *Trochammina hadai, T.* cf. *japonica* and *Ammonia beccarii* forma 2, and some brackish-water species such as *Miliammina fusca, Goesella iizukae* and *Quinqueloculina rhodiensis* occur at the innermost part. The distribution of these facies is quite analogous to that of the chlorinity-temperature character of the bottom water, but some subfacies diverge because of the influence of other factors.

For an attempt for non-specific faunal division, Motomura's law of geometrical progression in animal association was applied to the foraminiferal assemblages of Matsushima Bay in simplified manner. The result correlated well with the facies distribution, general trends of the Foraminifera and bottom water characters, but not with the subfacies.

The ratio of the living benthonic Foraminifera in Matsushima Bay of the different facies showed higher value in the inner bay area where the Takagi River drains, and indicates the relative rate of sedimentation.

The foraminiferal assemblages of Matsushima Bay are compared with some other bays and brackish-water lakes along the coast of the Japanese Islands, and the general features of the Japanese bay foraminiferal fauna are described.

One species is described as new to science.

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INTRODUCTION AND ACKNOWLEDGMENTS

This study was undertaken to compare the living foraminiferal populations with the dead populations in the bay, to establish if possible, faunal assemblages, to compare their distribution with the various environments, to attempt zonation by the non-specific faunal characteristics, to investigate the relative rates of sedimentation by the Foraminifera, and to make a systematic study of the Recent Foraminifera of Matsushima Bay, Miyagi Prefecture, and to compare the foraminiferal fauna with those of other bays and brackish-water lakes along the coasts of Japan. Forty-seven samples were collected from the innermost part of the bay (depth 0.4 m) to the bay mouth (depth 12.5 m) during the autumn of 1965 and 1966. The samples were taken by Phleger's bottom sampler with one exception and the Foraminifera washed out from the top part of each of the sediment cores were studied distinguishing the living from the dead specimens. The percentage-abundance distribution of the important species as related to the distribution of the physical and chemical factors were analysed and the results are shown in the maps in this article.

The writer expresses his deep appreciation to Professor Kiyoshi Asano of the Institute of Geology and Paleontology, Tohoku University, who supervised the entire work, to Professor Kotora Hatai of the same Institute for advice and reading the manuscript, to Professor Jun-ichi Iwai, Associate Professors Taro Kanaya, Nobu Kitamura and Tamio Kotaka, and Dr. Yokichi Takayanagi of the same Institute for their suggestions. He is also indebted to Dr. Mutsuo Hattori of the Idemitsu Kosan Co. and Dr. Tadamichi Oba of the Kyushu Oil Development Co. for their kind help in collecting the samples. Particular thanks are due to Dr. Hisashi Kanno of the Tohoku Regional Fisheries Research Laboratory, Shiogama, for his suggestions and loan of his original data on the hydrography of Matsushima Bay and the adjacent sea. Thanks are also due to Professor Kazuo Huzioka and Associate Professor Taisuke Takayasu of the Institute of Mining Geology, Mining College, Akita University for providing every facilities for preparing the manuscript.

DESCRIPTION OF THE AREA STUDIED

The area studied is located at approximately 38°18′ to 38°23′ N. Lat. and about 141°02′ to 141°09′ E. Long. This area (Fig. 1) is known as Matsushima Bay, and is separated from but connected by several narrow channels with Sendai Bay. It has a series of islets, *e.g.* Mahanashi-shima, Katsura-shima, Nono-shima, Sabusawa-shima, and Miyato-shima in the area of the bay mouth (Fig. 2). The bay is roughly elliptical in outline, about 10 km in length, nearly 5 km in width, and the long axis is parallel with the coast of Sendai Bay. The coast-line of Matsushima Bay is very irregular and there are many inlets in the bay. The only coastal plain bordering the bay is in the Tona area. Many islets, approximately 260 in total, are distributed in the northwestern and south-eastern parts of the bay. The land area surrounding the bay consists of siltstone, tuff, tuff breccia and agglomerate of Miocene age, and they form cliffs. The Takagi River drains into the innermost part of the bay at the north, and the Tona and Teizan Canals feed the bay at the northeast and southwest parts.

The bay is about one to three meters in depth in general (at mean low tide) and the floor is rather flat except for the three narrow channels each of about ten meters in depth at the bay mouth; one of them, deepened artificially, extends westwards to Shiogama

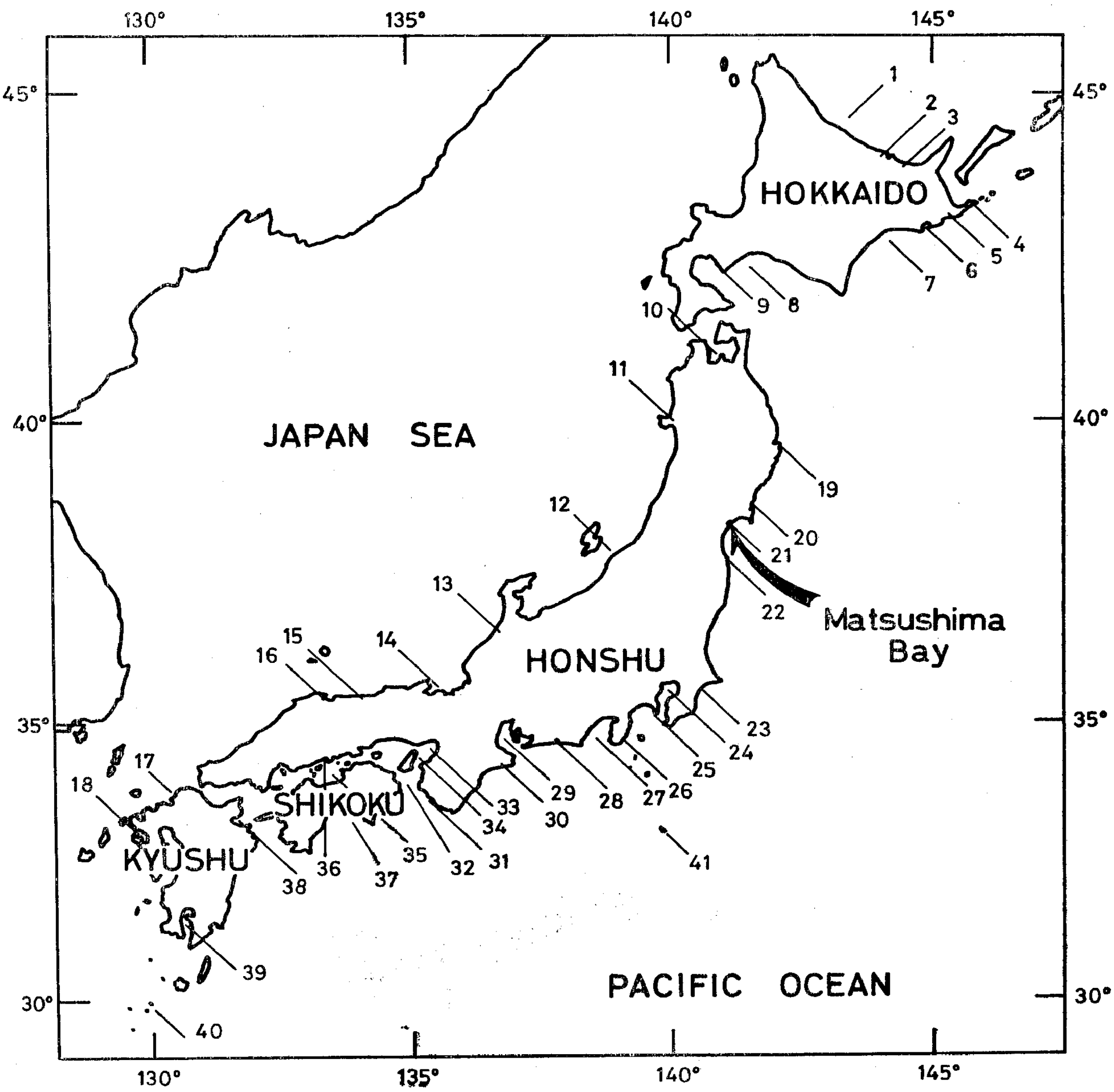

Fig. 1. Location of the area investigated, and of the shallow water Foraminifera studied by authors (see text, p. 8).

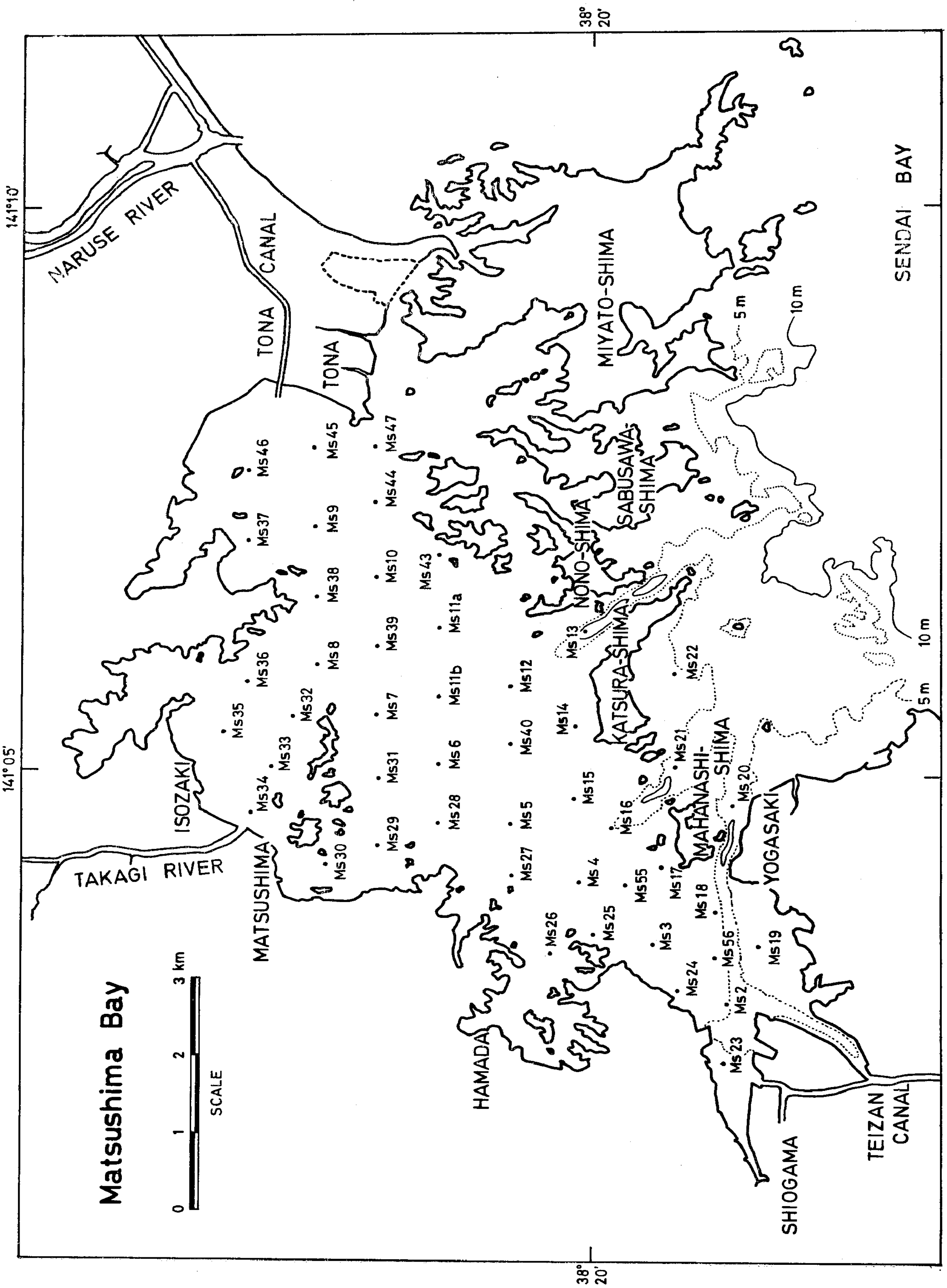

Fig. 2. Stations in Matsushima Bay of the foraminiferal samples used in the present study.

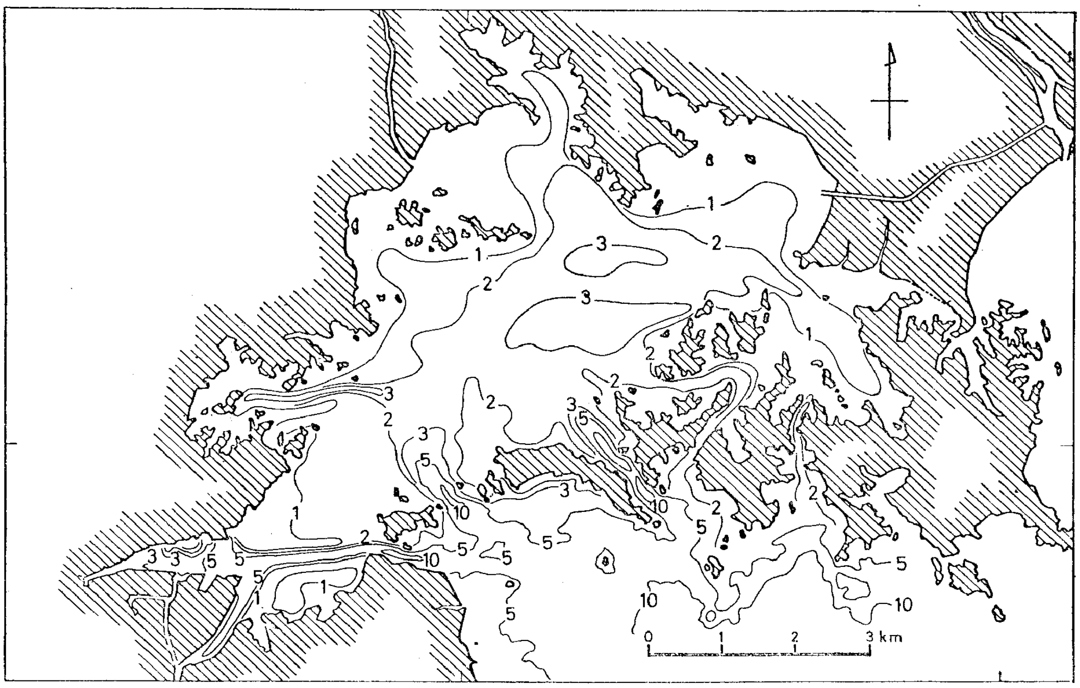

Fig. 3. Bathymetrical chart (in meters) of Matsushima Bay.

Harbor (Fig. 3). The northeastern middle part of the bay has a saucer-shaped depression with a maximum depth of 3.6 m, and there is another of narrow channel form of four to five meters in depth off Hamada, which suggests a submerged older river.

The sea off the Pacific coast of northeast Honshu is called "the Transition Area" of the warm water Kuroshio and cold water Oyashio currents (Kawai, 1955). In winter a

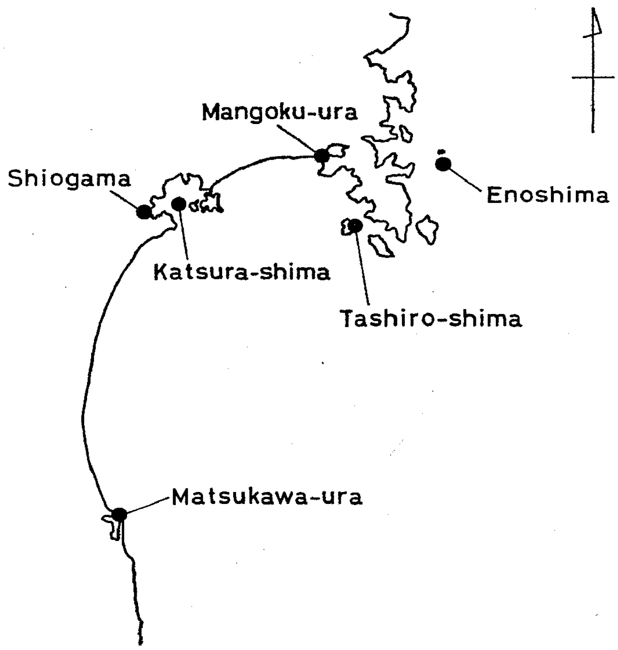

Fig. 4. Stations of the long-period observations of the nearshore surface water temperature of Matsushima Bay (Shiogama and Katsura-shima) and the vicinity.

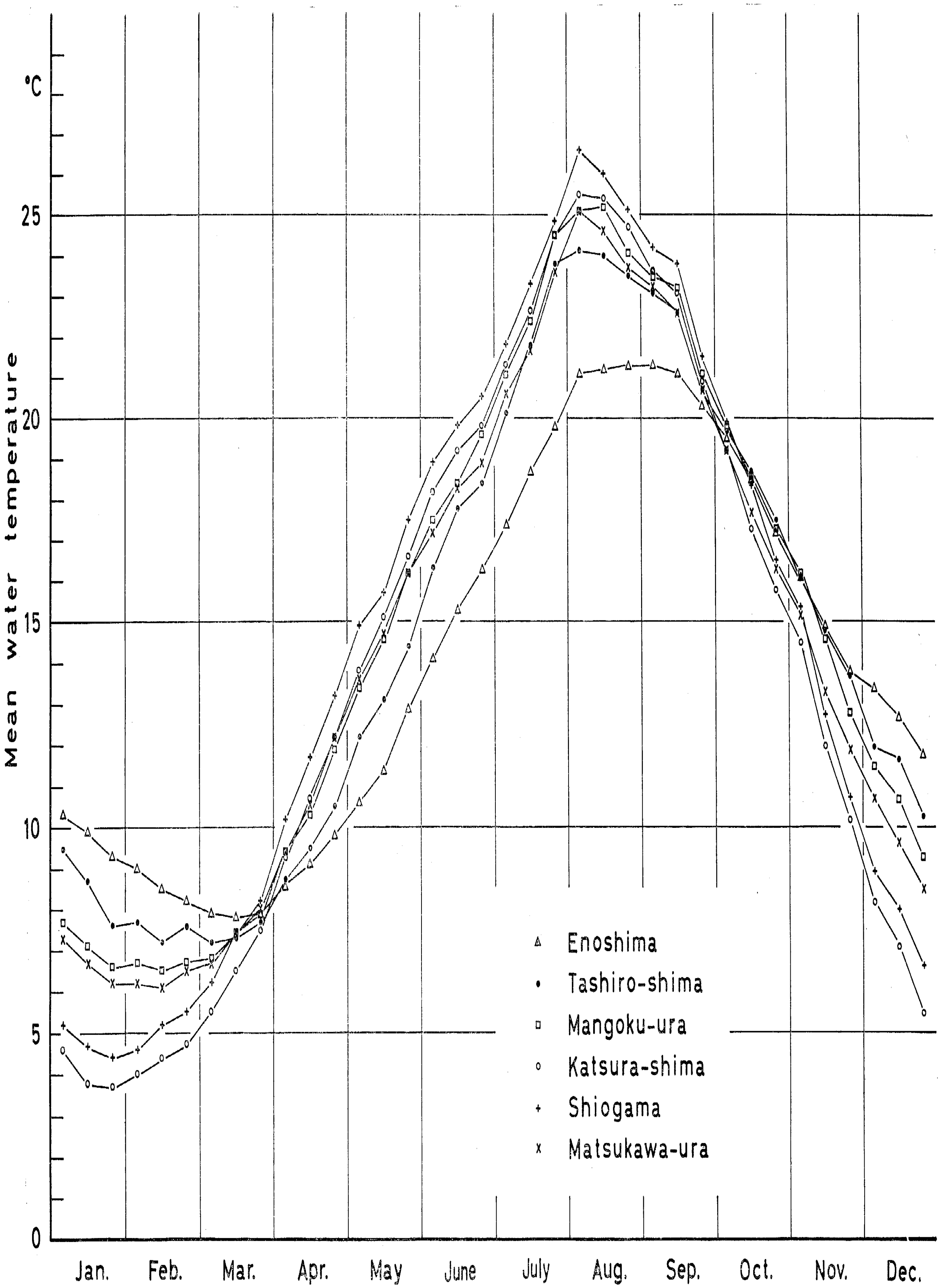

Fig. 5. Ten days mean nearshore surface water temperature (°C) through ten years (1953-1962) of Matsushima Bay and the vicinity at the stations shown in Fig. 4 (compiled from Tohoku Reg. Fish. Res. Lab., 1965).

branch of the Oyashio flows southwards from the north along the coast to off Sendai Bay or farther south. Consequently the annual range of the surface water temperature is about 14°C off Sendai Bay and 18°C off the northern end of Honshu (Masuzawa *et al.*, 1962). The ten days mean near shore surface water temperature through ten years (1953–1962) of Matsushima Bay and the vicinity is shown in Figs. 4, 5.

PREVIOUS STUDIES

There are many papers on the Recent shallow water Foraminifera of Japan, and because they are brought into comparison with the foraminiferal fauna of Matsushima Bay, a brief review of them is given here.

Hada (1931) made a taxonomic study of the Recent Foraminifera of Mutsu Bay, Aomori Prefecture. He described 100 species and varieties including 11 new species from the sediments dredged from about 30 stations each of less than 33 fathoms in depth. Later he (Hada, 1957) summarized the Japanese brackish-water Foraminifera and listed 15 species as brackish-water forms living in a minimum water-chlorinity up to 13.84%. He considered that they are inhabitants of the cold-water seas.

Asano (1937) listed 78 species and subspecies and described several species including two new species of Foraminifera from Shiogama Bay in Matsushima Bay. Further he (Asano, 1938) studied the Foraminifera of 17 samples from depths of 11 to 1100 m in Onagawa and Ogachi bays and the vicinity, Miyagi Prefecture.

Morishima (1947, 1948a) studied the distribution of the Foraminifera of Obama Bay, Fukui Prefecture, and Maizuru Bay, Kyoto Prefecture, and recognized five assemblages, namely *Globigerina*, *Rotalia papillosa*, *Textularia hauerii* - *Nonion boueana*, *Rotalia beccarii*, and *Trochammina* assemblages. They are stated to be distributed from the bay mouth to the inner parts in both bays. He (Morishima 1948b, 1950) reported that the assemblages of *Globigerina*, *Amphistegina-Elphidium crispum*, *Rotalia papillosa-Quinqueloculina lamarckiana*, *Elphidium craticulatum-Textularia hauerii*, and *Trochammina* are distributed from the bay mouth to the inner bay in the bottom sediments of Ago Bay, Mie Prefecture.

Morishima and Chiji (1952) studied the distribution of the Recent Foraminifera of Akkeshi Bay and Akkeshi Lake of eastern Hokkaido. They distinguished five foraminiferal assemblages from 27 samples in the bay and lake, namely, *Trochammina globigeriniformis-Rotalia* cf. *R. beccarii* (Lake), *Trochammina globigeriniformis*, *Bolivina decussata*, *Rotalia japonica-Nonion japonicum*, and *Nonionella pulchella* (Bay) in the order from the lake, innermost part of the bay to the bay mouth. The latter four assemblages are included into one group called the *Eponides frigidus-Elphidium* sp. A Group.

Yoshida (1954) reported on the Foraminifera from the brackish-water Saroma Lake of eastern Hokkaido. He recognized 12 assemblages from 21 sediment samples in the lake but their areal distributions were not described.

Takayanagi (1955) described the distribution of the Foraminifera in the Matsukawa-ura lagoon and its vicinity, Fukushima Prefecture. He distinguished two facies and one subfacies from 180 samples in the lagoon and open shallow sea of about 20 m in depth just outside the lagoon. The Matsukawa-ura facies covers the lagoon except the mouth area, the Isobe facies is the open shallow sea outside the lagoon, and the Matsukawa-minato subfacies is the mouth area of the lagoon.

In her study on the Foraminifera of Tokyo Bay, Maruhashi (1948) analysed 21 samples of bottom sediments from depths of 7.5 m to 35.5 m at the inner half part of the bay and recognized three assemblages, namely, *Ammoglobigerina-Rotalia*, *Quinqueloculina-Lagena*, and *Rotalia* assemblages. Morishima (1955) listed 126 species and subspecies of Foraminifera from 22 bottom samples from Tokyo Bay. Kuwano *et al.* (1957) studied about 90 samples from the depths of 5 m to 200 m from around the mouth of Tokyo Bay and its vicinity, and distinguished eight assemblages in the thanatocoenose and 16 assemblages in the biocoenose, and stated that the populations living at depths shallower than 20 m changes by area compared with the fauna of deeper water which have more uniform distribution.

Ishiwada (1958) made an ecological study of the brackish-water Hamana-ko lake, Shizuoka Prefecture. He divided the foraminiferal thanatocoenoses into three groups; Open-coast subfacies, Transitional facies and Hamana-ko proper facies. The Hamana-ko proper facies extends almost throughout the lake except for the mouth area, and is subdivided into three subfacies. The Open-coast subfacies is at the mouth of the lake and the Transitional facies at the transitional area.

Studies on the Foraminifera of inland and shallow seas of Japan are enumerated below in the order from Hokkaido at the north, southwards to Kyushu. The number of each locality is indicated in Fig. 1.

The coast of Hokkaido: 1, Okhotsk Sea (Kuwano, 1953–54); 2, Saroma Lake (Yoshida, 1954); 3, Mokoto Lake (Yoshida, 1953); 4, Tosamporo Lake (Hada, 1957); the coast of Oshoro, Akkeshi and Nemuro (Hada, 1929); 5, Hijirippu and Mochirippu Lakes (Hada, 1936); 6, Akkeshi Lake and Akkeshi Bay (Morishima and Chiji, 1952; Yoshida, 1953; Hada, 1957); 7, the coast of Kushiro (Ishiwada, 1964); 8, the coast of Noboribetsu (Uchio, 1959); 9, the inlet of Usu (Hada, 1957).

The Japan Sea coast of Honshu and Kyushu: 10, Mutsu Bay (Hada, 1931), 11, Hachiro-gata (Hada, 1931; Iwasa, 1954); 12, the coast of Niigata (Oinomikado and Stach, 1948; Uchio, 1962b, c); 13, the six lakes in the region of Hokuriku (Hada, 1955); 14, Obama and Maizuru Bays (Morishima, 1947, 1948a); 15, Koyama Lake (Hada, 1937); 16, Nakanoumi (Hada, 1939); 17, the coast of Tsuyazaki (Shuto, 1965); 18, Omura Bay (Shuto, 1953).

The Pacific coast of Honshu, Shikoku and Kyushu: 19, Miyako Bay (Ujiié and Kusuzawa, 1968); 20, Onagawa and Ogachi Bays (Asano, 1938); 21, Shiogama Bay in Matsushima Bay (Asano, 1937); 22, Matsukawa-ura (Takayanagi, 1955); 23, the coast of Kujukuri-hama (Harrington, 1960); 24, Tokyo Bay (Maruhashi, 1948; Morishima, 1955; Kuwano *et al.*, 1957); 25, the coast of the Miura Peninsula (Ikari, 1927; Fukuta, 1951; Higuchi, 1954); 26, the coast of Shimoda (Aoki, 1967); 27, Suruga Bay (Nagahama, 1954); 28, Hamana-ko lake (Hada, 1957; Ishiwada, 1958); 29, Ise Bay (Nagahama, 1951); 30, Ago Bay (Morishima, 1948b, 1950); 31, the coast of Wakayama (Uchio, 1962, 1968); 32, Kii Strait (Sawai, 1958); 33, Osaka Bay (Nakaseko, 1953); 34, Izumi-nada (Takayanagi, 1953); 35, Hiuchi-nada (Sawai, 1955); 36, Matsunaga Bay (Nagahama, 1951); 37, Tosa Bay (Asano, 1937); 38, Beppu Bay (Nagahama, 1951); 39, Kagoshima Bay (Nagahama, 1951; Kuwano, 1962–63); 40, the coast of the Tokara Islands (Kuwano, 1956); 41, the coast of Hachijo Island (Uchio, 1952).

From the studies on the benthonic organisms other than Foraminifera in Matsushima Bay, Yamamoto (1955) divided the bay and its vicinity into five areas including one outside the bay, chiefly based on molluscs. Recently Kitamori and Kanno (1967) studied the benthonic communities, chiefly polychaetes and molluscs, in Matsushima Bay and its vicinity, and recognized five different areas of distribution of the bottom fauna, including one outside the bay.

METHOD OF STUDY

FIELD WORK

Sediment samples were collected from the 47 stations each of about 700 m to 1000 m apart, forming a grid pattern in Matsushima Bay (Fig. 2) during one season of the two consecutive years; November 3, 1965 (Stations Ms 2–Ms 22) and October 26, 1966 (Stations Ms 23–Ms 56).

All the samples were taken by the Phleger sampler (Phleger, 1951, 1960) except for one. This sampler obtains a short, relatively undisturbed core of 1 3/8 inches (about 3.5 cm) in diameter; approximately 10 cm^2 in area. The uppermost one centimeter in thickness, comprising approximately 10 cc of wet sediment, was cut off from each core and placed in a sample jar with the sea water from just above the sediment surface. Neutralized formalin in a concentration of approximately 5 per cent was added. A small amount of sodium carbonate was added to each sample to maintain an alkaline solution. One sample (Ms 22) was obtained by a small hand sampler consisting of a steel pipe with an inner diameter of 6.5 cm and length of 20 cm. This sampler fails to collect a constant area and volume of surface sediment. But for supplemental use for consideration of the distribution of species, 10 cc of the sediment was taken and preserved in formalin.

In addition to sampling of the sediments, measurements were made of the surface and bottom water temperatures. The bottom water temperature was measured on board a small boat from the water obtained by the Phleger sampler before taking the sediment.

LABORATORY WORK

All the samples preserved in neutralized formalin were confirmed as to whether the pH value exceeded 7.0 before washing. Sediment samples were washed over a screen with average openings of 0.074 mm (200-mest) and the residues were stained with rose Bengal fication of the living specimens (Walton, 1952).

Kuwano (1956) confirmed the validity of the rose Bengal staining method, and reported on the relation between the concentration of the rose Bengal solution, the time required for staining and the condition of the stained specimens. For counting living specimens, he proposed the dry method in contrast to Walton's wet method. After staining the sediment sample was dried before counting the living specimens. Although there may be difficulties and errors in distinguishing the living specimens, a dried sample is convenient for study.

The writer prepared an aqueous solution of rose Bengal by dissolving 0.5 g of rose Bengal in 1 liter of water. This was added to the washed sediment contained in a beaker, the volume of the sample with water and the solution being the same. After keeping for about 24 hours in the rose Bengal solution, the sample was washed through a sieve of the same mesh size mentioned above, and then preserved in hot water at about 80°C for several hours, after which it was washed again and then dried. The dried sample was divided by the splitter described by Parker (1948) to obtain a workable size from which approximately 300 specimens of living and dead benthonic Foraminifera was counted. All the specimens including planktonic Foraminifera and Ostracoda were picked out from the split-part. One sample contained only 53 specimens of benthonic Foraminifera. The total population was first analyzed, then the living specimens were counted with much care, wetting each specimen. Before counting the living specimens in a dry sample, the condition of the dried protoplasm was examined with specimens taken from some of the wet samples.

The total and living members of Foraminifera in each sample are listed in Table 3, and their occurrences are given in percent. The sizes of the total and living benthonic populations and planktonic population per sample, as well as numbers actually counted, are given in the table. In this table the numbers per sample are calculated for the equal wet volume (about 10 cc) of the sediment sample from the top one centimeter of the core taken by the Phleger sampler. Because the size of the living population is rather small in many samples, the occurrences of the living species are not of sufficient reliability and therefore used only roughly for consideration.

ENVIROMENTS OF THE BAY

HYDROGRAPHY

The tidal range in Matsushima Bay is about one meter and during tidal change the sea water flows through several channels. The direction and velocity of the tidal currents during rising and ebbing tide (Yamauchi, 1954) during November 9–16, 1953, are shown in Figs. 6 and 7. These were measured at 1–2 m below the sea water surface. The maximum velocity of 0.75–1.25 knots was in the channel between Katsura-shima and Nono-shima, and the three channels including it are the most important water ways. The current velocity inside the bay was 0.23–0.55 knots in general.

The hydrographic observations during June to October, 1964, were reported by Kanno *et al.*, (1965) and those during September, 1965, to March, 1966, by Kanno and other members of the Tohoku Regional Fisheries Research Laboratory, Shiogama. An outline of the bay water properties is described below based on the published and unpublished data and the part compiled in Table 1 covers all seasons nearly bimonthly, and the stations are shown in Fig. 8.

Water temperature: The distributions of the surface and bottom water temperatures in summer and the surface water temperature in winter are shown in Figs. 9 and 10. The bottom and surface water temperature in summer (Aug. 1) exceeds 29°C at the innermost part of the bay, but rapidly decreases towards the bay mouth where it becomes less than 26°C at the surface and less than 23°C at the bottom of the deep channels at the bay mouth. The water temperature of winter (Jan. 24) shows little variation both vertically and horizontally, ranging from about less than 1°C to more than 4°C, from the innermost part to the outer part of the bay at the surface.

Chlorinity: The distribution of the chlorinity of the surface and bottom water in summer and the surface water in winter is shown in Figs. 11 and 12. The surface water chlorinity in summer (mean of July 7, Aug. 1, 21) is 14–16‰ in the larger part, and less than 14‰ at the innermost part of the bay especially at the mouth of the river and canals. The bottom water chlorinity (mean of July 7, Aug. 1) is rather uniform throughout the bay, being 14–17‰. and more than 17‰. in the obttom of the deep channels. The chlorinity of the winter (mean of Dec. 20, Jan. 24) is more uniform than that of summer, being about 17–18‰ at the surface.

Saturation rate of oxygen: The distribution of the saturation rate of oxygen of the bottom water in summer (mean of July 7, Aug. 1) and the surface water in winter (mean of Dec. 20, Jan. 24) is shown in Fig. 13. The figure shows the rates of more than 90 percent almost throughout the bay indicating the well aerated condition of the bay water, except for the extremely low rates in the area of Shiogama Harbor where sewages of the city and the industries flow in.

pH: The distribution of pH value of the bottom water in summer (July 7, Aug. 1) is shown in Fig. 14. The lowest, pH 7.6, is in the Shiogama Harbor area and it increases to more than pH 8.0 in the eastern half of the bay including the bay mouth area. In general, the area of the lower pH value extends from Shiogama Harbor northeastwards along the northeastern coast of the bay.

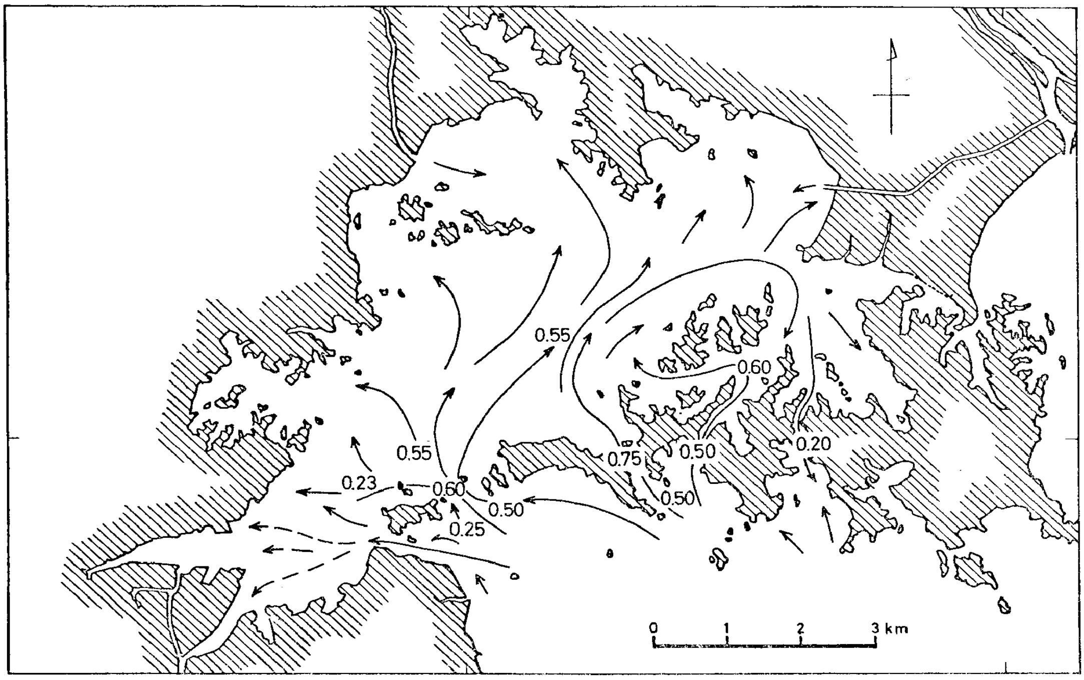

Fig. 6.

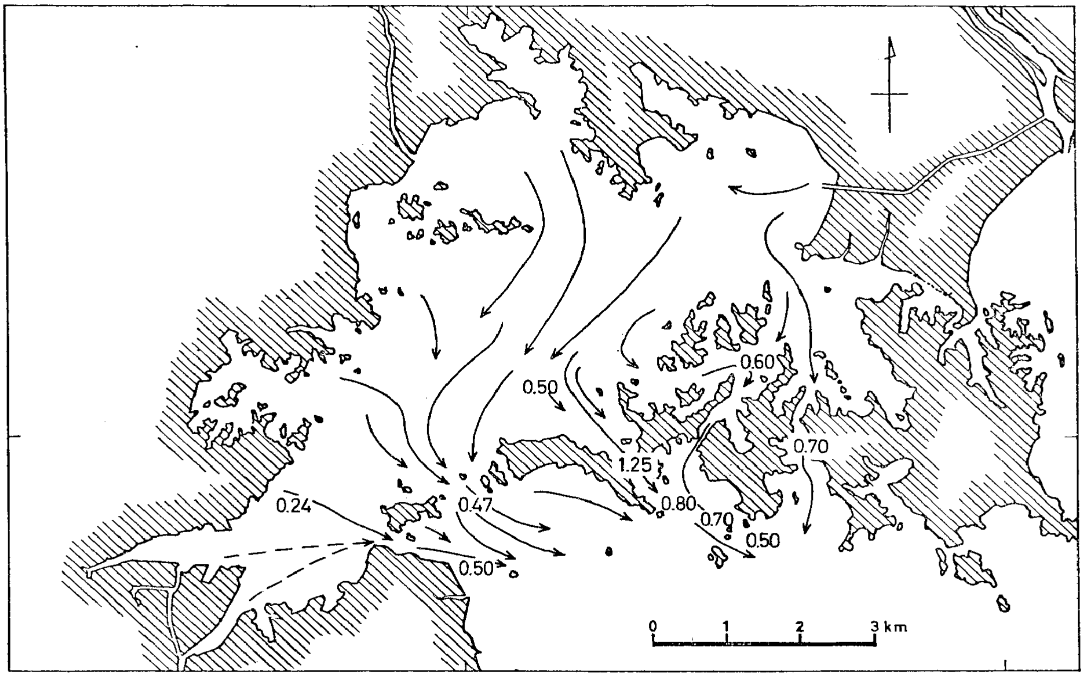

Fig. 7.

Figs. 6, 7. Direction and velocity of the tidal current during rising tide (Fig. 6) and ebbing tide (Fig. 7) (after Yamauchi, 1954). Numerals are velocity in knots.

The temperature and chlorinity of the surface and bottom waters given in Table 1 are plotted in the T-Cl diagram in Fig. 15, showing the general seasonal variation ranges. The numerals in the diagram indicate the station number shown in Fig. 8. Stations 9–13 of the inner part of the bay are always lower in chlorinity being especially so from late spring to

Table 1. Surface and bottom water characters of Matsushima Bay observed during 1964 to 1966 (compiled from Kanno *et al.*, 1965 and the original data of the Tohoku Reg. Fish. Res. Lab., Shiogama).

Surface water

Station	Date	Temperature °C	Chlorinity ‰	pH	Dissolved oxygen cc/l	Saturation of oxygen %	Total-N mg/l	Total-P mg/l
1	June 2, '64	18.4	15.58	7.30	4.47	78	—	—
	Aug. 1, '64	26.3	15.27	8.02	3.06	61	3.040	0.022
	Oct. 7, '64	19.3	16.56	7.35	0.14	3	1.000	0.174
2	June 2, '64	18.2	15.58	7.40	5.99	104	—	—
	Aug. 1, '64	25.4	14.83	7.30	1.44	28	2.640	0.037
	Oct. 7, '64	19.3	15.97	7.25	—	—	2.375	0.206
3	June 2, '64	17.8	16.58	7.73	4.62	81	0.675	—
	Aug. 1, '64	26.1	15.47	8.06	3.73	146	1.446	0.016
	Oct. 7, '64	19.0	18.26	7.55	1.32	24	0.930	0.384
	Nov. 24, '65	11.0	17.83	—	4.01	62	1.250	0.202
	Jan. 24, '66	4.2	17.99	—	8.24	112	0.750	—
	Mar. 15, '66	7.5	17.83	—	5.24	76	1.370	0.112
4	June 2, '64	19.2	16.33	7.85	5.26	93	0.412	—
	Aug. 1, '64	26.2	15.57	7.75	5.92	118	1.020	0.042
	Oct. 7, '64	18.4	16.74	7.70	2.73	48	0.610	0.273
	Nov. 24, '65	12.0	18.12	—	5.98	96	0.460	0.162
	Jan. 24, '66	4.2	17.92	—	7.35	100	0.840	—
	Mar. 15, '66	6.9	17.76	—	6.01	86	1.000	0.146
5	June 2, '64	19.4	16.33	7.90	5.58	100	0.422	—
	Aug. 1, '64	27.2	15.52	7.75	6.39	129	0.960	0.037
	Oct. 7, '64	18.4	16.61	7.75	4.27	75	0.550	0.186
6	June 2, '64	20.0	16.12	7.85	4.92	89	0.231	—
	Aug. 1, '64	27.6	15.32	7.80	5.47	111	1.260	0.074
	Oct. 7, '64	18.3	—	—	—	—	—	—
	Nov. 24, '65	9.6	17.66	—	6.33	95	0.780	0.134
	Jan. 24, '66	3.0	17.70	—	8.71	114	0.950	—
	Mar. 15, '66	7.7	17.37	—	6.72	97	0.860	0.140
7	June 2, '64	20.8	15.88	7.90	6.19	113	—	—
	Aug. 1, '64	28.2	15.23	7.48	4.82	99	0.900	0.022
	Oct. 7, '64	18.2	16.46	7.78	4.85	80	0.370	0.115
8	June 2, '64	19.6	16.40	8.00	6.73	120	0.225	—
	Aug. 1, '64	27.3	15.30	7.60	5.49	111	0.540	0.050
	Oct. 7, '64	18.5	16.47	7.80	4.83	85	0.295	0.096
	Nov. 24, '65	9.5	17.94	—	7.24	110	0.350	0.106
	Jan. 24, '66	2.3	17.79	—	8.51	109	0.570	—
	Mar. 15, '66	7.7	17.52	—	7.05	103	0.570	0.096
9	June 2, '64	19.6	15.17	8.10	7.02	124	0.318	—
	Aug. 1, '64	27.7	14.90	7.56	5.30	107	0.740	0.040
	Oct. 7, '64	18.3	16.03	7.80	5.14	90	0.250	0.138
	Nov. 24, '65	8.0	17.54	—	7.52	110	0.530	0.072
	Jan. 24, '66	2.0	17.79	—	8.27	106	0.690	—
	Mar. 15, '66	7.8	16.81	—	7.05	102	0.530	0.106
10	June 2, '64	20.0	13.85	8.05	5.94	104	0.456	—
	Aug. 1, '64	28.0	14.82	7.75	6.28	128	1.080	0.029
	Oct. 7, '64	18.2	15.67	7.75	4.61	80	0.395	0.134

Table 1 (Continued)

Station	Date	Temperature °C	Chlorinity ‰	pH	Dissolved oxygen cc/l	Saturation of oxygen %	Total-N mg/l	Total-P mg/l
11	June 2, '64	21.4	8.03	8.10	5.85	99	0.660	—
	Aug. 1, '64	28.8	13.59	7.80	6.62	134	0.960	0.050
	Oct. 7, '64	17.9	15.08	7.80	4.66	80	0.460	0.165
12	June 2, '64	21.0	14.72	8.02	5.51	99	0.372	—
	Aug. 1, '64	29.4	14.23	7.70	7.04	146	1.200	0.016
	Oct. 7, '64	18.2	15.57	7.91	5.37	108	0.365	0.130
	Nov. 24, '65	8.4	16.95	—	7.13	105	0.320	0.062
	Jan. 24, '66	0.8	16.87	—	7.85	96	0.500	—
	Mar. 24, '66	8.2	16.35	—	7.15	103	0.570	0.124
13	June 2, '64	19.6	15.25	8.25	7.22	128	0.251	—
	Aug. 1, '64	28.9	14.85	7.81	2.62	54	0.400	0.037
	Oct. 7, '64	18.3	15.82	7.88	5.10	89	0.370	0.127
14	June 2, '64	18.0	16.81	8.02	6.35	111	0.315	—
	Aug. 1, '64	26.1	15.79	7.82	6.15	122	1.60	0.034
	Oct. 7, '64	18.6	16.87	7.86	4.69	83	0.385	0.088
	Nov. 24, '65	11.8	18.20	—	6.26	100	0.320	0.072
	Jan. 24, '66	4.2	18.19	—	7.77	105	0.580	—
	Mar. 15, '66	7.3	17.79	—	6.80	98	0.500	0.078
15	June 2, '64	18.6	16.31	8.02	5.53	97	0.191	—
	Aug. 1, '64	27.0	—	7.85	6.64	—	0.960	0.037
	Oct. 7, '64	18.4	16.56	7.78	4.35	77	0.460	0.201
	Nov. 24, '65	11.5	18.20	—	6.37	101	0.380	0.074
	Jan. 24, '66	3.5	18.09	—	8.22	110	0.460	—
	Mar. 15, '66	7.3	17.56	—	6.58	95	0.640	0.106
16	Nov. 24, '65	11.8	18.21	—	7.13	114	0.320	0.072
	Jan. 24, '66	4.3	18.26	—	7.49	103	0.390	—
	Mar. 15, '66	7.1	18.19	—	6.64	96	0.530	0.096
17	Nov. 24, '65	11.6	18.14	—	6.21	98	0.320	0.074
	Mar. 15, '66	7.2	18.25	—	6.62	96	0.570	0.078
18	Nov. 24, '65	12.2	18.16	—	7.04	112	0.240	0.058
	Mar. 15, '66	7.2	18.10	—	6.53	95	0.530	0.118

Bottom water

Station	Date	Temperature °C	Chlorinity ‰	pH	Dissolved oxygen cc/l	Saturation of oxygen %	Total-N mg/l	Total-P mg/l
1	June 2, '64	16.9	17.08	7.80	4.00	69	—	—
	Aug. 1, '64	22.6	17.16	7.70	3.07	58	1.200	0.062
	Oct. 7, '64	19.4	17.16	7.50	0.88	16	0.830	0.174
2	June 2, '64	16.4	17.21	7.60	2.96	51	—	—
	Aug. 1, '64	22.6	17.18	7.52	3.07	58	1.320	0.037
	Oct. 7, '64	19.2	16.86	7.48	—	—	0.735	0.201
3	June 2, '64	1.60	17.27	7.80	4.30	73	—	—
	Aug. 1, '64	25.5	17.38	7.68	7.21	144	0.660	0.016
	Oct. 7, '64	19.3	17.40	7.70	3.12	56	0.405	0.248

Table 1 (Continued)

Station	Date	Temperature °C	Chlorinity ‰	pH	Dissolved oxygen cc/l	Saturation of oxygen %	Total-N mg/l	Total-P mg/l
4	June 2, '64	16.0	17.35	7.88	5.32	91	—	—
	Aug. 1, '64	20.1	17.94	7.80	6.26	115	0.580	0.047
	Oct. 7, '64	19.2	17.50	7.80	4.02	72	0.450	0.186
	Nov. 24, '65	11.5	18.20	—	5.89	93	0.600	0.106
	Jan. 24, '66	4.1	17.99	—	6.97	94	0.750	—
	Mar. 15, '66	7.0	18.15	—	6.48	94	0.640	0.078
5	June 2, '64	18.7	16.48	7.90	4.78	84	—	—
	Aug. 1, '64	26.2	15.91	7.73	5.66	109	0.866	0.022
	Oct. 7, '64	18.2	16.61	7.80	3.96	69	0.500	0.218
7	June 2, '64	19.1	16.30	7.88	4.71	83	—	—
	Aug. 1, '64	27.7	15.22	7.45	4.95	100	0.706	0.019
	Oct. 7, '64	18.3	16.46	7.80	4.49	79	0.270	0.145
8	June 2, '64	19.4	16.21	8.02	5.60	100	—	—
	Aug. 1, '64	26.2	15.62	7.60	5.29	105	0.960	0.059
9	June 2, '64	18.7	16.81	8.05	5.48	97	—	—
	Aug. 1, '64	26.7	15.31	7.62	5.30	100	0.706	0.037
	Oct. 7, '64	18.8	16.61	7.77	4.16	74	0.300	0.130
11	June 2, '64	20.8	13.18	8.00	5.55	98	—	—
	Aug. 1, '64	28.0	13.63	7.78	6.06	121	0.646	0.037
	Oct. 7, '64	18.2	15.27	7.85	4.26	74	0.360	0.161
12	June 2, '64	20.4	15.20	8.02	5.41	97	—	—
	Aug. 1, '64	29.4	14.33	7.85	7.68	159	1.030	0.040
	Oct. 7, '64	18.3	15.77	7.93	5.20	90	0.425	0.113
13	June 2, '64	18.4	15.49	8.20	7.14	124	—	—
	Aug. 1, '64	27.4	14.93	7.85	6.59	133	0.890	0.016
	Oct. 7, '64	18.5	16.34	7.91	4.84	85	0.280	0.062
14	June 2, '64	17.5	16.77	8.02	6.33	110	—	—
	Aug. 1, '64	22.6	17.57	7.90	6.50	124	0.960	0.031
	Oct. 7, '64	18.6	16.87	7.90	4.89	87	0.335	0.144
	Nov. 24, '65	10.9	18.11	—	6.34	99	0.600	0.062
	Mar. 15, '66	6.9	18.15	—	6.55	94	0.600	0.078
15	June 2, '64	17.4	16.68	8.00	5.53	96	—	—
	Aug. 1, '64	22.0	—	7.80	5.67	—	0.830	0.040
	Oct. 7, '64	18.6	17.00	7.82	4.34	77	0.425	0.196
	Nov. 24, '65	11.1	18.21	—	6.33	99	0.460	0.094
	Jan. 24, '66	3.6	18.20	—	8.54	114	0.390	—
	Mar. 15, '66	6.9	18.09	—	6.54	94	0.640	0.090
16	Nov. 24, '65	11.3	18.21	—	6.31	100	0.460	0.072
	Jan. 24, '66	4.2	18.27	—	7.58	104	0.680	—
	Mar. 15, '66	6.7	18.12	—	6.52	94	0.710	0.072

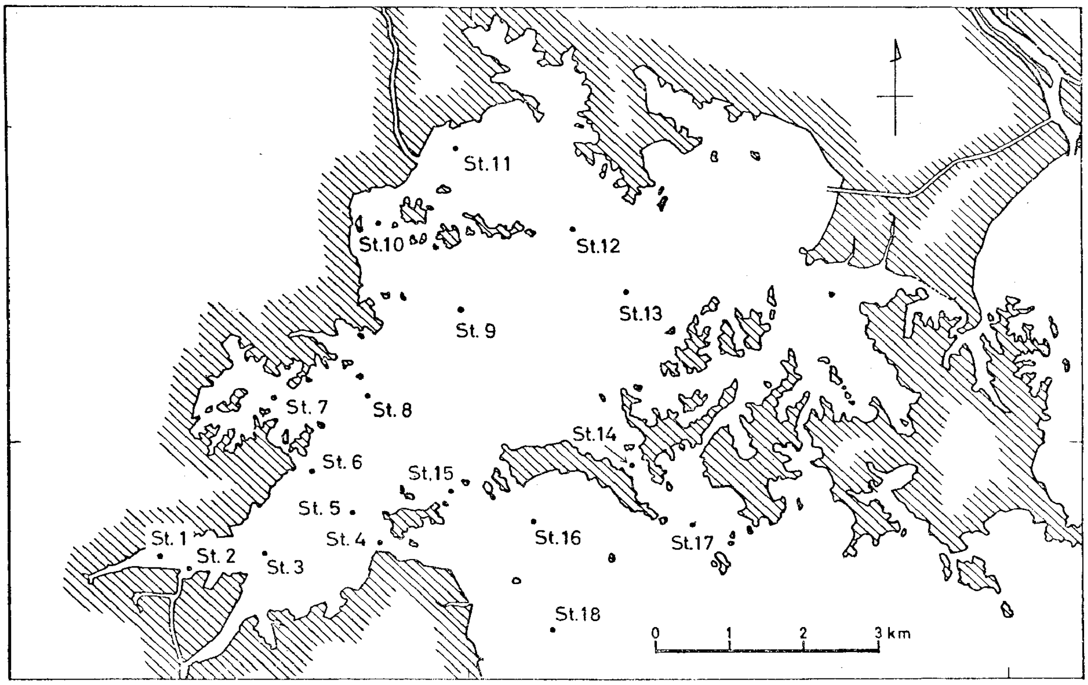

Fig. 8. Stations of the hydrographic observations made during **1964** to **1966**.

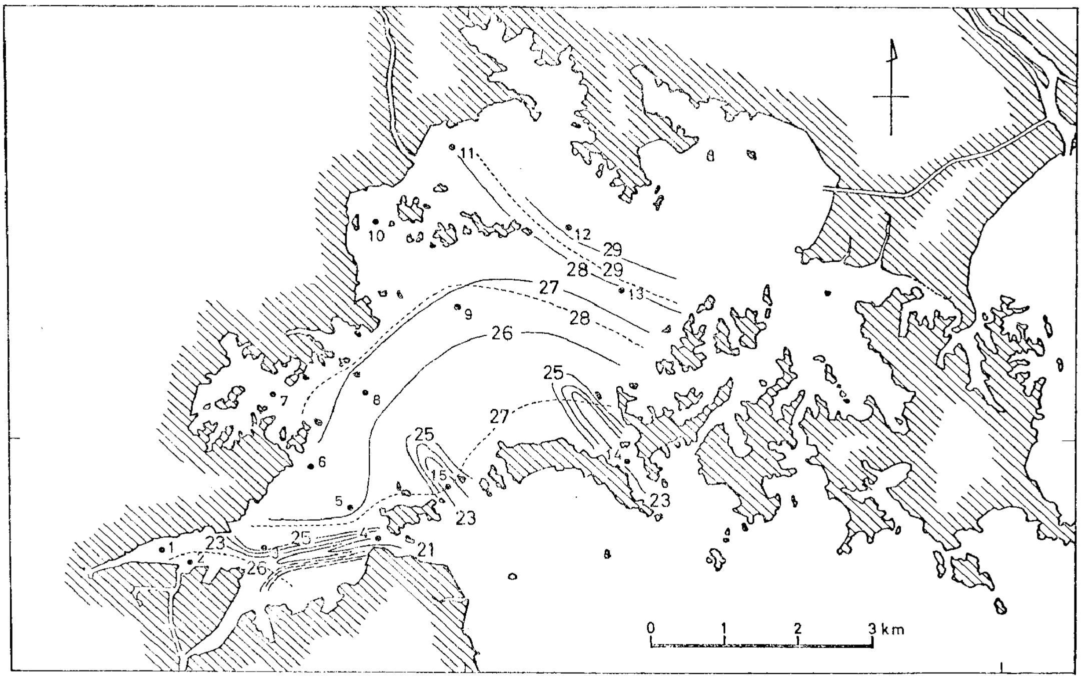

Fig. 9. Distribution of the surface (dashed line) and bottom (solid line) water temperatures (°C) in summer (Aug. 1, 1964).

early autumn and of larger temperature variation.

The approximate annual variation range of both temperature and chlorinity of the bottom water at each station were examined, and the stations having similar ranges were combined. By this procedure the stations can be classified into seven types of variation

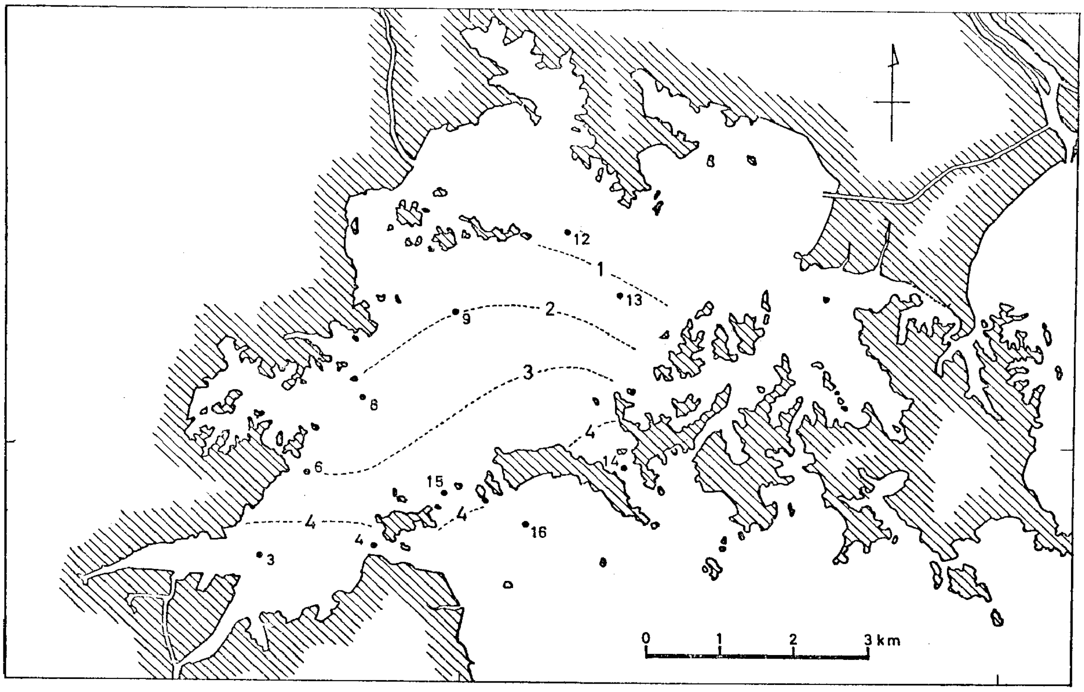

Fig. 10. Distribution of the surface water temperature (°C) in winter (Jan. 24, 1966).

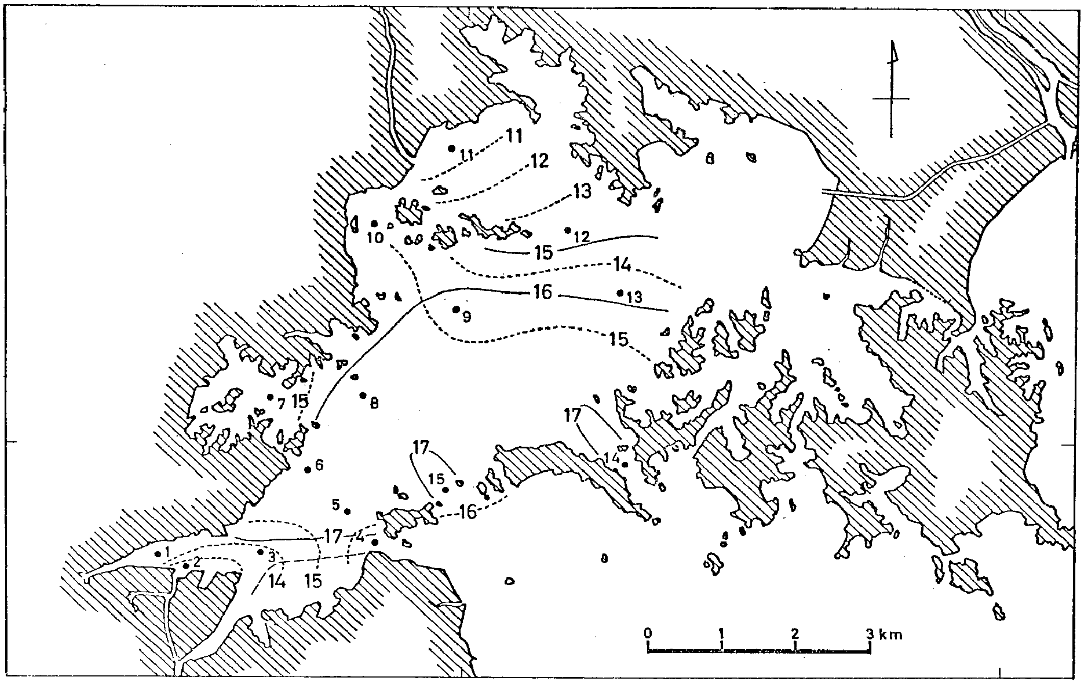

Fig. 11. Distribution of the average surface (dashed line) and bottom (solid line) water chlorinities (‰) in summer (July 7, 21, Aug. 1, 21, 1964).

ranges of T-Cl as shown in Fig. 16. In this procedure the data of the surface water of winter were used when no data of the bottom were available. The figures of each type are elliptical in (a) and (b) of the bay mouth area and foot-shaped inside the bay except for type (d) of Shiogama Harbor which is very large in chlorinity range and small in

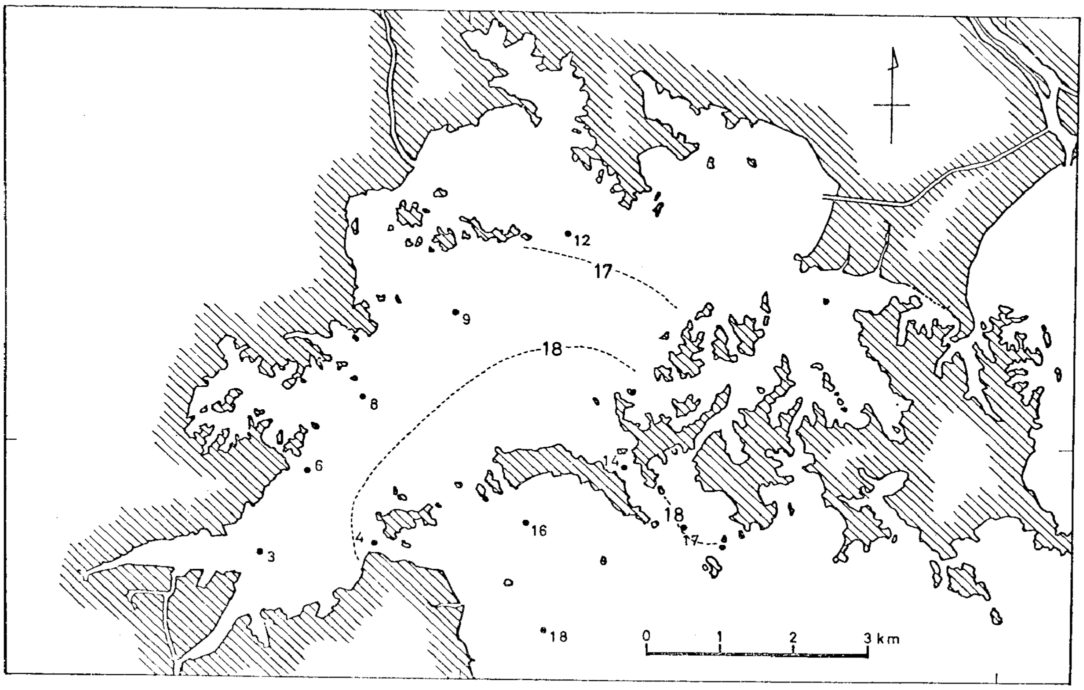

Fig. 12. Distribution of the average surface water chlorinity (‰) in winter (Dec. 20, 1965, Jan. 24, 1966).

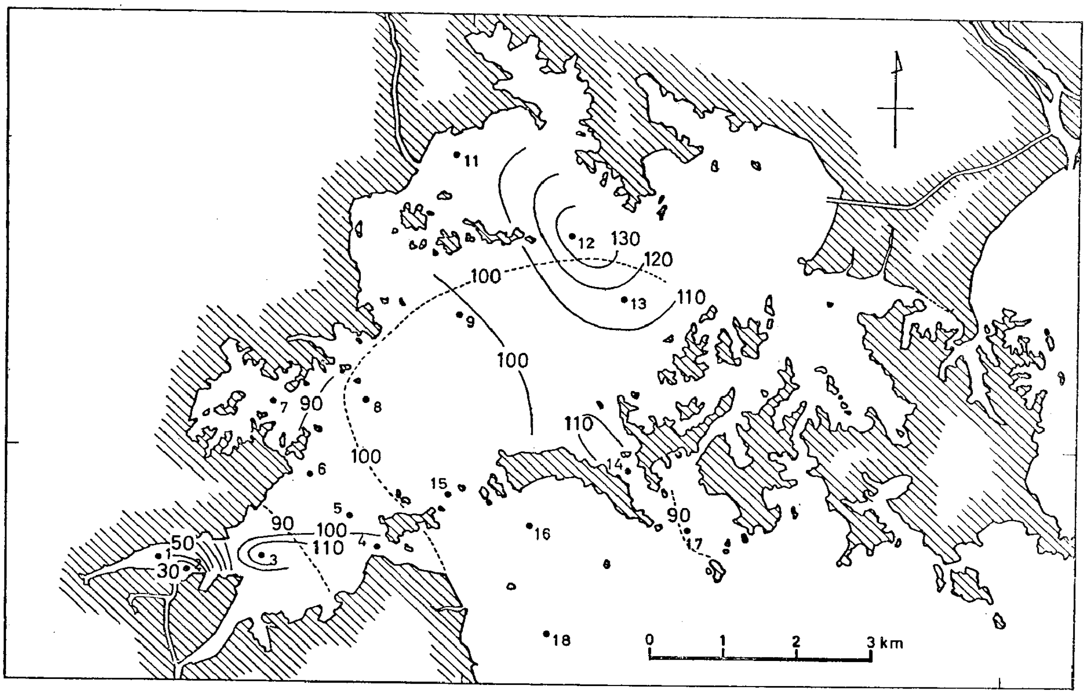

Fig. 13. Distribution of the average saturation rates (%) of oxygen of the bottom water in summer (solid line, July 7, Aug. 1, 1964) and the surface water in winter (dashed line, Dec. 20, 1965, Jan. 24, 1966).

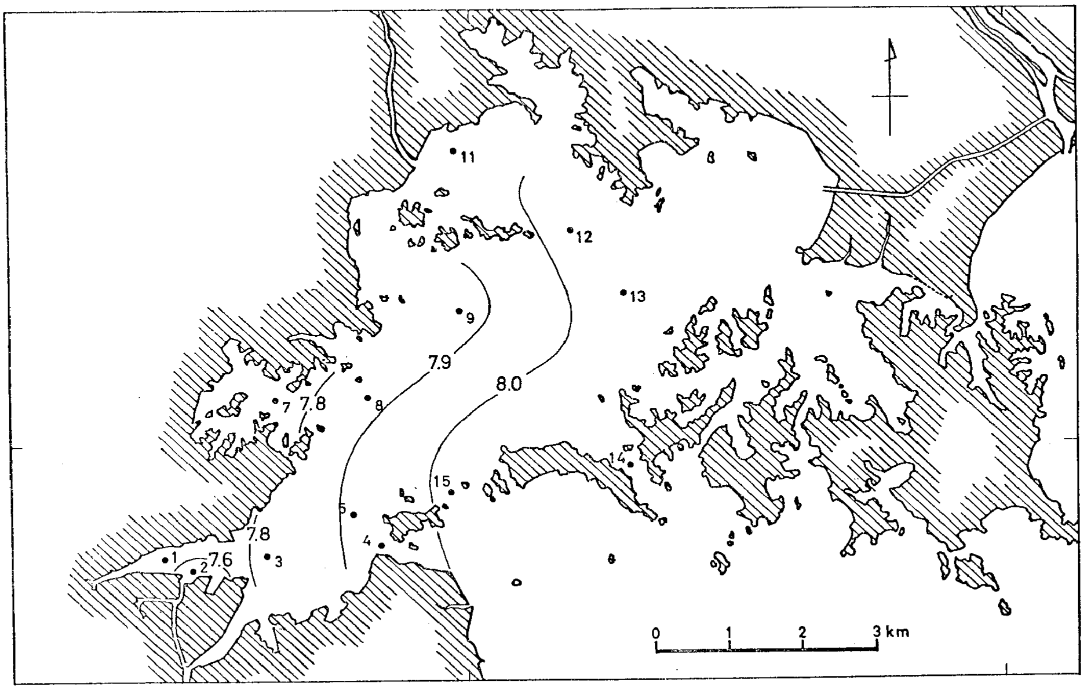

Fig. 14. Distribution of the average pH of the bottom water in summer (July 7, Aug. 1, 1964).

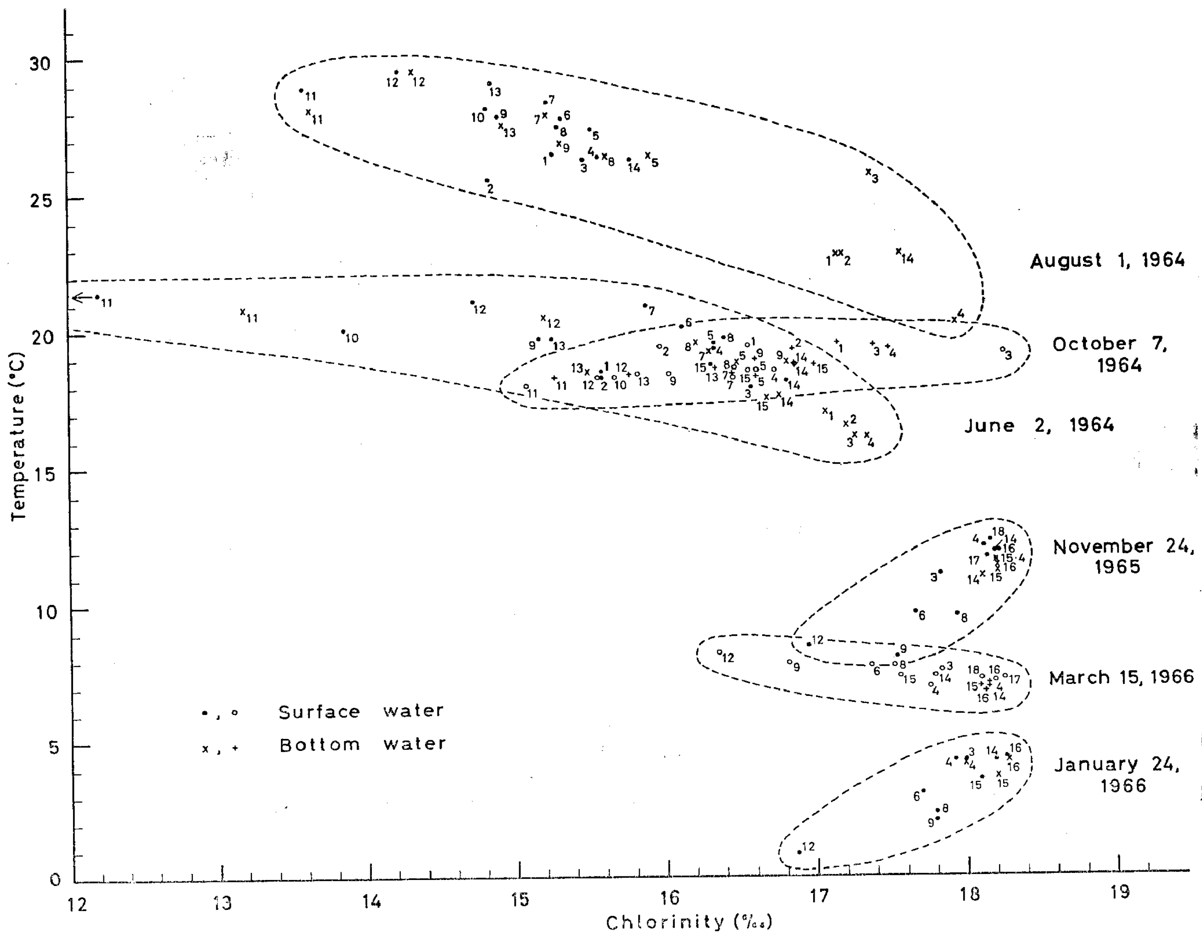

Fig. 15. Seasonal variation ranges of the temperature and chlorinity of the surface and bottom waters. Numerals in the graph are the station numbers shown in Fig. 8.

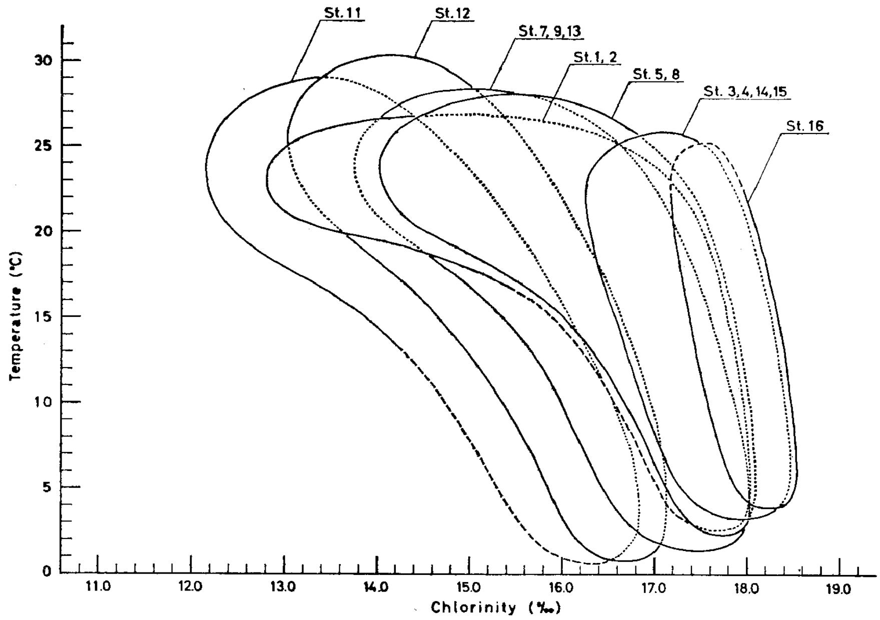

Fig. 16. Approximate variation ranges of the temperature and chlorinity of the bottom water at each station or group of stations shown in Fig. 8. Dashed line indicates assumed ranges.

Station 16 is type (a), Stations 3, 4, 14 and 15 are type (b), Stations 5 and 8 are type (c), Stations 1 and 2 are type (d), Stations 7, 9 and 13 are type (e), Station 12 is type (f) and Station 11 is type (g).

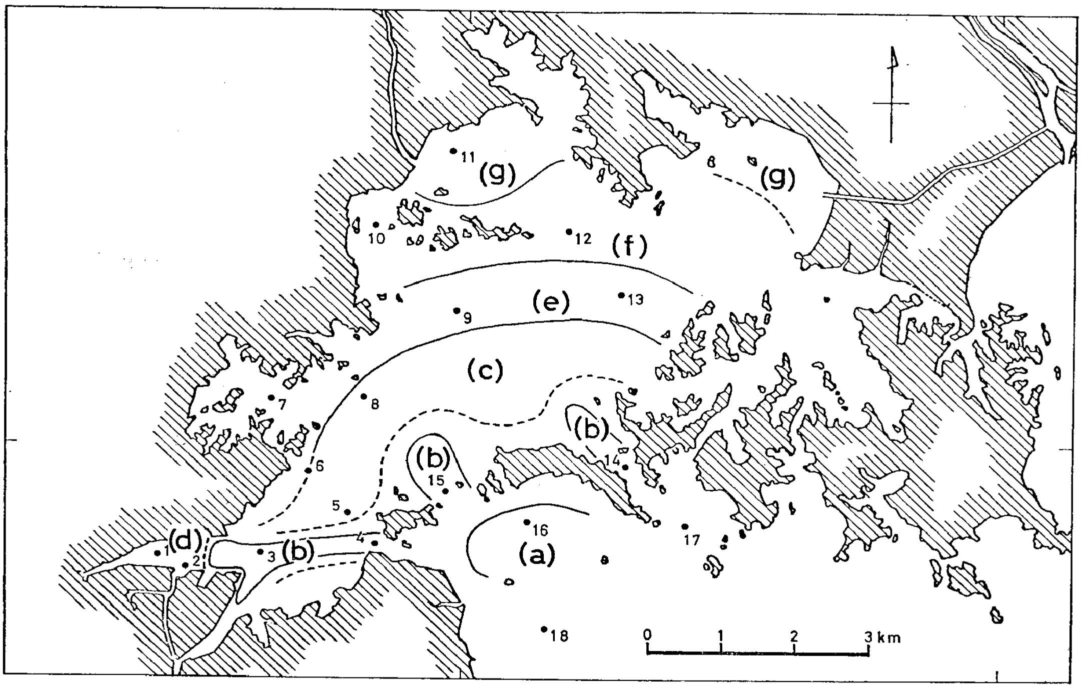

Fig. 17. Areal distribution of the bottom water characters in the variation ranges of the temperature and chlorinity shown in Fig. 16. Dashed line indicates assumed boundaries. Numerals in the figure are the station number.

temperature range. The peculiar figure of type (d) is caused by the mixing of the water from the deep channel with the inflow from the Teizan Canal. The geographic distribution of these water types are shown in Fig. 17. Near the bay mouth a type transitional between (b) and (c) is presumed from the chemico-physical oceanographical features.

SEDIMENTS

Mud content: The distribution of the ratio of mud contents of grain size of less than 53 μ is shown in Fig. 18, slightly modified from Kanno *et al.*, (1965). The ratios are about 70–90 percent in the larger part of the bay with a tendency of becoming higher from the bay mouth towards the inner parts and to exceed 90 percent in the inner bay except for at the river mouth. In the shallow areas just outside the bay coarser materials of fine to medium sand are distributed (Okuda and Sato, 1955).

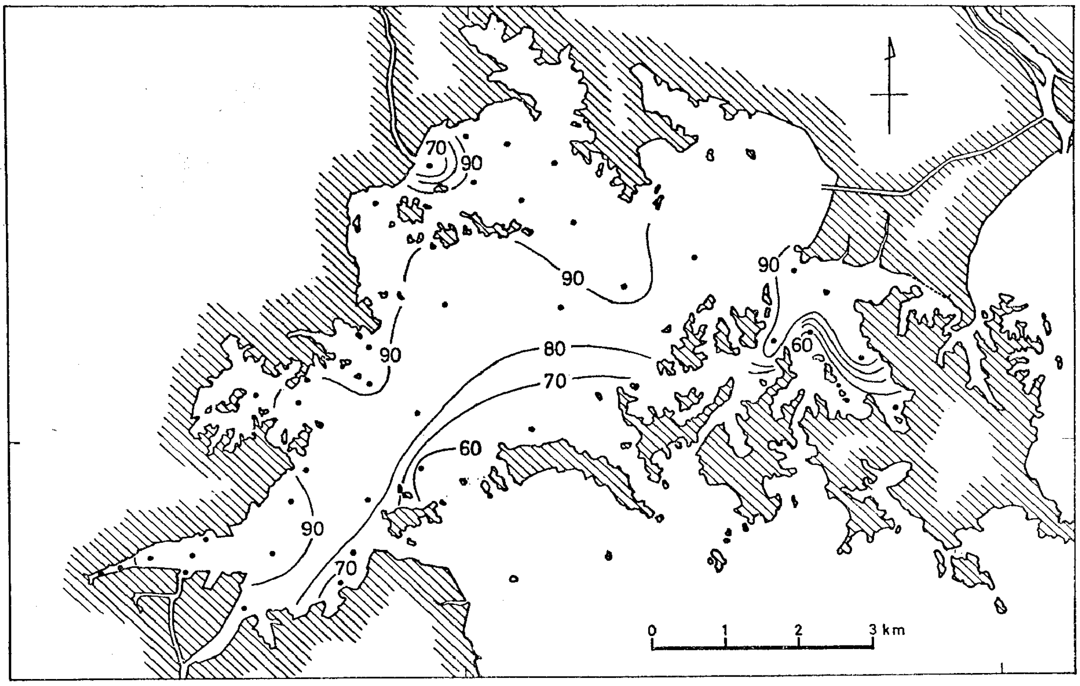

Fig. 18. Distribution of the mud content (%) of less than 53 μ of the surface sediments (partly modified from Kanno *et al.*, 1965).

Seaweeds show thick growth almost throughout the bay except in the areas of Shiogama Harbor and the bay mouth. *Zostera marina* occupies the larger part and *Z. nana* is found near the coast of the inner bay (Okuda and Sato, 1955; Yamamoto, 1955; Kitamori and Kanno, 1967).

Contents of organic carbon, total nitrogen and total sulfide: The distribution of the contents of organic carbon, total nitrogen and total sulfide of the bottom sediments are shown in Figs. 19–21 (after Kanno *et al.*, 1965). The organic carbon contents are 3–4 percent in most parts of the bay and 3 percent in the bay mouth area. At some places at the inner bay they exceed 4 percent and are much higher in the area of Shiogama Harbor. The content of total nitrogen is approximately 1–2 permil near the bay mouth and 2–3 permil in the middle bay, and exceeds 3 permil at places especially along the northwestern coast from Shiogama to Matsushima and in the area extending from the north middle part of the bay northwestwards. The total sulfide is 0.5–1.0 permil in the relatively large area of the middle part of the bay and less than 0.5 permil at the bay mouth. Contents higher than 1.0 permil are seen along the northwestern coast and in some areas in the middle part of the bay, among which the highest content of 6.0 permil is found in Shiogama Harbor.

From the data of the content of organic matter and sulfide it is obvious that the water

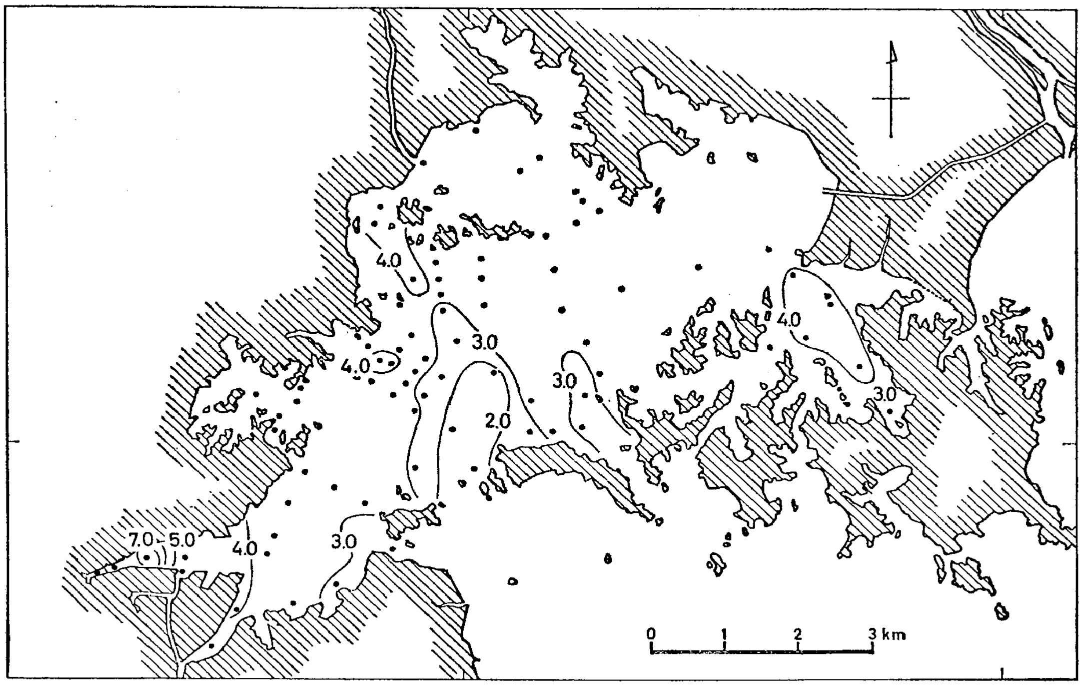

Fig. 19. Distribution of the organic carbon content (%) in the surface sediments (after Kanno *et al.*, 1965).

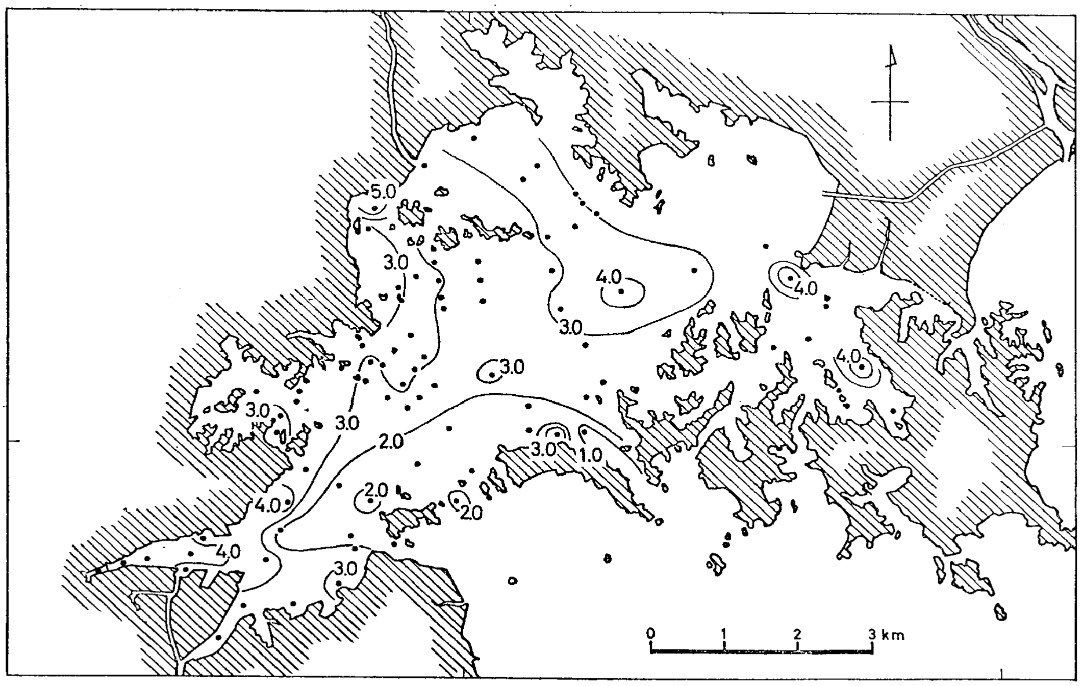

Fig. 20. Distribution of the total nitrogen (‰) in the surface sediments (after Kanno *et al.*, 1965).

of Shiogama Harbor is contaminated by the sewage of the city as pointed out by other workers (Kanno *et al.*, 1965). Kitamori and Kanno (1967) suggested that the influence of the sewage of Shiogama City extends northeastward along the coast. This may also be inferred from the distribution of pH (Fig. 14). Similar contamination by sewage is

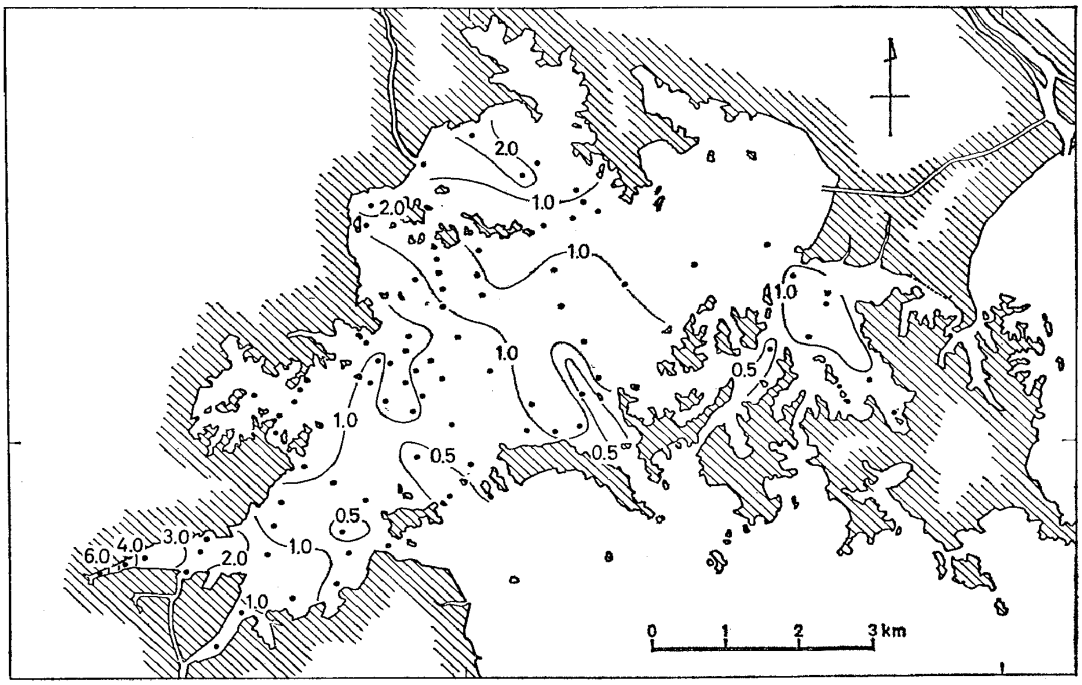

Fig. 21. Distribution of the total sulfide (‰) in the surface sediments (after Kanno *et al.*, 1965).

noticed from the sediments in a small area off Matsushima Town. The cause of the concentration of organic matter and sulfide in the bottom sediments of the bay is complicated. It is chiefly related to the hydrographic condition, the inflow of sewage and the decomposition of seaweeds (Okuda and Sato, 1955). The oyster rafts which are distributed in many areas in the bay are also related with the distribution of organic mattter and sulfide and with the water movement in the bay (Kanno *et al.*, 1965).

DISTRIBUTION OF THE FORAMINIFERA

PLANKTONIC FORAMINIFERA

A few empty tests of planktonic Foraminifera were found in some bottom samples; those were transfered in number per equal volume of sample (Table 3). Their geographic distribution is shown in Fig. 22. The total population of planktonic Foraminifera is almost confined in distribution in the bay to its outer part. They increase abruptly at the bay mouth especially near the widest channel between Katsura-shima and Mahanashi-shima where more than 50 specimens per sample with the maximum of 192 individuals were found. Their ratios to the total (planktonic + benthonic) Foraminifera are 0.3 to 2.2 percent.

Four planktonic species have been found in the bottom samples; *Globigerina bulloides* d'Orbigny, *G.* cf. *quinqueloba* Natland, *Globigerinoides tenellus* Parker and *Globigerinita glutinata* (Egger). Among them *Globigerina* cf. *quinqueloba* is most abundant. All the planktonic specimens of the bay have smaller size and thinner and rather transparent test wall compared with those of the open sea. No living specimens were found in the bottom sediments.

Phleger (1951) stated that planktonic Foraminifera are characteristic of offshore water masses, not abundant in the inner shelf water, and seldom caught in plankton tows in shoal areas. He also said that mixing of water at the edges of the currents of different

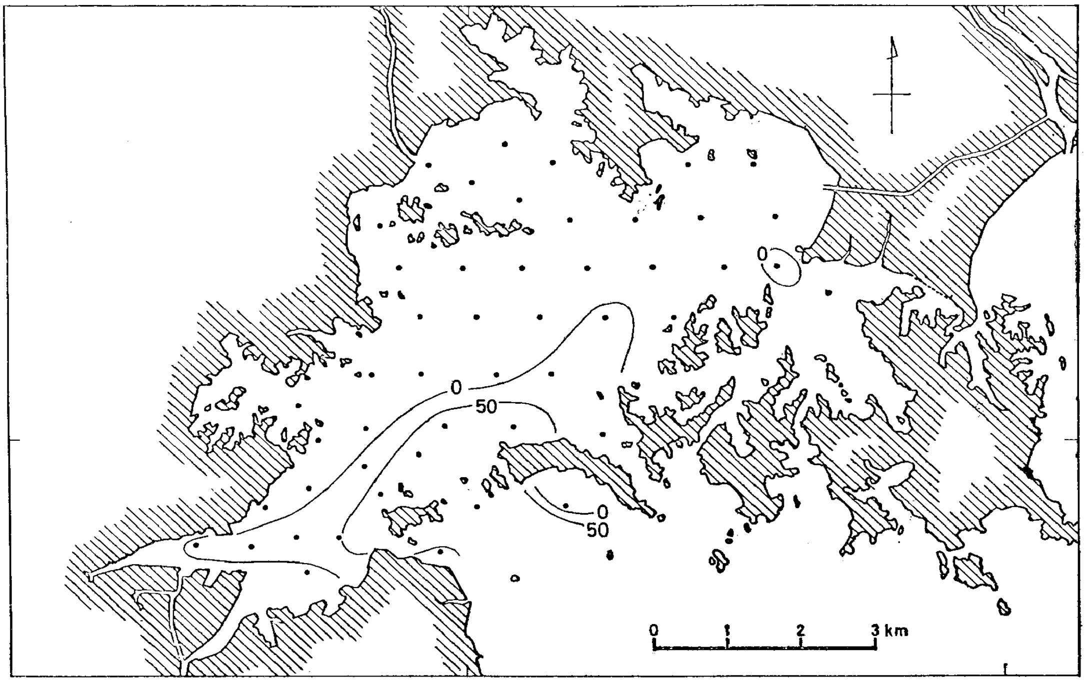

Fig. 22. Distribution of the planktonic Foraminifera in number of specimens per sample.

productivity may cause deposition of specimens which are killed because of unfavorable ecological conditions. Phleger (1954) reported planktonic Foraminifera in very low frequencies in the open-gulf facies of the Mississippi Sound area in the Gulf of Mexico and numerous small globigerinids with *Globigerinoides rubra* and *Globigerina bulloides* among them. Funnell (1967) suggested the possibility that the life cycle of planktonic Foraminifera may require a vertical migration through a deep water column, and that reproduction of planktonic Foraminifera might be inhibited in shallow-water, thereby allowing individuals to drift in from nearby oceanic waters and grow as long as the salinity and clarity of the waters was suitable, but will not reproduce. Planktonic Foraminifera found around the mouth of Matsushima Bay may not have lived or at least reproduced in the water directly above the area, but were probably transported into the bay from nearby waters of Sendai Bay.

BENTHONIC FORAMINIFERA

(1) General trends

Several parameters have proved to be useful for the interpretation of the ecology and significant for the distribution of the Foraminifera in Matsushima Bay. They are the size of the total and living benthonic populations the number of species and the agglutinated, calcareous porcelaneous and hyaline groups of benthonic Foraminifera.

Distribution of the total benthonic populations: The size of the total (living+dead) population shows a tendency to be largest at the bay mouth and to gradually decrease towards the inner parts of the bay (Fig. 23). The numbers of the total benthonic Foraminifera per sample are less than 1,000 individuals at the innermost part, a minimum of 53 specimens at the mouth of Takagi River (Ms 34) and amount to 1,000–4,000 in the middle bay area with variation in their number. At the bay mouth area the individual number rapidly increases to more than 5,000 and exceeds 10,000 in some samples. The total

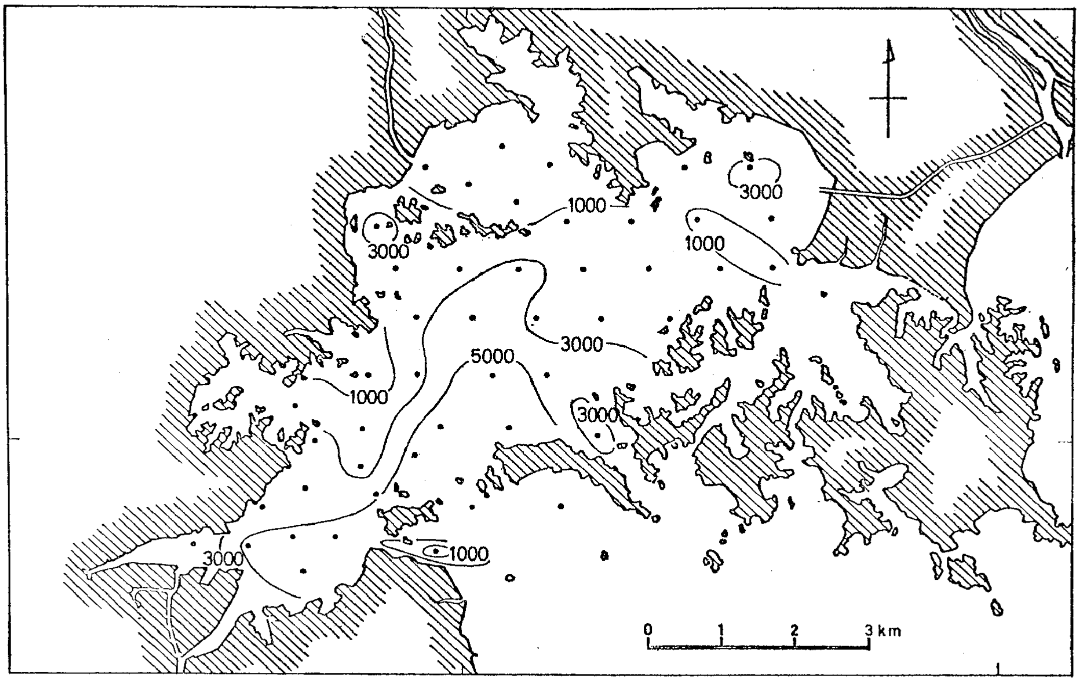

Fig. 23. Distribution of the total (living+dead) population of benthonic Foraminifera in number of specimens per sample.

populations of the samples from the bottom of the deep channels at the bay mouth are small (526 of Ms 20, 220 of Ms 13).

The general trend of the size of the total (living+dead) population diminishing in direct proportion to their relative distance from the entrance of the bay has been reported from Ago Bay (Morishima, 1948b, 1950), Tokyo Bay (Morishima, 1955) and many other bays. Although most Foraminifera are adapted to normal salinity of the open sea, as discussed later, the tests of the Foraminifera are diluted by detrital sediments from rivers at the inner parts of the bays.

In the present study the samples used are of equal wet volume. When these data are applied for the interpretation of paleoecology of consolidated rocks emendations are needed for the values, because equal wet volume at the original deposition is impossible and dry weight is most reliable for the unit sample for such rocks. The writer measured approximately from 3.5 g (clayey silt) to 15 g (pebbly sand) dry weight of some sediment samples collected by the already described methods from Sendai Bay. The dry weight of the middle to inner bay samples may be near the minimum value and those of the bay mouth area slightly larger except for Ms 22 which exceeds 10 g. Supposing the size of the total population per unit dry weight, the difference between the inner and the outer bay areas may become smaller but no consequent differences are probable in the trend.

Distribution of the living population: The distribution of the size of the living population, in general, is largest in two separated areas in the bay (Fig. 24) as can be seen by the isopleth for 300 specimens per sample; one in the inner-middle part of the bay where the maximum of 956 (Ms 37) was found, and the other in the bay mouth area where the maximum of 736 (Ms 21) was found. The smallest size populations are at the innermost parts of the bay; in Shiogama Harbor and the northernmost areas of the bay where less than 100 specimens were found. A minimum count of 8 individuals was found at the mouth of the Takagi River (Ms 34). The mean number of living specimens per sample is

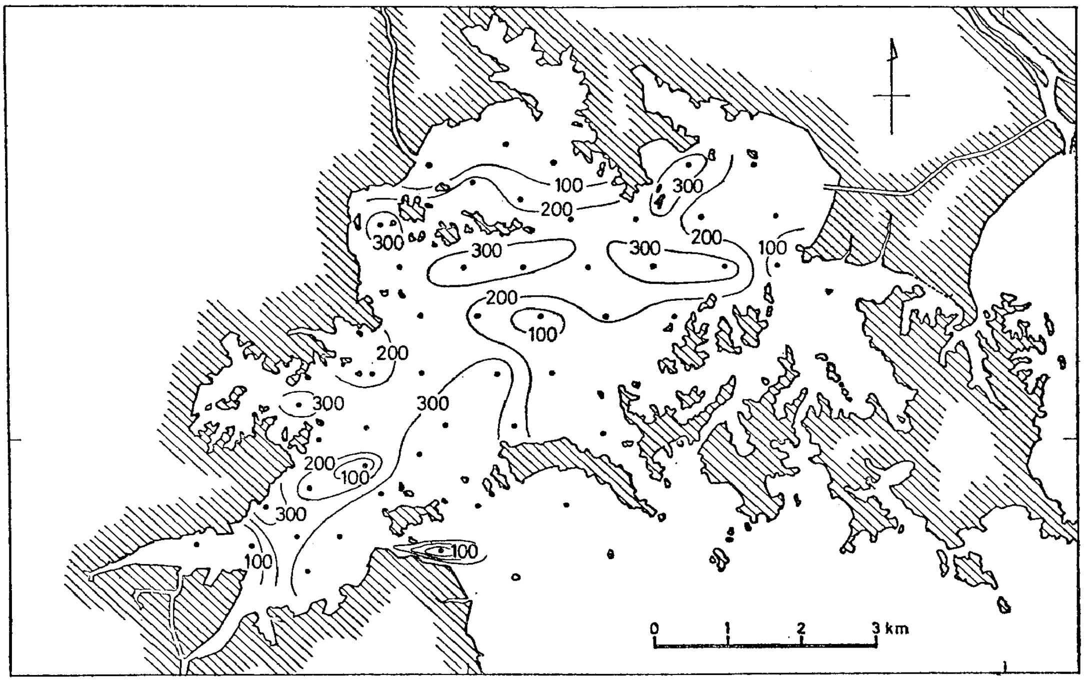

Fig. 24. Distribution of the living benthonic population in number of specimens per sample.

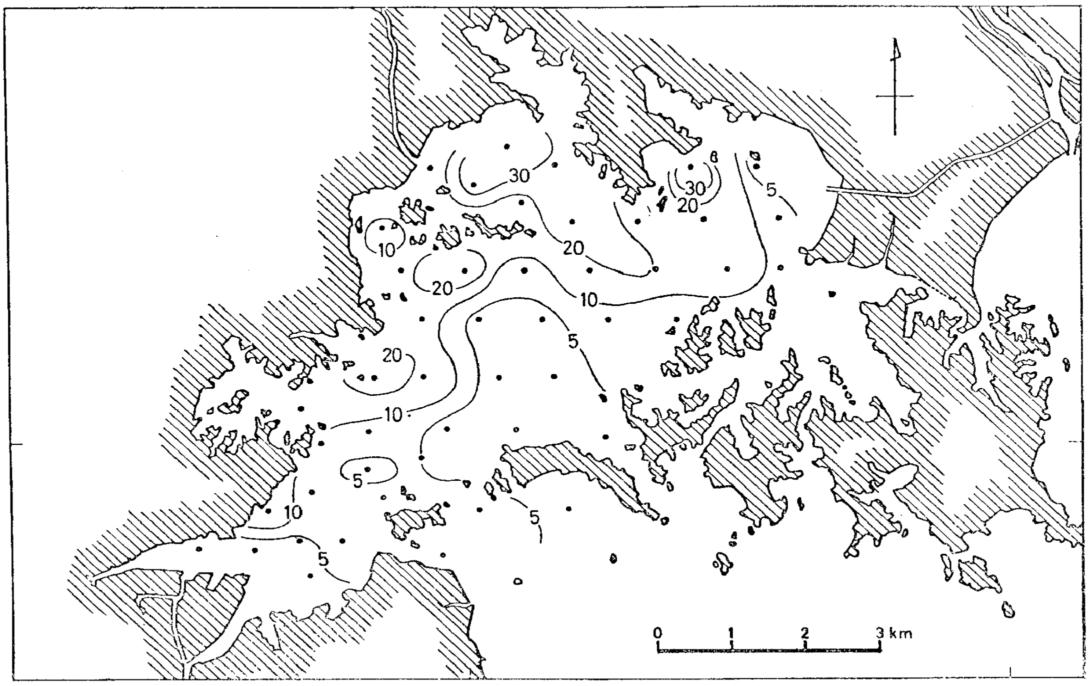

Fig. 25. Distribution of the ratio (%) of the living population to the total population (L/T).

258 in Matsushima Bay, excluding sample Ms 22 which was collected by a different kind of sampler.

Phleger (1955) reported the size of the living population of 0-474 specimens per sample in the shallow bays and the largest populations of 500–1,000 specimens per sample in the inshore part of the open-gulf stations in the southeastern Mississippi Delta area based upon

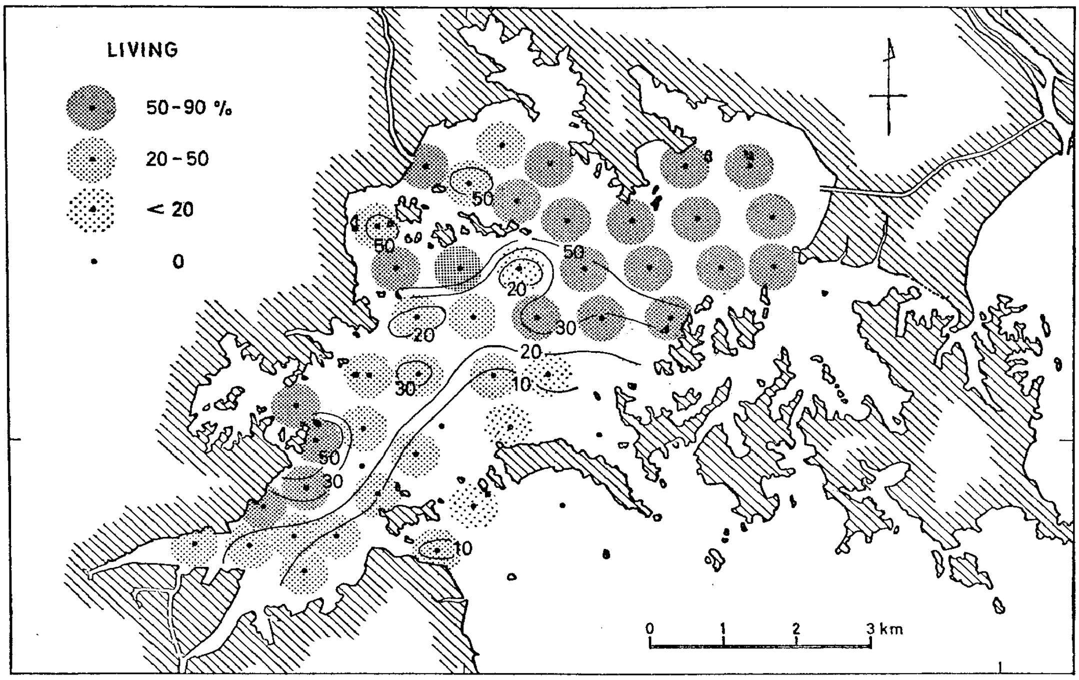

Fig. 26. Distribution of the ratio (%) of the agglutinated Foraminifera in total (isopleth) and living (shaded) populations.

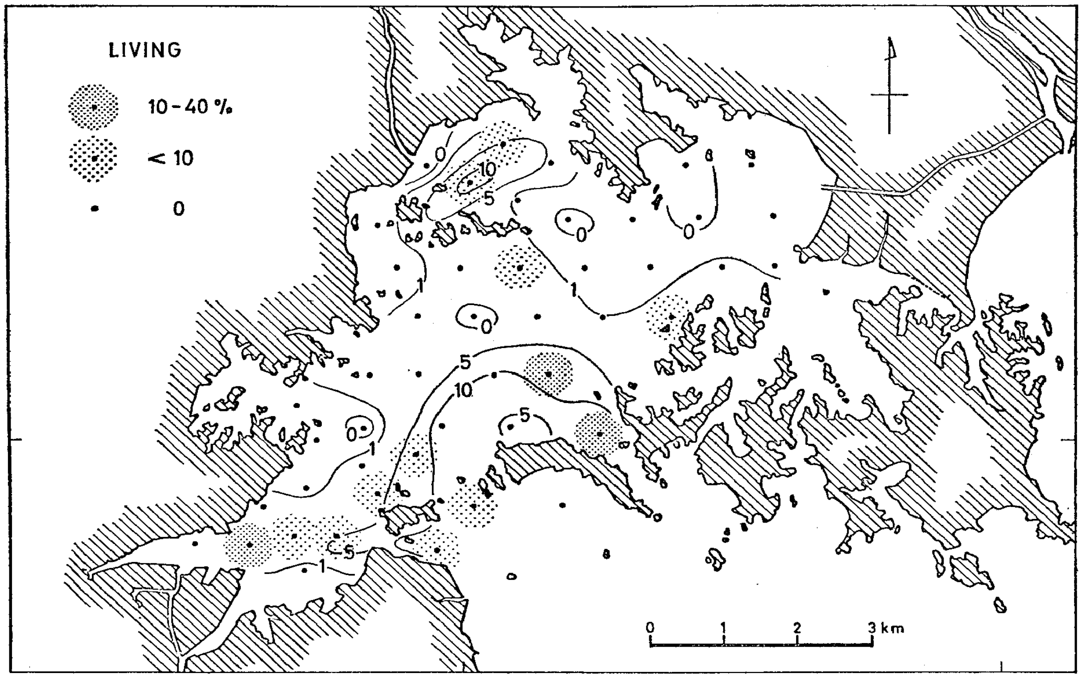

Fig. 27. Distribution of the ratio (%) of the calcareous porcelaneous Foraminifera in the total (isopleth) and living (shaded) populations.

the samples collected during two seasons (Nov.–Dec. and Apr.–June). He (1956) also reported approximately 50–200 living specimens per sample and the largest living population of 2579 specimens in San Antonio and other bays on the coast of Texas from the

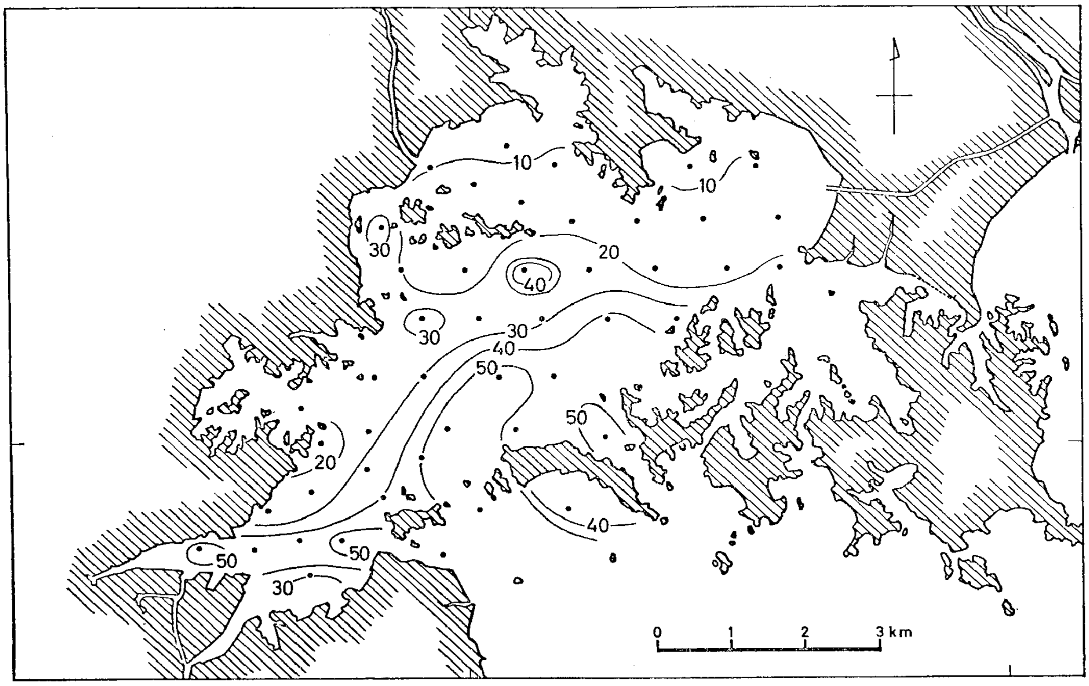

Fig. 28. Distribution of the number of species of the benthonic Foraminifera in the total population.

collection during June. His sampler and methods are almost the same as used in the present study. The number of living specimens per sample is subjected to seasonal variations as already reported by Walton (1955), Phleger and Lankford (1957) and Parker and Athern (1959). The living population of Matsushima Bay collected during a single season (Oct.–Nov.), however, do not seem to be much different from those reported by workers from other areas.

Distribution of the number of species of the benthonic Foraminifera: The number of species includes species, subspecies, varieties and forms. The distribution of the number of species in the total (living+dead) population is shown in Fig. 28. The number of species tends to be greatest or more than 50, maximum of 68 (Ms 13), at the mouth area of the bay and to gradually decrease towards the inner part and become less than 10, minimum of 7 (Ms 37), at the innermost part of the bay. The number is 10–50 in most areas of the bay. It is, however, noteworthy that large numbers of species extend to the inner part of Shiogama Harbor.

Morishima as the result of his studies on the Recent Foraminifera noticed this general trend in the distribution of the number of species in the bays of Japan (the inlets of Wakasa Bay, 1947, 1948a; Ago Bay, 1948b, 1950; Tokyo Bay, 1955). Takayanagi (1955) reported that the average number of species is 3 in the Matsukawa-ura lagoon, 24 in the mouth area of the lagoon, and 37 in the open shallow-sea area just outside the lagoon.

Distribution of agglutinated and calcareous porcelaneous Foraminifera: The benthonic Foraminifera here concerned are classified from their composition and types of test wall into agglutinated, calcareous porcelaneous and hyaline groups. Agglutinated and calcareous hyaline tests are dominant in Matsushima Bay. The agglutinated Foraminifera tend to be abundant in the inner part of the bay and to decrease towards the bay mouth (Fig. 26). The agglutinated Foraminifera in the population are more than 50 percent in the inner part of the bay, reach a maximum of 89 percent near the mouth of the Tona Canal (Ms 46), and decrease to 20-50 percent in the middle part of the bay. In the outer bay area the agglutinated

Foraminifera decrease abruptly and become less than 10 percent, the minimum being 0.7 percent (Ms 22). The agglutinated Foraminifera show similar distribution pattern to the number of species (Fig. 28), the size of the total population (Fig. 27) and in some extent to the size of the planktonic population (Fig. 22), but the abundancy trend is the reverse of them.

The calcareous porcelaneous Foraminifera have two separate areas of abundant occurrence; one in a small area of the inner part of the bay and the other at the bay mouth area as seen by the isopleth for 5 percent in Fig. 27. The maximum percentage in the total population is 10 in the innermost part (Ms 33) and 27 percent at the bay mouth area (Ms 20). In most parts of the bay the rates of the porcelaneous Foraminifera are 0–5 percent but this rather abruptly increases near the bay mouth to more than 10 percent.

(2) Specific faunal trend

The living population was distinguished by staining the samples collected during a single season. The post-moral movement of the foraminiferal tests on the muddy bottom overgrown with *Zostera* is not so expected, and the data show no important differences between the distribution of the living and total (living+dead) Foraminifera. For inland bays such facts were reported (Phleger, 1956; Ishiwada, 1958). Besides seasonal variations in the distribution of Foraminifera have been reported from several areas. It is, therefore, considered that the total (living+dead) population will give a better picture of the distribution of the Foraminifera than the living population because seasonal collections were not made.

For quantitative faunal analyses, the assemblages are usually realized as species combination and often denominated with the most dominant or important one or two species or genus name. According to the ecological conditions, however, the so called dominant species are actually variable in their dominancy. Sometimes it is difficult to pick up a few species from the assemblages as the dominant one(s) because the differences in the abundancy of the occurrence between taxa are small and the order of species in abundancy occurrence is sometimes reverse in samples of a certain assemblage. Therefore, the writer examined the abundancy occurrence of the species, the order of species in abundancy and the difference in the abundancy for each assemblage as related with station.

From the abundancy occurrences of the total (living+dead) Foraminifera three facies and six subfacies were distinguished in the bay; facies A or the outer bay facies, facies B or the middle bay facies and facies C or the inner bay facies including minor subdivisions in the latter two. In this faunal grouping, the species in the assemblage of each sample were arranged in order of abundancy occurrence, and those comprising 50 percent of the assemblage in cumulation of the percentages from the most abundant one were taken into account as to their taxonomic name, the order and the number of taxa (Table 2). One or two species succeeding to them but exceeds 50 percent in the assemblage in cumulation are added in parentheses to several samples for consideration if needed. Comparing the different species and their ranking in the abundancy occurrences with one another, as well as the number of taxa which indicates in general the difference in abundancy between taxa, of assemblange of each sample, a faunal grouping was attained (Table 2), and the geographic distribution of the respective facies and subfacies are shown in Fig. 29. The average frequency distributions of the important Foraminifera in those facies and subfacies are summarized in Fig. 30, and the characteristics of those facies and subfacies are described below.

Facies A (*outer bay facies*): Facies A, the outer part of the bay and the bay mouth area, extends to Shiogama Harbor and as sporadic occurrence in the middle part of the bay. This facies is characterized by *Pararotalia nipponica*, *P.* ? *minuta*, *Elphidium*

Table 2. Order of the abundancy occurrence and the number of species of benthonic Foraminifera in each sample which comprise more than 50 percent of each assemblage cumulating the frequencies from the first order, and faunal group. One or two species succeeding in order are added in parentheses for some assemblages.

Faunal group	Sample	Name and order of species comprising 50% of assemblage	Number of species
A	Ms 7	E_6-E_7-Pm-(E_5-A_2)	3
	Ms 12	Pm-A_2-E_4-E_5-Eg-E_6-Bu-E_1	8
	Ms 13	E_5-Aj-Pm-E_6-Pn-Bu-Qu-Rc-Tk	9
	Ms 14	Pm-E_6-Bu-A_2-E_5	5
	Ms 15	Pm-E_6-E_3-Pn-E_5-A_2-Bu-Rb-E_1	9
	Ms 16	Pn-Pm-E_6-E_5-Ci-A_2-Bu	7
	Ms 17	E_6-Pm-A_2-E_7-Bu	5
	Ms 18	E_6-Pm-E_5-Aj-Tj-A_1	6
	Ms 19	Pn-E_6-E_1-(Pm)	3
	Ms 20	E_6-Pm-Tk-Mi-Pn-Rv-E_7-Cy	8
	Ms 21	Pm-E_6-E_5-Pn-Rv-Aj	6
	Ms 22	Pn-Pm-Ci-(E_1)	3
	Ms 23	E_5-E_6-Pn-Tj-Th-Eg-Pm	7
	Ms 40	E_6-Pm-Eg-E_5-A_2-Aj-Ci	7
	Ms 56	E_6-Pm-A_2-E_5	4
B_1	Ms 2	A_2-E_6-Tj-Pm-E_5	5
	Ms 4	E_6-Tj-A_2-Aj	4
	Ms 6	E_6-A_2-Eg-(Tj-Th)	3
	Ms 24	E_6-Th-A_2-A_1(Tj)	4
	Ms 26	E_6-A_2-Tj-(Th)	3
	Ms 27	E_6-A_2-Tj-Gl-(Th)	4
	Ms 28	E_6-A_2-Tj-Bu	4
	Ms 55	A_2-E_6-Eg-Tj-E_2-Bu	6
B_2	Ms 11a	A_2-Bu-Th-Tj-Pm-(Eg-E_6)	5
	Ms 11b	Eg-Tj-Bu-A_2-(Aj-Th)	4
	Ms 39	Tj-Th-A_2-Eg-(Bu-E_6)	4
	Ms 43	A_2-Tj-Eg-Th-Bu-(E_6)	5
C_1	Ms 3	Tj-Th-A_2-(A_1-E_6)	3
	Ms 5	Th-E_6-Tj-(A_2)	3
	Ms 25	Tj-Th-(A_2-E_6)	2
	Ms 29	Tj-Th-(E_6-A_2)	2
	Ms 30	Tj-E_6-Th-(A_2)	3
	Ms 31	Th-Tj-(E_6-A_2)	2
C_2	Ms 8	Tj-Th-(A_2-Eg)	2
	Ms 9	Th-Tj-(A_2-Eg)	2
	Ms 10	Tj-Th-(Eg-A_2)	2
	Ms 32	Th-Tj-(A_2)	2
	Ms 38	Tj-Th-(A_2-Eg)	2
	Ms 44	Th-Tj-(A_2-Eg)	2
	Ms 45	Th-Tj-(A_2)	2
	Ms 47	Tj-Th-(A_2)	2
C_3	Ms 37	Tj-(Th-A_2)	1
	Ms 46	Th-(Tj)	1
C_4	Ms 33	A_2-Va-Tj-(Th)	3
	Ms 34	Tj-A_2-Th-(A_1)	3
	Ms 35	Tj-A_2-(Th)	2
	Ms 36	Th-A_2-(Tj)	2

Table 2 (Continued)

Abbreviations of the species names listed in the table.

A_1:	*Ammonia beccarii* forma 1	A_2:	*A. beccarii* forma 2	Aj:	*A. japonica*
Bu:	*Buccella frigida*	Ci:	*Cibicides lobatulus*	Cy:	*Cyclogyra planorbis*
Eg:	*Eggerella scabra*	E_1:	*Elphidium crispum*	E_2:	*E. kusiroense*
E_3:	*E.* cf. *kusiroense*	E_4:	*E.* cf. *reticulosum*	E_5:	"*E*". *somaense*
E_6:	*E. subarcticum*	E_7:	*E. subarcticum* var.	Gl:	*Glabratella* cf. *chasteri*
Mi:	*Miliolinella* ? sp.	Pm:	*Pararotalia*? *minuta*	Pn:	*P. nipponica*
Qu:	*Quinqueloculina* cf. *curta*	Rb:	*Rosalina bradyi*	Rc:	*R. columbiensis*
Rv:	*R. vilardeboana*	Th:	*Trochammina hadai*	Tj:	*T.* cf. *japonica*
Tk:	*Tiphotrocha kellettae*	Va:	*Valvulineria hamanakoensis*		

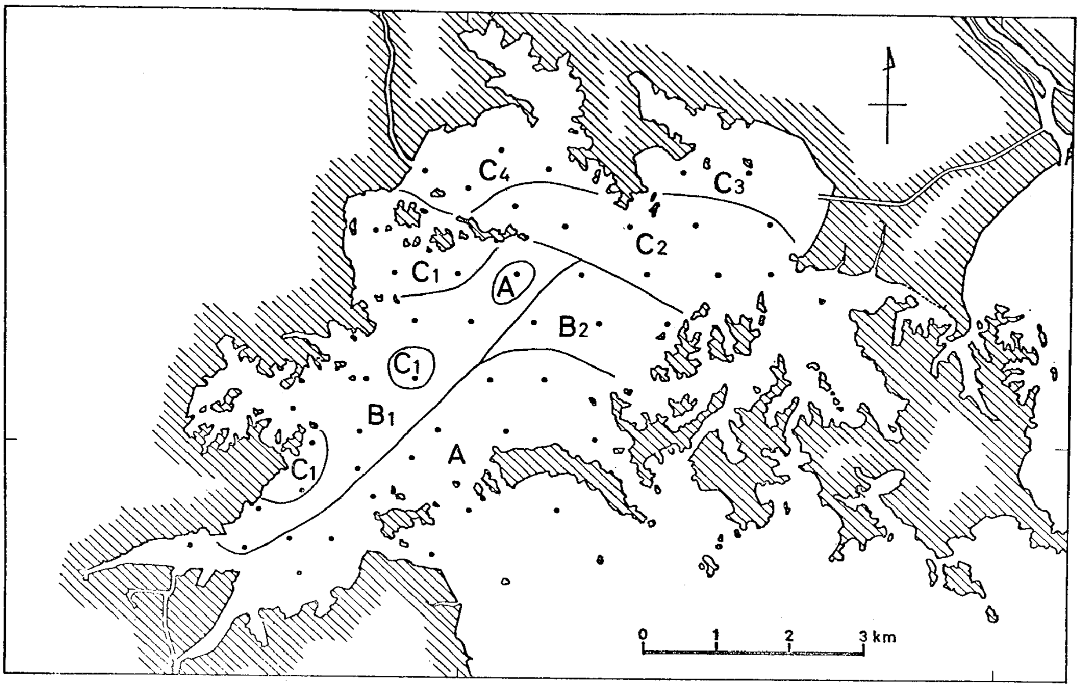

Fig. 29. Distribution of the distinguished foraminiferal facies and subfacies. Facies A, B and C are the outer bay, middle bay and inner bay facies respectively.

subarcticum, "*E.*" *somaense*, *E. crispum*, *Ammonia japonica*, *A. beccarii* forma 2, *Nonionella stella*, *Buccella frigida*, *Eggerella scabra*, and *Trochammina* cf. *japonica*. *Pararotalia nipponica* and *P.* ? *minuta* are the most important species of the fauna and in the assemblages of all samples either or both ranks at the top to third in abundancy. The two species as well as others are distributed also in the other facies. *Trochammina* cf. *japonica*, *Eggerella scabra*, *Elphidium subarcticum* and *Buccella frigida* which occur in this facies are most abundant in the other facies. The species which are known in the open shallow-seas and occur in the assemblage of this facies but in low frequencies are, *Rosalina bradyi*, *R. vilardeboana*, *Ammonia ketienziensis*, *Buccella*? *makiyamae*, *Pseudononion japonicum*, *Buliminella eleganitissiuma*, species of *Glabratella*, and most species of the miliolids, etc.

The number of species comprising 50 percent of each assemblage is the largest in facies A but the number varies from 3 to 9 species. The total number of species of more than 40 is largest in this facies. The large number of species, the rather variable composition or order of the dominant species in the samples are the characteristics of this facies. This facies is also characterized by the fewest occurrence of the agglutinated Foraminfera (less

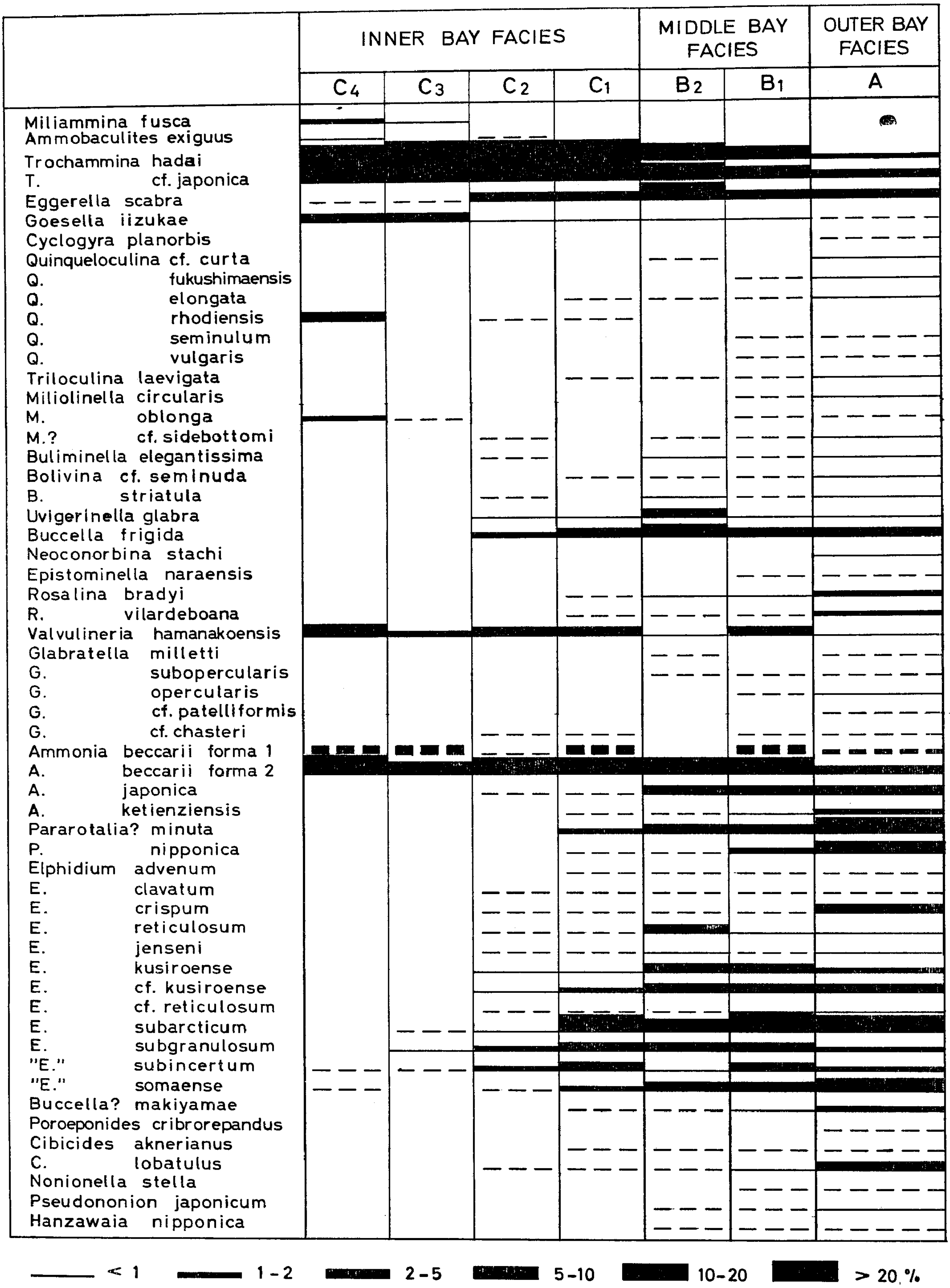

Fig. 30. Generalized frequency distribution of the important benthonic Foraminifera (in the total population) in facies and subfacies. Dashed line indicates the sporadic occurrence in each facies and subfacies.

than 20%, usually less than 10%). The planktonic Foraminifera are almost confined to this facies.

Facies B (middle bay facies): Facies B, in the middle part of the bay, is characterized by the mixed occurrences of forms of the inner and outer facies. No species characterizes this facies so far as is concerned the restriction or most dominant occurrence of the species, but a few species show relatively higher abundancy in this facies than the others. *Ammonia beccarii* forma 2, *Elphidium subarcticum, Trochammina hadai, T.* cf. *japonica, Eggerella scabra*, and *Buccella frigida* are the dominant species of this facies. This facies is also characterized by the intermediate occurrence of agglutinated Foraminifera at the level of 20–50 percent and the intermediate number of species at the level of 20–40 percent. Four or five forms comprise 50 percent of the assemblage but in some samples the number of species is 3 to 6. This facies is subdivided into two subfacies by the composition of the dominant forms.

Subfacies B_1 is situated at the western part of the middle-bay and is characterized by the dominance of *Elphidium subarcticum* and *Ammonia beccarii* forma 2. The former species is most dominant in almost all samples accompaning the latter. *Trochammina* cf. *japonica* and *T. hadai* are next in abundance. Subfacies B_2 is at the eastern part of the middle-bay and is distinguished from subfacies B_1 by the less occurrence of *Elphidium subarcticum* and fairly abundant occurrence of *Eggerella scabra, Buccella frigida, Uvigerinella glabra* and *Elphidium hokkaidoense.* The dominant species vary greatly but *Trochammina* cf. *japonica* and *T. hadai* are also abundant.

Other forms which are found in facies A and B rather abundantly are *Ammonia japonica, Pararotalia minuta, Elphidium kusiroense, E.* cf. *kusiroense, E. subgranulosum* and *"E." somaense. Valvulineria hamanakoensis* is most abundant in the inner bay facies but is also found in subfacies B_1 rather abundantly. Many other forms of open shallow-sea types which characterize facies A extend to this facies and the next inner bay facies especially to its outer part with rare and sporadic occurrence.

Facies C (inner bay facies): Facies C, the inner part of the bay and two small areas in the middle-bay area, is characterized by the dominant occurrence of *Trochammina hadai, T.* cf. *japonica* and *Ammonia beccarii* forma 2. The agglutinated Foraminifera are very abundant and occure at the level of more than 50 percent. The number of total species is few, commonly less than 20, and one to three forms comprise 50 percent of the assemblage in each sample. This facies is subdivided into four subfacies.

Subfacies C_1 is off Matsushima and in small areas in the middle-bay and is characterized and distinguished from the other subfacies by the abundant occurrence of *Elphidium subarcticum* in addition to *Trochammina* and *Ammonia beccarii* forma 2. Many forms which are seen in facies A and B are also found in this subfacies and *Eggerella scabra, Buccella frigida, Valvulineria hamanakoensis, Elphidium subgranulosum,* and *"E." subincertum* are fairly abundant. Two or three forms comprise more than 50 percent of the assemblage. Subfacies C_2 is at the eastern side of subfacies C_1 and differs from it by the very rare occurrence of *Elphidium subarcticum. Eggerella scabra* and *Valvulineria hamanakoensis* are next in abundant to the three species of *Trochammina* and *Ammonia.* Several open shallow-water type forms extend to subfacies C_1 and C_2 but are generally rare and sporadic in occurrence, and most of them are limited in inward distribution to subfacies C_1 and C_2. Two forms comprise more than 50 percent of the assemblage of subfacies C_2.

Subfacies C_3 at the mouth of the Tona Canal is characterized by the dominant occurrence of either *Trochammina hadai* or *T.* cf. *japonica,* comprising more than 50 percent with one species, and *Ammonia beccarii* forma 2 is next in abundance to the two species of *Trochammina. Miliammina fusca* and *Goesella iizukae,* both brackish-water species, occur in this subfacies. Subfacies C_4 is at the mouth of the Takagi River and is distinguished from the other subfacies of facies C by the relatively more abundant occurrence of *Ammonia beccarii* forma 2, and this form ranks at the top or the second in abundancy. Two or three species comprise more than 50 percent of the assemblage. The occurrence of the brackish-water species, *Miliammina fusca*, *Ammobaculites exiguus*, *Goesella iizukae* and *Quinqueloculina rhodiensis* are characteristic of the subfacies. *Valvulineria hamanakoensis* seems to be most abundant in this subfacies though it occurs in facies B and C rather abundantly. The open-sea species are almost absent in subfacies C_3 and C_4. *Ammonia beccarii* forma 1, both living and dead, occurs in subfaces C_1, C_3 and C_4 in the inner part of the bay rather abundantly, and also in some parts of subfacies B_1 to facies A near the bay mouth.

(3) Non-specific faunal trend

Walton (1964) stated, "In contrast to criteria based on specific and generic characteristics, the following characteristics are free of such restrictions as evolutionary changes and changes in environmental tolerance of modern species and genera back through geologic history." He continued, "The basic ecological principle involved is that animal populations, regardless of their species composition, have characteristics that reflect the variability of their environment (*i.e.*, the degree of variation of many physical, chemical, and biological factors that characterize a particular environment). In modern oceans, environmental variability is related to distance offshore and depth of water — that is, as the shoreline (marginal-marine condition) is approached and depth decreases, the environements become more variable. As the shoreline and marginal-marine conditions have existed in all oceans throughout geologic time, modern faunal characteritics which result from the variability of the environment will be valid regardless of the species composition of geologic age of the fauna." And he introduced the two concepts of "faunal dominance" and "faunal diversity" as faunal measures.

Among several laws concerning the quantitative study for faunal constitution, Motomura's law has been widely accepted by Japanese ecologists. Motomura (1932) proposed the law of geometrical progression of the population density in an animal association, and established the formula, $\log y + ax = b$, between the rank of dominance of species (x) and their correspondent density of species (y), where a is a constant meaning diversity of the community and was considered by some workers to express the intensity of competition among species, and b represents a sort of population density. As b is merely an abstract expression the equation was modified as $\log y + a\ (x-1) = b_1$ (Hamai, 1955; Ujiié, 1962), here b_1 shows a logarithm of the theoretical number of individuals of the most abundant species. The law of geometrical progression has been ascertained to be well substantiated in the biotic communities of many taxa having nearly the same niche and individual size with one another, and in the samples of small size (Shinozaki, 1955). Ujiié (1962) applied the law to the fossil foraminiferal populations from the Holocene Yurakucho Formation, and with other statistical analyses successfully demonstrated a slight but significant faunal change within an environment compared to the middle bay fauna of the Recent Tokyo Bay.

The writer attempted to apply the law to the total population of benthonic Foraminifera from Matsushima Bay with the purpose to faunal division for application for fossil populations in a simplified method. Instead of the number of specimens the percentage frequencies of each form were taken (y) in logarithm and plotted against their rank in dominance (x) in the graph disregarding forms less than 2 percent in abundancy. Many samples seem to fit the law showing a straight line (Fig. 31a-e) but some show a concave curve of a logarithmic series type (Fig. 31f). Supposing all the populations fit the law without statistical examination, a straight line was written intuitively in each graph. a expresses a tangent of the angle of inclination of the line and, for an expedience, "a" is

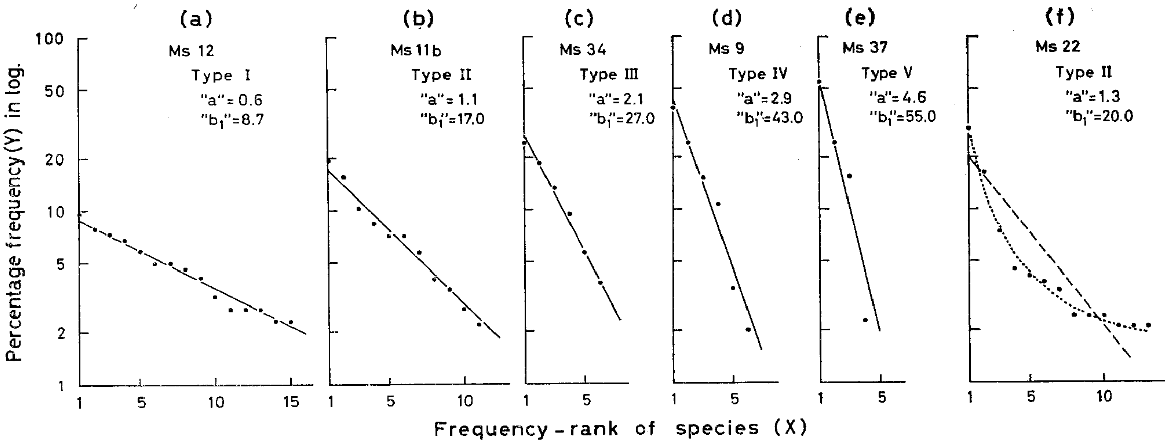

Fig. 31. The relation between percentage frequencies of each species (y) in log. and their frequency-rank (x) in the total population in some samples. Forms less than 2.0% in frequencies are neglected.

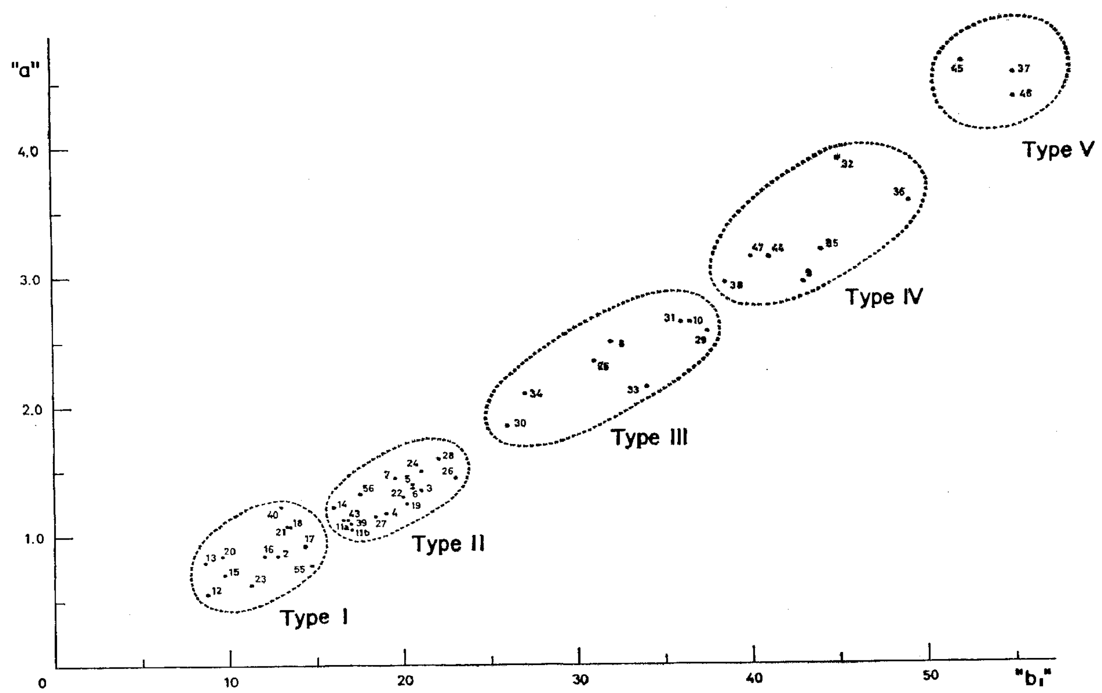

Fig. 32. The relation between the constants "a" and "b_1" in the law of geometrical progression. Numerals by the dots in the graph are the sample number.

substituted for a measured in the graph. Similarly "b_1" is measured in the graph. Thus "a" is not an absolute value but a relative one and is comparable only in this work, and "b_1" is of approximation. Then the values of "a" and "b_1" measured from all samples were plotted in another graph (Fig. 32), which exhibits a linear distribution of the dots. All samples were tentatively divided into five types in the graph; type I is less than 1.3 in "a" and less than 15 in "b_1", type II is 1.0–1.8 in "a" and 15–24 in "b_1", type III is 1.8–2.8 in "a" and 24–38 in "b_1", type IV is 2.8–4.0 in "a" and 38–50 in "b_1", and type V is more than 4.0 in "a" and more than 50 in "b_1".

The geographic distribution of these faunal types (Fig. 33) shows a systematic pattern, resembling the distribution of the biofacies (Fig. 29). Type I approximately corresponds to facies A and type II to facies B, but does not indicate the differentiation of

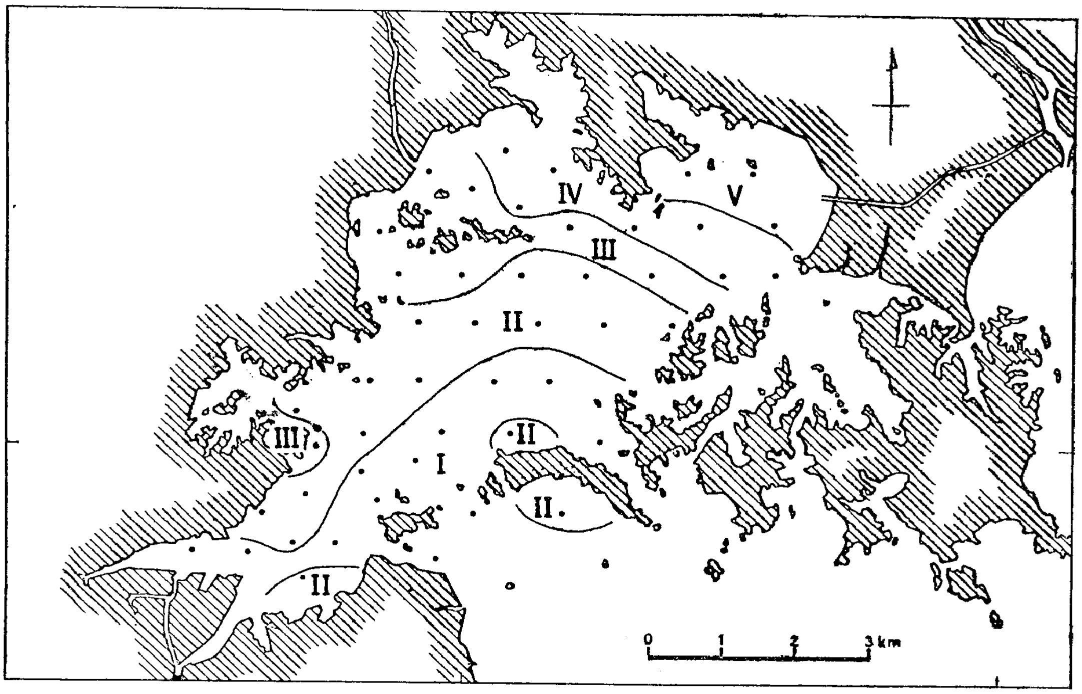

Fig. 33. Geographic distribution of Types I-V shown in Fig. 32.

subfacies B_1 and B_2. Type III, IV and V correspond to facies C but the subdivisions of the biofacies do not coincide with them excepting the type V and subfacies C_3. Further the distribution of these faunal types has a trend similar to the distribution of the other non-specific characteristics such as the distribution of the agglutinated Foraminifera (Fig. 26), number of forms (Fig. 28), distribution of the planktonic Foraminifera (Fig. 22), and the distributional trend of the bottom water character indicated by the temperature and chlorinity (Fig. 17).

RATIO OF THE LIVING POPULATION

The possibility of using the ratio of the living population to the total population as a measure of the relative rate of sedimentation has been discussed by Phleger (1951). He (1955) stated on the general coincidence of the relative rates of sedimentation shown by the percentage of the living population and the sedimentation rates inferred from the depth changes as recorded on charts covering the period 1860–1962 in the southeastern Mississippi Delta area. Walton (1955) suggested that the ratio of the living population to the dead population was a good index for the relative rates of sedimentation and he described the relation with the sediment types in Todos Santos Bay, Baja California.

The areal distribution of the living populations in percentage of the total Foraminifera (L/T) in the top one centimeter of the short cores from Matsushima Bay is shown in Fig. 25. A large living population relative to the total population should indicate relatively rapid dilution with the sediments, and a small one relative to the total should indicate a slow rate of supply of the sediments. The area of higher L/T value at the level of more than 10 percent is in the northern (inner) half of the bay, and values of more than 20 percent are in some areas of the innermost bay. In the southern (outer) half of the bay the values of L/T are lower than 10 percent; but less than 5 percent in several samples. This suggests that more sediments are being deposited at present in the inner part of the bay. Among the three drainages of land waters, the Takagi River is more important than the Tona and

Teizan Canals as can be noticed from the distribution of the current directions (Figs. 6, 7) and chlorinity distribution of the surface water (Fig. 11). Therefore the Takagi River must be supplying a large part of the sediments of the bay.

DISCUSSION

FORAMINIFERA AND ENVIRONMENTS

Presentation of data: For the quantitative analyses of Foraminifera, there seems to be no standard method concerning the presentation of the species occurrence and the type of sample from which the count of Foraminifera should be made. Each author uses the method most suitable for his purpose and for this reason it is difficult for different workers to correlate their results with one another. Some authors represent species occurrences in percentage in each population (Hada, 1936; Morishima, 1948; Parker, 1948; Phleger, 1951; Bandy, 1954; Ishiwada, 1958; Uchio, 1959), and others with the number of specimens in a sample of equal dry weight (Said, 1950; Kuwano, 1954–54; Takayanagi, 1955; Morishima, 1955) or equal volume (Walton, 1955; Kuwano, 1962–63). Similarly, to represent the actual abundance of the population two methods have been used; one sample per equal dry weight (Said, 1950; Takayanagi, 1955; Morishima, 1959), and the other of per equal wet volume (Parker, 1948; Morishima, 1948; Phleger, 1952; Walton, 1955; Kuwano, 1962–63). On the other hand, Bandy (1954, 1956) represented the abundance of populations in percentage, by weight of the Foraminifera in the sediments, and Hada (1939) compared the abundance of populations per samples with volume (cc) of Foraminifera in 1 liter of wet sediments. These different methods in presentation of the species and population abundance have been used in the studies of Recent and fossil Foraminifera. The distributions and relative abundancy of the Foraminifera in modern sediments are related with many complex ecologic factors. Concerning the living populations and assuming that Foraminifera live at or just below the sediment surface, the natural measure of populations for comparative purpose should be the number of specimens per unit area. We need, however, a method which can be applied to fossil populations in consolidated sediments. For this purpose, therefore, some units of sediments, not the area, such as equal volume or equal weight should be taken and have been used, but each method give quite different informations as stated by Walton (1955). For comparison of the abundancy of specimens in the unit sample, either living or total, both methods of equal volume and equal weight have their own validity. Equal wet volume may only be significant when the sediments are not consolidated and an equal area is taken as done by Walton (*op. cit.*) and the present study. Equal dry weight, on the other hand, does not present the real abundancy of specimens of the population when it lived, but will be suitable as a basis for comparing the population abundancies in both Recent and older sediments.

Concerning the representation of each species occurrence, Said (1950) maintained that counts of Foraminifera should be given in number of specimens in equal dry weight of sediment and each species be presented with the number of specimens per one gram dry weight of sediment (foraminiferal number). Several workers followed this method (Takayanagi, 1955; Morishima, 1955) and some others recorded the species with the number of specimens in the equal dry weight of sediment, *e. g.*, in 100 g (Kuwano, 1953–54). On the other hand, Walton (1955) considered that wet volume of sediment, instead of dry weight, is the natural base to which living populations can be referred for comparative purpose, and recorded living species with number of specimens in a unit volume of the top one centimeter of the cores. Kuwano (1962–63) recorded the individual number of each form in 50 ml. wet sample basis in his study on the foraminiferal biocoenoses. Many authors, however, recorded the occurrences of different species by their percentage in a given population.

When we intend to study the foraminiferal ecology based upon living specimens, it may be better to indicate the species occurrences by the actual number per equal area as stated earlier. In the case of Recent death (or total) assemblages, however, equal areas do not have strict meaning. In the case of fossil assemblages it is meaningless and impossible to take the unit area of the original sea bottom. Some ecologists or paleoecologists, therefore, take equal wet volume or equal dry weight of sediment as the basis for the presentation of species occurrences as mentioned already. The distribution of Foraminifera is a function of complicated environments. Although the supply of sediments may be one of the ecologic factors, it is also a function of other physical environments as already pointed out by Asano (1953). We need to understand the many environmental factors affecting the Foraminifera.

Ishiwada (1954), in his study on the Recent Foraminifera from the brackish water lake Hamana-ko, stated that a definite correlation could not be seen between the type of assemblage and foraminiferal number, and from this fact he suggested that it is more reasonable to use the relative abundancy in a population than the actual number of specimens for representation of species occurrences. Great difference is also seen in the distribution of the living and total populations in equal volume (and equal area) of the surface sediment in Matsushima Bay, and no direct correlation is noticed between the distributions. This may suggest that the total population, as well as fossil population, in the sediment sample does not indicate the real relative population density of living Foraminifera but is formed as a result of some physical factors after or before death. Therefore, it is concluded that the occurrences of each species should be represented with their relative abundance (percentage) in each population, instead of the number of specimens per equal weight or volume of sediment. This will become usefull for death (or total) assemblages as well as for fossils for comparison. Another merit of the percentage presentation in the studies of Recent Foraminifera is that the reliability is greater than by the use of the number of specimens when comparison is made of the assemblages in samples which were collected by different instruments and methods as pointed out by Phleger (1952).

Living population and total population: The distribution of the living population shows two separated areas of larger size; one in the inner-middle part of the bay and the other in the bay mouth area. The faunal compositions in the two areas are quite different representing the middle to inner bay facies and the outer bay facies respectively. Large foraminiferal populations near river mouths are found off some of the tributaries of the Mississippi River (Phleger, 1955), and living populations are higher in the direction of river mouths on the continental shelf off San Antonio Bay on the Texas coast (Phleger, 1956). Phleger and Lankford (1957) showed the presence of larger living populations in all seasons in upper San Antonio Bay fed by the Gaudalupe River, and suggested some possible influences of the river; an abundance of particular food may be introduced by river water into the marine environment to which the populations are adapted, and abundant nutrients may be brought by river water into the marine environment and cause high production of plant materials which provide food for the Foraminifera.

The large living population in the inner-middle part of Matushima Bay may be considered to be subjected to conditions similar to those mentioned above. That is to say, the Takagi River feeds the inner part of the bay. However, the area of large living population as well as that of the outer bay show no relation with the contents of the organic matter in the bottom sediments. In the innermost bay areas, Shiogama Harbor and off the mouth of the Takagi River, living populations are very small and show the minimum values. The two areas of the smallest population seem to be related with the high content of total sulfide (mostly more than 2.0‰) in the sediments. Abundant sewages of the city and the industries flow into Shiogama Harbor and such are slight off the mouth of the Takagi River. The rather smaller living populations in the southeastern part of the outer to inner bay also seem to be related with the rather high content of total sulfide in the bottom sediments. The large living populations in the bay mouth area are considered to be related with the smaller content of sulfide in the bottom sediment and/or with the higher chlorinity of the bottom water. Perhaps, from the open sea nature of the faunal compositions as well as the general trend of the number of forms, the Foraminifera of the area may be adapted to normal marine chlorinity, as already pointed out by Morishima (1955).

In Matsushima Bay, direct correlations can not be seen between the size of the living population and other physical and chemical factors such as quantity of mud, organic carbon and total nitrogen in the bottom sediment as well as oxygen content, pH chlorinity of the water, except for the extreme case in Shiogama Harbor. In general, small living populations per unit volume (and unit area) are considered to have more relation with the content of total sulfide in this bay than the other environmental factors. In other words, the abundancy of living Foraminifera are subjected chiefly to the quantity of total sulfide of the bottom sediment.

In contrast to the living population, the distribution of the total population shows a fairly simple trend of becoming larger as the distance from the shore increases and the bay mouth is approached. Such a general trend is known in most studies of Foraminifera. This trend is caused by the different rate of supply of sediments in the different areas; the higher dilution of the tests by the sediments in the inner bay areas of a small total population, and from such phenomenon, a measurement of the relative rate of sedimentation using Foraminifera was suggested by Phleger (1951). Therefore, it is obvious that an estimation of the productivity of Foraminifera can not be made directly from the total population in modern sediments as well as of the fossil population in older rocks presented on the basis of unit sediment even though it is based on equal volume or equal weight.

General trends of Foraminifera and environments: Planktonic Foraminifera are distributed in the outer bay area and extend to Shiogama Harbor though the occurrences are rare. The distribution seems to be related directly with the distribution of chlorinity and temperature of the bay water. All planktonic specimens found in the bay are immature or dwarfed and no living specimens were seen. From the open sea nature of the planktonic Foraminifera it is most probable that they were transported into the bay by tidal currents at least from the near shore water of Sendai Bay as stated already. The distribution of the planktonic Foraminifera to the inner part of Shiogama Harbor apparently reflects the peculiar water condition of the area as shown by chlorinity and temperature; the open-sea water flows into the inner part through the long, artificial deep channel.

Agglutinated Foraminifera, predominant in the inner bay, decrease as the bay mouth is approached showing a fairly uniform pattern. Basing chiefly on this distribution three major faunal facies can be defined; the outer bay, middle bay and inner bay facies. Agglutinated Foraminifera, apparently related to the chlorinity and temperature of the bay water, has general correlation with the distribution of the bottom water characteristics basing on the approximate variation ranges in T-Cl. Such dominantly agglutinated foraminiferal assemblages in inner bays and brackish-water lakes are known from many studies. Phleger (1954) reported the predominant agglutinated character of foraminiferal faunas in the Mississippi Sound in contrast to the predominantly calcareous faunas in the open Gulf of Mexico. Hada (1957) listed 14 species of brackish-water Foraminifera, of Japan among which ten are agglutinated forms, and considered their abundancy to be due to that calcium carbonate which is an important substance for calcareous foraminifers is less soluble in brackish than in sea water. Further he (Hada, 1957) considered that those brackish-water species are inhabitants in the cold-water seas and that water temperature is most important. Walton (1964) in his study on the Recent foraminiferal ecology in the northeastern Gulf of Mexico stated that a principal characteristic of the marginal-marine faunas in the area is their agglutinated character, and further that predominantly agglutinated faunas indicate marginal-marine conditions.

Uchio (1962b, c) in his study on the foraminiferal thanatocoenoses reported abundant *Trochammina hadai,* well known from many brackish-waters of Japan as *T. globigeriniformis,* from the open-sea coast of the Japan Sea just off and influenced by the Shinano River. The salinity, however, of the bottom water in the area is as high as the normal sea water as the river water does not reach the sea floor. From this fact Uchio (*op. cit.*) considered that the characteristics of fresh water (temperature, salinity, etc.) have no influences on the benthonic Foraminifera but, on the contrary, the detrital sediments and organic fragments carried by the river and deposited on the sea floor may have influence. In the Los Angeles County outfall area, California, Bandy *et al.* (1964) reported dominant agglutinated foraminiferal specimens in a dead population under much of the sewage field, whereas in the living population agglutinated specimens show the lowest values in the area. From the high organic content in the bottom sediment of the area they considered that the abundancy of agglutinated spec imens in the dead population around the outfall was due to the destruction of calcareous tests as opposed to agglutinated tests.

Other occurrences of dominantly agglutinated faunas are known in areas on the continental shelf and slope and on the ocean floor, and several factors such as sediment type, temperature, chlorinity, food, oxygen, pH, etc. and their combination are suggested and discussed. The constitutents of such faunas differ in different environmental categories and may have relations with the different factors. Therefore, at present, it is difficult to draw any general conclusions for the factors affecting the predominantly agglutinated faunas. So far as marginal-marine conditions are concerned, it may be possible that agglutinated Foraminifera are related to river waters directly or indirectly and indicate the influence of lower chlorinity and/or deeper embyaments.

Porcelaneous Foraminifera have a bimodal trend in Matsushima Bay. The high occurrence in the innermost part of the bay is due to the occurrence mostly of one brackish-water species of *Quinqueloculina rhodiensis* accompanied with *Miliolinella oblonga,* whereas in the outer bay the porcelaneous population consists of many species of miliolids. Abundant porcelaneous faunas are well known in the open shallow seas, and those seen in the outer part of Matsushima Bay are distributed into the bay and their distributions are thought to be related to that of the open-sea water of normal chlorinity. The abundancy of porcelaneous Foraminifera, regardless of the special case in the innermost part of the bay, have correlation with the bottom water characteristics (approximate variation ranges in T-Cl) and thus seems to indicate the chlorinity of the bottom water. Phleger and Lankford (1957) suggested that the distribution of the miliolids is related to the type of substrate and they prefer a sand or shell bottom. In Matsushima Bay, the distribution of porcelaneous Foraminifera, except for the innermost part of the bay, is seemingly related with the distribution of mud content in the bottom sediment. However, in samples Ms 20 Ms, 13 and Ms 21 from the bottom of the channels at the bay mouth, which consist of mud, miliolids are most abundant (27%, 22% and 16% respectively), but total 10 percent in fine sand of Ms 22.

It is well known that brackish waters contain only a small number of species. Walton (1955) considered that the occurrence of relatively few species may be due to the extreme variations of temperature and chlorinity in marsh environments and such phenomena limit the viability or reproduction of many species thus relatively few species whose tolerances fall within the limits can live there. In Matsushima Bay the number of foraminiferal species shows a general trend of increasing from the inner part of the bay to the outer, and this distribution is apparently related to the chlorinity and corresponds with the trend of the bottom water characteristics of approximate variation ranges in T-Cl. However, the variation ranges in temperature and chlorinity are not significant in the inner and middle bay areas and the mean chlorinity values or lower limits differ distinctly each other. Therefore it may be considered that chlorinity is more important than the variation ranges in temperature for supporting the number of forms in the bay. This may imply that the majority of Foraminifera are adapted to normal marine chlorinity.

Conclusively it is obvious that the general trends of Foraminifera such as the number of forms, agglutinated and porcelaneous forms, and planktonic Foraminifera primarily have correlation with the distribution of chlorinity of bay water rather than with other environmental factors, though it affects Foraminifera directly or indirectly.

Biofacies and ecologic factors: Physical oceanographers recognize different water masses chiefly on the basis of their chlorinity and temperature characteristics. For ecologic purposes the concept of water masses may include all the physical, chemical and biological features of any marine water body which seem to have a uniform ecologic effect. Such a water mass is expected to bear assemblages with a certain kind of uniformity and to form a faunal facies. In Matsushima Bay, however, the environments are too variable seasonally and periodically to conform such water masses. Fresh water draining into the innermost part of the bay and the open-sea water flowing through the channels at the bay mouth area mix with the bay water, and the extent of the inflows and their mixing greatly vary daily, seasonally and periodically, but there is a general trend in the chlorinity of becoming lower as the distance from the bay mouth increases. Therefore the hydrographic environments in the bay differ gradually and slightly area by area, forming a nearly parallel pattern with the bay mouth. Furthermore, the sewage of Shiogama brings organic and inorganic matters into the bay, and the thick growth of seaweeds and their decomposition also influence the character of the bay water. Because of such conditions of the bay, the abundancy distributions of the many species do not necessarily show systematic patterns, and this makes it difficult to define any faunal facies; no single form is a dependable criterion.

By means of the abundant occurrences of several forms which comprise more than half of each assemblage, three major faunal facies, the outer bay, middle bay and inner bay facies are recognized, and the distribution of many forms whose occurrences are rare conform with them although several others do not. The major facies trend which is chiefly characterized by the abundancy of such agglutinated forms as *Trochammina hadai*, *T.* cf. *japonica* and *Eggerella scabra* is related to the general trends of the Foraminifera such as the number of forms, porcelaneous and planktonic ones as well as the agglutinated ones. It is obvious that the major facies trend has relation essentially with the water chlorinity rather than with other factors, in other words they are controlled by the influence of the river and open-sea waters invading the bay. The extension of the outer bay facies into Shiogama Harbor is due to the open-sea water of high chlorinity. The sporadic occurrences of the other facies in the middle bay facies area may reflect the local complex water circulation perhaps due to local objects as seaweeds and oyster rafts.

There seems to be a general correlation between the major facies trend and the mud content of the sediments in Matsushima Bay. The sediment characteristics are considered to be one of the important ecologic factors of the bottom dwellers, and several workers have tired to explain the faunal distributions by sediment types. Although preference of sediment type is presumable and in fact some Foraminifera such as species of *Cibicides* and *Rosalina* are known to have sessile habitat, the relation between sediment type and each species is still not clear in the majority of benthonic Foraminifera. Sediments themselves reflect the effects of complex hydrographic processes which produce independent environments and control the distribution of Foraminifera. Phleger (1955) found no obvious correlation between the distributions of foraminiferal facies and sediments but pointed out that the facies boundaries cut across the sediment type boundaries in the southeastern Mississippi Delta area. Lankford (1959), finding a general coincidence of sediment characteristics and faunal associations in the same area, suggested that there is no causal relation between sediment and fauna. When sediment is coarse and water currents move foraminiferal tests selectively to some extent and when thanatocoenoses are concerned, the relation between sediment and Foraminifera must become intimate (Takayanagi, 1955).

The outer bay facies is almost composed of forms as seen in the shallow bottom of the open Sendai Bay and this may be due to the strong influence of the open-sea water. Each assemblage in this facies is not always uniform but fairly different in the dominant forms. It is known that areal faunal changes are much larger in such shallow seas than in deeper water (Kuwano *et al.*, 1957), because of the variable local environment. The middle bay and inner bay facies are differentiated into subfacies named B_1, B_2, C_1, C_2, C_3 and C_4. Subfacies B_1 and C_1, characterized by the abundant occurrence of *Elphidium subarcticum*, are discordant with the general trend of chlorinity and the other major trends, and have no relation with the known physical and chemical environments, except for the lower pH values of the bottom water. The lower pH values in Matsushima Bay are considered to be due chiefly to the inflow of sewage (Kitamori and Kanno, 1967), but other factors such as decomposition of seaweeds, smaller extent of photosynthesis of sea plants, inflow of river waters, and the influence of open-sea water may also be related therewith. At present, it is unknown whether the dominancy of *Elphidium subarcticum* is directly related to pH or is controlled by some other factors related therewith. The species is distributed in the bay and on the continental shelf area of the open Sendai Bay where it is one of the most abundant of the inner shelf fauna.

The inner bay facies is characterized by abundant *Trochammina hadai* and *T.* cf. *japonica* associated with *Ammonia beccarii* forma 2. The two species of *Trochammina* differ from each other in their order and abundancy per sample. Todd and Low (1961) studied the living Foraminifera from beaches and inlets and stated that Foraminifera may live in more or less transitory colonies unevenly distributed irrespective of the suitability of the individual parts of the area. Specimens of the two species of *Trochammina* in the total population (L+D) from the inner part of the bay are of abundant living ones. The laboratory experiments on *Ammonia beccarii tepida* (Cushman) show great tolerances to temperature, salinity and other ecologic factors (Bradshaw, 1961) and this may fit many other euryhaline species such as *Trochammina hadai* and *T.* cf. *japonica*.

Subfacies C_1 and C_2, and C_3 and C_4 seem to be controlled by the influence of river waters, being characterized by the low chlorinity, and stronger influence is seen in the latter two subfacies as indicated by the occurrence of the well known brackish-water species as *Miliammina fusca*. Subfacies C_4 represents the lowest chlorinity condition in the bay due to the inflow from the Takagi River, and several brackish-water species are almost confined to or most abundant in the subfacies. It is still unknown whether most of the brackish-water species are related directly to the lower chlorinity or to some other factors which have relation to river water as in the case of *Trochammina hadai* (Uchio, 1962b, c). But it may be true that such species have different torelances and limits to chlorinity and other factors (Hada, 1957; Bradshaw, 1961).

Among the Foraminifera from Matsushima Bay, *Ammonia beccarii* forma 1 has a distribution (Fig. 51) quite different from the others being discordant with facies distribution, other general trends of the Foraminifera, and with many of the known ecologic factors. It occurs rather abundantly in separated areas, in some parts of subfacies C_1, C_3,

C_4 and B_1 and extends to the western part of the outer bay facies; in general, it is distributed in the three areas of Shiogama Harbor and its vicinity, off the mouth of the Takagi River, and off the mouth of the Tona Canal. Although there are no precise data to explain the phenomenon mentioned above, the inflows of sewage and river water seem to be related to the distribution of the form regardless of the great differences in the bottom water characteristics between the inner part of the bay and the bay mouth area. If such relation can be accepted a similar condition exists off the Shinano River where *Trochammina hadai* occurs abundantly in the bottom water of nearly normal chlorinity under the layer of the river water (Uchio, 1962b, c). Ishiwada (1958) reported *Rotalia beccarii* var. A from the brackish-water lake Hamana-ko; it is closely similar to *Ammonia beccarii* forma 1 of Matsushima Bay. He found that *R. beccarii* var. A prefers higher chlorinity than other brackish-water species and suggested that it has a greater tolerance to the smaller values of dissolved oxygen than others. In Matsushima Bay, however, *Ammonia beccarii* forma 1 shows no relation with the oxygen content or chlorinity.

Non-specific faunal types: Basing on Motomura's law of geometrical progression, with highly simplified manner, the foraminiferal assemblages of Matsushima Bay are tentatively classified into five types, and from their distribution the bay can be divided into areas. Their trend in distribution is in accordance with the major specific faunal facies distribution areas, namely the outer bay, middle bay and inner bay facies, and with other non-specific general trends of the agglutinated and porcelaneous Foraminifera, and number of forms. These trends have correlations with the distribution of the bottom water characteristics designated by the approximate variation ranges in temperature and chlorinity. These non-specific faunal types, however, show no indication of the differentiation of subfacies B_1 and B_2 and show some difference in the subdivision of the inner bay facies.

Walton (1964) introduced the two concepts of "faunal diversity" and "faunal dominance" as measures for foraminiferal paleoecology. The former is "the number of ranked species of a counted or estimated foraminiferal population whose cumulative percentage constitutes 95% of the total population", and the latter is "the percentage occurrence of the most common species in a foraminiferal population". He showed a relationship between the faunal diversity and the faunal dominance in the Gulf of Mexico and showed both to have a general correlation with depth. So far as percentage is taken instead of individual number, the constants a and b_1 of the law of geometrical progression have essentially the same meaning as Walton's faunal diversity and faunal dominance; the faunal dominance is near to b_1 and the faunal diversity is nearly inversely proportional to a. The disadvantage to the faunal diversity is that the percentage occurrences of all the species are required as pointed out by Walton or that the total numbers of species are needed instead. On the other hand, abundancy occurrences of about ten species in the order of abundancy are of use for the law of geometrical progression, and the latter is easier if the simplified method is taken as a and b_1 and measured on a graph.

For non-specific faunal division and environmental interpretation of thanatocoenoses and fossil assemblages by the method mentioned above the limits of application should be recognized, as they often do not represent the original assemblage which lived at or near the site. Mixing of the fauna from other environments may happen, and a burried population may not be perfectly preserved because of mechanical destruction of the weaker tests and chemical dissolution of the calcareous tests.

Rates of sedimentation: Although there are no direct measures of the rate of sedimentation in Matsushima Bay, hydrographic observations show the largest inflow of freshwater from the Takagi River at the innermost part of the bay suggest thedra inage from land to be the important source of the bay sediments. The ratios of the living populations are higher in the inner part of the bay than the outer, and the measurement of the relative rate of sedimentation by means of the ratio of living to total or dead population of Foraminifera (Phleger, 1955; Walton, 1955) is considered to be valid in this bay. The ratio of living to total population in Matsushima Bay are smaller than in the Mississippi Delta area (Phleger, 1955), being similar to its low to intermediate areas (I and II), and are much larger than Aransas, Mesquite and San Antonio bays (Phleger, 1956). These data imply that the relative sedimentation rates are slower here than in the Mississippi Delta area and faster than in Aransas, Mesquite and San Antonio bays. But the season of abundant or rare living populations in each area and the seasons of sampling are here out of consideration in the comparison.

Uchio (1960) suggested the possibility of estimating the absolute rate of sedimentation, if the stations where there are no displaced Foraminifera are selected and if the average reproductive period of all the species and the living populations at those stations are known. Assuming the populations are in a stable condition (in equilibrium between environmental factors and population) and all the tests are preserved in the sediments, he introduced the equation, $1 \div R = T \div L/P$, where R is the rate of sedimentation (cm/year), P is the average reproductive period (year), and T and L are total and living populations. He calculated the rate of sedimentation to be one centimeter per 0.36 years, that is about 3 cm per year in the nearshore area (6.5–11 fathoms in depth) off San Diego, California, assuming a reproductive period for the species at this depth to be one month basing on the previous studies on laboratory cultures. In Matsushima Bay the rates of sedimentation can be calculated to be 1.2 cm per year at 10 percent in L/T and 2.4 cm per year at 20 percent in L/T assuming the average reproductive period of the species in the bay to be tentatively one month. These rates of sedimentation seems to be very high for the fine sediments of mud. The assumed reproductive period may be much shorter as Uchio (*op. cit.*) considered, but the possibility that the above assumptions may not be correct also remains. The total thickness of the sediment deposited during the Recent cycle, however, does not necessarily indicate the present rates of sedimentation.

COMPARISON WITH THE FORAMINIFERAL FAUNA OF OTHER BAYS

It is of interest to compare the fauna and their distribution in Matsushima Bay with those of other areas along the coasts of Japan. Because of the different methods used for quantitative analyses, the listing of species without illustrations, and the lack of detail data of the environments, only several bays or brackish-water lakes along the Pacific and Okhotsk coasts of Japan can be taken for comparison.

Saroma Lake facing the Okhotsk Sea is situated in northeastern Hokkaido. It is about 26 km in length and 12 km in width with a maximum depth of 19.5 m and is separated from the open-sea by a narrow sand bar. Yoshida (1954) reported 26 species of Foraminifera from 21 samples distributed in three areas in the lake. In this *Trochammina japonica* (=*T.* cf. *japonica*), *Verneuilina polystropha* (=*Eggerella scabra*), *Rotalia beccarii* (=*Ammonia*), *Eponides frigidus* (=*Buccella frigida*), *Elphidium etigoense* (=*E. subarcticum* ?), *E. jenseni*, and *E.* cf. *subincertum* are most abundant, and in the inner part of the lake *Miliammina fusca*, *Ammobaculites cassis* and *Haplophragmoides canariensis* occur abundantly. Other species which occur rather abundantly in some samples are *Textularia parvula*, *Buliminella elegantissima*, *Discopulvinulina isabelleana* (=*Rosalina*), *Elphidium advenum*, *E. subgranulosum*, *E. hughesi foraminosum* (*E. clavatum*) and *Bigenerina nodosaria*. He recognized 12 types of assemblages but no facies division of the lake was made. The fauna of Saroma Lake is quite similar to that of Matsushima Bay, especially to those of the middle and inner bay facies.

Akkeshi Bay on the Pacific coast of eastern Hokkaido is about 9 km in width and 12 km in length, and Akkeshi Lake of approximately 5 km in diameter is contiguous to the bay, being connected to the innermost part of the bay with a narrow channel. Morishima and Chiji (1952) recognized five assemblages in the bay and lake from 27 samples. *Trochammina globigeriniformis* (=*T. hadai*) - *Rotalia* cf. *beccarii* Assemblage occurs in the lake and in addition to the two species *Eponides frigidus*, *Elphidium incertum* and *E.* sp. A are rather abundant. *Trochammina globigeriniformis* Assemblage occurs only at the innermost part of the bay near the channel connecting the bay and lake, and is characterized by the predominance of the species. *Bolivina decussata* (=?), *Rotalia japonica* (=*Ammonia*)-*Nonion japonicum*, and *Nonionella pulchella* assemblages occur in the order from the inner to outer parts of the bay, and in all the three assemblages *Eponides frigidus* and *Elphidium* sp. A are very abundant associated with *Buliminella elegantissima* and *Elphidium* cf. *etigoense* (=*E. subarcticum* ?). *Trochammina globigeriniformis-Rotalia* cf. *beccarii* and *T. globigeriniformis* assemblages are similar to subfacies C_4 and C_3 of Matsushima Bay respectively. *Bolivina decussata* and *Rotalia japonica-Nonion japonicum* assemblages may have some similarity to the outer bay facies of Matsushima Bay but differ by the abundant occurrences of *Buccella frigida* and *Buliminella elegantissima* showing a water condition colder than Matsushima Bay.

Matsukawa-ura lagoon, situated about 60 km south of Matsushima Bay at the southern end of Sendai Bay, is separated from the open sea by a sand bar and is connected with Sendai Bay by a narrow channel. The lagoon is about 5 km in length and 1.5 km in width and is mostly less than 1 m in depth, developing rather large tidal flats. Takayanagi (1955) studied the Foraminifera from the lagoon and adjoining open shallow sea, and recognized two facies and one subfacies. The species compositions of these facies and subfacies are quite the same as those in Matsushima Bay. The assemblages of the Matsukawa-ura facies which occur in most parts of the lagoon excepting the mouth consist chiefly of *Haplophragmoides canariensis*, *Ammobaculites agglutinans* (=*A. exiguus*), *Goesella iizukae*, *Miliammina fusca*, *Trochammina globigeriniformis* (=*T. hadai*), *T. inflata*, *T.* cf. *nana* (=*T.* cf. *japonica*), *Elphidium matsukawauraense* (="*E*". *subincertum*) and *Rotalia beccarii* forma A (=*Ammonia beccarii* forma 1 and 2), and especially *Haplophragmoides canariensis* is most dominant in the facies. The assemblages of the Isobe facies in a strict sense, in the open shallow sea outside the lagoon, are composed chiefly of the species of *Quinqueloculina*, *Pseudononion*, *Elphidium*, *Buliminella*, *Discopulvinulina* (=*Rosalina* and *Neoconorbina*), *Eponides* (=*Eponides*, *Buccella* and *Buccella?*), *Cibicides* and *Globigerina*. The Matsukawa-minato subfacies at the mouth area of the lagoon is characterized by assemblages transitional between the two facies, but closely resembles the latter. The Matsukawa-ura facies is somewhat similar to subfacies C_4 and C_3 of Matsushima Bay but has the chlorinity lower than any facies of Matsushima Bay. *Haprophragmoides canariensis*, a well known brackish-water species, is one of the most dominant species in the Matsukawa-ura facies especially in the inner part, while it is almost absent in Matsushima Bay. The Matsukawa-minato subfacies resembles the outer bay facies of Matsushima Bay being characterized by *Pararotalia minuta*, *P. nipponica* and other open sea shallow water species with the mixing of some inner bay species. Therefore the middle and inner bay facies of Matsushima Bay are not represented in Matsukawa-ura where a facies corresponding to the outer bay facies of Matsushima Bay is almost directly adjacent to a facies with chlorinity lower than the inner bay facies of Matsushima Bay. This condition is easily suspected from the outline of the lagoon, the bottom configuration, and the position and width of the channel connecting the lagoon with the open sea.

In the inner part of Tokyo Bay, Maruhashi (1948) found three assemblages at the depths of 7.5 to 35.5 m. The *Ammoglobigerina-Rotalia* Assemblage, distributed in the innermost part, consists chiefly of *Ammoglobigerina globigeriniformis* (=*Trochammina hadai*) and *Rotalia beccarii*. The *Quinqueloculina-Lagena* Assemblage occurs in a small area of the western inner part and is characterized by *Quinqueloculina* sp. and *Lagena marginata spinifera* (=*Fissurina*). The *Rotalia* Assemblage occurs in the middle part of the bay and is characterized by dominant *R. beccarii* and subdominant *Elphidium subgranulosum* and *Nonion manpukuziense*. Morishima (1955) listed the Foraminifera expressed by the species abundancy with number of specimens per one gram dry sediments in 22 samples distributed almost over the entire bay, but no faunal or facies divisions were made. His data show the abundant occurrence of *Trochammina globigeriniformis* in the inner part of the bay. In the middle part of the bay *Nonionella miocenica stella* and *Rotalia japonica* become abundant, and in the bay mouth area Miliolidae, *Cassidulina, Cibicides, Eponides, Textularia conica, T. abbreviata* and *Amphistegina radiata* are dominant or characteristic. The assemblage of the inner part of Tokyo Bay is similar to that of the inner bay facies of Matsushima Bay, and the assemblage of the middle part of Tokyo Bay somewhat resembles that of the outer bay facies of Matsushima Bay. Further comparisons of the two bays are impossible because of different hydrographic conditions and the too scattered distribution and few samples from Tokyo Bay.

The brackish-water lake Hamana-ko on the Pacific coast of central Honshu is about 12 km in diameter and is connected with the Pacific Ocean by a very narrow and shallow channel. The main basin in the inner half of the lake has a maximum depth of 12 m, and the bottom deeper than 8–9 m is oovered by an anaerobic layer in a stagnant period and hydrogen sulfied is produced simultaneously. Ishiwada (1958) classified the lake based upon the Foraminifera into three facies and subfacies. The open-coast subfacies, at the mouth of the lake, is characterized by *Pseudononion japonicum, Elphidium subgranulosum* and *Rotalia beccarii* var. A (=*Ammonia beccarii* forma 1). The transitional facies occurs inside at the mouth area and is characterized by *Reophax* sp., *Goesella iizukae, Ammobaculites exiguus, Textularia* sp., *Elphidium* spp., *Rotalia beccarii* var. A and *Anomalina hamanakoensis* (=*Valvulineria*). The Hamana-ko proper facies, extending almost over the whole area of the lake excepting the mouth area, is characterized by *Millettella rotunda* (=*Centropyxis*, not Foraminifera), *Haplophragmoides canariensis, Trochammina globigeriniformis, Rotalia beccarii* var. A and *R. beccarii aomoriensis*, and associated with them are *Proteonina* cf. *eocenica* (=*Reophax*), *P. lagenaria, Miliammina fusca* and *Elphidium kaneharai*. Further he subdivided the Hamana-ko proper facies into three subfacies by the composition of the dominant species; *Haplophragmoides, Rotalia beccarii* var. A and *Haplophragmoides-Trochammina* subfacies. He washed his sediment samples with a 120 mesh sieve, so the relative abundancies of the species may differ when washed with a 200 mesh sieve as in the present study as well as in Takayanagi's Matsukawa-ura and Morishima's Tokyo Bay materials and thus strict comparison becomes difficult. However, the transitional facies and some assemblages in the Hamana-ko proper facies seem to resemble subfacies C_2 and C_1 of Matsushima Bay. Most assemblages of the Hamana-ko proper facies represent a cholorinity condition lower than the inner bay facies of Matsushima Bay.

From the known studies on the Foraminifera from bays and brackish-water lakes of Japan, some generalized features can be seen. Hada (1957) listed 15 species as the brackish-water Foraminifera in Japan and arranged them in the order of minimum water chlorinity of tolerance. *Proteonina limnetica* (*P. difflugiformis* var. *limnetica* Hada, 1937) is the first in the list lives in water less than 0.20‰ in chlorinity, *Ammobaculites agglutinans* and *Miliammina obliqua* more than 0.20‰, *M. fusca* and *Rotalia beccarii* more than 2.04‰, *Quinqueloculina boueana, Eponides frigidus* and *Buliminella elegantissima* more than 6.90‰, *Trochammina globigeriniformis* more than 11‰ and *Trochammina nitida* more than 13.76‰ for example. A fauna which is characterized by abundant *Haplophragmoides canariensis* associated with *Miliammina fusca* occurs in brackish-water lakes and lagoons in waters of chlorinity condition lower than the inner part of Matsushima Bay. A fauna which is characterized by dominant *Trochammina hadai* and/or *T.* cf. *japonica* associated with some form of *Ammonia beccarii* and similar to the inner bay facies of Matsushima Bay occurs at the mouth areas of brackish-water lakes and lagoons and in the innermost part of bays. The composition of assemblages in the inner region of various bays is almost similar regardless of their location either on the Pacific coast or the Japan Sea side as already pointed out by Morishima (1955). The fauna, on the other hand, which consists of open shallow-sea species like that of the outer bay facies of Matsushima Bay occurs in bay mouth areas, and in middle regions in some bays, and such a fauna does not always have uniform compositions but differs by the locality being controlled by the colder or warmer water condition of the area and other local hydrographic configurations.

CONCLUSIONS

1) No significant differences are seen between the distributions of the living and total (living+dead) Foraminifera in Matsushima Bay.

2) The size of the total population has a monotonous trend becoming larger as the bay mouth is approached, while that of the living population shows a bimodal distributional trend. The former is due to the higher dilution of foraminiferal tests by detritus in the inner part of the bay than at the outer. The latter may be partly due to the high concentration of food materials in the inner bay area and partly to the different faunal composition of each area. But the higher content of total sulfide shows the inhibition of the living population.

3) By the abundancy occurrences of total Foraminifera three facies and six subfacies are recognized in the bay. For the faunal divisions, species with their order in abundancy and their number comprising more than half of each population cumulating the frequencies from the first order are taken into account. Many species whose occurrences are not so abundant distribute almost concordantly with the facies distribution but some do not.

4) The inner bay facies is characterized by dominant occurrences of a few species such as *Trochammina hadai*, *T.* cf. *japonica* and *Ammonia beccarii* forma 2, and the outer bay facies by *Pararotalia? minuta*, *P. nipponica*, "*Elphidium*" *somaense* and many other open shallow-sea species. The middle bay facies is a transitional one and is characterized by a mixed fauna of the inner and outer bay facies.

5) The three major facies, distributed almost parallel with each other and nearly concentrically with the bay mouth area, are quite concordant with the general trend of the bottom water characteristics in chlorinity and temperature and are chiefly caused by the influences of the inflow of the river and sea waters respectively.

6) On the contrary the subfacies in the middle and inner bay facies are not concordant with the general trend of water chlorinity, being affected with the inflow of sewages and river waters which cause the organic and inorganic deformation of the water and thes ediment, and ith other compwlicated biological and physico-chemical conditions because of thick-growing seaweeds and their decomposition, and oyster cultures in the bay.

7) Planktonic Foraminifera, of dwarfed forms, occur rarely in the bay and are limited in distribution almost to the outer bay facies.

8) General trends of foraminiferal characters such as agglutinated and calcareous porcelaneous Foraminifera and the number of species, having similar trends with the major facies

distribution, show good correlation with the major trend in the bottom water chlorinity, but do not indicate the different subfacies.

9) The facies divisions based upon non-specific faunal types, showing similar trend to the major specific faunal facies and other general trends of Foraminifera, have correlation with the major trend in chlorinity, but do not necessarily indicate the differentiation of the subfacies in specific faunal division.

10) Ratio of living to total population indicates the relative rate of sedimentation in the bay and proves the Takagi River to be the important source of the bay sediments.

11) For the quantitative foraminiferal analyses, each species should be represented with percentage rather than by individual number in equal dry weight or wet volume of sediment, and the size of the populations with individual number in equal dry weight, not volume, so far as fossil assemblages are concerned.

12) Comparisons with the foraminiferal fauna of several bays, lagoons and brackish-water lakes along the coast of Japan reveals that fresh to brackish-water fauna are almost similar regardless of their locations whereas the middle to outer bay fauna differ according to their geographic positions and oceanographic conditions.

FAUNAL REFERENCE LIST

All species and subspecies of Foraminifera identified from Matsushima Bay are listed below in alphabetic order including some unnamed forms. Many of them are illustrated in the plates of this article, arranged systematically. The original references are given for all named forms, and a few subsequent references for several forms. The occurrences in the bay are also included, and brief notes on taxonomy and distribution are added if needed. The distributions in Matsushima Bay are shown for several species in Figs. 34～64 in both living and total populations. The figures in the plates were made by the writer retouching microphotographs. All the types are catalogued and deposited in the Institute of Geology and Paleontology, Tohoku University, Sendai.

Ammobaculites exiguus Cushman and Bronnimann........................Pl. 1, figs. 7a, b, 8.

Cushman and Bronnimann, 1948, *Cushman Lab. Foram. Res., Contr.*, v. 24, pt. 2, p. 38, pl. 7, figs. 7, 8; Ishiwada, 1958, *Geol. Surv. Japan, Rep.*, no. 180, pl. 1, figs. 8, 9. *Ammobaculites agglutinans* (d'Orbigny), Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser. (Biol.)*, v. 6, no. 3, p. 65, text-fig. 17; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 40, pl. 1, fig. 3.

This is one of the typical brackish-water species and occurs in the subfacies C_4 of the inner bay facies. The distribution is shown in Fig. 35.

Occurrence: Stations Ms 17, 32, 33, 34, 35, 44.

Ammonia beccarii (Linné)

Nautilus beccarii Linné, 1758, *Syst. Nat., ed.* **10**, p. 710 (*fide* Ellis and Messina, 1940).

Three forms are here tentatively included under this specific name. Each one, however, seems to be an independent species rather than a variant or a subspecies, but future studies are needed concerning this species group in Japan.

Ammonia beccarii (Linné) forma 1 ....Pl. 5, figs. 8a-c, 9a-c.

Rotalia beccarii (Linné) forma A, Takayanagi, 1955 (part), *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 44, text-figs. 31a-c (not 30a-c).

Rotalia beccarii (Linné) var. A, Ishiwada, 1958, *Geol. Surv. Japan, Rep.*, no. 180, pl. 2, figs. 1–8.

Ammonia sp. A, Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C.*, no. 79, pl. 2, figs. 12a–c.

Streblus beccarii (Linné), Chiji, 1963, *Osaka Mus. Nat. Hist., Bull.*, no. 16, p. 64, pl. 7, figs. 4a, b.

Rather flat dorsal and ventral sides, broadly rounded periphery, limbate but nearly flush sutures on both sides, rather coarsely perforated and yellowish colored test wall, and relatively large size in adult are characteristics of this form. Takayangi (1955) described and figured two types in his *Rotalia beccarii* forma A. Here the two types are treated as forms distinct from one another; *Ammonia beccarii* forma 1 and *A. beccarii* forma 2. The distribution of this form in the bay is interesting as already discussed. It is shown in Fig. 51.

Occurrence: Stations Ms 2, 3, 4, 5, 7, 17, 18, 19, 20, 23, 24, 25, 26, 30, 33, 34, 38, 46, 56.

Ammonia beccarii (Linné) forma 2 .... Pl. 5, figs. 10a-c, 11a-c, 12a-c.

Rotalia cf. *R. beccarii* (Linné), Morishima and Chiji, 1952, *Kyoto Univ., Coll. Sci., Mem., ser. B*, v. 20, no. 2, pl. 2 (13), figs. 5a-c.

Rotalia beccarii (Linné) forma A, Takayanagi, 1955 (part), *Tohoku Univ., Inst. Geol. Pal. Contr.*, no. 45, p. 44, text-figs. 30a-c (not 31a-c).

Ammonia aff. *beccarii* (Linné), subsp. *soblina* (Shupack) and var., Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, p. 236, pl. 2, figs. 8a-c, 9a-c.

This form has convex dorsal and nearly flat ventral sides, narrowly rounded periphery, raised sutures except for later portion on the dorsal side, and brownish color especially in the central part of the dorsal side. Some specimens have a small umbilical plug (figs. 10a-c). Wall finely perforated except for proximal narrow parts in each of last few chambers on the dorsal side, along spiral and radial sutures, which are transparent. This form is variable in number of chambers in last whorl (usually 8–9 but rarely 5–6), lobulation of periphery, and flatness or convexity of ventral side. This form is the most important one of the inner bay calcareous Foraminifera. The distribution is shown in Fig. 52.

Occurrence: All stations in and just outside of the bay.

Ammonia beccarii (Linné) forma 3 .... Pl. 5, figs. 13a-c.

Rotalia beccarii (Linné) forma B, Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 45, text-figs. 32a-c, 33a-c.

This form has biconvex and rather thick test, moderately narrowly rounded periphery, and small umbilical plug. Dorsal sutures slightly limbated but not raised, and ventral sutures excavated near the umbilical region where both sides of sutures are ornamented with beads. This form occurs very rarely in the outer bay facies but is fairly abundant in the open shallow sea outside the Matsukawa-ura lagoon.

Occurrence: Station Ms 40.

Ammonia japonica (Hada) .... Pl. 5, figs. 14a-c, pl. 6, figs. 1a-c.

Rotalia japonica Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser.* (*Biol.*), v. 6, no. 3, p. 137, text-figs. 93a-c.

Some specimens of this species show high spire and globose appearance of test. *Rotalia inflata* (Seguenza) of Takayanagi (1955, pl. 2, figs. 18a-c) seems to be a variant of this species. This species occurs in the middle to outer bay facies. The distribution is shown in Fig. 53.

Occurrence: Stations Ms, 2, 3, 4, 6, 7, 10, 11a, 11b, 12, 13, 14, 15, 16, 17, 18, 20, 21, 26, 27, 39, 40, 43, 55.

Ammonia ketienziensis (Ishizaki) .... Pl. 6, figs. 2a-c.

Streblus ketienziensis Ishizaki, 1943, *Taiwan Tigaku Kizi*, v. 16, nos. 3–4, p. 59, pl. 2 (1 on the plate), figs. 5a-c; 1948, *Acta Geol. Taiwan.*, v. 2, no. 1, p. 59, pl. 1, figs. 2a-c.

This species occurs rarely almost in the outer bay facies. The distributon is shown in Fig. 54.

Occurrence: Stations Ms, 2, 4, 11a, 12, 13, 15, 16, 18, 19, 20, 21, 22, 23, 28, 40, 55, 56.

Ammoscalaria pseudospiralis (Williamson) .... Pl. 1, figs. 9a, b.

Proteonina pseudospiralis Williamson, 1858, *Rec. Foram. Great Britain*, p. 2, pl. 1, figs. 2, 3.

Ammobaculites pseudospirale (Williamson), Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser.* (*Biol.*), v. 6, no. 3, p. 66, text-figs. 18a, b.

Very rare in the inner bay facies.

Occurrence: Station Ms 47.

Anomalina ? pauperata (Balkwill and Wright)

Nonionina pauperata Balkwill and Wright, 1885, *Roy. Irish Acad., Trans.*, v. 28 (Sci.), p. 353, pl. 13, figs. 25, 26.

Nonion pauperatum (Balkwill and Wright), Cushman, 1939, *U.S. Geol. Surv. Prof. Paper* **191**, p. 24, pl. 6, figs. 21a-23b.

Anomalina ? pauperata (Balkwill and Wright), Kuwano, 1962, *Res. Inst. Nat. Resour., Misc. Rep.*, nos. 58–59, pl. 14, figs. 5a-6b.

Occurrence: Station Ms 23

Bolivina pseudoplicata Heron-Allen and Earland ....Pl. 3, figs. 25a, b.
Heron-Allen and Earland, 1930, *Roy. Micr. Soc., Jour.*, v. 50, p. 81, pl. 3, figs. 36–40; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, pl. 2, fig. 2.
Occurrence: Stations Ms 2, 7.

Bolivina robusta Brady ....Pl. 3, figs. 26a, b.
Brady, 1881, *Quart. Jour. Micr. Sci., London*, v. 21, p. 57; 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 421, pl. 53, figs. 7–9.
Occurrence: Stations Ms 18, 22.

Bolivina cf. *seminuda* Cushman ....Pl. 3, figs. 27a, b.
Cf. *Bolivina seminuda* Cushman, 1911, *U.S. Nat. Mus. Bull.* 71, pt. 2, p. 34, text-fig. 55.
Bolivina seminuda Cushman, Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser.* (*Biol.*), v. 6, no. 3, p. 132, text-figs. 89a, b.
Occurrence: Stations Ms, 2, 7, 11a, 13, 14, 16, 18, 20, 21, 30, 40, 56.

Bolivina striatula Cushman ....Pl. 3, figs. 28a, b.
Cushman, 1922, *Carnegie Inst. Washington, Pub.* 311, p. 27, pl. 3, fig. 10.
This species occurs rarely in the outer and middle bay facies and sporadically in the inner bay facies. The distribution is shown in Fig. 42.
Occurrence: Stations Ms, 5, 7, 11a, 11b, 12, 13, 14, 15, 17, 18, 20, 23, 24, 26, 28, 30, 39, 40, 43, 47, 55, 56.

Bolivina cf. *tokiokai* Uchio ....Pl. 3, figs. 29a, b.
Cf. *Bolivina tokiokai* Uchio, 1962, *Seto Mar. Biol. Lab., Pub.*, v. 10, no. 2, p. 389, pl. 18, figs. 5a, b.
This form is similar to Uchio's especially in its coarsely pitted or finely reticulated wall, but differs from it in not having so large aperture.
Occurrence: Stations Ms 15, 20, 55.

Bolivina sp. aff. *B. durrandii* Millett ....Pl. 3, figs. 30a, b.
Aff. *Bolivina durrandii* Millett, 1900, *Roy. Micr. Soc. London, Jour.*, p. 544, pl. 4, figs. 7a, b.
This species is similar to Millett's from the Malay Archipelago in general appearance in front view, but differs from it in thicker test, more inflated chambers and the costae weaker, fewer and regular rather than broken irregular.
Occurrence: Station Ms 20.

Buccella frigida (Cushman)...Pl. 4, figs. 1a-c, 2a-c.
Pulvinulina frigida Cushman, 1922, *Canad. Biol., Contr.*, no. 9 (1921), p. 12.
Eponides frigida (Cushman) var. *calida* Cushman and Cole, 1930, *Cushman Lab. Foram. Res., Contr.*, v. 6, pt. 4, p. 98, pl. 13, figs. 13a-c.
Eponides frigidus (Cushman), Hada, 1936, *Zool. Mag.*, v. 48. nos. 8–10, text-figs. 12-c; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 44, pl. 2, figs. 11a, b.
Buccella frigida (Cushman), Andersen, 1952, *Washington Acad. Sci., Jour.*, v. 42, no. 5, p. 144, figs. 4a-6c; Matoba, 1967, *Tohoku Univ., Sci. Rep., 2nd ser.* (*Geol.*), v. 38, no. 2, p. 252, pl. 26, figs. 8a-9c.
The present specimens show great variation in thickness of test, number of chambers in last whorl and condition of peripheral margin. Many specimens have rather strongly compressed test, not so lobulate and narrowly rounded periphery with transparent margin similar to the variety from Choshi (Matoba, 1967, pl. 26, figs. 8a-c) but the number of chambers in a whorl is fewer than the latter. This species occurs commonly except for the innermost areas. The distribution is shown in Fig. 44.
Occurrence: Stations Ms 2, 3, 4, 5, 6, 7, 8, 9, 10, 11a, 11b, 12, 13, 14, 15, 16, 17, 18, 19, 20 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 39, 40, 43, 44, 47, 55, 65.

Buccella? makiyamae Chiji ....Pl. 7, figs. 13a-c.
Chiji, 1961, *Prof. J. Makiyama, Mem. Vol., Kyoto*, p. 234, text-figs. 2a-c, pl. 1, figs. 13a-14b.
Eponides scheibersii (d'Orbigny), Morishima and Chiji, 1952, *Univ. Kyoto, Coll. Sci., Mem., Ser. B*, v. 20, no. 2, pl. 2 (13), figs. 6a-c.
Eponides cf. *nipponicus* (Husezima and Maruhashi), Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p, 44, pl.2, figs. 12a-c.
Prosorotalia makiyamae (Chiji), Matoba, 1967, *Tohoku Univ., Sci. Rep., 2nd ser.* (*Geol.*), v. 38, no. 2, p. 256, pl. 27, figs. 12a-13c.
Once the writer referred this species to *Porosorotalia* (Voloshinova, 1958) in fossil specimens.

The thin sections of well preserved specimens show a monolamellar septa, suggesting the species to belong to Discorbacea. This species was originally described as *Buccella*, but supplementary apertures on the ventral sutures can not be seen. This species occurs rarely in the outer and middle bay facies. The distribution is shown in Fig. 45.

Occurrence: Stations Ms, 2, 3, 4, 5, 7, 11a, 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 27, 28, 40, 56.

Bulimina marginata d'Orbigny ....Pl. 3, fig. 32.

d'Orbigny, 1826, *Ann. Sci. Nat., Paris, sér.* 1, v. 7, p. 269, pl. 12, figs. 10–12.

Bulimina aculeata d'Orbigny, Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser.* (*Biol.*), v. 6, no. 3, p. 127, text-figs. 84a, b.

Occurrence: Station Ms 13.

Buliminella elegantissima (d'Orbigny) ....Pl. 3, fig. 24.

Bulimina elegantissima d'Orbigny, 1839, *Voy. Amér. Mérid., Foraminifères*, v. 5, pt. 5, p. 51, pl. 7, figs. 13, 14.

This species occurs rarely in the outer and middle bay facies and sporadically in the inner bay facies. The distribution is shown in Fig. 41.

Occurrence: Stations Ms 2, 7, 8, 11a, 11b, 13, 14, 15, 16, 17, 18, 20, 21, 23, 28, 40, 43, 55, 56.

Caribeanella ogiensis (Matsunaga)

Oinomikadoina ogiensis Matsunaga, 1954, *Palaeont. Soc. Japan, Trans. Proc., N.S.*, no. 15, p. 163, text-figs. 1–3.

Occurrence: Station Ms 14.

Chrysalidinella dimorpha (Brady) ....Pl. 3, figs. 34a, b.

Chrysalidina dimorpha Brady, 1881, *Quart. Jour. Micr. Sci., London*, v. 21, p. 54; 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 388, pl. 46, figs. 20, 21a, b.

Occurrence: Stations Ms 2, 22, 28, 30, 40.

Cibicides aknerianus (d'Orbigny) ....Pl. 8, figs. 4a-c.

Rotalina akneriana d'Orbigny, 1846, *Foram. Foss. Bas. Tert. Vienne*, p. 156, pl. 8, figs. 13–15.

Occurrence: Stations Ms 13, 14, 21, 23, 28, 30, 40, 56.

Cibicides lobatulus (Walker and Jacob)..............................Pl. 8, figs. 5a-c, 6a-c.

Nautilus lobatulus Walker and Jacob, 1798, *Adams' Essays*, p. 642, pl. 14, fig. 36.

The immature form is high conical (figs. 6a-c) like *Cibicides refulgens* Montfort but in the adult its test becomes relatively compressed plano-convex. It is common in the outer bay facies and rare and sporadic in the middle and inner bay facies. The distribution is shown in Fig. 63.

Occurrence: Stations Ms 2, 4, 5, 6, 7, 8, 11a, 12, 13, 14, 15, 16, 17, 19, 18, 20, 21, 23, 27, 28, 40, 43, 55, 56.

Cibicides pseudoungerianus (Cushman)

Truncatulina pseudoungeriana Cushman, 1922, *U.S. Geol. Surv. Prof. Paper*, 129-E, p. 97, pl. 20, fig. 9.

Occurrence: Stations Ms 13, 15, 20, 21.

Cyclogyra planorbis (Schultze) ....Pl. 2, figs. 1a, b.

Cornuspira planorbis Schultze, 1854, *Organisms Polythal.*, p. 40, pl. 2, fig. 21; Cushman and Todd, 1947, *Cushman Lab. Foram. Res., Spec. Pub.*, no. 21, p. 7, pl. 1, fig. 24.

This species is rare in the outer bay facies.

Occurrence: Stations Ms 13, 18, 20, 23, 56.

Cymbaloporetta bradyi (Cushman) ....Pl. 8, figs. 7a-c.

Cymbalopora poey (d'Orbigny) var. *bradyi* Cushman, 1915, *U.S. Nat. Mus., Bull.* 71, pt. 5, p. 25, pl. 10, fig. 2; pl. 14, fig. 2.

Occurrence: Stations Ms 22, 40.

Dentalina ittai Loeblich and Tappan ....Pl. 3, fig. 13.

Loeblich and Tappan, 1953, *Smith. Misc. Coll.*, v. 121, no. 7, p. 56, pl. 10, figs. 10–12.

Dentalina cf. *calomorpha* (Reuss), Cushman ,1948, *Cushman Lab. Foram. Res., Spec. Pub.*, no 23, p. 44, pl. 5, figs. 4, 5; Cushman and McCulloch, 1950, *Allan Hancock Pacific Exped.*, v. 6, no. 6, p. 317, pl. 41, fig. 6.

Occurrence: Station Ms 30.

Dyocibicides perforata Cushman and Valentine

Cushman and Valentine, 1930, *Stanford Univ., Dept. Geol. Contr.*, v. 1, no. 1, p. 31, pl. 10, figs. 3a-c.

Occurrence: Station Ms 56.

Eggerella propinqua (Brady) ....Pl. 1, figs. 20a, b.

Verneuilina propinqua Brady, 1884 (part), *Voy. Challenger, Rep., Zool.*, v. **9**, p. **387**, pl. 47, figs. 8–12 (not 13, 14).

Eggerella propinqua (Brady), Cushman, 1937, *Cushman Lab. Foram. Res., Spec. Pub.*, no. 8, pl. 5, figs. 21a-22b; Takayangi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, pl. 1, fig. 8.

Occurrence: Stations Ms 2, 11a, 12, 13, 20, 21, 43.

Eggerella scabra (Williamson) ....Pl. 1, figs. 21, 22.

Bulimina scabra Williamson, **1858**, *Rec. Foram. Great Britain*, p. 65, pl. 5, figs. 136, **137** (*B. arenacea* in explanation of plate).

Verneuilina polystropha (Reuss), Hada, **1931**, *Tohoku Imp. Univ., Sci. Rep., 4th ser. (Biol.)*, v. 6, no. 3, p. 74, text-figs. 27a, b.

Eggerella scabra (Williamson), Cushman, *Cushman Lab. Foram. Res., Spec. Pub.*, no. **8**, p. 50, pl. 5, figs. 10a-11b.

The present specimens are smaller and more slender than those of Mutsu Bay, but much larger than *Eggerella advena* (Cushman) which occurs in the open shallow-sea of Sendai Bay, just outside of Matsushima Bay. This species occurs commonly almost throughout the bay but is rare in the innermost part of the bay and bay mouth area, and is one of the important agglutinated species in the bay next to *Trochammina hadai*, and *T.* cf. *japonica.* The distribution is shown in Fig. 38.

Occurrence: All the stations except Stations Ms 33, 35, 36, 37.

Elphidium advenum (Cushman)

Polystomella advena Cushman, 1922, *Carnegie Inst. Washington, Pub.* 311, p. 56, pl. **9**, figs. 11, 12.

Polystomella subnodosa (Münster), Brady, 1884, *Voy. Challenger, Rep., Zool.*, v. **9**, p. 734, pl. 110, figs. 1a, b.

Elphidium subnodosum (Münster), Hada, **1931**, *Tohoku Imp. Univ., Sci. Rep., 4th ser. (Biol.)*, v. 6, no. 3, p. 123, text-figs. 81a, b.

Occurrence: Stations Ms 2, 4, 6, 7, 11a, 12, 15, 16, 19, 23, 24, 25, 26, 40, 55, 56.

Elphidium clavatum Cushman ....Pl. 6, figs. 11a, b.

Elphidium incertum (Williamson) var. *clavatum* Cushman, 1930, *U.S. Nat. Mus., Bull.* **104**, pt. 7, p. 20, pl. 7, fig. 10.

Elphidium decipiens (Costa), Hada, **1931**, *Tohoku Imp. Univ., Sci. Rep.*, **4th** *ser.* v. 6, no. **3**, p. 126, text-figs. 83a, b.

Elphidium hughesi foraminosum Cushman, Asano, 1950, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 1, p. 8, text-figs. 46, 47.

Elphidium clavatum Cushman, Loeblich and Tappan, 1953, *Smith. Misc. Coll.*, v. 121, no. 7, p. 98, pl. 19, figs. 8–10; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 42, pl. 1, fig. 25.

Occurrence: Stations Ms 2, 7, 11a, 11b, 12, 16, 17, 18, 20, 21, 25, 47.

Elphidium crispum (Linné) ....Pl. 7, figs. 1a, b.

Nautilus crispus Linné, 1758, *Syst. Nat., ed.* **10**, p. 709 (*fide* Ellis and Messina, 1940).

Elphidium fax barbarense Nicol, Asano, 1950, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 1, p. 7, text-figs. 40, 41; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 42, pl. 1, fig. 27.

Elphidium crispum (Linné), Asano, 1960, *Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), Spec. Vol.*, no. 4, p. 197, pl. 22, figs. 6a, b.

This species occurs commonly in the outer bay facies and is rare in the middle bay facies. The distribution is shown in Fig. 57.

Occurrence: Stations Ms 2, 3, 5, 6, 7, 10, 12, 13, 14, 15, 16, 17, 18, 19, 21, 22, 23, 28, 30, 40, 55, 56.

Elphidium hanzawai Asano ....Pl. 7, figs. 2a, b.

Asano, 1939, *Geol. Soc. Japan, Jour.*, v. 46, no. 551, p. 426, figs. 3, 4a, b; 1950, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 1, p. 8, text-figs. 42, 43.

Occurrence: Stations Ms 12, 28.

Elphidium jenseni (Cushman) ....Pl. 7, figs. 3a, b.

Polystomella jenseni Cushman, 1924, *Carnegie Inst. Washington, Pub.* 342, p. 49, pl. 16, figs. 4, 6.

Elphidium jenseni (Cushman), Asano, 1960, *Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), Spec. Pub.*, no. 4, p. 199, pl. 22, figs. 5a, b.

Occurrence: Stations Ms 2, 6, 11a, 11b, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 25, 26, 29, 30, 38, 40, 43, 47, 55.

Elphidium kusiroense Asano ....Pl. 7, figs. 4a, b.

Asano, 1938, *Geol. Soc. Japan, Jour.*, v. 45, no. 538, p. 590, pl. 14, fig. 2; 1960, *Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), Spec. Vol.*, no. 4, p. 200, pl. 22, figs. 13a-14b.

This species occurs commonly in the outer and middle bay facies but is rare or absent in the inner bay facies. The distribution is shown in Fig. 58.

Occurrence: Stations Ms 2, 4, 5, 6, 7, 8, 9, 10, 11a, 11b, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 26, 28, 29, 30, 38, 39, 40, 43, 44, 45, 47, 55, 56.

Elphidium cf. *kusiroense* Asano ....Pl. 7, figs. 5a, b.

This form differs from *E. kusiroense* in the less compressed test, more inflated chambers, and shorter and not so distinct sutural pores. Its distribution is similar to *E. kusiroense*.

Occurrence: Stations Ms 2, 3, 4, 5, 6, 7, 8,9, 11a, 11b, 12, 14, 15, 16, 17, 18, 19, 20,21, 23, 24, 25, 26, 27, 28, 29, 30, 38, 39, 40, 43, 44, 45, 47, 55, 56.

Elphidium reticulosum Cushman ....Pl. 6, figs. 12a, b.

Cushman, 1933, *U.S. Nat. Mus., Bull.* 161, pt. 2, p. 51, pl. 12, figs. 5a, b.

This species is characteristic in the wall being ornamented by a very fine network.

Occurrence: Stations Ms 4, 5, 6, 7, 9, 11a, 11b, 12, 14, 16, 17, 18, 23, 24, 25, 27, 28, 30, 39, 40, 43, 56.

Elphidium cf. *reticulosum* Cushman ....Pl. 6, figs. 13a, b.

This form is somewhat similar to *E. reticulosum* in the wall character, but differs from it in the character of the retral processes and in less thickness of the test.

Occurrence: Stations Ms 2, 6, 7, 10, 11a, 12, 15, 17, 20, 23, 26, 30, 32, 39, 40, 43, 45, 47, 55, 56.

Elphidium subarcticum Cushman ....Pl. 7, figs. 6a, b, 7a, b.

Cushman, 1944, *Cushman Lab. Foram. Res., Spec. Pub.*, no. 12, p. 27, pl. 3, figs. 34, 35; Loeblich and Tappan, 1953, *Smith. Misc. Coll.*, v. 121, no. 7, p. 254, pl. 27, figs. 5a-7; Matoba, 1967, *Tohoku Univ., Sci. Rep., 2nd ser. (Geol.)*, v, 38, no. 2, p. 254, pl. 27, figs. 10a–11.

Elphidium fabum (Fichtel and Moll), Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser. (Biol.)*, v. 6, no. 3, p. 125, text-figs. 82a, b.

Elphidium etigoense Husezima and Maruhasi, Asano, 1950, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 1, p. 7, text-figs. 38, 39; 1960, *Tohoku Univ., Sci. Rep., 2nd ser. (Geol.), Spec. Vol.*, no. 4, p. 198, pl. 22, figs. 8–9b; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 42, pl. 1, fig. 26.

Elphidium aff. *magellanicum* Heron-Allen and Earland, Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, p. 241, pl. 3, figs. 28a, b.

This species is variable in the size and relative thickness of the test, number of chambers per whorl, and sutures which are nearly radial to strongly curved. The species is small for the genus but larger specimens occur in the middle bay facies. This species is one of the most abundant calcareous ones in the bay except for the innermost area and is most abundant in subfacies B_1 and C_1. It also occurs in the open sea of Sendai Bay where it is one of the important species in the inner shelf fauna. The distribution of the species in Matsushima Bay is shown in Fig. 59.

Occurrence: Stations Ms 2, 3, 4, 5, 6, 7, 8, 11a, 11b, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 39, 40, 43, 44, 45, 46, 47, 55, 56.

Elphidium subarcticum Cushman var. ....Pl. 7, figs. 8a, b.

This form differs from the typical one in the more depressed sutures and rather rapidly increasing chambers as added.

Occurrence: Stations Ms 2, 3, 4, 5, 6, 7, 8, 11a, 11b, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 24, 26, 28, 29, 30, 32, 39, 43, 47, 56.

Elphidium subgranulosum Asano ....Pl. 7, figs. 9a, b.

Asano, 1938, *Geol. Soc. Japan, Jour.*, v. 45, no. 538, p. 586, pl. 14, figs. 4a, b; 1950, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 1 p. 10, text-figs. 54, 55: 1960, *Tohoku Univ., Sci. Rep., 2nd* *ser.* (*Geol.*), *Spec. Vol.*, no. 4, p. 201, pl. 22, figs. 7a, b; Aoki, 1961, *Palaeont. Soc. Japan, Trans. Proc., N.S.*, no. 41, p. 18, pl. 3, figs. 9a, b; *Elphidium* cf. *subgranulosum* Asano, Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, p. 241, pl. 3, figs. 23–25.

This species is common in the middle part of the bay and rare in the inner and outer parts. The distribution is shown in Fig. 60.

Occurrence: Stations Ms 2, 3, 4, 5, 6, 7, 8, 9, 10, 11a, 11b, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 37, 38, 39, 40, 43, 44, 45, 46, 47, 55, 56.

"*Elphidium*" *somaense* Takayanagi ....Pl. 7, figs. 11a-12b.

Elphidium somaense Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 43, 52, text-figs. 28a, b.

Elphidiella tokyoensis Aoki, 1960, *Hydrgr. Office of Japan, Mar. Res. Lab., Contr.*, v. 2, no. 2, p. 99, pl. 1. figs. 1–4.

Elphidium tokyoensis (Aoki), Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, p. 240, pl. 3, figs. 16–19.

Elphidium tokyoensis (Aoki) described from the Pleistocene Tokyo Formation and distributed in the Pleistocene and Holocene deposits around Tokyo Bay (Aoki, 1960; Ujiié, 1963) is considered to be a synonym of this species. Aoki originally referred his species to *Elphidiella*. Later Ujiié (1963) re-exmained Aoki's species and transfered it to *Elphidium* but made no comparison with *Elphidium somaense*. "*Elphidium*" *somaense* has a wall of granular microstructure rather than the radial wall of Elphidiidae, and therefore is considered to belong to a new genus. This species differs from *Elphidiella nitida* Cushman and *Protelphidium orbiculare* (Brady) primarily in its granular wall structure. This species occurs almost throughout the bay except for the innermost areas, and is most abundant in the bay mouth area. The distribution is shown in Fig. 62.

Occurrence: Stations Ms 2, 3, 4, 5, 6, 7, 8, 10, 11a, 11b, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 36, 38, 39, 40, 43, 55, 56.

"*Elphidium*" *subincertum* Asano..Pl. 7, figs. 10a, b.

Elphidium subincertum Asano, 1950, *Illust. Cat. Japan. Small. Foram.*, pt. 1, p. 10, text-figs. 56, 57; Chiji, 1963, *Osaka Mus. Nat. Hist., Bull.*, no. 16, p. 63, pl. 6, figs. 8, 9.

Elphidium incertum (Williamson), Morishima and Chiji, 1952, *Univ. Kyoto, Coll. Sci., Mem., ser. B*, v. 20, no. 2, pl. 2 (13), figs. 3a, b; Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, pl. 3, fig. 27.

Elphidium matsukawauraense Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 43, 51, text-figs. 27a, b; Ishiwada, 1958, *Geol. Surv. Japan, Rep.*, no. 180, pl. 1, fig. 21.

This species has a granular wall structure and may belong to a new genus with "*E*". *somaense* Takayanagi. This species occurs rarely throughout the bay except for the innermost parts and is most abundant in some areas of the middle and inner bay facies, although it occurs in the brackish-water of the Matsukawa-ura lagoon and is one of the characteristic species of the Matsukawa-ura facies. The distribution is shown in Fig. 61.

Occurrence: Stations Ms 2, 3, 4, 5, 6, 7, 8, 9, 10, 11a, 11b, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 24, 26, 27, 28, 29, 30, 31, 33, 36, 37, 38, 39, 40, 43, 45, 47, 55, 56.

Eoeponidella pulchella (Parker)..Pl. 4, figs. 3a-c.

Pninaella? pulchella Parker, 1952, *Harvard Coll., Mus. Comp. Zool., Bull.*, v. 106, no. 10, p. 420, pl. 6, figs. 18–20.

Asterellina pulchella (Parker), Anderson, 1963, *Micropaleontology*, v. 9, no. 3, p. 314, pl. 1, figs. 5–7.

Occurrence: Station Ms 56.

Epistominella naraensis (Kuwano)..Pl. 4, figs. 5a-c.

Pseudoparrella naraensis Kuwano, 1950, *Geol. Soc. Japan, Jour.*, v. 56, no. 657, p. 317, text-figs. 6a-c; *Epistominella naraensis* (Kuwano), Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 7, p. 6, text-figs. 34–36.

Occurrence: Stations Ms 4, 12, 20, 21, 23, 26, 40.

"*Eponides*" *orientalis* Asano..Pl. 8, figs. 3a-c.

Asano, 1937, *Saito Ho-on Kai Mus., Res. Bull.*, no. 13, p. 117, pl. 16, figs. 8a-c.

This species has a granular wall structure, not radial as in the Eponididae, and is only tentatively referred to the original genus. This species was originally described from the

Recent deposits of Shiogama Bay, an inlet at the southwestern end of Matsushima Bay. Nevertheless no specimens of the species were seen in the type area, and only a few were found in the sediment sample from just outside Matsushima Bay (Ms 22), suggesting a change of the ecological condition of the bay during about thirty years.

Occurrence: Station Ms 22.

Fissurina cf. *annectens* (Burrows and Holland) ....Pl. 3, figs. 21a, b.

Cf. *Lagena annectens* Burrows and Holland, 1895, *in* Jones, *Monogr. Foram. Crag.*, *Pal. Soc., London*, pt. 2, p. 203, pl.7, figs. 11a, b.

Occurrence: Stations Ms 4, 6, 7, 11a, 14, 17, 21.

Fissurina cucurbitasema Loeblich and Tappan ....Pl. 3, figs. 22a, b.

Loeblich and Tappan, 1953, *Smith. Misc. Coll.*, v. 121, no. 7, pl. 14, figs. 10, 11.

Occurrence: Stations Ms 11a, 12, 13, 15, 18, 23, 27, 28, 39, 40, 43.

Fissurina cucurbitasema bispinata Ujiié ....Pl. 3, figs. 23a, b.

Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, p. 232, pl. 1, figs. 9–11.

Occurrence: Stations Ms 3, 12, 13, 18, 21, 23, 26, 27, 38, 46.

Fursenkoina complanata (Egger)

Virgulina schreibersiana Czjzek var. *complanata* Egger, 1893, *K. Bayer, Akad. Wiss., München, Math. Phys. Cl., Abhandl.*, v. 18, pt. 2, p. 292, pl. 18, figs. 91, 92.

Occurrence: Stations Ms 39, 43.

Gaudryina matusimai Asano

Gaudryina (*Siphogaudryina*) *matusimai* Asano, 1937, *Geol. Soc. Japan, Jour.*, v. 44, no. 531, p. 1234, text-figs. 1–3; 1950, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 5, p. 3, text-figs. 13, 14.

Occurrence: Station Ms 15.

Glabratella cf. *chasteri* (Heron-Allen and Earland)............................Pl. 5, figs. 1a-c.

Cf. *Discorbina chasteri* Heron-Allen and Earland, 1913, *Roy. Irish Acad., Proc.*, v. 31, pt. 64, p. 128, pl. 13, figs. 1–3.

Cf. *Discrobis chasteri* (Heron-Allen and Earlan), Cushman, 1948, *Cushman Lab. Foram. Res., Spec. Pub.*, no. 23, p. 69, pl. 7, figs. 13a-c.

The distribution is shown in Fig. 49.

Occurrence: Stations Ms 7, 8, 13, 16, 18, 20, 21, 27, 28, 29, 30, 31, 38.

Glabratella cf. *globosa* (Sidebottom) ....Pl. 4, figs. 14a-c.

Cf. *Pluvinulina globosa* Sidebottom, 1909, *Manchester Lit. Philos. Soc., Mem. Proc.*, v. 53, no. 21, p. 9, pl. 4, fig. 3.

Cf. *Glabratella globosa* (Sidebottom), Seiglie and Bermúdez, 1965, *Geos, Caracas*, no. 12, p. 31, pl. 6, figs. 4–5b.

Occurrence: Stations Ms 55, 56.

Glabratella milletti (Wright) ....Pl. 5, figs. 2a-c.

Discorbina milletti Wright, 1911, *Belfast Nat. Field Club, Proc., ser.* 2, v. 6, append. no. 2, p. 13, pl. 2, figs. 14–17.

Occurrence: Stations Ms 11a, 12, 14, 16, 20, 23.

Glabratella nakamurai (Asano)

Discorbis nakamurai Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 2, text-figs. 8–10.

Occurrence: Stations Ms 12, 15, 16, 18.

Glabratella opercularis (d'Orbigny) ....Pl. 5, figs. 4a-c.

Rosalina opercularis d'Orbigny, 1839, *Foraminifères*, *in* de la Sagra, *Hist. Phys. Pol. Nat. Cuba*, p. 93, pl. 3, figs. 24, 25; pl. 4, fig. 1.

Discorbis opercularis (d'Orbigny), Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 2, text-figs. 11–13.

This species occurs rarely in the outer bay facies and the distribution is shown in Fig. 48 together with *G. subopercularis*.

Occurrence: Stations Ms 2, 4, 12, 13, 14, 19, 21, 22, 23, 40.

Glabratella cf. *patelliformis* (Brady) ....Pl. 5, figs. 3a-c.

Cf. *Discorbina patelliformis* Brady, 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 647, pl. 88, figs. 3a-c; pl. 89, figs. 1a-c.

Occurrence: Stations Ms 13, 19, 21, 22.

Glabratella subopercularis (Asano) ....Pl. 5, figs. 5a-c.

Discorbis subopercularis Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 3, text-figs. 17–19.

The distribution is similar to that of *G. opercularis* and is shown in Fig. 48 with it.

Occurrence: Stations Ms 2, 11a, 14, 15, 18, 21, 22, 28, 40.

Globigerina bulloides d'Orbigny .... Pl. 7, fig. 15.

d'Orbigny, 1826, *Ann. Sci. Nat. Paris, sér.* 1, v. 7, p. 277, no. 1; Modèles no. 76 and no. 17.

Occurrence: Stations Ms 12, 13, 18, 21.

Globigerina cf. *quinqueloba* Natland .... Pl. 7, figs. 14a, b.

Cf. *Globigerina quinqueloba* Natland, 1938, *Scripps Inst. Oceanogr., Bull., Tech. ser.*, v. 4, no. 5, p. 149, pl. 6, fig. 7.

Occurrence: Stations Ms 2, 11a, 13, 14, 15, 16, 17, 18, 20, 21, 23, 47, 55, 56.

Globigerinita glutinata (Egger) .... Pl. 7, figs. 17a, b.

Globigerina glutinata Egger, 1893, *K. Bayer, Akad. Wiss., München, Math.-Phys. Cl., Abhandl.*, v. 18, pt. 2, p. 371, pl. 13, figs. 19–21.

Occurrence: Stations Ms 20, 21.

Globigerinoides tenellus Parker .... Pl. 7, figs. 16a, b.

Parker, 1958, *Swedish Deep-Sea Exped., Rep.*, fasc. 2, p. 280, pl. 6, figs. 7–11.

Occurrence: Station Ms 13.

Goesella iizukae Takayanagi .... Pl. 1, figs. 23.

Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.* no. 45, p. 41, 50, text-figs. 25a, b; Ishiwada, 1958, *Geol. Surv. Japan, Rep.*, no. 180, pl. 1, fig. 7.

This species is one of the brackish-water Foraminifera and occurs commonly in the innermost areas of the bay. The distribution is shown in Fig. 39.

Occurrence: Stations Ms 2, 3, 4, 9, 11b. 23, 24, 25, 26, 27, 30, 32, 33, 34, 35, 36, 37, 39, 43, 44, 45, 46, 47, 55.

Hanzawaia nipponica Asano .... Pl. 8, figs. 10a-c.

Asano, 1944, *Geol. Soc. Japan, Jour.*, v. 51, no. 606, p. 99, pl. 4, figs. 1a-2b.

Occurrence: Stations Ms 2, 11a, 14, 19, 22, 56.

Haplophragmoides canariensis (d'Orbigny) .... Pl. 1, figs. 6a, b.

Nonionina canariensis d'Orbigny, 1839, *Foram. Îles Canaries, in* Barker-Webb and Berthelot, *Hist. Nat. Îles Canaries*, v. 2, pt. 2, p. 128, pl. 2, figs. 33, 34.

Haplophragmoides canariensis (d'Orbigny), Hada, 1937, *Zool. Mag.*, v. 49, no. 10, p. 343, text-figs. 1a-c; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 40, pl. 1, figs. 2a, b; Ishiwada, 1958, *Geol. Surv. Japan, Rep.*, no. 180, pl. 1, figs. 10, 11.

This species is one of the typical brackish-water ones and is very abundant in brackish-water lakes and lagoons in Japan. In Matsushima Bay, however, it occurs rarely and sporadically.

Occurrence: Stations Ms 10, 34, 56.

Haplophragmoides hancocki Cushman and McCulloch .... Pl. 1, figs. 5a, b.

Cushman and McCulloch, 1939, *Allan Hancock Pacific Exped.*, v. 6, no. 1, p. 79, pl. 6, figs. 5, 6.

Occurrence: Station Ms 21.

Helenina anderseni (Warren) .... Pl. 4, figs. 4a-c.

Pseudoeponides anderseni Warren, 1957, *Cushman Found. Foram. Res., Contr.*, v. 8, pt. 1, p. 39, pl. 4, figs. 12–15; Parker and Athern, 1959, *Jour. Pal.*, v. 33, no. 2, p. 341, pl. 50, figs. 28–31.

Helenina anderseni (Warren), Saunders, 1957, *Washington Acad. Sci., Jour.*, v. 47, p. 374, pl., figs. 1, 2; Todd and Low, 1961, *Cushman Found. Foram. Res., Contr.*, v. 12, pt. 1, p. 18, text-fig. 2, figs. 2a, b.

Occurrence: Station Ms 47.

Lagena distoma Parker and Jones .... Pl. 3, fig. 14.

Parker and Jones, 1864, *in* Brady, *Linn. Soc. London, Trans.*, v. 24, pt. 3, p. 467, pl. 48, fig. 6; Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser.* (*Biol.*), v. 6, no. 3, p. 106, text-fig. 62.

Occurrence: Stations Ms 7, 16.

Lagena laevis (Montagu) .... Pl. 3, fig. 15.

Vermiculum laeve Montagu, 1803, *Test. Britannica*, p. 524.

Lagena laevis (Montagu), Loeblich and Tappan, 1953, *Smith. Misc. Coll.*, v. 121, no. 7, p. 61, pl. 11, figs. 5–8.

Occurrence: Stations Ms 15, 17.

Lagena cf. *perlucida* (Montagu) .... Pl. 3, fig. 16.

Cf. *Vermiculum perlucidum* Montagu 1803, *Test. Britannica*, p. 525, pl. 14, fig. 3.

Lagena perlucida (Montagu), Cushman and McCulloch, 1950, *Allan Hancock Pacific Exped.*, v. 6, no. 6, p. 342, pl. 46, figs. 1a–2b.

The present specimen has very short, longitudinal costae near the base of the test.

Occurrence: Station Ms 30.

Lagena semilineata Wright .... Pl. 3, fig. 17.

Wright, 1886, *Belfast Nat. Field Club, Proc., N.S.*, v. 1, append. 9, p. 320, pl. 26, fig. 7; Loeblich and Tappan, 1953, *Smith. Misc. Coll.*, v. 121, no. 7, p. 65, pl. 11, figs. 14–22.

The present specimen has a rather short neck and a very short basal spine.

Occurrence: Ms 16.

Massilina inaequaris Cushman .... Pl. 2, figs. 15a, b.

Cushman, 1921, *U. S. Nat. Mus., Proc.*, v. 59, p. 72, pl. 17, figs. 12, 13.

Occurrence: Stations Ms 2, 13, 16, 21, 43.

Massilina milletti (Wiesner) .... Pl. 2, figs. 16a, b.

Spiroloculina milletti Wiesner, 1912, *Archiv Protist.*, v. 25, p. 207.

Spiroloculina nitida d'Orbigny, Brady, 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 149, pl. 9, figs. 9a–10.

Occurrence: Stations Ms 13, 21.

Massilina secans (d'Orbigny) .... Pl. 2, figs. 17a, b.

Quinqueloculina secans d'Orbigny, 1826, *Ann. Sci. Nat., Paris*, v. 7. p. 303, no. 43, Modèle, no. 96; Fornasini, 1900, *Acc. Sci. Bologna, Mem., ser.* 5, v. 8, p. 101, fig. 11.

Occurrence: Stations Ms 14, 39.

Massilina sp. .... Pl. 2, figs. 18a, b.

Occurrence: Stations Ms 11a, 13, 14, 15, 16, 21, 56.

Miliammina fusca (Brady) .... Pl. 1, figs. 4a, b.

Quinqueloculina fusca Brady, 1870, *Ann. Mag. Nat. Hist., ser.* 4, v. 6, p. 47 (286), pl. 11, figs. 2a–3.

Miliammina fusca (Brady), Hada, 1936, *Zool. Mag.*, v. 48, nos. 8–10, p. 853, text-figs. 5a-c; Takayanagi, 1955, *Tohoku Univ., Inst Geol. Pal., Contr.*, no. 45, p. 41, pl. 1, figs. 10a, b; Ishiwada, 1958, *Geol. Surv. Japan, Rep.*, no. 180, pl. 1, fig. 12.

This is a well-known brackish-water species and occurs in Matsushima Bay just off the mouth of the Takagi River and the Tona Canal. The distribution is shown in Fig. 34.

Occurrence: Stations Ms 33, 34, 46.

Miliolinella circularis (Bornemann) .... Pl, 3, figs. 5a, b.

Triloculina circularis Bornemann, 1855, *Deutsch. Geol. Ges., Zeitschr.*, v. 7, no. 2, p. 349, pl. 19,figs. 4a-c.

Occurrence: Stations Ms 12, 13, 15, 18, 20, 21, 40.

Miliolinella oblonga (Montagu) .... Pl. 3, figs. 6a, b.

Vermiculum oblongum Montagu, 1803, *Test. Britannica*, p. 522, pl. 14, fig. 9.

Occurrence: Stations Ms 13, 16, 26, 33, 35, 36, 38, 40.

Miliolinella? cf. *sidebottomi* (Martinotti) .... Pl. 3, figs. 7a, b, 8a, b, 9a, b.

Cf. *Sigmoilina sidebottomi* Martinotti, 1920, *Atti. Soc. Ital. Sci. Nat.*, v. 59, pl. 2, fig. 29, text-figs. 59–61.

Cf. *Triloculina sidebottomi* (Martinotti), Parker, Phleger and Peirson, 1953, *Cushman Found. Foram. Res., Spec. Pub.*, no. 2, p. 14, pl. 2, figs. 25–28, text-figs. 3, 4.

The present specimens show variation in the apertural tooth from a small simple projection to a rather small flap like that of *Miliolinella*, and no tooth is seen in several specimens.

Occurrence: Stations Ms 2, 10, 11a, 11b, 12, 13, 15, 16, 17, 18, 20, 21, 23, 26, 27, 33, 36, 40, 44, 45.

Miliolinella sublineata (Brady) .... Pl. 3, figs. 10a, b.

Miliolina circularis (Bornemann) var. *sublineata* Brady, 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 169, pl. 4, figs. 7a-c.

Occurrence: Station Ms 15.

Miliolinella? sp. .... Pl. 3, figs. 11a–12b.

Small, ovate but compressed form, with treminal oval aperture with everted margin and very thin wall is here tentatively referred to this genus. Superficially slight suture-like depressions are seen but no internal chamber partitions can be seen, perhaps being destroyed, and the chamber arrangement as well as other features are almost unrecognizable. It may represent an immature stage of a certain miliolid, but no living specimens are found to be identical with it.

Occurrence: Stations Ms 13, 15, 16, 20, 21.

Neoconorbina stachi (Asano) .... Pl. 4, figs. 6a-c.

Discopulvinulina stachi Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 7, text-figs. 46–48.

Occurrence: Station Ms 13, 15, 19, 20, 23.

Nonionella stella Cushman and Moyer .... Pl. 8, figs. 8a-c.

Nonionella miocenica Cushman var. *stella* Cushman and Moyer, 1930, *Cushman Lab. Foram. Res., Contr.*, v. 6, pt. 1, p. 56, pl. 7, figs. 17a-c.

Nonionella pulchella Hada, Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 42, pl. 1, figs. 23a-c; Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, pl. 1, figs. 20a–21c.

This species occurs rarely in the outer bay facies and is common on the continental shelf area of open Sendai Bay. *Nonionella pulchella* Hada, a form similar to this species, which has more compressed test and smaller size, occurs rarely in the nearshore area of Sendai Bay, but is not seen in Matsushima Bay.

Occurrence: Stations Ms 13, 16, 17, 18, 20, 27, 40.

Oolina costata (Williamson) .... Pl. 3, fig. 18.

Entosolenia costata Williamson, 1858, *Rec. Foram. Great Britain*, p. 9, pl. 1, fig. 18.

Occurrence: Station Ms 12.

Oolina melo d'Orbigny .... Pl. 3, fig. 19.

d'Orbigny, 1839, *Voy. Amér Mérid., Foraminifères*, v. 5, pt. 5, p. 20, pl. 5, fig. 9.

Occurrence: Station Ms 14.

Oolina sp. .... Pl. 3, figs. 20a, b.

Occurrence: Stations Ms 11b, 16.

Pararotalia nipponica (Asano) .... Pl. 6, figs. 3a–c, 4a–c.

Rotalia nipponica Asano, 1936, *Geol. Soc. Japan, Jour.*, v. 43, no. 515, p. 614, pl. 31, figs. 2a–c; 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 15, text-figs. 112–114; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 45, pl. 2, figs. 14a–c.

Rotalia ozawai Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 15, text-figs. 115–117; Takayanagi, 1951, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 45, pl. 2, figs. 17a, b.

Pararotalia nipponica (Asano), Ujiié, 1966, *Palaeont. Soc. Japan, Trans. Proc., N.S.*, no. 61, p. 192, text-figs. 1–3, pl. 24, figs. 1–7; pl. 25, figs. 1–5.

Ujiié (1966) examined this species and placed it in *Pararotalia*, and reported on the synonym of *Rotalia ozawai* Asano. The specimens of this species from Matsushima Bay also show the co-existance of the non-spinate *nipponica*-type and spinate *ozawai*-type, and are always of larger size in the former and smaller in the latter. Besides in some well preserved large specimens of the *nipponica*-type, an earlier stage of the *ozawai*-type with peripheral spines can be observed through the test wall from the outside, and some specimens have a few peripheral spines only in the earlier part of the last whorl (pl. 31, figs. 3a–c). The writer, therefore, retains Ujiié's opinion concerning the synonymy of the two species. This species occurs commonly in the outer bay facies and rarely in the middle bay facies. The distribution is shown in Fig. 56.

Occurrence: Stations Ms 2, 4, 5, 6, 7, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 27, 28, 40, 43, 55, 56.

Pararotalia ? *globosa* (Millett) .... Pl. 6, figs. 8a–c.

Discorbina imperatoria (d'Orbigny) var. *globosa* Millett, 1903, *Roy. Micr. Soc. London, Jour.*, p. 701, pl. 7, figs. 6a–c.

Rotalia erinacea Heron-Allen and Earland, 1915, *Zool. Soc. London, Trans.*, v. 20, pt. 17, p. 720, pl. 53, figs. 23–26.

"*Eponides*" *globosus* (Millett), Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., ecs. C*, no. 79, p. 233, pl. 1, figs. 26–29.

Streblus murrayi (Heron-Allen and Earland), Chiji, 1964, *Hamamatsu City, Geol. Surv., Rep.*,

v. 3, pl. 1, figs. 10a, b.

Pararotalia murrayi, Konda, 1967, *Osaka Mus. Nat. Hist., Bull.*, no. 20, pl. 4, figs. 10a, b.

Heron-Allen and Earland (1915) referred this species to *Rotalia* and proposed the new name, *Rotalia erinacea*, because the name was preoccupied by *Rotalia globosa* (Hagenow, 1842). But this new name is invalid because both species do not belong to *Rotalia* (s.s.) (Ujiié, 1963). This species closely resembles *Rotalia murrayi* Heron-Allen and Earland (1915, *Zool. Soc. London, Trans.*, v. 20, pt. 17, p. 721, pl. 53, figs. 27–34) and some authors referred to it, but this species differs from *R. murrayi* in the fewer chambers per whorl and marginal spines. Millett's original type is from the Malay Archipelago and has prominant long spines, but Heron-Allen and Earland reported that most of the specimens are consistently spinous but show only a few spines, at irregular intervals, on the cuspid margins of the chambers in the specimens from the Kerimba Archipelago and even the most advanced Kerimba specimens rarely attain the proportions in the development of spines of Millett's figure. The Japanese specimens do not have so numerous and prominant spines as the Malay specimens.

Occurrence: Stations Ms 20, 21.

Pararotalia? *minuta* (Takayanagi) .... Pl. 6, figs. 5a–c, 6a–c, 7a–c.

Rotalia? *minuta* Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 45, 52, text-figs. 29a–c.

? *Pararotalia murrayi* (Heron-Allen and Earland), Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, p. 239, pl. 3, figs. 3a–9.

Ujiié (1963) placed this species in *Pararotalia* and referred to *P. murrayi* (Heron-Allen and Earland). This species, however, has nearly flat dorsal and strongly convex ventral sides and almost acute periphery with pustulous fringe except for the last few chambers of some specimens, and appears to have little resemblance to Heron-Allen and Earland's species (1915, *loc. cit.*) which has a subglobular test, highly convex dorsal side and rounded periphery without fringe. The specimens that have been referred to *Streblus murrayi* (Chiji, 1964, *loc. cit.*), *Pararotalia murrayi* (Konda, 1967, *loc. cit.*) and *Pararotalia minuta* and var. (Matoba, 1967) do not belong to *P.*? *murrayi* nor *P.*? *minuta*. "*Rotalia*" *murrayi* Heron-Allen and Earland figured by Graham and Militante (1959, *Stanford Univ. Pub., Geol. Sci.*, v. 6, no. 2, p. 100, pl. 15, figs. 5a–c) from northern Mindoro resembles *P.*? *globosa* (Millett) from the Kerimba Archipelago rather than *P.*? *murrayi*, except for the greater number of chambers per whorl. *P.*? *minuta*, as well as *P. nipponica*, is one of the characteristic species of the outer bay facies, and occurs there abundantly and is common in the middle bay facies, but is almost absent in the inner bay facies. The distribution is shown in Fig. 55.

Occurrence: Stations Ms 2, 3, 4, 5, 6, 7, 11a, 11b, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 40, 43, 55, 56.

Patellina corrugata Williamson .... Pl. 5, figs. 6a–c.

Williamson, 1858, *Rec. Foram. Great Britain*, p. 46, pl. 3, figs. 86–89.

Occurrrence: Stations Ms 13, 23.

Poroeponides cribrorepandus Asano and Uchio .... Pl. 8, figs. 1a–c.

Asano and Uchio, 1951, *Illust. Cat. Japan. Tert. Small Foram.*, pt. 14, p. 18, text-figs. 132, 133; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, pl. 2, figs. 19a, b.

Occurrence: Stations Ms 12, 13, 15, 16, 22.

Poroeponides lateralis (Terquem) .... Pl. 8, figs. 2a–c.

Rosalina lateralis Terquem, 1878, *Soc. Géol. France, Mém., sér.* 3, v. 1, no. 3, p. 25, pl. 2, figs. 11a–c.

Occurrence: Station Ms 21.

Pseudononion japonicum Asano .... Pl. 8, figs. 9a–c.

Asano, 1936, *Geol. Soc. Japan, Jour.*, v. 43, no. 512, p. 347, text-figs. a–c; 1960, *Tohoku Univ., Sci. Rep., 2nd ser.* (*Geol.*), *Spec. Vol.*, no. 4, p. 193, pl. 21, figs. 2a–c.

This species occurs rarely in the outer and middle bay facies. The distribution is shown in Fig. 64.

Occurrence: Stations Ms 2, 7, 11b, 14, 15, 16, 18, 21, 22, 23, 28, 40, 55.

Pyrgo ezo Asano .... Pl. 2, figs. 20a, b.

Asano, 1938, *Japan. Jour. Geol. Geogr.*, v. 15, nos. 1–2, p. 93, pl. 9, figs. 1a, b; 1956, *Tohoku Univ., Sci. Rep., 2nd ser.* (*Geol.*), v. 27, p. 77, pl. 9, figs. 9a, b, 11, 16a, b(?).

Occurrence: Stations Ms 2, 15.

Quinqueloculina contorta d'Orbigny .... Pl. 2, figs. 6a, b.

d'Orbigny, 1846, *Foram. Foss. Bas. Tert. Vienne*, p. 298, pl. 20, figs. 4–6.

Occurrence: Stations Ms 21, 43.

Quinqueloculina costata d'Orbigny .... Pl. 2, figs. 4a, b.

d'Orbigny, 1826, *Ann. Sci. Nat.*, v. 7, p. 301, no. 3; Terquem, 1878 (part), *Soc. Geol. France, Mém., sér.* 3, v. 1, no. 3, p. 63, pl. 11, figs. 4a–5c; Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 6, p. 3, text-figs. 14–16; 1956, *Tohoku Univ., Sci. Rep., 2nd ser.* (*Geol.*), v. 27, p. 58, pl. 7, figs. 14a–c.

Occurrence: Stations Ms 6, 7, 13,21, 27, 40.

Quinqueloculina cf. *curta* Cushman .... Pl. 2, figs. 3a, b.

Cf. *Quinqueloculina disparilis* var. *curta* Cushman, 1917, *U.S. Nat. Mus., Bull.* 71, pt. 6, p. 49, pl. 14, figs. 1–3.

Quinqueloculina curta Cushman, Hada, 1931, *Tohoku. Imp. Univ., Sci. Rep., 4th ser.* (*Biol.*), v. 6, no. 3, p. 80, text-figs. 33a–c; Asano, 1937, *Saito Ho-on Kai Mus., Res. Bull.*, no. 13, pl. 15, figs. 1a–c; 1956, *Tohoku Univ., Sci. Rep., 2nd ser.* (*Geol.*), v. 27, no. 58, p. 59, pl. 7, figs. 13a, b.

Cribrolinoides curta (Cushman), Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 6, p. 9, text-figs. 63, 64.

Q. curta Cushman is the type species of *Cribrolinoides* Cushman and LeRoy, and Loeblich and Tappan (1964) placed it in the Nubeculariidae rather than the Miliolidae. The Japanese form seems to be a true *Quinqueloculina* and may be a distinct species.

Occurrence: Stations Ms 2, 13, 15, 16, 17, 18, 20, 21, 22, 40, 55.

Quinqueloculina elongata Natland .... Pl. 2, figs. 8a, b.

Natland, 1938, *Scripps Inst. Oceanogr., Bull., Tech. Ser.*, v. 4, no. 5, p. 141, pl. 4, fig. 5.

Occurrence: Stations Ms 11b, 12, 13, 14, 15, 16, 18, 20 21, 22, 23, 39, 40.

Quinqueloculina fukushimaensis Takayanagi .... Pl. 2, figs. 9a, b.

Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 41, 51, text-figs. 26a-c. This species was described from the shallow sea just outside the Matsukawa-ura lagoon. This species is somewhat variable in the breadth of test but is generally more slender than the original figure. Very finely agglutinated wall is characteristic of this species.

Occurrence: Stations Ms 5, 13, 14, 15, 16, 18, 20, 21, 22, 28, 40.

Quinqueloculina cf. *lamarckiana* d'Orbigny .... Pl. 2, figs. 7a, b.

Cf. *Quinqueloculina lamarckiana* d'Orbigny, 1839, *Foraminifères, in* de la Sagra, *Hist. Phys. Pol. Nat. Cuba*, p. 189, pl. 11, figs. 14, 15.

Occurrence: Station Ms 13.

Quinqueloculina rhodiensis Parker .... Pl. 2, figs. 11a, b.

Parker, 1953, *in* Parker, Phleger and Peirson, *Cushman Found. Foram. Res., Spec. Pub.*, no. 2, p. 12, figs. 15–17.

Quinqueloculina costata d'Orbigny, Terquem, 1878 (part), *Soc. Géol. France, Mém., sér.* 3, v. 1, no. 3, p. 63, pl. 11, figs. 3a–c (not figs. 4a–5c).

Quinqueloculina boueana d'Orbigny, Hada, 1936, *Zool. Mag.*, v. 48, nos, 8–10 p. 854, text-figs. 9a–10b.

Although most species of miliolids live in the open shallow-waters, this species has been reported from only brackish-waters in Japan; Hijirippu and Mochirippu Lakes (Hada, 1936), Akkeshi Lake (Yoshida, 1953; Hada, 1957), the inlet of Usu (Hada, 1957), and Nakanoumi (Hada, 1939). In these reports this species is associated with other brackish-water species such as *Trochammina hadai*, *Ammonia beccarii*, *Miliammina fusca* except for Nakanoumi where it is associated with many open shallow-water species as well as other miliolids. In Matsushima Bay this species occurs commonly in the subfacies C_4 and sporadically in the other subfacies of the inner bay facies, associated with several brackish-water species. The distribution is shown in Fig. 40.

Occurrence: Stations Ms 3, 5, 23, 25, 29, 31, 32, 33, 36, 43, 44, 47.

Quinqueloculina seminulum (Linné) .... Pl. 2, figs. 10a, b.

Serpula seminulum Linné, 1758, *Syst. Nat., ed.* 10, p. 786 (*fide* Ellis and Messina).

Occurrence: Stations Ms 2, 13, 22, 23, 24, 40, 56.

Quinqueloculina vulgaris d'Orbigny .... Pl. 2, figs. 5a, b,

d'Orbigny, 1826, *Ann. Sci. Nat.*, v. 7, p. 302, no. 33; Asano, 1956, *Tohoku Univ. Sci. Rep.*, *2nd ser.* (*Geol.*), v. 27, p. 63, pl. 8, figs. 10a–c, 13a–c.
Occurrence: Stations Ms 12, 13, 22, 28, 40, 56.

Quinqueloculina yabei Asano
Asano, 1936, *Geol. Soc. Japan, Jour.*, v. 43, no. 519, p. 942, pl. 51, figs. 1a–c; 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 6, p. 8, text-figs. 57–59.
Occurrence: Stations Ms 13, 15.

Quinqueloculina sp. 4 .... Pl. 2, figs. 12a, b.
Occurrence: Stations Ms 12, 15

Quinqueloculina sp. 5 .... Pl. 2, figs. 13a, b.
Occurrence: Stations Ms 13, 20, 21, 23.

Quinqueloculina sp. 6 .... Pl. 2, figs. 14a, b.
Occurrence: Station Ms 13.

Rectobolivina raphana (Parker and Jones) .... Pl. 3, fig. 31.
Uvigerina (*Sagrina*) *raphanus* Parker and Jones, 1865, *Roy. Soc. London, Philos. Trans.*, v. 155, p. 364, pl. 18, figs. 16, 17.
Siphogenerina raphanus (Parker and Jones), Asano, 1950, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 2, p. 14, text-figs. 56, 57.
Occurrence: Station Ms 16.

Reophax nana Rhumbler .... Pl. 1, fig. 1.
Rhumbler, 1911, *Ergeb. Plankton-Exped. Humboldt-Stiftung*, v. 3, pt. 1 (1909), pl. 18, figs. 6–12; 1913, *ibid.* pt. 2, p. 471.
Occurrence: Stations Ms 39, 43.

Reophax gracilis (Kiaer) .... Pl. 1, fig. 2.
Nodulina gracilis Kiaer, 1900, *Norweigan Fish. Mar. Invest., Rep.*, v. 1, no. 7, p. 24, text-figs. 1, 2.
Reophax gracilis (Kiaer), Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser.* (*Biol.*), v. 6, no. 3, p. 61, text-fig. 13.
Occurrence: Station Ms 11b.

Reophax scottii Chaster .... Pl. 1, fig. 3.
Chaster, 1892, *Southport Soc. Nat. Sci., 1st Rep.* (1890–1891), Append., p. 57, pl. 1, fig. 1.
Occurrence: Station Ms 23.

Reussella pacifica Cushman and McCulloch .... Pl. 3, figs. 33a, b.
Cushman and McCulloch, 1948, *Allan Hancock Pacific Exped.*, v. 6, no. 5, p. 251, pl. 31, figs. 6a, b.
Occurrence: Stations Ms 14, 22, 24, 56.

Rosalina australis (Parr) .... Pl. 4, figs. 7a–c.
Discorbis australis Parr, 1932, *Roy. Soc. Victoria, Proc., N.S.*, v. 44, pt. 2, p. 227.
Discorbina valvulata (d'Orbigny), Brady, 1884, *Voy. Challenger, Rep., Zool.*, v. 9, p. 644, pl. 87, figs. 5–7.
Discopulvinulina australis (Parr), Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 3, text-figs. 20–22.
Occurrence: Stations Ms 13, 14, 19, 22, 28.

Rosalina bradyi (Cushman) .... Pl. 4, figs. 8a–c.
Discorbis globularis var. *bradyi* Cushman, 1915, *U.S. Nat. Mus., Bull.* 71, pt. 5, p. 12, pl. 8, figs. 1a–c.
Discopulvinulina bradyi (Cushman), Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 14, p. 4, text-figs. 25, 26; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 44, pl. 2, figs. 5a, b.
This species is rare in the outer bay facies and very rare in the middle bay facies. The distribution is shown in Fig. 46.
Occurrence: Stations Ms 2, 4, 5, 6, 7, 11a, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 27, 28, 30, 39, 40, 43.

Rosalina columbiensis (Cushman) .... Pl. 4, figs. 9a–c.
Discorbis columbiensis Cushman, 1925, *Cushman Lab. Foram. Res., Contr.*, v. 1, pt. 2, p. 43, pl. 6, figs. 13
Occurrence: Stations Ms 13, 19, 40.

Rosalina globularis d'Orbigny....................................Pl. 4, figs. 10a–c.
d'Orbigny, 1826, *Ann. Sci. Nat.*, v. 7, p. 271, no. 1, pl. 13, figs. 1–4; Modèle no. 69.
Occurrence: Station Ms 22.

Rosalina vilardeboana d'Orbigny....................................Pl. 4, figs. 11a–c.
d'Orbigny, 1839, *Voy. Amér. Mérid., Foraminifères*, v. 5, pt. 5, p. 44, pl. 6, figs. 13–15; Matoba, 1967, *Tohoku Univ., Sci. Rep., 2nd ser. (Geol.)*, v. 38, no. 2, p. 257, pl. 26, figs. 15a–c.
This species occurs rarely in the outer bay facies and sporadically in the middle bay facies. The distribution is shown in Fig. 47.
Occurrence: Stations Ms 2, 7, 11a, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 28, 30, 33, 40, 55, 56.

Siphonaperta macbeathi Vella....................................Pl. 2, figs. 19a, b.
Vella, 1957, *New Zealand Geol. Surv., Pal. Bull.* 28, p. 19, pl. 4, figs. 60, 61, 63; Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, pl. 1, figs. 5a–c.
Occurrence: Stations Ms 7, 15, 16, 22, 46.

Spirillina cf. *vivipara* Ehrenberg....................................Pl. 5, figs. 7a–c.
Cf. Ehrenberg, 1843, *K. Adad. Wiss. Berlin, Abhandl.* (1841), p. 442, pl. 3, fig. 41.
Occurrence: Station Ms 13.

Spiroplectammina biformis (Parker and Jones)....................................Pl. 1, figs. 10a, b.
Textularia agglutinans var. *biformis* Parker and Jones, 1865, *Roy. Soc. London, Philos. Trans.*, v. 155, p. 370, pl. 15, figs. 23, 24.
Spiroplectammina biformis (Parker and Jones), Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, pl. 1, fig. 4.
Occurrence: Station Ms 24.

Spiroplectammina typica Lacroix....................................Pl. 1, figs. 11a, b.
Lacroix, 1931, *Inst. Oceanogr., Monaco, Bull.*, no. 582, p. 14, fig. 9; *ibid.*, no. 591, p. 7, figs. 2a–3b; Takayanagi, 1955, *Tohoku Univ., Inst. Geol., Pal., Contr.*, no. 45, pl. 1, fig. 6.
Occurrence: Station Ms 23.

Textularia candeiana d'Orbigny....................................Pl. 1, figs. 13a, b.
d'Orbigny, 1839, *Foraminifères, in* de la Sagra, *Hist. Phys. Pol. Nat. Cuba*, p. 143; *ibid.*, v. 8, pl. 1, figs. 25–27.
Occurrence: Stations Ms 17, 19, 21, 22.

Textularia earlandi Parker....................................Pl. 1, fig. 12.
Parker, 1952, *Harvard Coll., Mus. Comp. Zool., Bull.*, v. 106, no. 10, p. 458 (footnote).
Textularia tenuissima Earland, 1933, *Discovery Rep.*, v. 7, p. 95, pl. 3, figs. 21–30.
Occurrence: Stations Ms 5, 7, 9, 11a, 11b, 13, 17, 20, 23, 26, 27, 29, 30, 33, 38, 39, 43, 47, 56.

Tiphotorcha kellettae (Thalmann)....................................Pl. 1, figs. 19a–c.
Trochammina kellettae Thalmann, 1932, *Eclog. Geol. Helv.*, v. 25, no. 2, p. 313; Cushman and McCulloch, 1939, *Allan Hancock Pacific Exped.*, v. 6, no. 1, p. 101, pl. 11, figs. 1a–c; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, pl. 1, figs. 18a, b.
Occurrence: Stations Ms 5, 7, 10, 11a, 12, 13, 14, 18, 20, 23, 25, 26, 27, 29, 32, 33, 39, 43, 44, 55, 56.

Triloculina brevidentata Cushman
Cushman, 1944, *Cushman Lab. Foram Res., Spec. Pub.*, no. 12, p. 16, pl. 2, figs. 25a, b.
Occurrence: Stations Ms 12, 13.

Triloculina laevigata d'Orbigny....................................Pl. 2, figs. 21a, b.
d'Orbigny, 1826, *Ann. Sci. Nat. Paris, sér.* 1, v. 7, p. 300, no. 15; Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 6, p. 15, text-figs. 103–105.
Occurrence: Stations Ms 3, 5, 7, 11b, 13, 14, 15, 17, 18, 20, 21, 22, 23, 24, 27, 28, 30, 40, 43, 56.

Triloculina rotunda d'Orbigny....................................Pl. 2, figs. 22a, b.
d'Orbigny, 1826, *Ann. Sci. Nat. Paris, sér.* 1, v. 7, p. 299, no. 4; Asano, 1951, *Illust. Cat. Japan. Tert. Small. Foram.*, pt. 6, p. 16, text-figs. 106, 107.
Occurrence: Stations Ms 13, 22.

Triloculina terquemiana (Brady)....................................Pl. 3, figs. 1a, b.
Milolina terquemiana Brady, 1884, *Voy. Challenger, Rep. Zool.*, v. 9, p. 166, pl. 114, figs. 1a, b.
Occurrence: Station Ms 15.

Triloculina cf. *terquemiana* (Brady) ....Pl. 3, figs. 2a, b.

This form differs from *T. terquemiana* in having a nearly circular aperture with a short neck.

Occurrence: Stations Ms 13, 23, 40.

Triloculina trigonula (Lamarck) ....Pl. 3, figs. 3a, b.

Miliolites trigonula Lamarck, 1804, *Paris, Mus. Nat. Hist., Ann.*, v. 5, p. 151; 1807, *ibid.*, v. 9, pl. 17, figs. 4a–c.

Occurrence: Station Ms 22.

Triloculina sp. ....Pl. 3, figs. 4a,b.

Occurrence: Stations Ms 12, 13, 15, 21, 23, 36, 47, 55.

Trochammina discorbis Earland

Earland, 1934, *Disocvery Rep.*, v. 10, p. 104, pl. 3, figs. 28–31; Cushman and McCulloch, 1939, *Allan Hancock Pacific Exped.*, v. 6, no. 1, p. 106, pl. 11, figs. 10a–c.

Occurrence: Stations Ms 10, 11a.

Trochammina hadai Uchio ....Pl. 1, figs. 14a–c, 15a–c.

Uchio, 1962, *Seto Mar. Biol. Lab., Pub.*, v. 10, no. 2, p. 387, pl. 18, figs. 9a–c.

Trochammina globigeriniformis (Parker and Jones), Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser.* (*Biol.*), v. 6, no. 3, p. 91, text-figs. 44a–c; Morishima and Chiji, 1952, *Univ. Kyoto, Coll. Sci., Mem., ser. B*, v. 20, no. 2, pl. 1 (12), figs. 11a–c; Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 42, pl. 1, figs. 17a–c; Ishiwada, 1958, *Geol. Surv. Japan, Rep.*, no. 180, pl. 1, figs. 13, 14.

This species is widely distributed in the brackish-waters of Japan, and has been reported as *Trochammina* (or rarely *Ammoglobigerina*) *globigeriniformis* (Parker and Jones) or *T.* cf. *globigeriniformis*. Uchio (1962c) distinguished this species from *T. globigeriniformis* which is a very common and widely distributed species in the deep, cold waters. This is one of the most abundant species in the inner and middle bay facies. The distribution is shown in Fig. 36.

Occurrence: All the stations except Station Ms 22.

Trochammina inflata (Montagu)

Nautilus inflatus Montagu, 1808, *Test. Britannica, Suppl.*, p. 81, pl. 18, fig. 3.

Trochammina inflata (Montagu), Hada, 1931, *Tohoku Imp. Univ., Sci. Rep., 4th ser.* (*Biol.*), v. 6, no. 3, p. 90, text-figs. 43a, b.

Occurrence: Stations Ms 2, 35, 44.

Trochammina cf. *japonica* Ishiwada ....Pl. 1, figs. 16a–c, 17a–c.

Cf. *Trochammina japonica* Ishiwada, 1950, *Geol. Surv. Japan, Bull.*, v. 1, no. 4, p. 190, pl., figs. 2a–c.

Trochammina japonica Ishiwada, Yoshida, 1954, *Tokyo Kyoiku Daigaku, Geol. Min. Inst., Stud.*, no. 3, pl., figs. 1a–c.

Trochammina cf. *nana* (Brady), Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, p. 42, pl. 1, figs. 20a, b.

This form is similar to *T. japonica* Ishiwada but differs from the latter in the more compressed test, less inflated chambers, less depressed sutures on both sides and less lobulate periphery. Besides *T. japonica* was described from the deep water of Toyama Bay and is distributed in the bathyal zone under the water mass peculiar to the Japan Sea in contrast to the brackish-water of Matsushima Bay. This is one of the most abundant species in the inner and middle bay facies associated with *T. hadai* and *Ammonia beccarii* forma 2. The distribution is shown in Fig. 37.

Occurrence: All the stations except Stations Ms 20, 21 and 22.

Trochammina pacifica Cushman ....Pl. 1, figs. 18a–c.

Cushman, 1925, *Cushman Lab. Foram. Res., Contr.*, v. 1, pt. 2, p. 39, pl. 6, figs. 3a–c; Cushman and McCulloch, 1939, *Allan Hancock Pacific Exped.*, v. 6, no. 1, p. 103, pl. 11, figs. 3a–c.

Occurrence: Stations Ms 12, 16.

Uvigerinella glabra (Millett) ....Pl. 3, figs. 35a, b.

Uvigerina auberiana var. *glabra* Millett, 1903 (part), *Roy. Micr. Soc. London, Jour.*, p. 268, pl. 5, figs. 8a, b (not fig. 9).

Hopkinsina pacifica Cushman, Takayanagi, 1955, *Tohoku Univ., Inst. Geol. Pal., Contr.*, no. 45, pl. 2, fig. 22.

Hopkinsina californica Cushman, Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, pl. 1, figs. 14, 15.

Hopkinsina glabra (Millett), Aoki, 1965, *Saitama Univ., Sci. Rep., ser. B*, v. 5, no. 1, p. 59, pl. 7, fig. 2.

This species occurs rarely in the bay except for the innermost parts, and its highest occurrence is in the middle part of the bay. The distribution is shown in Fig. 43.

Occurrence: Stations Ms 3, 5, 6, 7, 8, 9, 11a, 11b, 12, 14, 15, 16, 17, 18, 19, 21, 24, 26, 27, 28, 29, 30, 31, 39, 40, 43, 44, 55, 56.

Valvulineria hamanakoensis (Ishiwada) .... Pl. 4, figs. 12a–c, 13a–c.

Anomalina hamanakoensis Ishiwada, 1958, *Geol. Surv. Japan, Rep.*, no. 180, p. 18, text-figs. 3a–c, pl. 1, figs. 24–27.

Valvulineria cf. *polita* Parr, Ujiié, 1963, *Tokyo Kyoiku Daigaku, Sci. Rep., sec. C*, no. 79, p. 235, pl. 2, figs. 12a–b.

This minute species is similar to *Valvulineria osakaensis* Chiji (1956, *in* Nakaseko and Chiji, *Osaka Univ., Sci. Rep.*, no. 5, p. 63, text-figs. 6a–c) but differs from it in the fewer chambers in the last whorl and umbilical region on the ventral side covered with thin granular shell material. This species is common in the inner and middle bay facies. The distribution is shown in Fig. 50.

Occurrence: All the stations except Stations Ms 12, 20 and 22.

Wiesnerella auriculata (Egger) .... Pl. 2, figs. 2a, b.

Planispirina auriculata Egger, 1893, *K. Bayer, Akad. Wiss., München, Math. Phys. Cl., Abh.*, v. 18, pt. 2, p. 371, pl. 13, figs. 19–21.

Wiesnerella auriculata (Egger), Asano, 1951, *Illust. Cat. Japan. Tert. Small Foram.*, pt. 9, p. 2, text-figs. 6–8.

Occurrence: Station Ms 13.

DESCRIPTION OF NEW SPECIES

Order Foraminiferida Eichwald, 1830
Suborder Rotaliina Delage and Hérouard, 1896
Superfamily Rotaliacea Ehrenberg, 1839
Family Rotaliidae Ehrenberg, 1839
Genus *Pararotalia* Le Calvez, 1949
Pararotalia? *takayanagii* Matoba, n. sp.
Pl. 6, figs, 9a–c, 10a–c

Pararotalia minuta (Takayanagi) and var., Matoba, 1967, p. 256, pl. 27, figs. 5a, b, 6a, b.

Description: Test free, minute, trochospiral, plano-convex to concavo-convex, periphery subrounded, peripheral outline strongly lobulate and stellate, spiral side nearly flattened to concave but inflated at central portion, umbilical side convex, deeply umbilicate, without umbilical plug but covered with thin granular materials; chambers in two whorls, 5 to 5 1/2 in final whorl, each much inflated near umbilicus, forming nodelike elevation at umbilical shoulder, and curved towards spiral side at radially elongate end, forming a rhomboidal to triangular shape in peripheral view; sutures distinct, depressed, radial on umbilical side, slightly oblqiue on spiral side; wall calcareous, thin, very finely perforate, radially built, surface finely pustulous and ornamented with numerous short, blunt spines at narrowly rounded radial end of each chamber; aperture interiomarginal and extraumbilical-umbilical, with narrow lip; intercameral foramen areal, comma-shaped, consisting of portion of former aperture, oblique to base of apertural face.

Maximum diameter of holotype 0.17 mm, maximum thickness 0.07 mm. Maximum diameter of figured paratype 0.14 mm, maximum thickness 0.07 mm. Other paratypes range from 0.16 to 0.11 mm in maximum diameter and 0.08 to 0.06 mm in maximum thickness.

Types and occurrence: Holotype (pl. 6, figs. 9a–c), IGPS coll. cat. no. 91311, from Station Ms 7 (depth 2.5 m); figured paratype (pl. 6, figs. 10a–c), IGPS coll. cat. no. 91312A, from Station Ms 56 (depth 1.7 m), both from Matsushima Bay, Miyagi Prefecture, Lat. *ca.* 38°20'N., Long. *ca.* 141°05'E.

Remarks: This new species is similar to *Pararotalia*? *minuta* (Takayanagi), *P.* ? *globosa* (Millett) and *P.* ? *murrayi* (Heron-Allen and Earland) in the globigerinid-like appearance of the test, rough surface texture and minute size, but differs from them in the radially elongate and rhomboidal chambers both in axial and peripheral view, depressed and open umbilicus instead of closed, and large extraumbilical-umbilical aperture. Takayanagi (1955) included this new species in his species *Rotalia* ? *minuta*. After the writer's examination of Takayanagi's specimens from the Matsukawa-ura lagoon and its vicinity it was determined as a new species. The generic position of this species is close to *Pararotalia* Le Calvez in the apertural character, and the similar species, *Rotalia* ? *minuta* Takayanagi was assigned to *Pararotalia* by Ujiié (1963). But from the absence of the umbilical plug in this species the accurate generic position is questionable.

Occurrence: Rare in the Recent deposits of Matsushima Bay (Stations Ms 6, Ms 7, Ms 13, Ms 20, Ms 55, and Ms 56) and the mouth area and just outside of the Matsukawa-ura lagoon, but common in some samples from the Pliocene-Pleistocene deposits at Choshi, Chiba Prefecture.

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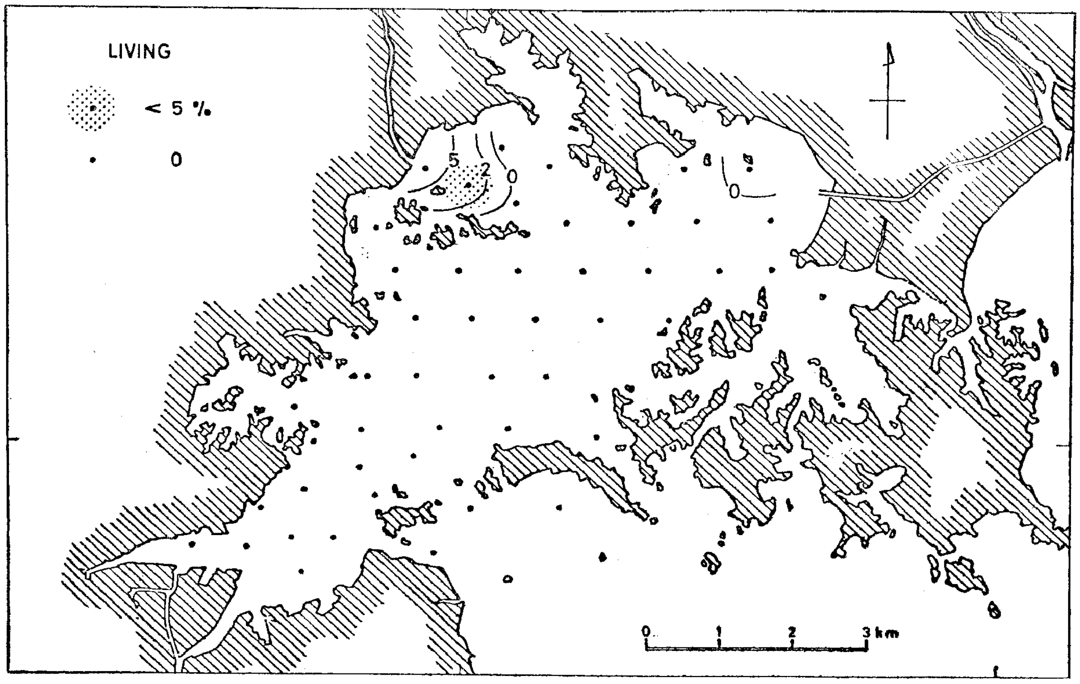


Fig. 34. Distribution of *Miliammina fusca* (Brady) in percent in the total (isopleth) and living (shaded) populations.

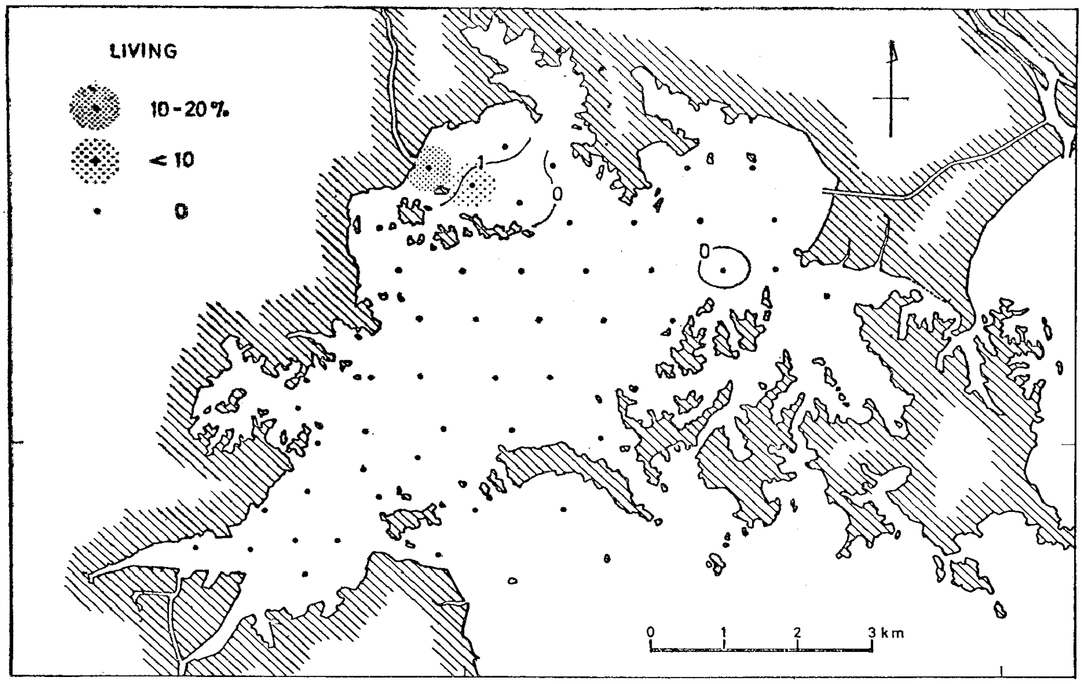


Fig. 35. Distribution of *Ammobaculites exiguus* Cushman and Bronnimann in percent in the total (isopleth) and living (shaded) populations.

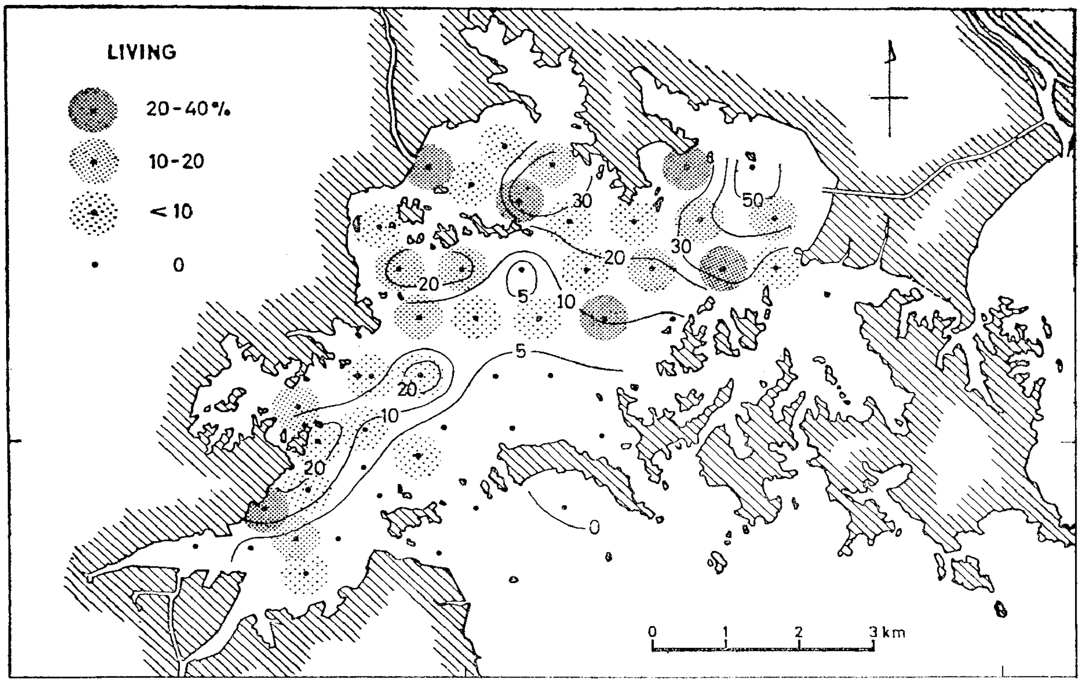


Fig. 36. Distribution of *Trochammina hadai* Uchio in percent in the total (isopleth) and living (shaded) populations.

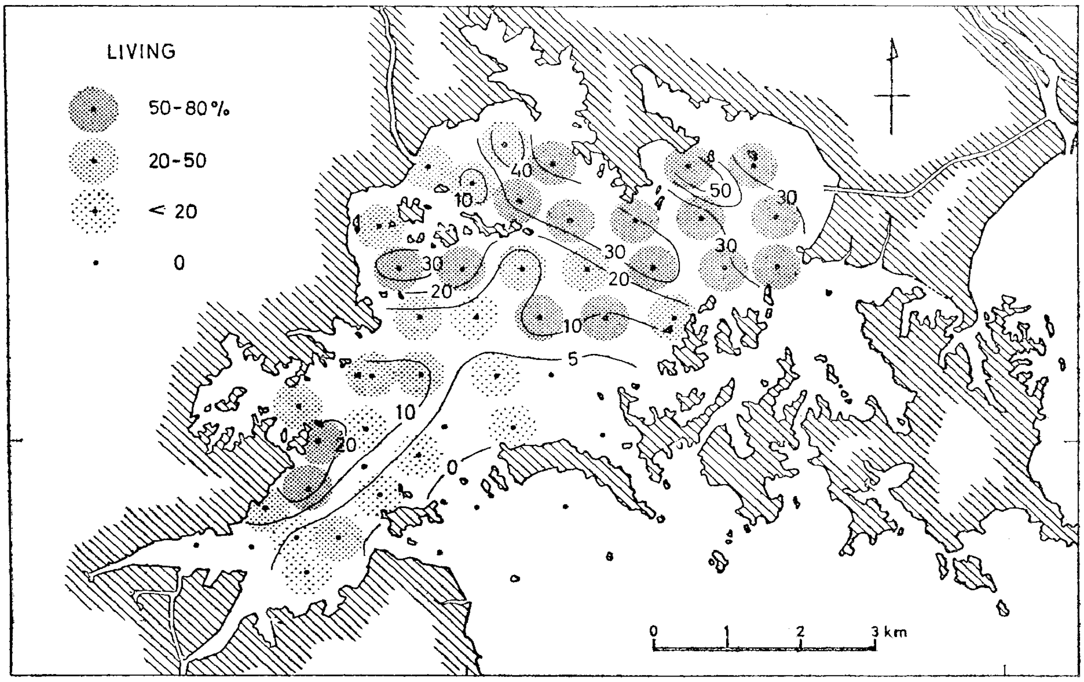


Fig. 37. Distribution of *Trochammina* cf. *japonica* Ishiwada in percent in the total (isopleth) and living (shaded) populations.

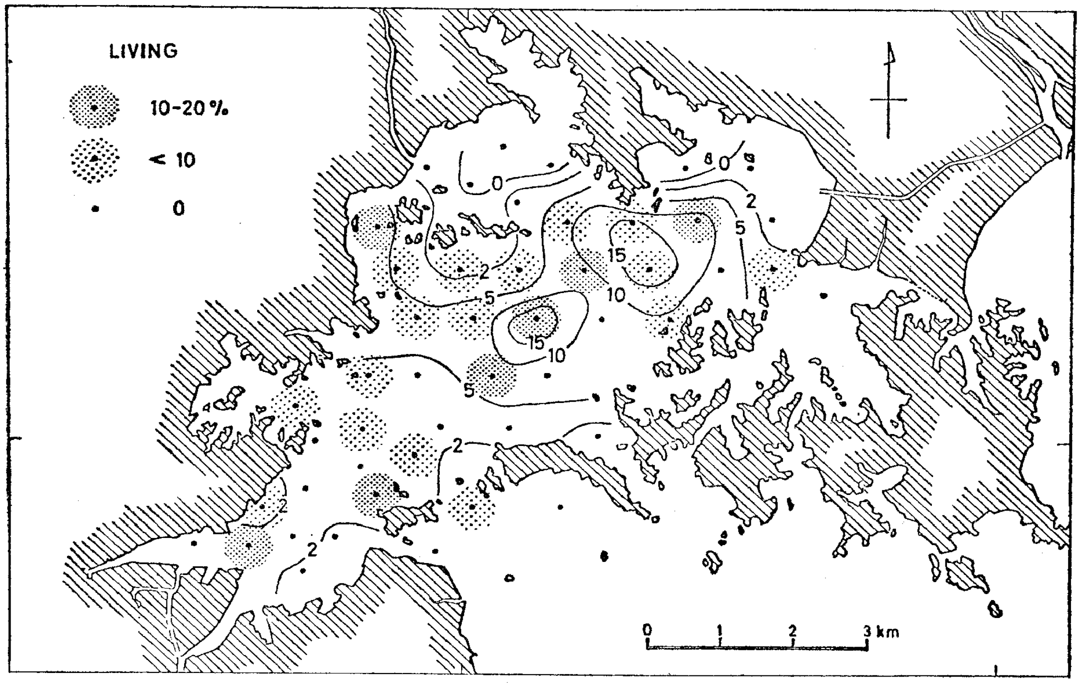


Fig. 38. Distribution of *Eggerella scabra* (Williamson) in percent in the total (isopleth) and living (shaded) populations.

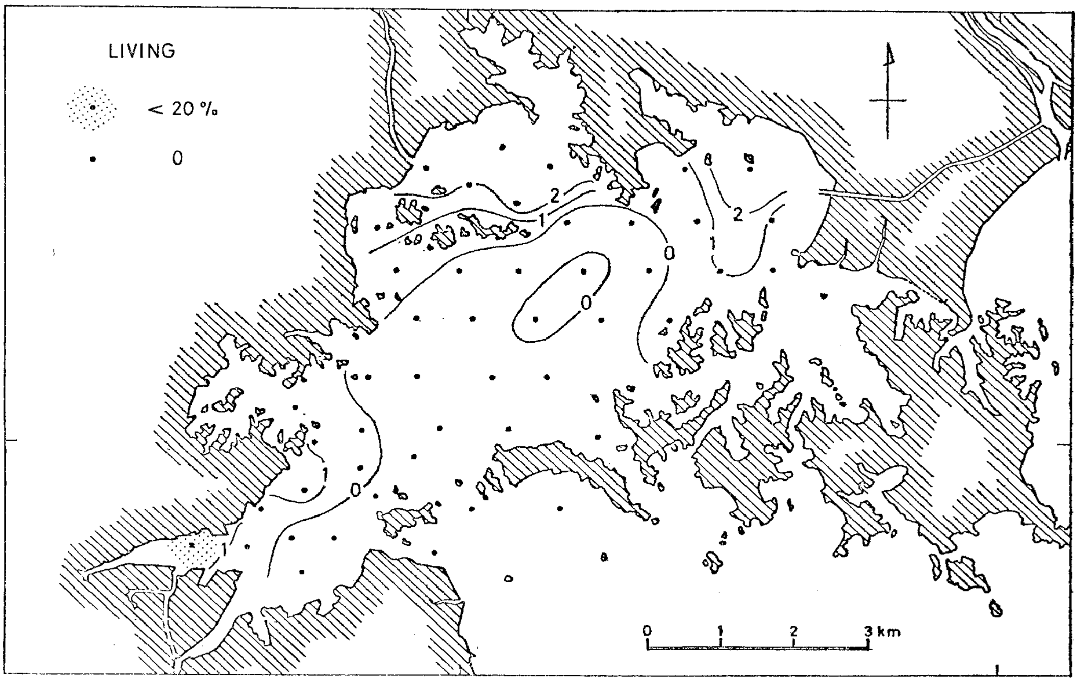


Fig. 39. Distribution of *Goesella iizukae* Takayanagi in percent in the total (isopleth) and living (shaded) populations.

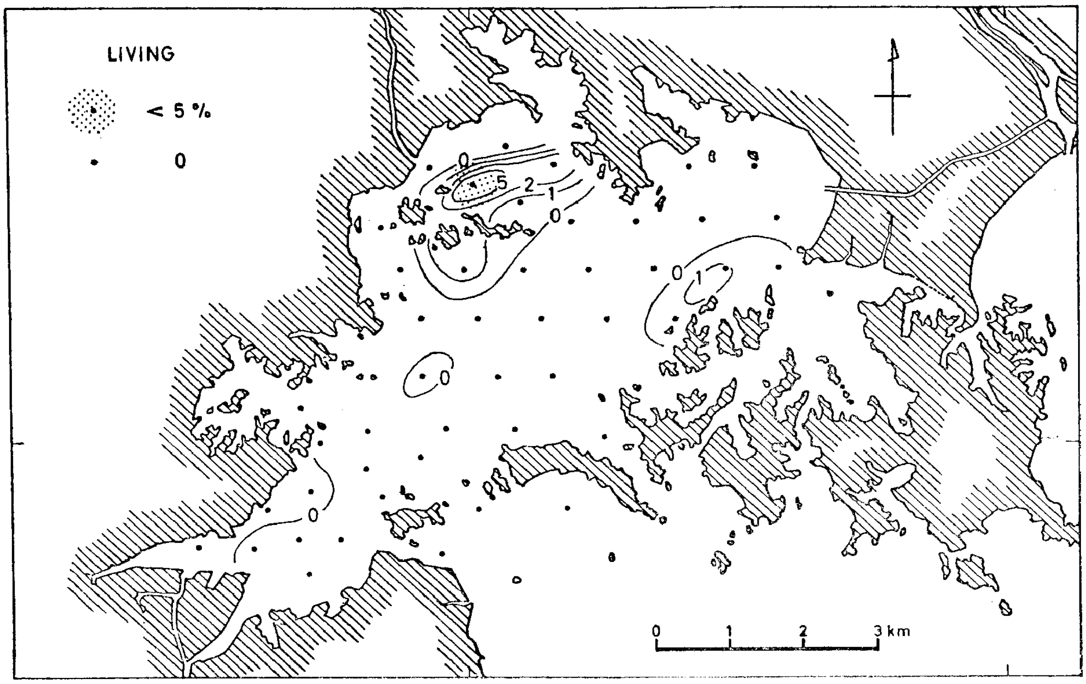


Fig. 40. Distribution of *Quinqueloculina rhodiensis* Parker in percent in the total (isopleth) and living (shaded) populations.

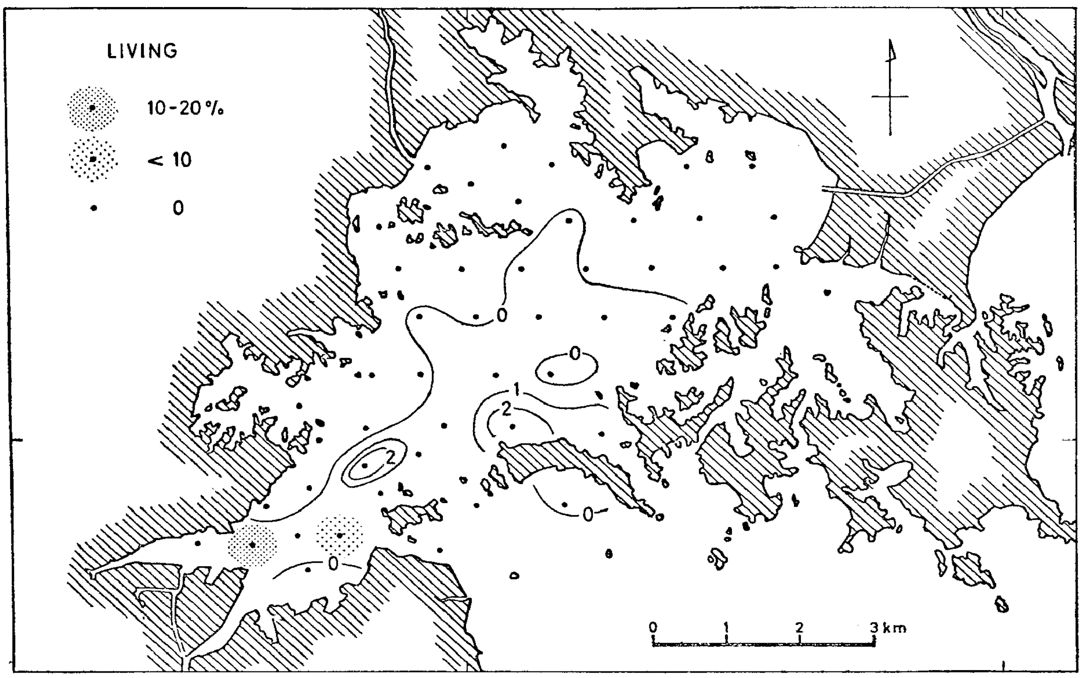


Fig. 41. Distribution of *Buliminella elegantissima* (d'Orbigny) in percent in the total (isopleth) and living (shaded) populations.

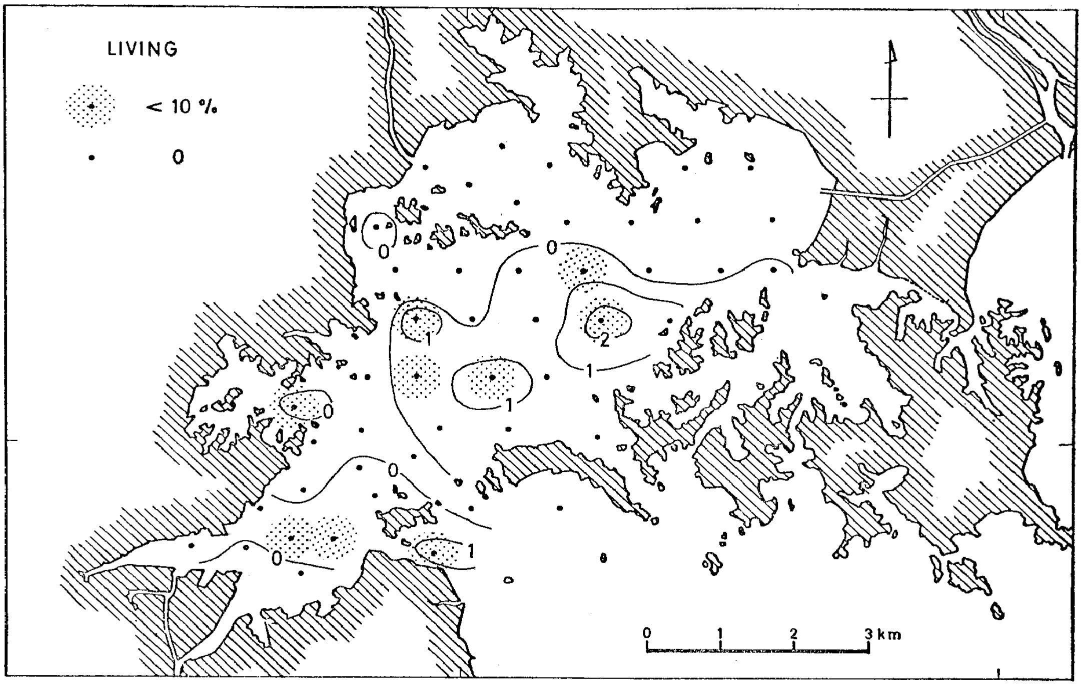


Fig. 42. Distribution of *Bolivina striatula* Cushman in percent in the total (isopleth) and living (shaded) populations.

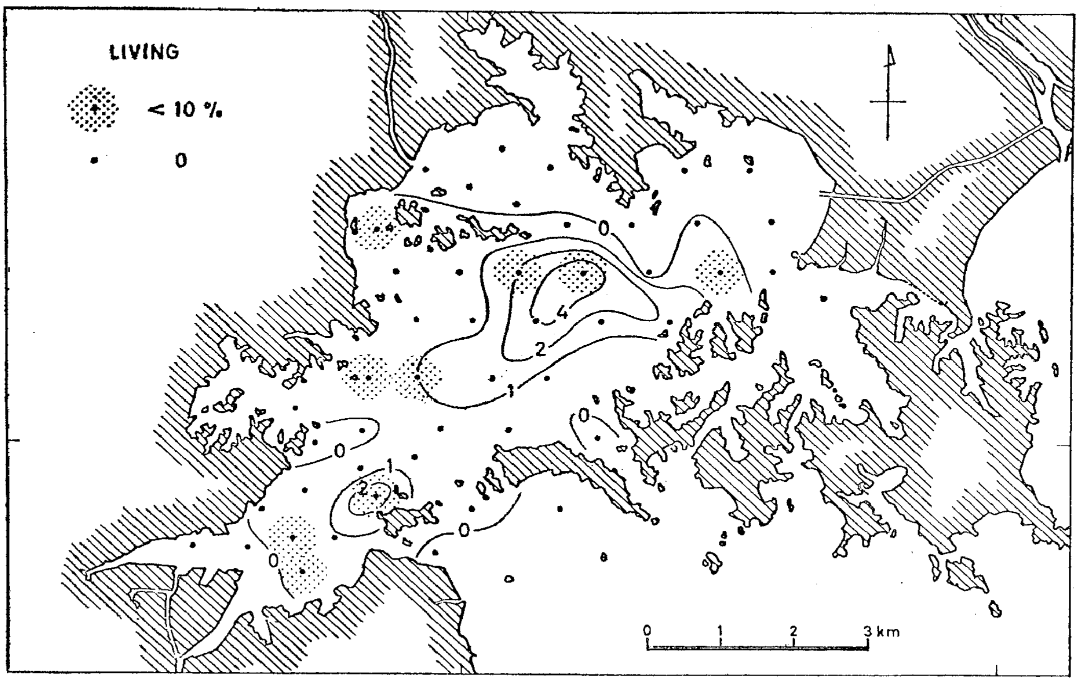


Fig. 43. Distribution of *Uvigerinella glabra* (Millett) in percent in the total (isopleth) and living (shaded) populations.

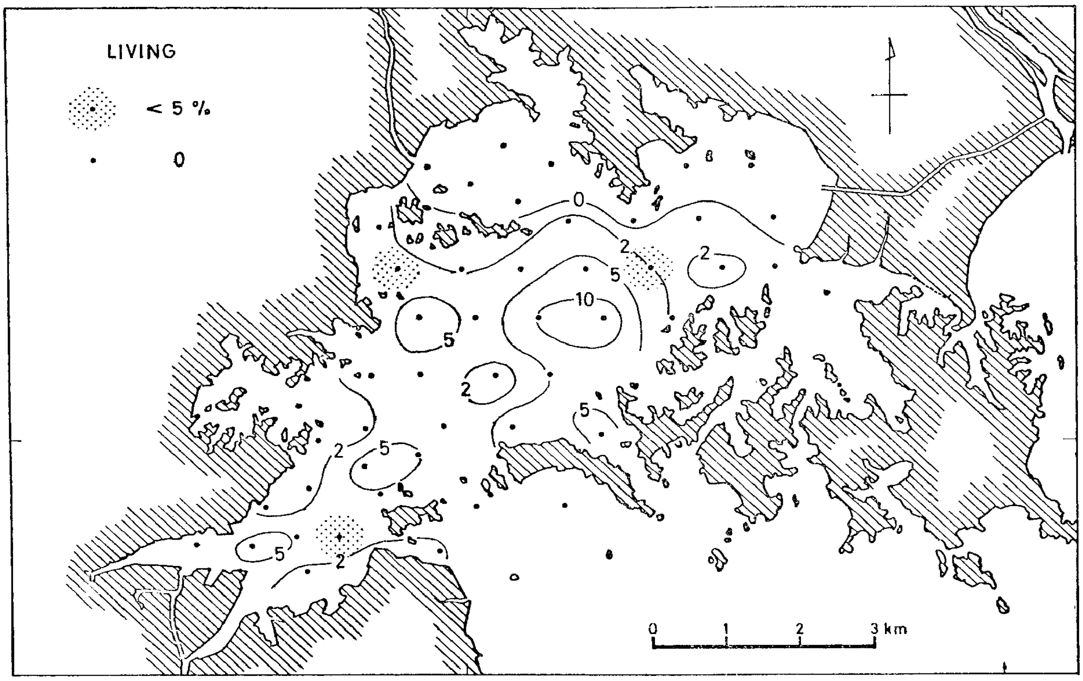


Fig. 44. Distribution of *Buccella frigida* (Cushman) in percent in the total (isopleth) and living (shaded) populations.

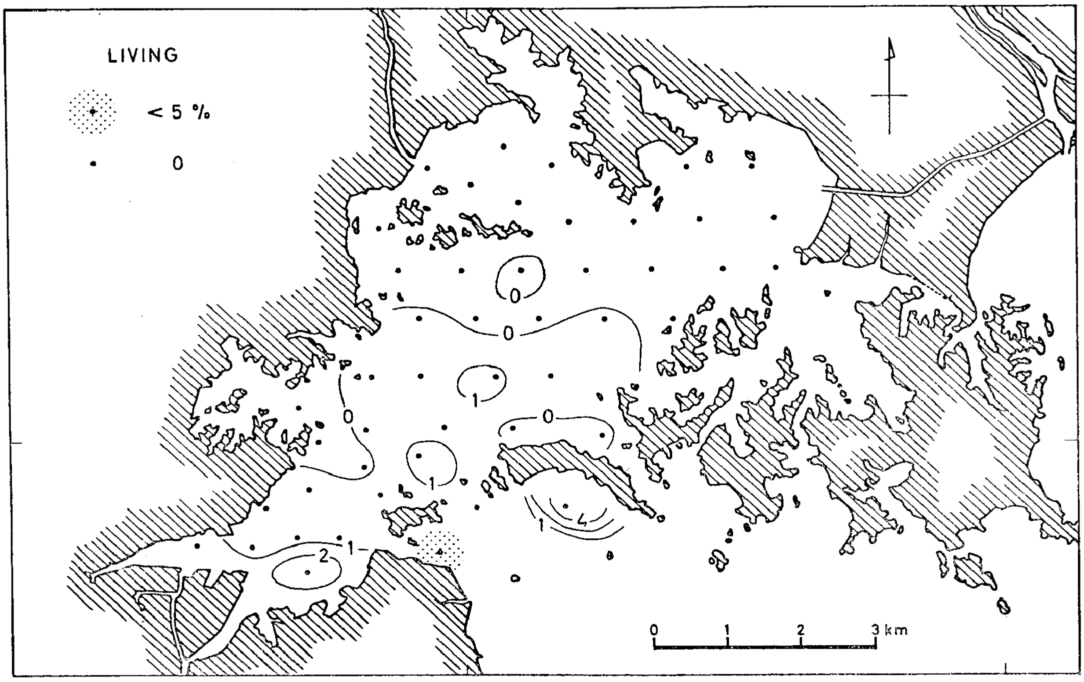


Fig. 45. Distribution of *Buccella*? *makiyamae* Chiji in percent in the total (isopleth) and living (shaded) populations.

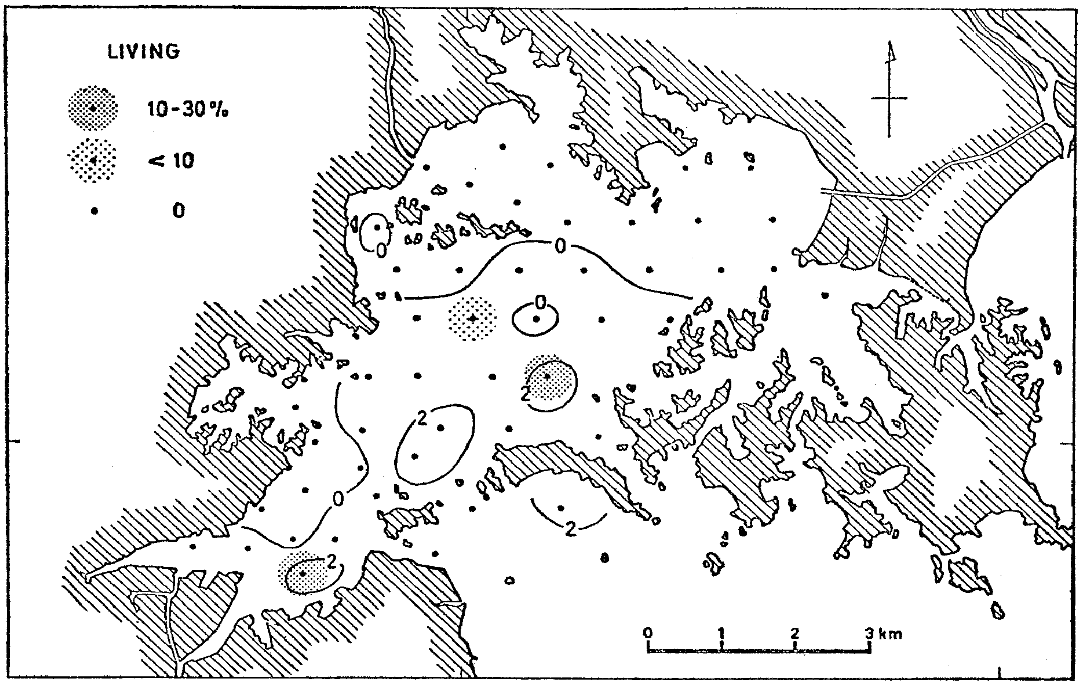


Fig. 46. Distribution of *Rosalina bradyi* (Cushman) in percent in the total (isopleth) and living (shaded) populations.

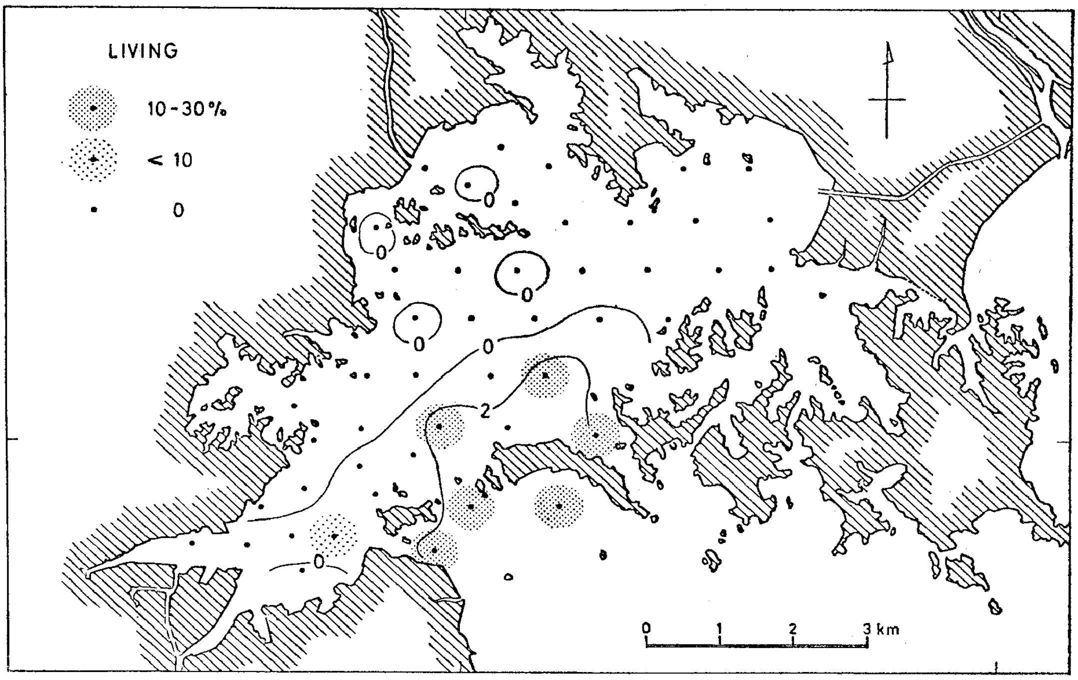


Fig. 47. Distribution of *Rosalina vilardeboana* d'Orbigny in percent in the total (isopleth) and living (shaded) populations.

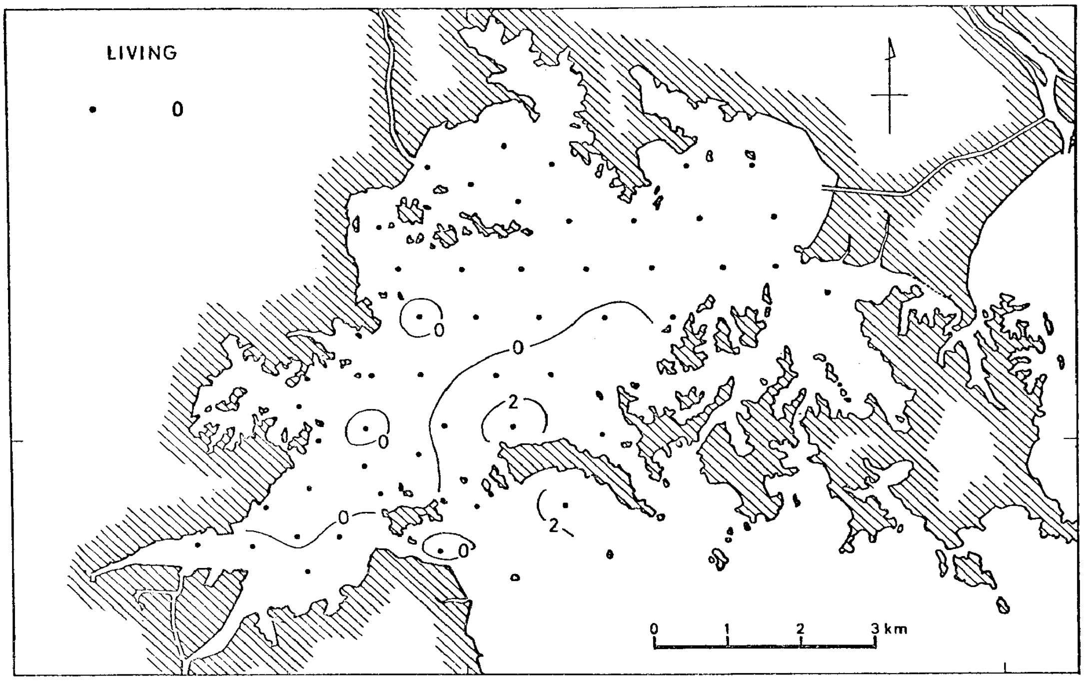


Fig. 48. Distribution of *Glabratella opercularis* (d'Orbigny) and *G. suboperculuris* (Asano) in percent in the total (isopleth) and living (shaded) populations.

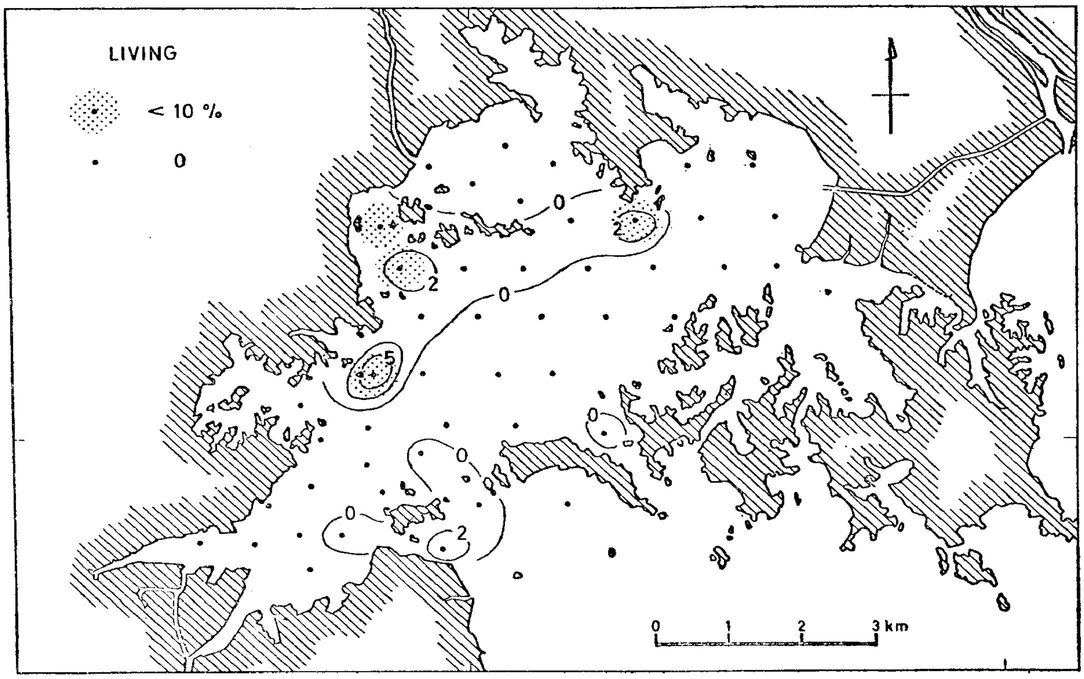


Fig. 49. Distribution of *Glabratella* cf. *chasteri* (Heron-Allen and Earland) in percent in the total (isopleth) and living (shaded) populations.

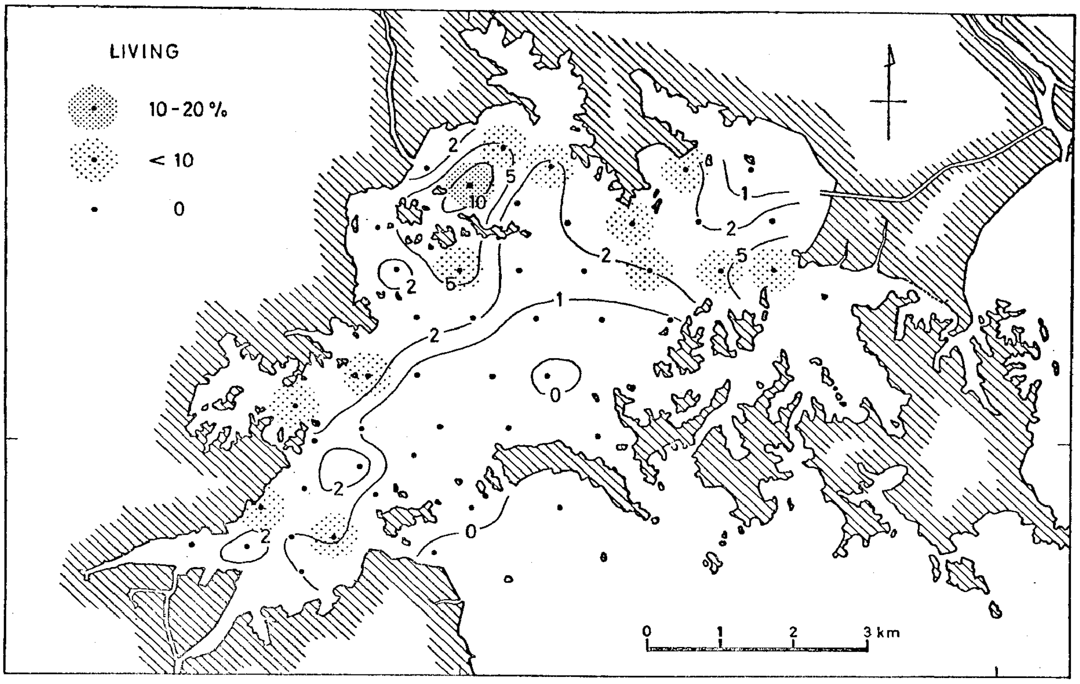


Fig. 50. Distribution of *Valvulineria hamanakoensis* (Ishiwada) in percent in the total (isopleth) and living (shaded) populations.

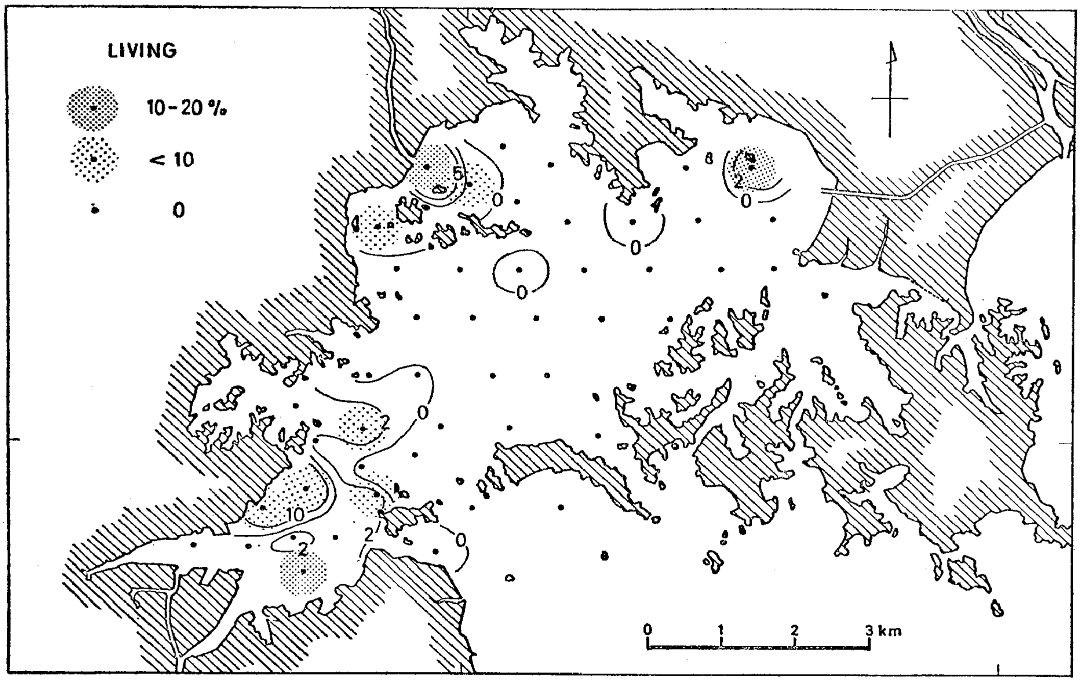


Fig. 51. Distribution of *Ammonia beccarii* (Linné) forma 1 in percent in the total (isopleth) and living (shaded) populations.

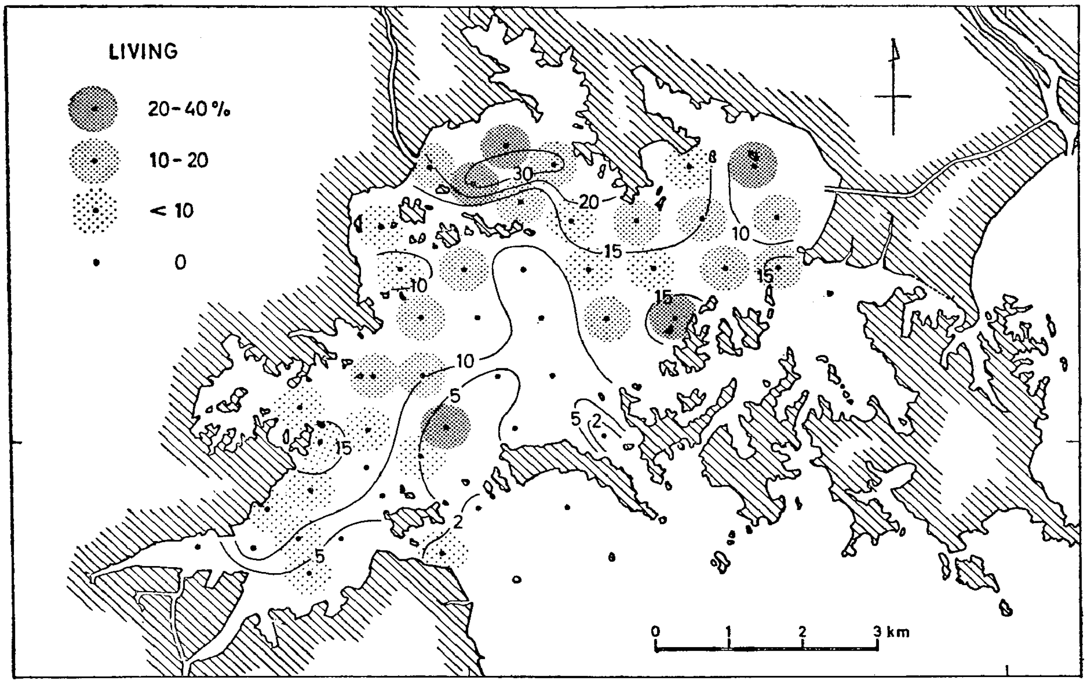


Fig. 52. Distribution of *Ammonia beccarii* (Linné) forma 2 in percent in the total (isopleth) and living (shaded) populations.

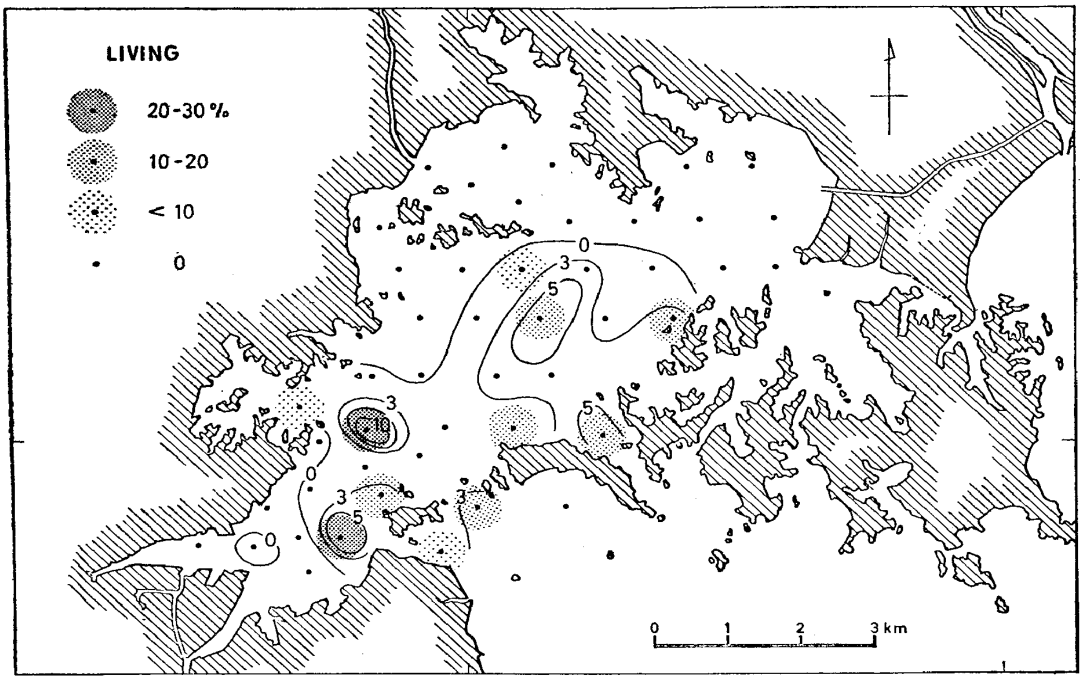


Fig. 53. Distribution of *Ammonia japonica* (Hada) in percent in the total (isopleth) and living (shaded) populations.

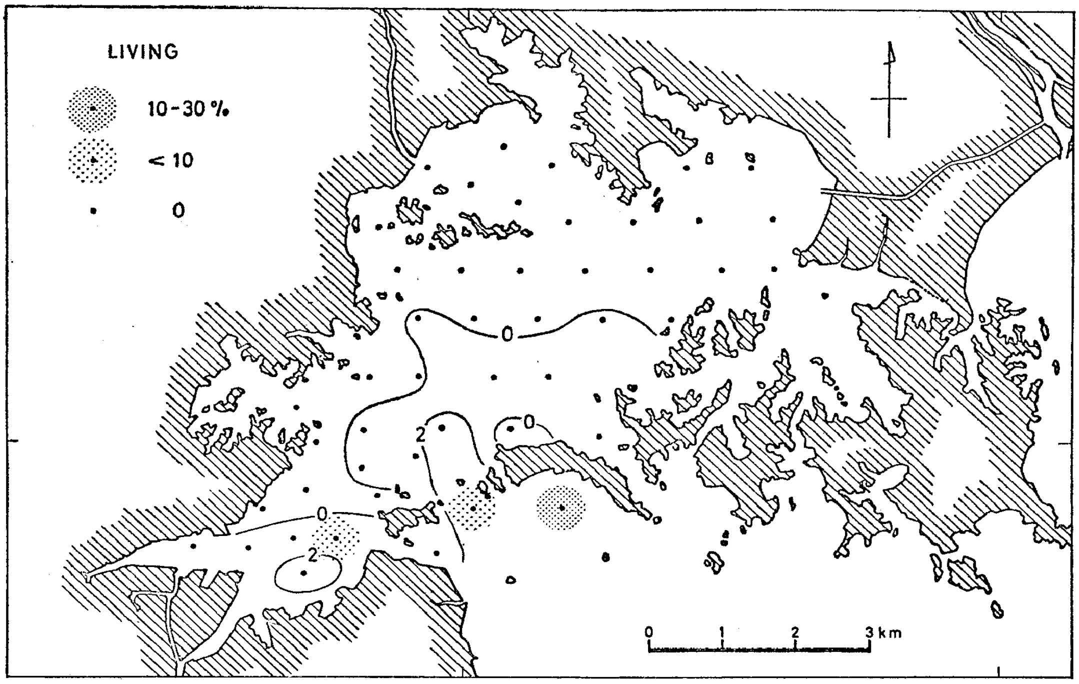


Fig. 54. Distribution of *Ammonia ketienziensis* (Ishizaki) in percent in the total (isopleth) and living (shaded) populations.

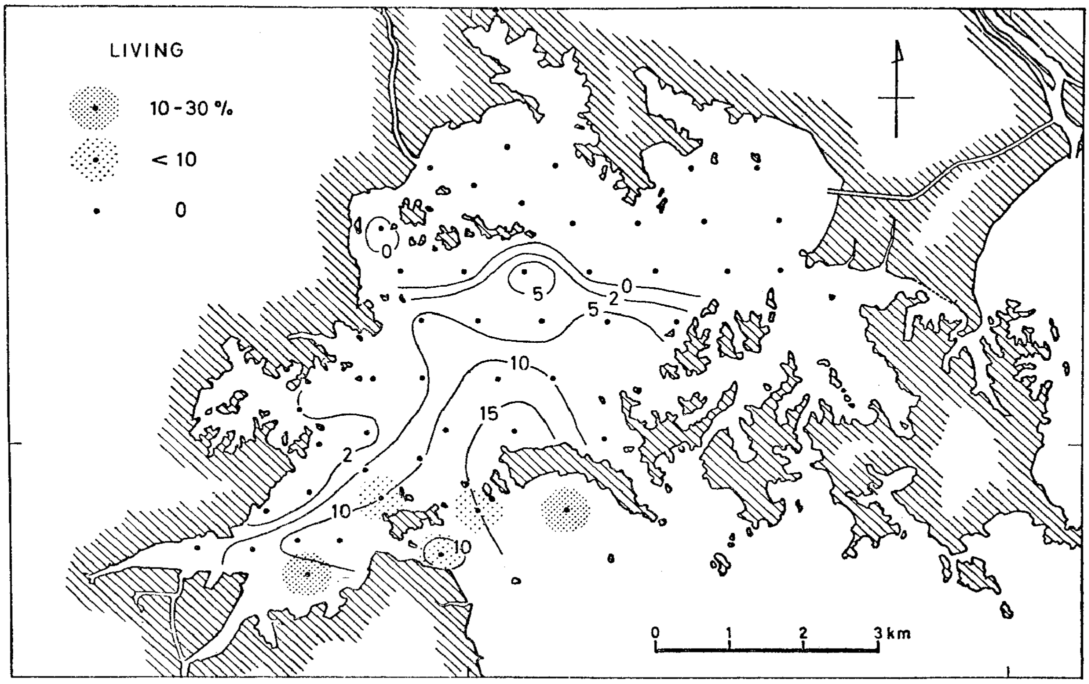


Fig. 55. Distribution of *Pararotalia? minuta* (Takayanagi) in percent in the total (isopleth) and living (shaded) populations.

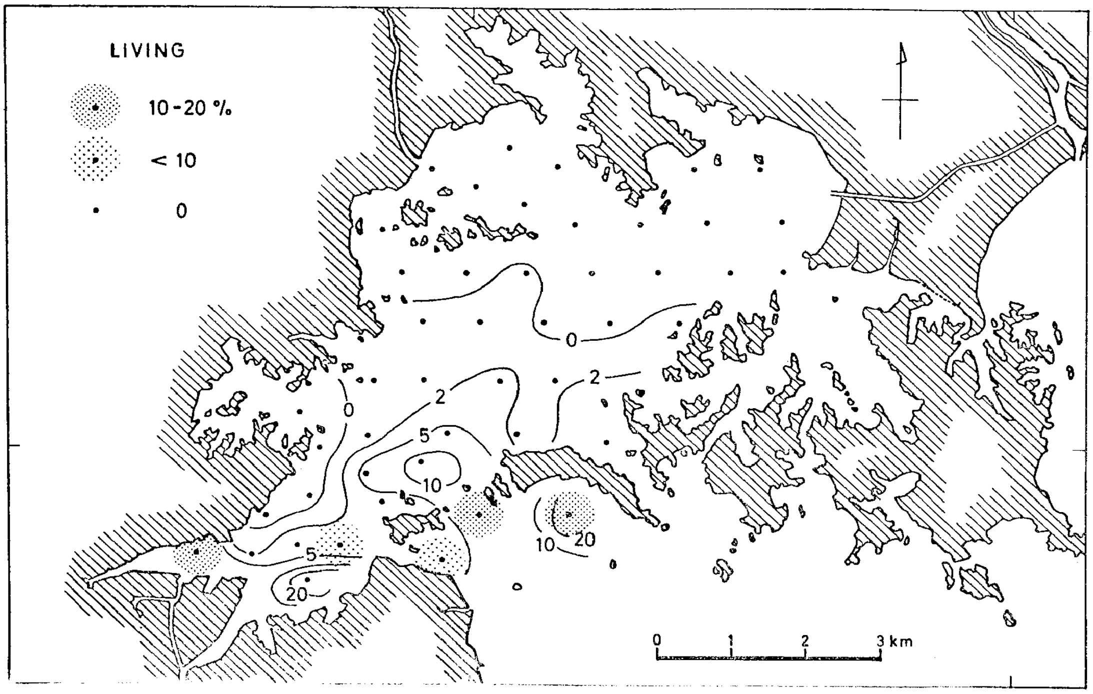


Fig. 56. Distribution of *Pararotalia nipponica* (Asano) in percent in the total (isopleth) and living (shaded) populations.

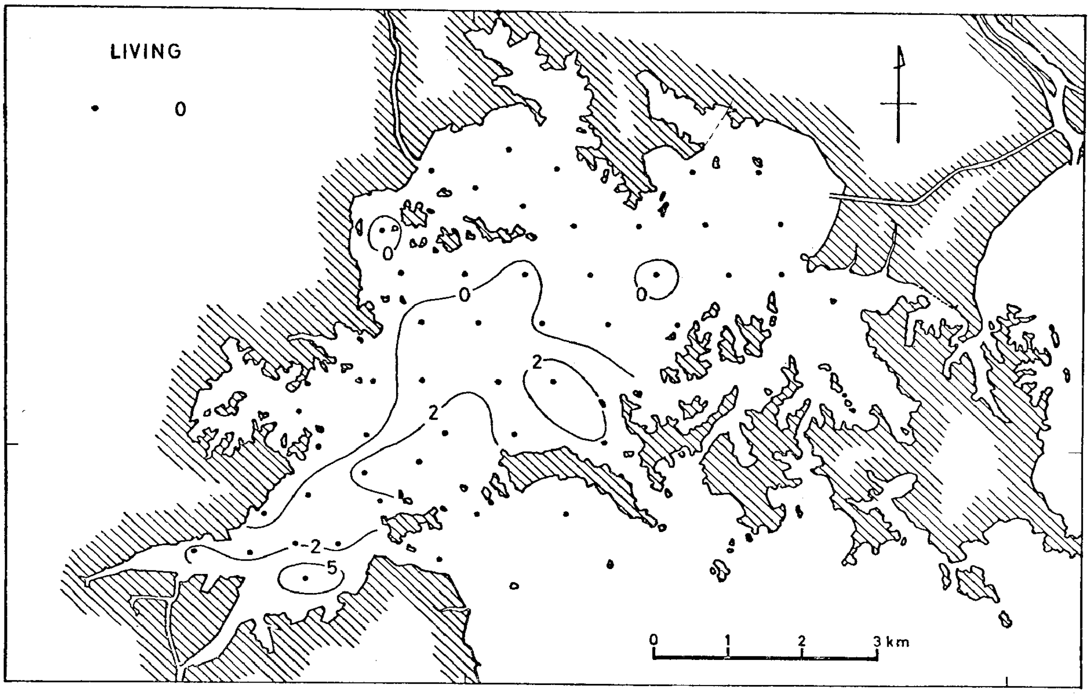


Fig. 57. Distribution of *Elphidium crispum* (Linné) in percent in the total population. No living specimens.

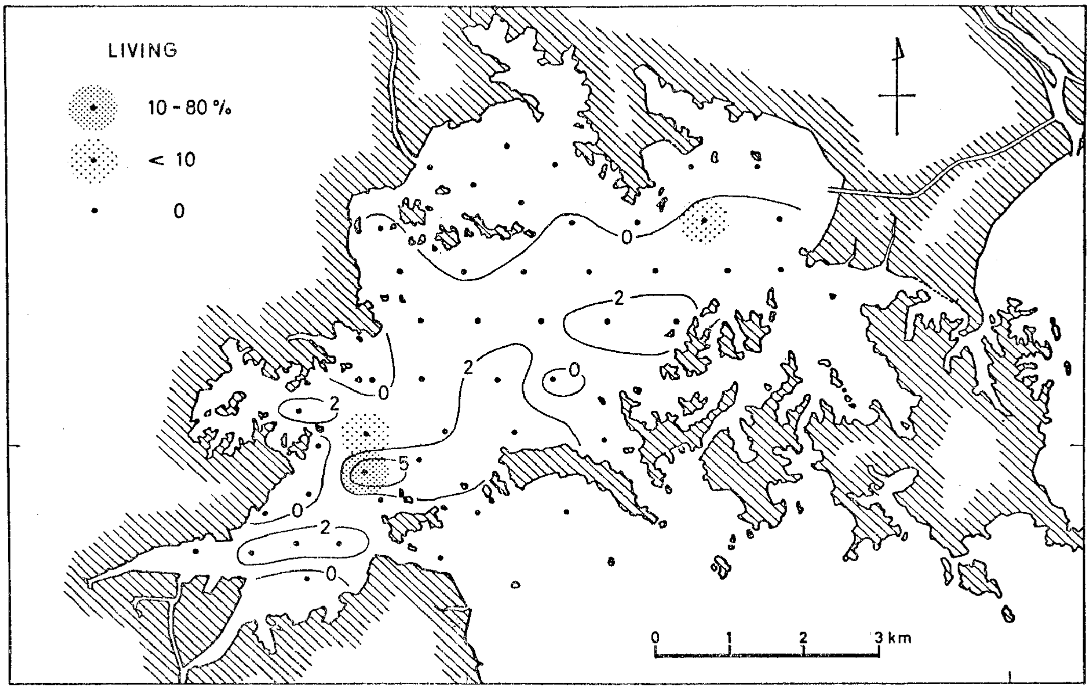


Fig. 58. Distribution of *Elphidium kusiroense* Asano in percent in the total (isopleth) and living (shaded) populations.

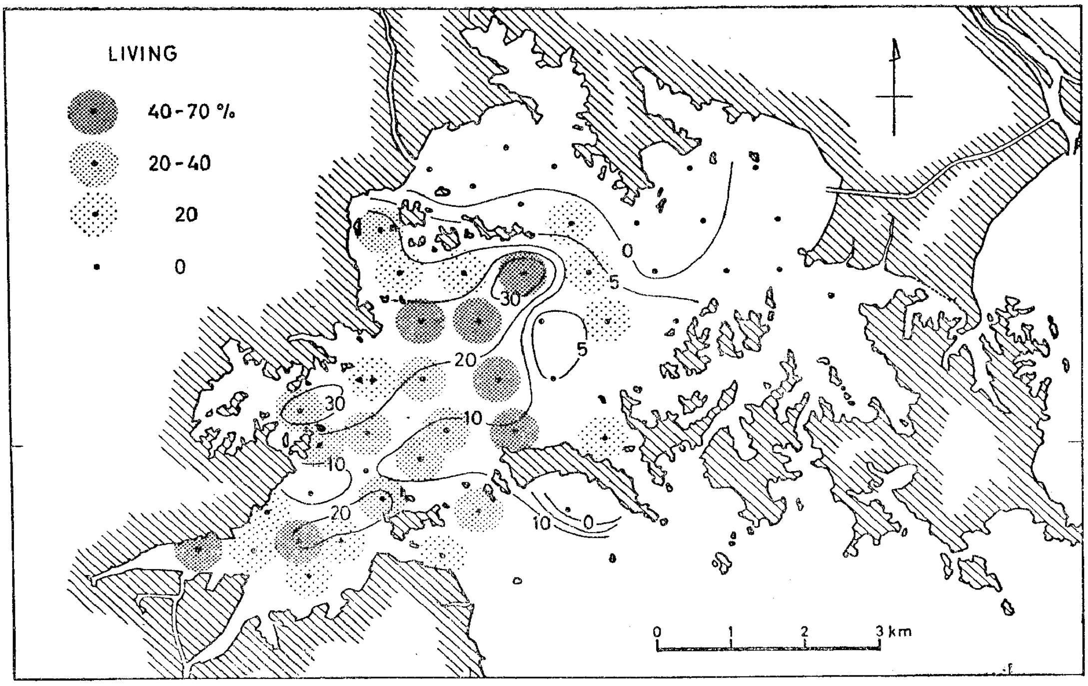


Fig. 59. Distribution of *Elphidium subarcticum* Cushman in percent in the total (isopleth) and living (shaded) populations.

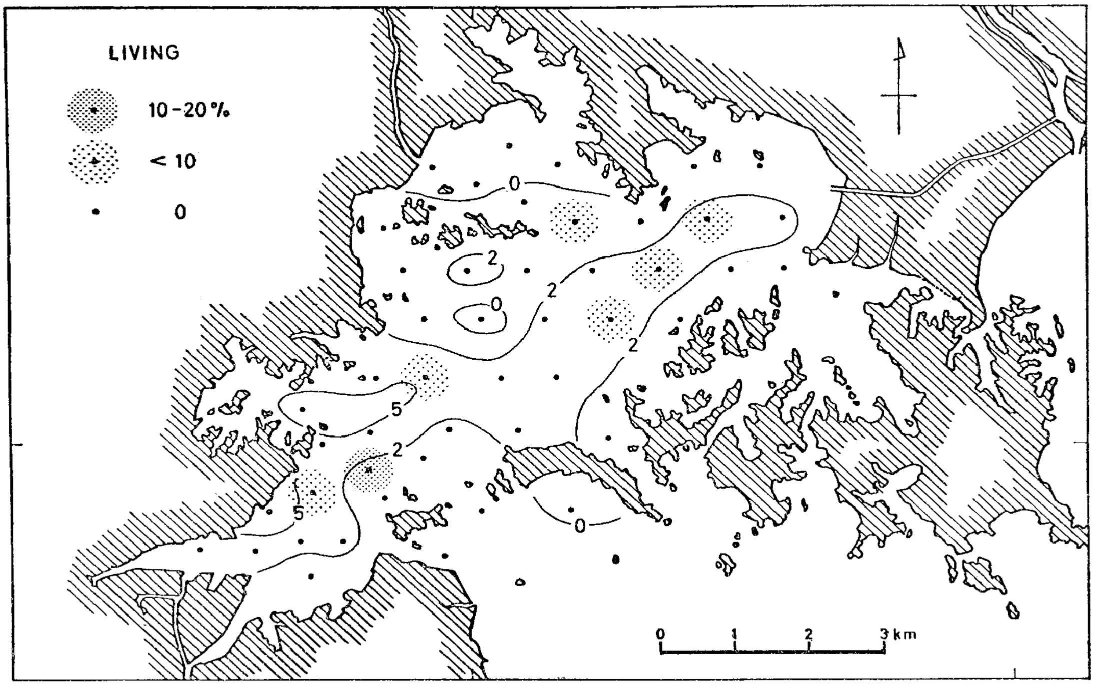


Fig. 60. Distribution of *Elphidium subgranulosum* Asano in percent in the total (isopleth) and living (shaded) populations.

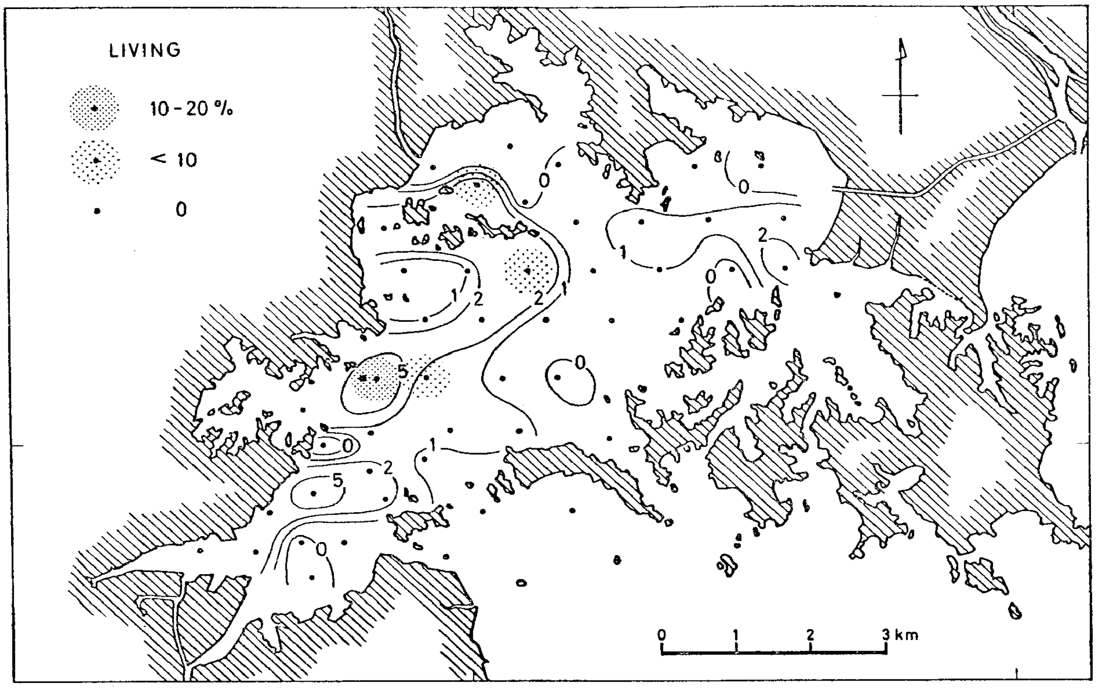


Fig. 61. Distribution of "*Elphidium*" *subincertum* Asano in percent in the total (isopleth) and living (shaded) populations.

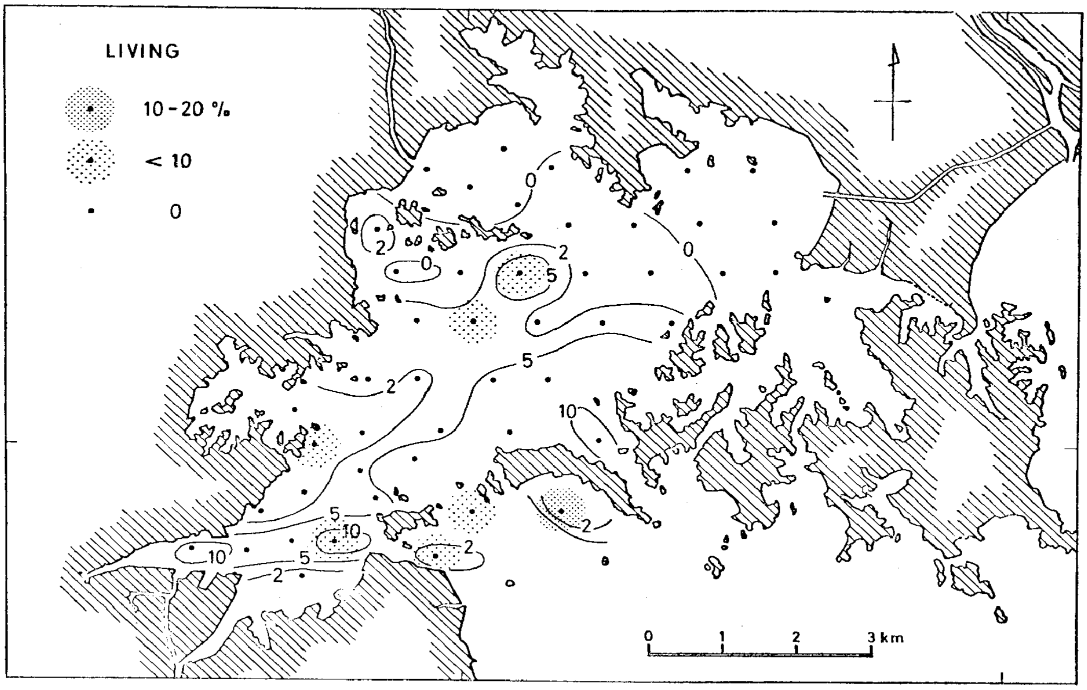


Fig. 62. Distribution of "*Elphidium*" *somaense* Takayangi in percent in the total (isopleth) and living (shaded) populations.

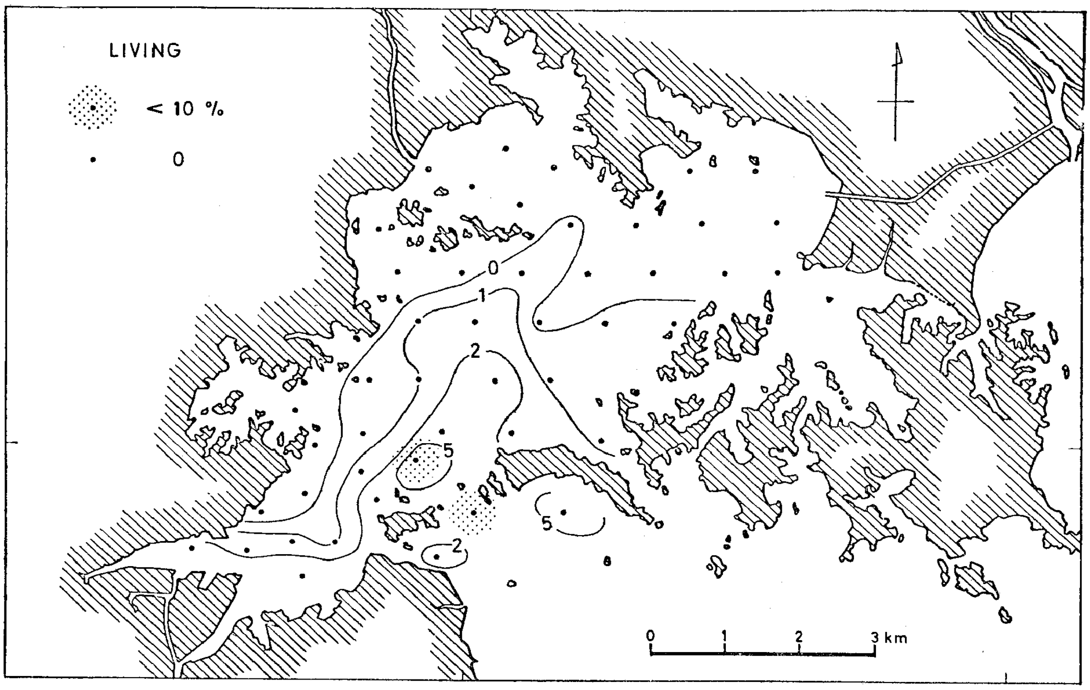


Fig. 63. Distribution of *Cibicides lobatulus* (Walker and Jacob) in percent in the total (isopleth) and living (shaded) populations.

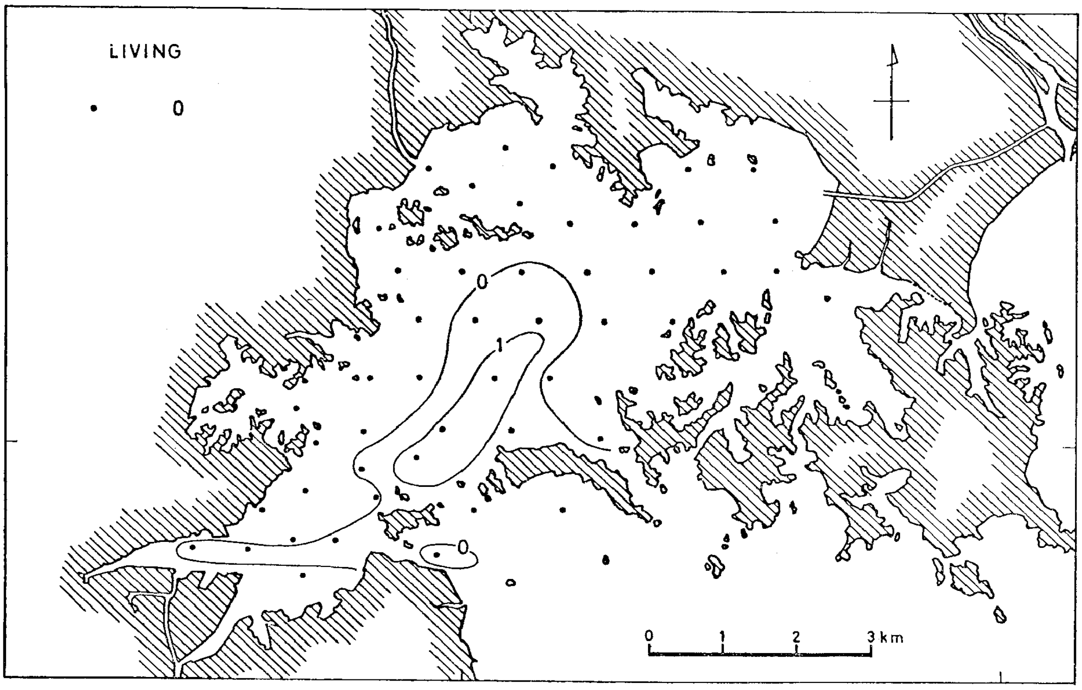


Fig. 64. Distribution of *Pseudononion japonicum* Asano in percent in the total populations. No living specimens.

Plate 1

Fig. 1. *Reophax nana* Rhumbler
IGPS coll. cat. no. 91201 from St. Ms 43, depth 2.5m, × 103.

Fig. 2. *Reophax gracilis* (Kiaer)
IGPS coll. cat. no. 91202 from St. Ms 11b, depth 3.2, × 103.

Fig. 3. *Reophax scottii* Chaster
IGPS coll. cat. no. 91203 from St. Ms 7, depth 2.5, ×103.

Figs. 4a, b. *Miliammina fusca* (Brady)
IGPS coll. cat. no. 91204 from St. Ms 33, depth 0.4m, ×96.

Figs. 5a, b. *Haplophragmoides hancocki* Cushman and McCulloch
IGPS coll. cat. no. 91205 from St. Ms 21, depth 5.7m, ×62.

Figs. 6a, b. *Haplophragmoides canariensis* (d'Orbigny)
IGPS coll. cat. no. 91206 from St. Ms 34, depth 0.4m, ×103.

Figs. 7a, b, 8. *Ammobaculites exiguus* Cushman and Bronnimann
IGPS coll. cat. no. 91207 A, B from St. Ms. 34, depth 0.4m, Ms 32, depth 1.3m, ×80.

Figs. 9a, b. *Ammoscalaria pseudospiralis* (Williamson)
IGPS coll. cat. no. 91208 from St. Ms 47, depth 2.0m, ×41.

Figs. 10a, b. *Spiroplectammina biformis* (Parker and Jones)
IGPS coll. cat. no. 91209 from St. Ms 24, depth 0.7m, ×103.

Figs. 11a, b. *Spiroplectammina typica* Lacroix
IGPS coll. cat. no. 91210 from St. Ms. 23, deph 2.5m, ×103.

Fig. 12. *Textularia earlandi* Parker
IGPS coll. cat. no. 91211 from St. Ms 11a, depth 3.2m, ×96.

Figs. 13a, b. *Textularia candeiana* d'Orbigny
IGPS coll. cat. no. 91212 from St. Ms 22, depth 4.4m, ×41.

Figs. 14a–c, 15a–c. *Trochammina hadai* Uchio
IGPS coll. cat. no. 91213 A, B from St. Ms 36, depth 1.3m, ×50.

Figs. 16a–c, 17a–c. *Trochammina* cf. *japonica* Ishiwada
16, IGPS coll. cat. no. 91214 from St. Ms, 35, depth 0.5m, ×50; 17, IGPS coll. cat. no. 91215 from St. Ms 37, depth 1.5m, ×50.

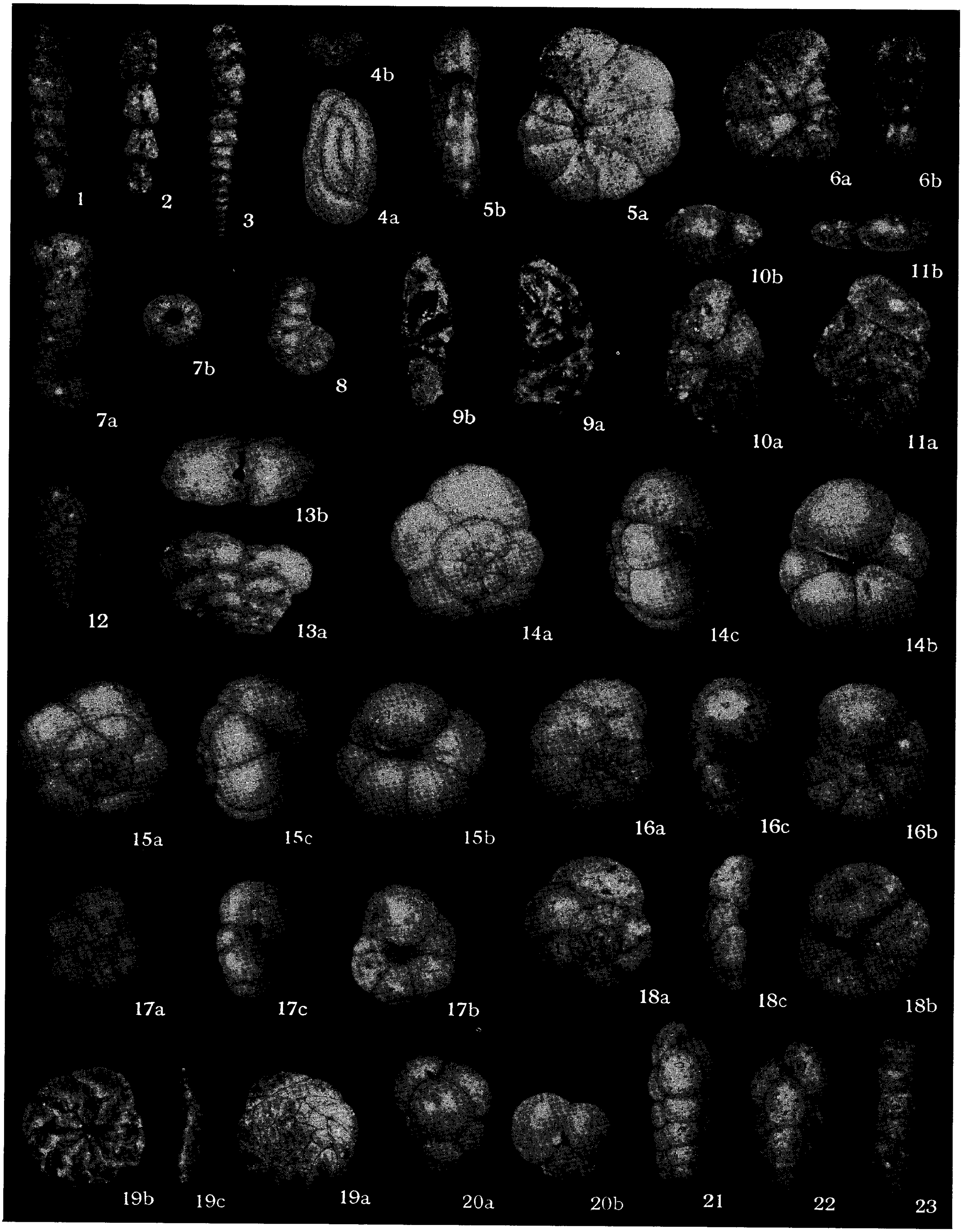
Figs. 18a–c. *Trochammina pacifica* Cushman
IGPS coll. cat. no. 91216 from St. Ms 16, depth 5.2m, ×77.

Figs. 19a–c. *Tiphotrocha kellettae* (Thalmann)
IGPS coll. cat. no. 91217 from St. Ms 13, depth 12.5m, ×103.

Figs. 20a, b. *Eggerella propinqua* (Brady)
IGPS coll. cat. no. 91218 from St. Ms 13, depth 12.5m, ×77.

Figs. 21, 22. *Eggerella scabra* (Williamson)
IGPS coll. cat. no. 91219 A, B from St. Ms, 38, depth 2.0m, ×75.

Fig. 23. *Goesella iizukae* Takayanagi
IGPS coll. cat. no. 91220 from St. Ms. 36, depth 1.3m, ×75.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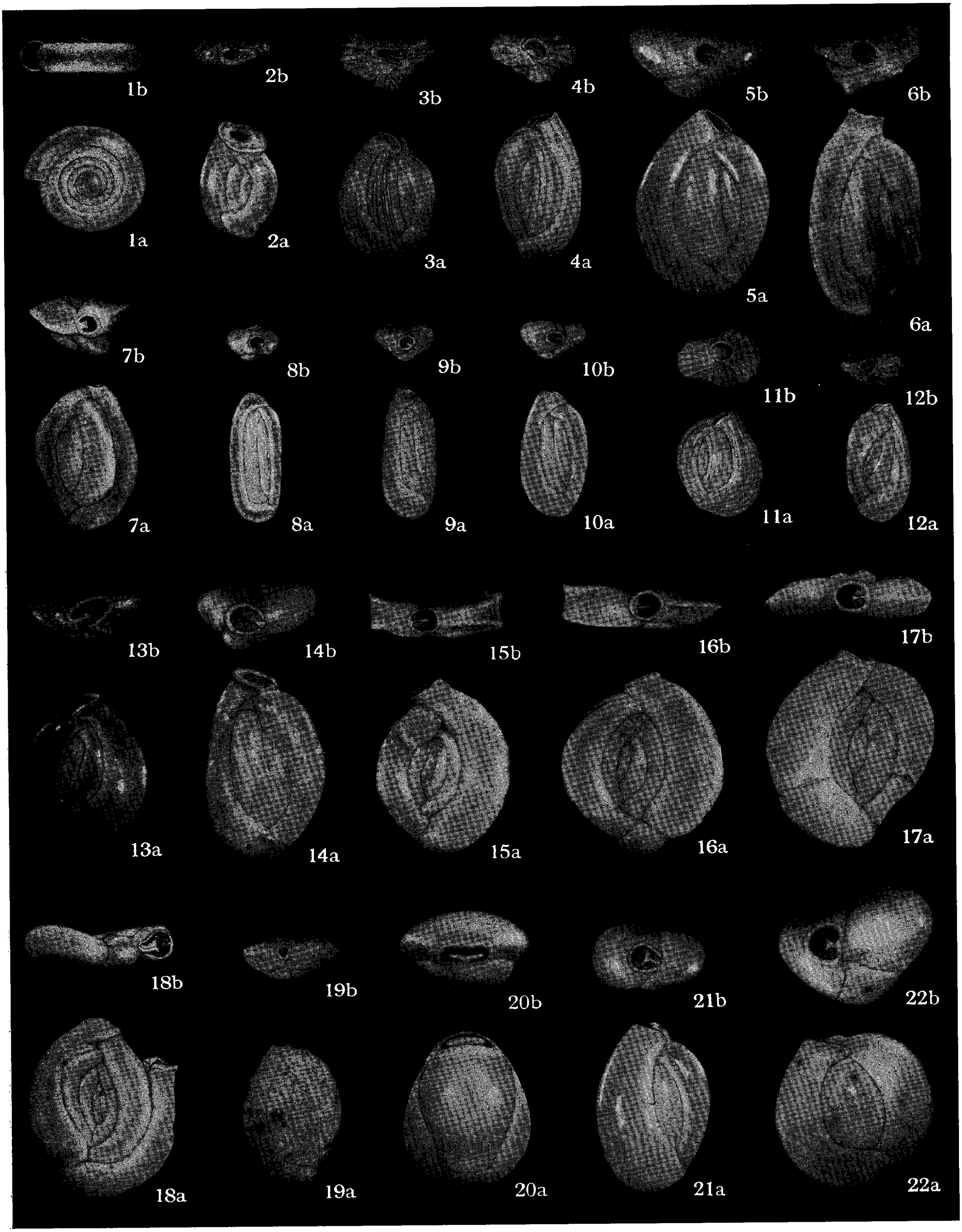
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Plate 2

Figs. 1a, b. *Cyclogyra planorbis* (Schultze)
IGPS coll. cat. no. 91221 from St. Ms 20, depth 8.7m, ×96.

Figs. 2a, b. *Wiesnerella auriculata* (Egger)
IGPS coll. cat. no. 91222 from St. Ms. 13, depth 12.5m, × 110.

Figs. 3a, b. *Quinqueloculina* cf. *curta* Cushman
IGPS coll. cat. no. 91223 from St. Ms 13, depth 12.5m, × 64.

Figs. 4a, b. *Quinqueloculina costata* d'Orbigny
IGPS coll. cat. no. 91224 from St. Ms 27, depth 1.2m, ×58.

Figs. 5a, b. *Quinqueloculina vulgaris* d'Orbigny
IGPS coll. cat. no. 91225 from St. Ms 22, depht 4.4m, ×58.

Figs. 6a, b. *Quinqueloculina contorta* d'Orbigny
IGPS coll. cat. no. 91226 from St. Ms 21, depth 5.7m, ×51.

Figs. 7a, b. *Quinqueloculina* cf. *lamarckiana* d'Orbigny
IGPS coll. cat. no. 91227 from St. Ms 13, depht 12.5m, ×62.

Figs. 8a, b. *Quinqueloculina elongata* Natland
IGPS coll. cat. no. 91228 from St. Ms 15, depht 3.5m, ×78.

Figs. 9a, b. *Quinqueloculina fukushimaensis* Takayanagi
IGPS coll. cat. no. 91229 from St. Ms 21, depht 5.7m, ×80.

Figs. 10a, b. *Quinqueloculina seminulum* (Linné)
IGPS coll. cat. no. 91230 from St. Ms 22, depth 4.4m, ×62.

Figs. 11a, b. *Quinqueloculina rhodiensis* Parker
IGPS coll. cat. no. 91231 from St. Ms 33, depth 0.4m, ×64.

Figs. 12a, b. *Quinqueloculina* sp. 4
IGPS coll. cat. no. 91232 from St. Ms 12, depth 2.7m, ×62.

Figs. 13a, b. *Quinqueloculina* sp. 5
IGPS coll. cat. no. 91233 from St. Ms 20, depth 8.7m, ×103.

Figs. 14a, b. *Quinqueloculina* sp. 6
IGPS coll. cat. no. 91234 from St. Ms 13, depth 12.5m, ×51.

Figs. 15a, b. *Massilina inaequaris* Cushman
IGPS coll. cat. no. 91235 from St. Ms 13, depth 12.5m, ×51.

Figs. 16a, b. *Massilina milletti* (Wiesner)
IGPS coll. cat. no. 91236 from St. Ms 13, depth 12.5, ×51.

Figs. 17a, b. *Massilina secans* (d'Orbigny)
IGPS coll. cat. no. 91237 from St. Ms 14, depth 2.4m, × 51.

Figs. 18a, b. *Massilina* sp.
IGPS coll. cat. no. 91238 from St. Ms 15, depth 3.5m, ×30.

Figs. 19a, b. *Siphonaperta macbeathi* Vella
IGPS coll. cat. no. 91239 from St. Ms 22, depth 4.4m, ×62.

Figs. 20a, b. *Pyrgo ezo* Asano
IGPS coll. cat. no. 91240 from St. Ms 2, depth 0.9m, ×58.

Figs. 21a, b. *Triloculina laevigata* d'Orbigny
IGPS coll. cat. no. 91241 from St. Ms 22, depth 4.4m, ×62.

Figs. 22a, b. *Triloculina rotunda* d'Orbigny
IGPS coll. cat. no. 91242 from St. Ms 22, depth 4.4m, × 62.

Plate 3

Figs. 1a, b. *Triloculina terquemiana* (Brady)
IGPS coll. cat. no. **91243** from St. Ms **15**, depth 3.5m, ×**62**.

Figs. 2a, b. *Triloculina* cf. *terquemiana* (Brady)
IGPS coll. cat. no. **91244** from St. Ms **13**, depth 12.5m ×**41**.

Figs. 3a, b. *Triloculina trigonula* (Lamarck)
IGPS coll. cat. no. **91245** from St. Ms **13**, depth 12.5m, ×**41**.

Figs. 4a, b. *Triloculina* sp.
IGPS coll. cat. no. **91246** from St. Ms **2**, depth 0.9m, ×**62**.

Figs. 5a, b. *Miliolinella circularis* (Bornemann)
IGPS coll. cat. no. **91247** from St. Ms **13**, depth 12.5m, ×**78**.

Figs. 6a, b. *Miliolinella oblonga* (Montagu)
IGPS coll. cat. no. **91248** from St. Ms **13**, depth 12.5m, ×**62**.

Figs. 7a, b, 8a, b, 9a, b. *Miliolinella*? cf. *sidebottomi* (Martinotti)
7, 8, IGPS coll. cat. no. **91249**A, B, from St. Ms3 **3**, depth 0.4m, St. Ms **13**, depth 12.5m, ×**62**; 9, IGPS coll. cat. no. **91250** from St. Ms **11**b, depth 3.2m, ×**78**.

Figs. 10a, b. *Miliolinella sublineata* (Brady)
IGPS coll. cat. no. **91251** from St. Ms **15**, depth 3.5m, ×**58**.

Figs. 11a, b, 12a, b. *Miliolinella*? sp.
IGPS coll. cat. no. **91252** A, B from St. Ms **20**, depth 8.7m, ×**103**.

Fig. 13. *Dentalina ittai* Loeblich and Tappan
IGPS coll. cat. no. **91253** from St. Ms **30**, depth 0.9m, ×**78**.

Fig. 14. *Lagena distoma* Parker and Jones
IGPS coll. cat. no. **91254** from St. Ms **7**, depth 2.5m, ×**62**.

Fig. 15. *Lagena laevis* (Montagu)
IGPS coll. cat. no. **91255** from St. Ms **15**, depth 3.5m, ×**62**.

Fig. 16. *Lagena* cf. *perlucida* (Montagu)
IGPS coll. cat. no. **91256** from St. Ms **30**, depth 0.9m, ×**62**.

Fig. 17. *Lagena semilineata* Wright
IGPS coll. cat. no. **91257** from St. Ms **16**, depth 5.2m, ×**103**.

Fig. 18. *Oolina costata* (Williamson)
IGPS coll. cat. no. **91258** from St. Ms **12**, depth 2.7m, ×**103**.

Fig. 19. *Oolina melo* d'Orbigny
IGPS coll. cat. no. **91259** from St. Ms **14**, depth 2.4m, ×**62**.

Figs. 20a, b. *Oolina* sp.
IGPS coll. cat. no. **91260** from St. Ms **16**, depth 5.2m, ×**146**.

Figs. 21a, b. *Fissurina* cf. *annectens* (Burrows and Holland)
IGPS coll. cat. no. **91261** from St. Ms **11**a, depth 3.2m, ×**146**.

Figs. 22a, b. *Fissurina cucurbitasema* Loeblich and Tappan
IGPS coll. cat. no. **91262** from St. Ms **21**, depth 5.7m, ×**110**.

Figs. 23a, b. *Fissurina cucurbitasema bispinata* Ujiié
IGPS coll. cat. no. **91263** from St. Ms **27**, depth 1.2m, ×**103**.

Fig. 24. *Buliminella elegantissima* (d'Orbigny)
IGPS coll. cat. no. **91264** from St. Ms **30**, depth 0.9m, ×**96**.

Figs. 25a, b. *Bolivina pseudoplicata* Heron-Allen and Earland
IGPS coll. cat. no. **91265** from St. Ms **22**, depth 4.4m, ×**103**.

Figs. 26a, b. *Bolivina robusta* Brady
IGPS coll. cat. no. **91266** from St. Ms **22**, depth 4.4m, ×**103**.

Figs. 27a, b. *Bolivina* cf. *seminuda* Cushman
IGPS coll. cat. no. **91267** from St. Ms **16**, depth 5.2m, × **92**.

Figs. 28a, b. *Bolivina striatula* Cushman
IGPS coll. cat. no. **91268** from St. Ms **11**a, depth 3.2m, ×**96**.

Figs. 29a, b. *Bolivina* cf. *tokiokai* Uchio
IGPS coll. cat. no. **91269** from St. Ms **15**, depth 3.5m, ×**103**.

Figs. 30a, b. *Bolivina* sp. aff *B. durrandii* Millett
IGPS coll. cat. no. **91270** from St. Ms **13**, depth 12.5m, ×**92**.

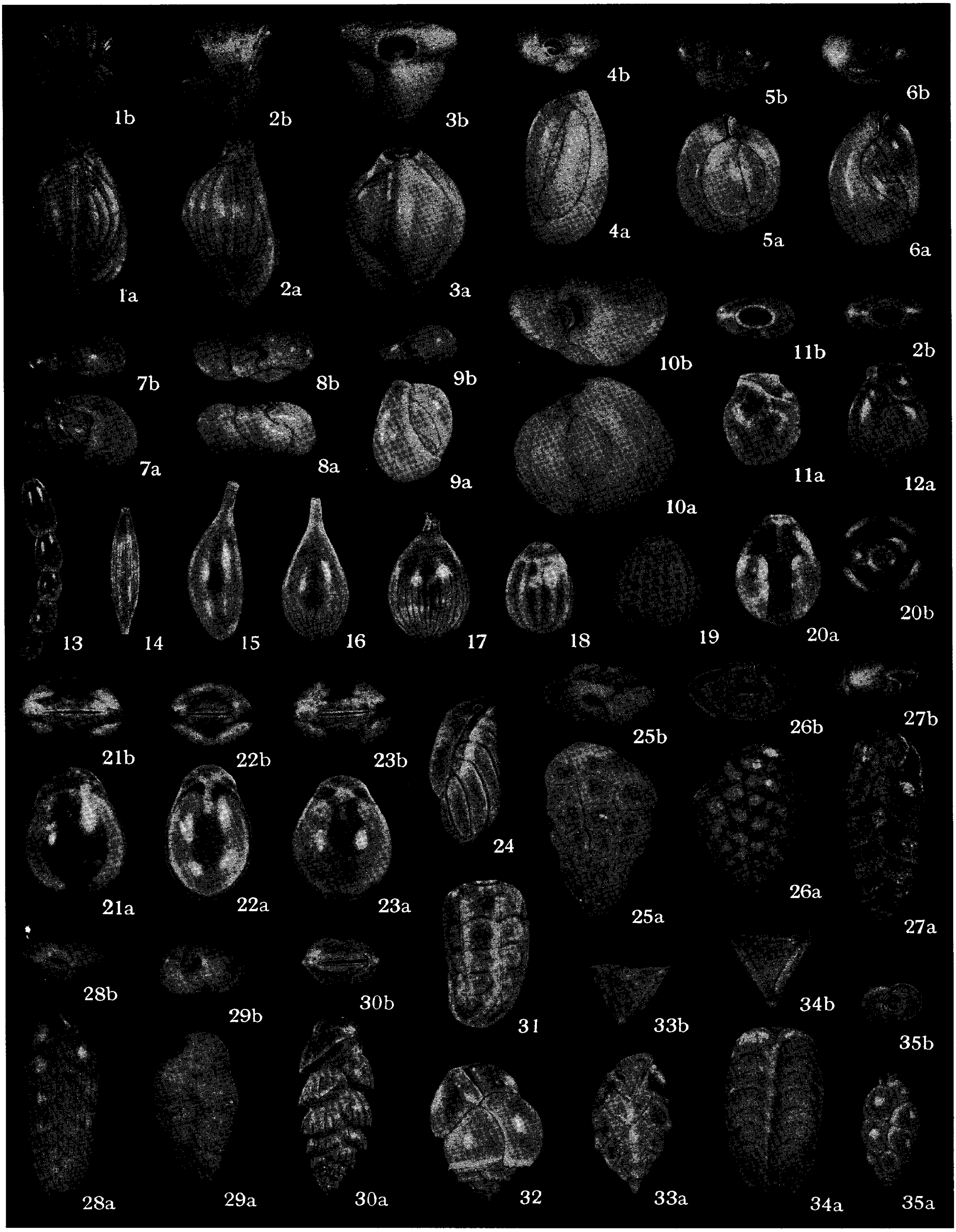
Fig. 31. *Rectobolivina raphana* (Parker and Jones)
IGPS coll. cat. no. **91271** from St. Ms **16**, depth 5.2m, ×**103**.

Fig. 32. *Bulimina marginata* d'Orbigny
IGPS coll. cat. no. **91272** from St. Ms, **13**, depth 12.5m, ×**146**.

Figs. 33a, b. *Reussella pacifica* Cushman and McCulloch
IGPS coll. cat. no. **91273** from St. Ms **22**, depth 4.4m, ×**103**.

Figs. 34a, b. *Chrysalidinella dimorpha* (Brady)
IGPS coll. cat. no. **91274** from St. Ms **22**, depth 4.4m, ×**41**.

Figs. 35a, b. *Uvigerinella glabra* (Millett)
IGPS coll. cat. no. **91275** from St. Ms **39**, depth 2.7m, ×**96**.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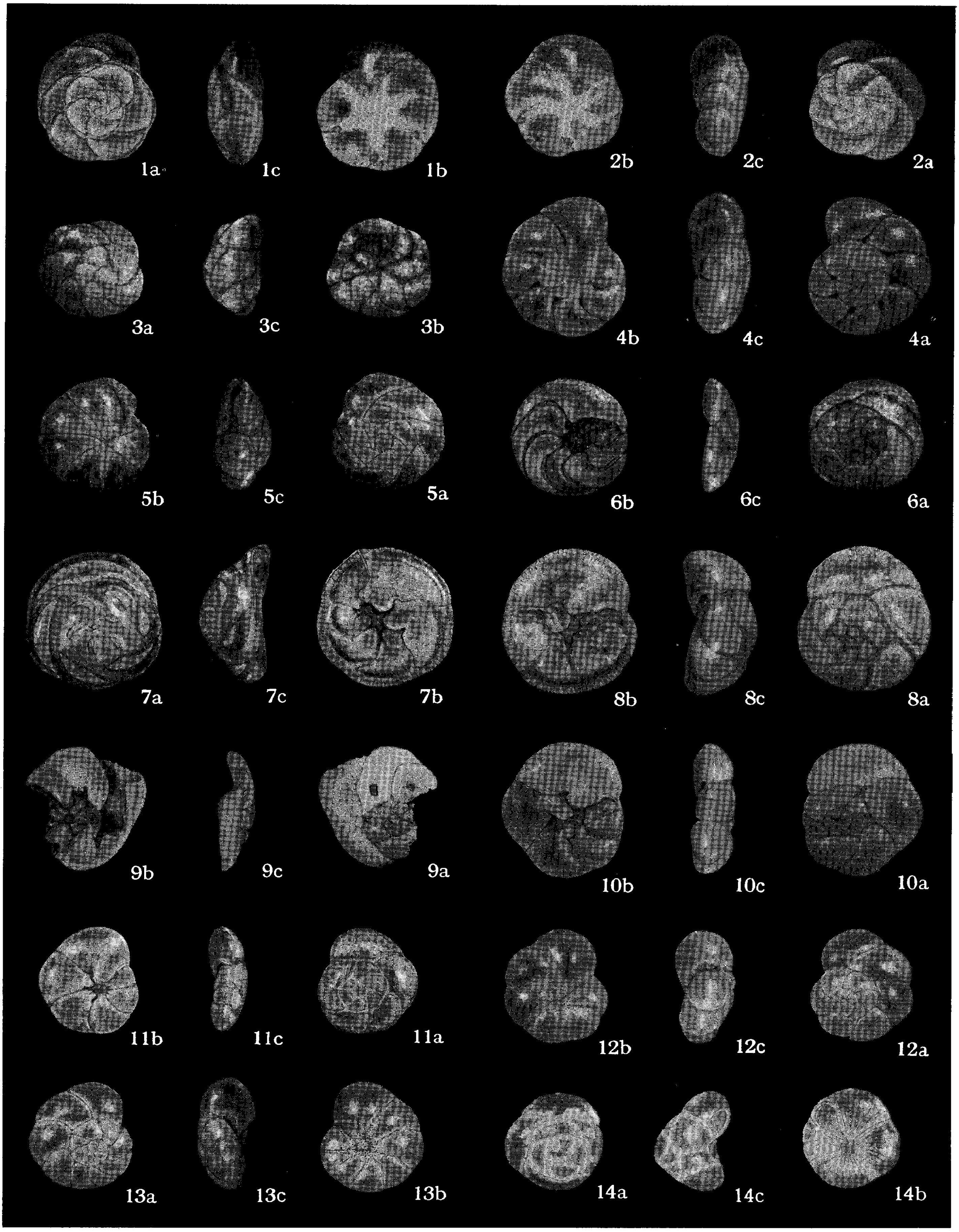
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Plate 4

Figs. 1a–c, 2a–c. *Buccella frigida* (Cushman)
IGPS coll. cat. no. 91276 A, B from St. Ms 11a, depth 3.2m ×80.

Figs. 3a–c. *Eoeponidella pulchella* (Parker)
IGPS coll. cat. no. 91277 from St. Ms 56, depth 1.7m, ×146.

Figs. 4a–c. *Helenina anderseni* (Warren)
IGPS coll. cat. no. 91278 from St. Ms 47, depth 2.0m, ×103.

Figs. 5a–c. *Epistominella naraensis* (Kuwano)
IGPS coll. cat. no. 91279 from St. Ms 12, depth 2.7m, ×146.

Figs. 6a–c. *Neoconorbina stachi* (Asano)
IGPS coll. cat. no. 91280 from St. Ms, 15, depth 3.5m, ×103.

Figs. 7a–c. *Rosalina australis* (Parr)
IGPS coll. cat. no. 91281 from St. Ms 22, depth 4.4m, ×62.

Figs. 8a–c. *Rosalina bradyi* (Cushman)
IGPS coll. cat. no. 91282 from St. Ms 22, depth 4.4m, ×50.

Figs. 9a–c. *Rosalina columbiensis* (Cushman)
IGPS coll. cat. no. 91283 from St. Ms 13, depth 12.5m, ×62.

Figs. 10a–c. *Rosalina globularis* d'Orbigny
IGPS coll. cat. no. 91284 from St. Ms 22, depth 4.4m, ×62.

Figs. 11a–c. *Rosalina vilardeboana* d'Orbigny
IGPS coll. cat. no. 91285 from St. Ms 22, depth 4.4m, ×62.

Figs. 12a–c, 13a–c. *Valvulineria hamanakoensis* (Ishiwada)
IGPS coll. cat. no. 91286, 91287 from St. Ms 33, depth 0.4m, St. Ms 30, depth 0.9m, ×96.

Figs. 14a–c. *Glabratella* cf. *globosa* (Sidebottom)
IGPS coll. cat. no. 91288 from St. Ms 56, depth 1.7m, ×146.

Plate 5

Figs. 1a–c. *Glabratella* cf. *chasteri* (Heron-Allen and Earland)
IGPS coll. cat. no. **91289** from **St. Ms, 27,** depth 1.2m, **×146.**

Figs. 2a, b. *Glabratella milletti* (Wright)
IGPS coll. cat. no. **91290** from **St. Ms 20,** depth 8.7m, **×146.**

Figs. 3a–c. *Glabratella* cf. *patelliformis* (Brady)
IGPS coll. cat. no. **91291** from **St. Ms 22,** depth 4.4m, **×62.**

Figs. 4a–c. *Glabratella opercularis* (d'Orbigny)
IGPS coll. cat. no. **91292** from **St. Ms 22,** depth 4.4m, **×41.**

Figs. 5a–c. *Glabratella subopercularis* (Asano)
IGPS coll. cat. no. **91293** from **St. Ms 21,** depth 5.7m, **×78.**

Figs. 6a–c. *Patellina corrugata* Williamson
IGPS coll. cat. no. **91294** from **St. Ms 13,** depth 12.5m, **×146.**

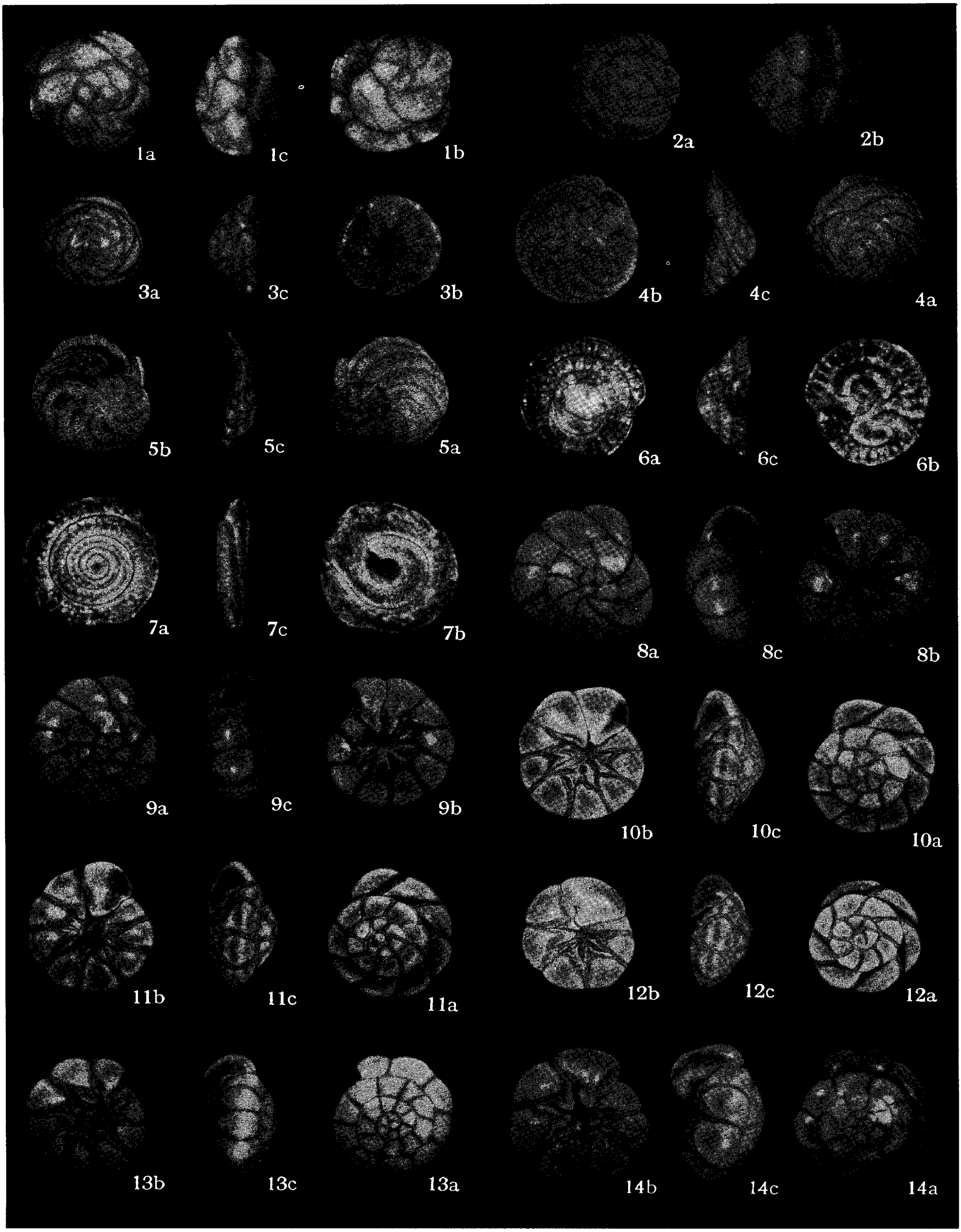
Figs. 7a–c. *Spirillina* cf. *vivipara* Ehrenberg
IGPS coll. cat. no. **91295** from **St. Ms 13,** depth 12.5m, **×146.**

Figs. 8a–c, 9a–c. *Ammonia beccarii* (Linné) forma 1
IGPS coll. cat. no. **91296, 91297** from **St. Ms 24,** depth 0.7m, **St. Ms, 19,** depth 1.2m, **×50.**

Figs. 10a–c, 11a–c, 12a–c. *Ammonia beccarii* (Linné) forma 2
IGPS coll. cat. no. **91298, 91299, 91300** from **St. Ms 38,** depth 2.0m, **St. Ms 27,** depth 1.2m, St. Ms 26, depth 0.9m, ×50.

Figs. 13a–c. *Ammonia beccarii* (Linné) forma 3
IGPS coll. cat. no. **91301** from **St. Ms 40,** depth 2.2m, **×50.**

Figs. 14a–c. *Ammonia japonica* (Hada)
IGPS coll. cat. no. **91302** from **St. Ms 13,** depth 12.5m, **×50.**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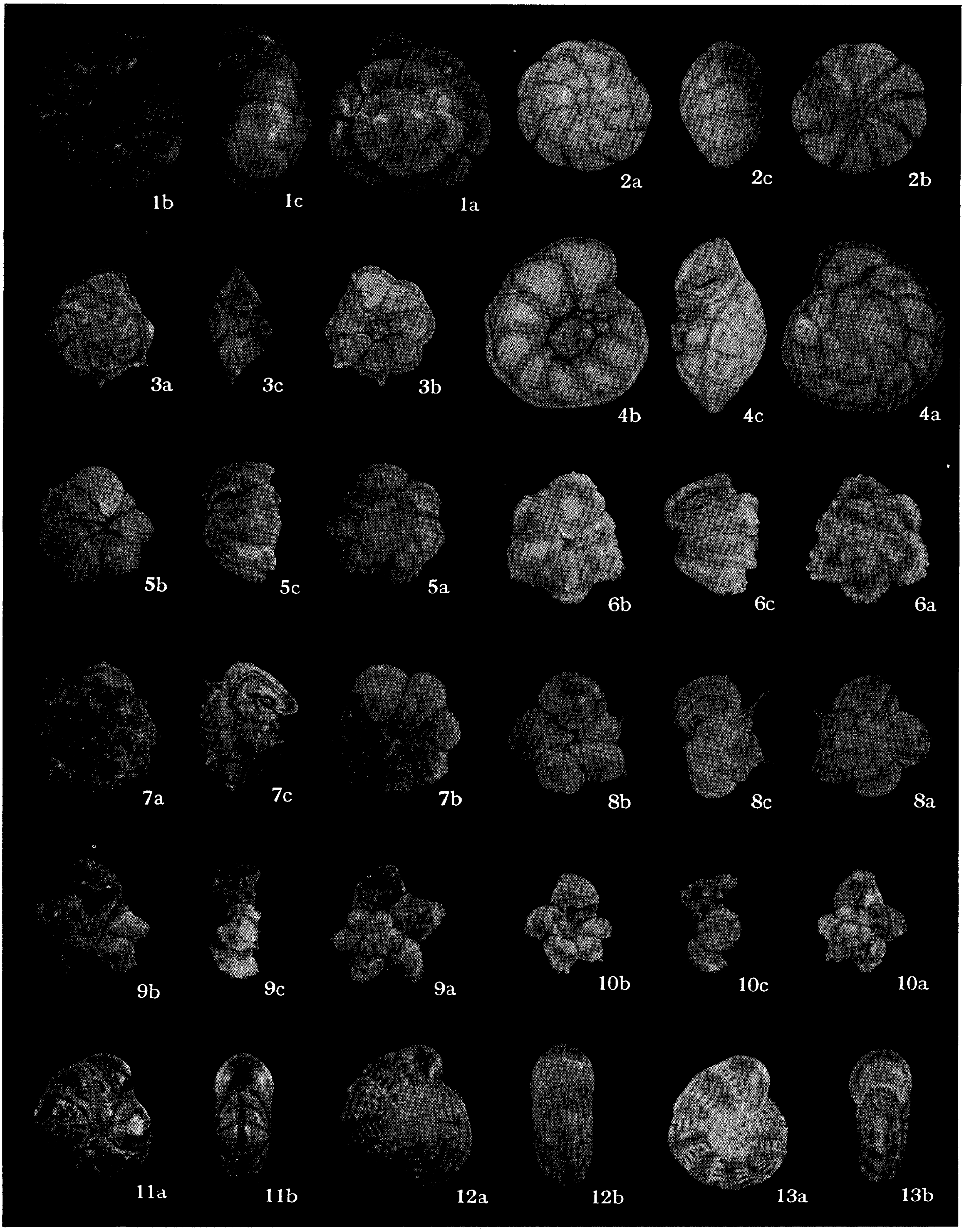
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Plate 6

Figs. 1a–c. *Ammonia japonica* (Hada)
IGPS coll. cat. no. **91303** from St. Ms **18**, depth 0.8m, ×**50**.

Figs. 2a–c. *Ammonia ketienziensis* (Ishizaki)
IGPS coll. cat. no. **91304** from St. Ms **22**, depth 4.4m, ×50.

Figs. 3a–c, 4a–c. *Pararotalia nipponica* (Asano)
IGPS coll. cat. no. **91305**, **91306** from St. Ms **13**, depth 12.5m, St. Ms **19**, depth 1.2m, ×50.

Figs. 5a–c, 6a–c, 7a–c. *Pararotalia? minuta* (Takayanagi)
5, 6, IGPS coll. cat. no. **91307**, **91308** from St. Ms **18**, depth 0.8m, St. Ms **14**, depth 2.4m, ×**103**;
7, IGPS coll. cat. no. **91309** from St. Ms 56, depth 1.7m. ×78.

Figs. 8a–c. *Pararotalia? globosa* (Millett)
IGPS coll. cat. no. **91310** from St. Ms **21**, depth 5.7m, ×**129**.

Figs. 9a–c, 10a–c. *Pararotalia? takayanagii* Matoba, n. sp.
9, holotype, IGPS coll. cat. no. **91311** from St. Ms **7**, depth 2.5m, ×**129**; 10, paratype, IGPS coll. cat. no. **91312A** from St. Ms 56, depth 1.7m, ×**129**.

Figs. 11a, b. *Elphidium clavatum* Cushman
IGPS coll. cat. no. **91313** from St. Ms **18**, depth 0.8m, ×**103**.

Figs. 12a, b. *Elphidium reticulosum* Cushman
IGPS coll. cat. no. **91314** from St. Ms **18**, depth 0.8m, ×77.

Figs. 13a, b. *Elphidium* cf. *reticulosum* Cushman
IGPS coll. cat. no. **91315** from St. Ms **39**, depth 2.7m, ×77.

Plate 7

Figs. 1a, b. *Elphidium crispum* (Linné)
IGPS coll. cat. no. **91316** from St. Ms **19**, depts 1.2m, ×**28**.

Figs. 2a, b. *Elphidium hanzawai* Asano
IGPS coll. cat. no. **91317** from St. Ms **12**, depth 2.7m, ×**58**.

Figs. 3a, b. *Elphidium jenseni* (Cushman)
IGPS coll. cat. no. **91318** from St. Ms **15**, depth 3.5m, ×**58**.

Figs. 4a, b. *Elphidium kusiroense* Asano
IGPS coll. cat. no. **91319** from St. Ms **40**, depth 2.2m, ×**63**.

Figs. 5a, b. *Elphidium* cf. *kusiroense* Asano
IGPS coll. cat. no. **91320** from St. Ms **12**, depth 2.7, ×**103**.

Figs. 6a, b, 7a, b. *Elphidium subarcticum* Cushman
6, IGPS coll. cat. no. **91321** from St. Ms **24**, depth 0.7m, ×**63**; **7**, IGPS coll. cat. no. **91322** from St. Ms **7**, depth 2.5m, ×80.

Figs. 8a, b. *Elphidium subarcticum* Cushman var.
IGPS coll. cat. no. **91323** from St. Ms **7**, depth 2.5m, ×**80**.

Figs. 9a, b. *Elphidium subgranulosum* Asano
IGPS coll. cat. no. **91324** from St. Ms **26**, depth 0.9, ×**64**.

Figs. 10a, b. "*Elphidium*" *subincertum* Asano
IGPS coll. cat. no. **91325** from St. Ms **3**, depth 1.2m, ×**80**.

Figs. 11a, b, 12a, b. "*Elphidium*" *somaense* Takayanagi
IGPS coll. cat. no. **91326** A, B from St. Ms **16**, depth 5.2m, ×**96**.

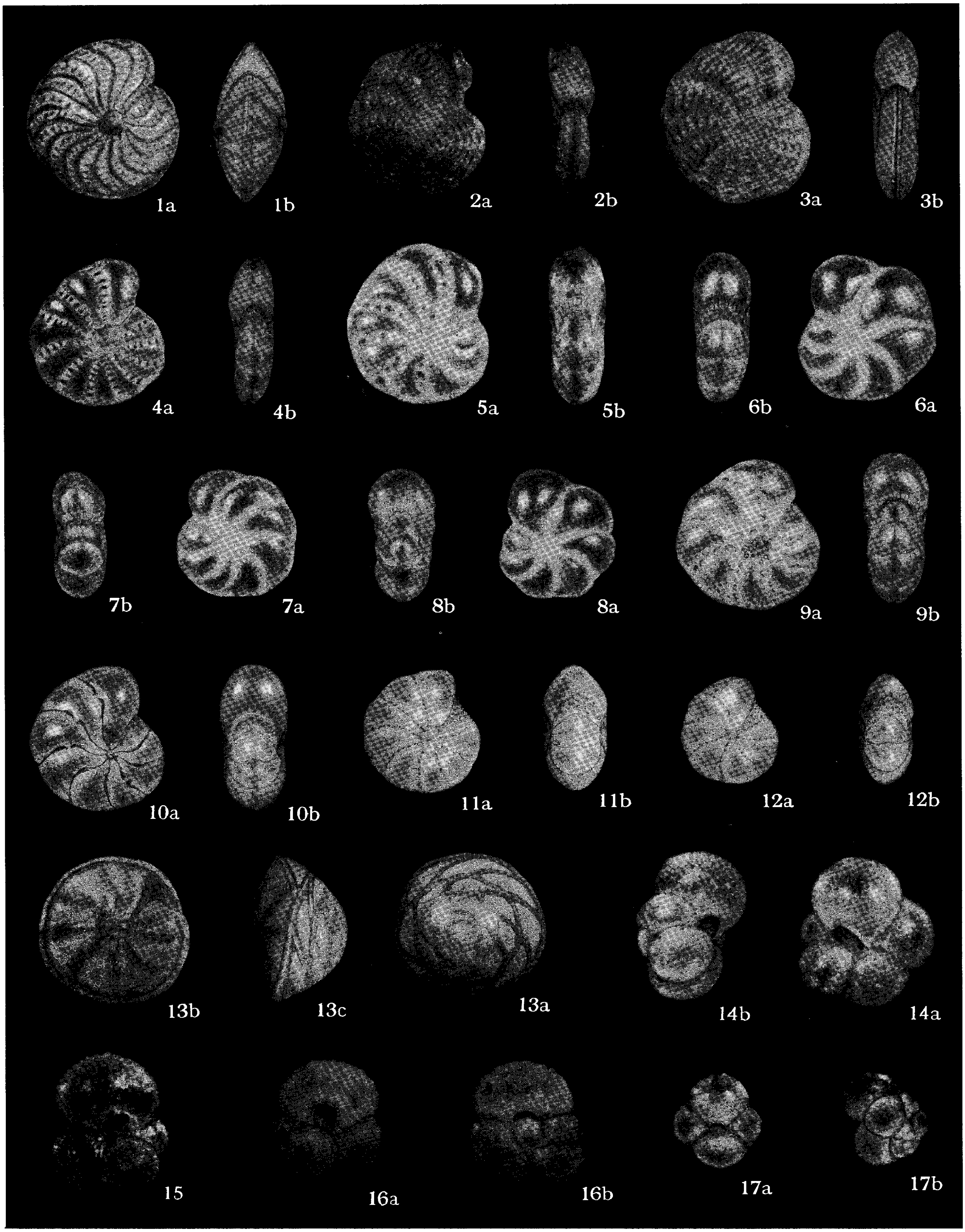
Figs. 13a–c. *Buccella* ? *makiyamae* Chiji
IGPS coll. cat. no. **91327** from St. Ms **22**, depth 4.4m, ×**50**.

Figs. 14a, b. *Globigerina* cf. *quinqueloba* Natland
IGPS coll. cat. no. **91328** from St. Ms **17**, depth 2.4m, ×**129**.

Fig. 15. *Globigerina bulloides* d'Orbigny
IGPS coll. cat. no. **91329** from St. Ms **13**, depth 12.5m, ×**129**.

Figs. 16a, b. *Globigerinoides tenellus* Parker
IGPS coll. cat. no. **91330** from St. Ms **13**, depth 12.5m, ×**129**.

Figs. 17a, b. *Globigerinita glutinata* (Egger)
IGPS coll. cat. no. **91331** from St. Ms **21**, depth 5.7m, ×**155**.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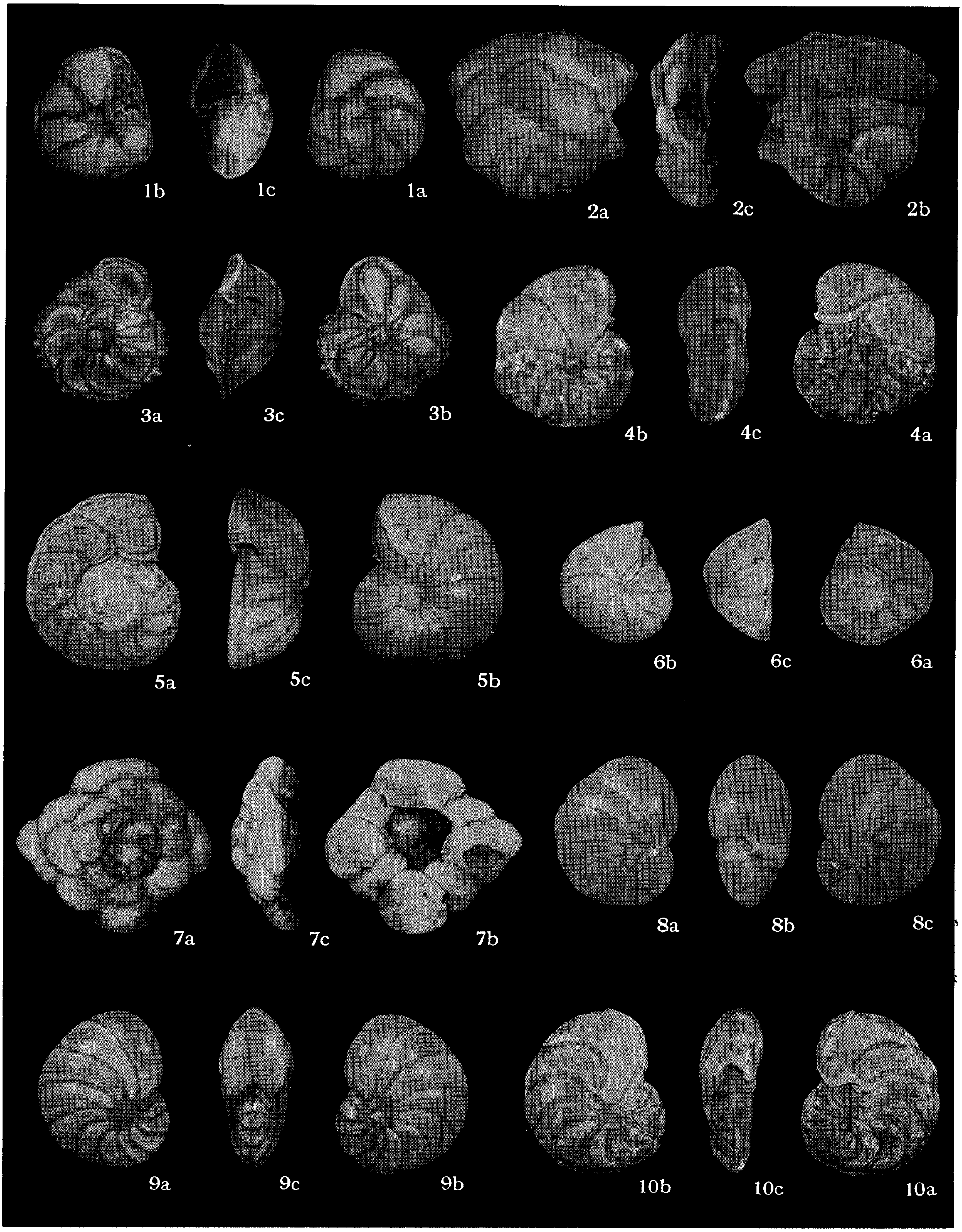

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Plate 8

Figs. 1a–c. *Poroeponides cribrorepandus* Asano and Uchio
IGPS coll. cat. no. **91332** from St. Ms **16**, depth 5.2m, ×41.

Figs. **2**a–c. *Poroeponides lateralis* (Terquem)
IGPS coll. cat. no. **91333** from St. Ms **21**, depth 5.7m, ×41.

Figs. **3**a–c. "*Eponides*" *orientalis* Asano
IGPS coll. cat. no. **91334** from St. Ms **22**, depth 4.4m, ×80.

Figs. 4a–c. *Cibicides aknerianus* (d'Orbigny)
IGPS coll. cat. no. **91335** from St. Ms **22**, depth 4.4m, ×103.

Figs. 5a–c, 6a–c. *Cibicides lobatulus* (Walker and Jacob)
IGPS coll. cat. no. **91336** A, B from St. Ms **22**, depth 4.4m, ×50.

Figs. 7a–c. *Cymbaloporetta bradyi* (Cushman)
IGPS coll. cat. no. **91337** from St. Ms 16, depth 5.2m, ×51.

Figs. 8a–c. *Nonionella stella* Cushman and Moyer
IGPS coll. cat. no. **91338** from St. Ms **13**, depth 12.5m, ×63.

Figs. **9**a–c. *Pseudononion japonicum* Asano
IGPS coll. cat. no. **91339** from St. Ms **16**, depth 5.2m, ×63.

Figs. 10a–c. *Hanzawaia nipponica* Asano
IGPS coll. cat. no. **91340** from St. Ms **22**, depth 4.4m, ×62.

Table 3. Occurrence of the total and living benthonic Foraminifera, each in percent of the total and living populations.

Station Number	Facies and Subfacies	Depth (m)	Benthonic Population in 10cc of surface sediment* T	Benthonic Population in 10cc of surface sediment* L	Benthonic Population actually counted T	Benthonic Population actually counted L
Ms 2	B1	0.9	5500	96	343	6
Ms 3	C1	1.2	3680	192	230	12
Ms 4	B1	1.7	2750	256	343	32
Ms 5	C1	2.2	1190	216	298	54
Ms 6	B1	2.2	3590	176	244	11
Ms 7	A	2.5	3580	304	448	38
Ms 8	C2	2.2	1060	296	271	74
Ms 9	C2	1.8	792	116	199	29
Ms 10	C2	2.7	1640	344	205	43
Ms 11a	B2	3.2	2350	216	294	27
Ms 11b	B2	3.2	1820	80	227	10
Ms 12	A	2.7	6510	144	219	9
Ms 13	A	12.5	2220	120	278	15
Ms 14	A	2.4	9750	224	269	7
Ms 15	A	3.5	8200	384	266	6
Ms 16	A	5.2	5960	352	218	11
Ms 17	A	2.4	4220	368	307	23
Ms 18	A	0.8	5460	544	342	34
Ms 19	A	1.2	[illegible]	640	206	10
Ms 20	A	8.7	526	44	263	22
Ms 21	A	5.7	[illegible]	736	353	23
Ms 22	A	4.4	[illegible]	512	292	8
Ms 23	A	2.5	[illegible]	20	304	5
Ms 24	B1	0.7	[illegible]	688	[illegible]	43
Ms 25	C1	1.5	[illegible]	224	[illegible]	14
Ms 26	B1	0.9	[illegible]	[illegible]	299	38
Ms 27	B1	1.2	[illegible]	104	[illegible]	52
Ms 28	B1	1.8	[illegible]	272	304	34
Ms 29	C1	1.3	1260	744	321	61
Ms 30	C1	0.9	4430	368	277	23
Ms 31	C1	1.3	1650	364	206	46
Ms 32	C2	1.3	536	172	234	43
Ms 33	C4	0.4	612	238	306	118
Ms 34	C4	0.4	53	8	53	5
Ms 35	C4	0.5	179	80	175	60
Ms 36	C4	1.3	264	76	264	76
Ms 37	C3	1.5	1380	956	345	239
Ms 38	C2	2.0	1680	256	210	32
Ms 39	B2	2.7	1700	208	213	26
Ms 40	A	2.2	5090	352	204	11
Ms 43	B2	2.5	1720	112	215	14
Ms 44	C2	2.2	1670	328	209	41
Ms 45	C2	1.3	1700	152	213	19
Ms 46	C3	0.9	3580	160	224	10
Ms 47	C2	2.0	720	66	360	33
Ms 55	B1	1.5	1110	20	278	5
Ms 56	A	1.7	5670	224	318	14

Total (T: living and dead) and Living (L)

Species	Ms 2 T	Ms 2 L	Ms 3 T	Ms 3 L
AGGLUTINATED FORAMINIFERA				
Reophax nana Rhumbler	%	%	·	
R. gracilis (Kiaer)	·		·	
R. scottii Chaster	·		·	
Miliammina fusca (Brady)	·		·	
Haplophragmoides canariensis (d'Orbigny)	·		·	
H. hancocki Cushman & McCulloch	·		·	
H. sp.	·		·	
H. spp. (fragments)	·		·	
Ammobaculites exiguus Cushman & Bronnimann	·		·	
Ammoscalaria pseudospiralis (Williamson)	·		·	
Spiroplectammina biformis (Parker & Jones)	·		·	
S. typica Lacroix	·		·	
Textularia candeiana d'Orbigny	·		·	
T. earlandi Parker	·		·	
T. sp.	·		·	
Tiphotrocha sp.	·		·	
T. kellettae (Thalmann)	·		·	
Trochammina discorbis Earland	.3		·	
T. hadai Uchio	4		17	8
T. inflata (Montagu)	.3		·	
T. cf. *japonica* Ishiwada	3		22	67
T. pacifica Cushman	·		·	
T. sp.	·		·	
Gaudryina matusimai Asano	·		·	
G. sp.	·		·	
Eggerella propinqua (Brady)	.3	17	·	
E. scabra (Williamson)	3	17	3	
Goesella iizukai Takayanagi	3		3	
CALCAREOUS PORCELANEOUS FORAMINIFERA				
Cyclogyra planorbis (Schultze)	·		·	
Wiesnerella auriculata (Egger)	·		·	
Quinqueloculina cf. *curta* Cushman	.9		·	
Q. elongata Natland	·		·	
Q. fukushimaensis Takayanagi	·		·	
Q. cf. *lamarckiana* d'Orbigny	·		·	
Q. costata d'Orbigny	·		·	
Q. rhodiensis Parker	·		.4	
Q. seminulum (Linné)	3		·	
Q. vulgaris d'Orbigny	·		·	
Q. yabei Asano	·		·	
Q. sp. 1	.3		·	
Q. sp. 2	·		·	
Q. sp. 3	3		·	
Q. sp. 4	·		·	
Q. sp. 5	·		·	
Q. sp. 6	·		·	
Q. sp. 7	·		·	
Q. spp. (fragments)	6		·	
Massilina inaequalis Cushman	3		·	
M. milletti (Wiesner)	·		·	
M. secans (d'Orbigny)	·		·	
M. sp.	·		·	
Siphonaperta macbeathi Vella	·		·	
Pyrgo ezo Asano	3		·	
Triloculina brevidentata Cushman	·		·	
T. laevigata d'Orbigny	·		4	
T. rotunda d'Orbigny	·		·	
T. terquemiana (Brady)	·		·	
T. cf. *terquemiana* (Brady)	·		·	
T. trigonula (Lamarck)	·		·	
T. sp.	·		·	
Miliolinella circularis (Bornemann)	·		·	
M. oblonga (Montagu)	·		·	
M. subrineata (Brady)	·		·	
M.? cf. *sidebottomi* (Martinotti)	6	17	·	
M.? sp.	·		·	
CALCAREOUS HYALINE FORAMINIFERA				
Dentalina ittai Loeblich & Tappan	·		·	
Lagena laevis (Montagu)	·		·	
L. cf. *perlucida* (Montagu)	·		·	
L. distoma Parker & Jones	·		·	
L. semilineata Wright	·		·	
Oolina costata (Williamson)	·		·	
O. melo d'Orbigny	·		·	
O. sp.	·		·	
Fissurina annectens (Burrows & Holland)	·		·	
F. cucurbitasema Loeblich & Tappan vars.	·		·	
F. cucurbitasema bispinata Ujiié	·		4	
F. sp. 1	·		·	
F. sp. 2	·		·	
F. sp. 3	·		·	
F. sp. 4	·		·	
F. sp. 5	·		·	
F. sp. 6	·		·	
Parafissurina sp. 1	·		·	
P. sp. 2	·		·	
Buliminella elegantissima (d'Orbigny)	9	17	·	
Bolivina pseudoplicata Heron-Allen & Earland	3		·	
B. robusta Brady	·		·	
B. cf. *seminuda* Cushman	3		·	
B. striatula Cushman	·		·	
B. cf. *tokiokai* Uchio	·		·	
B. sp. aff. *B. durrandii* Millett	·		·	
Bulimina marginata d'Orbigny	·		·	
Chrysalidinella dimorpha (Brady)	3		·	
Reussella pacifica Cushman & McCulloch	·		·	
Uvigerinella glabra (Millett)	·		4	
Buccella frigida (Cushman)	6		2	
B.? *makiyamae* Chiji	6		.2	
Epistominella naraensis (Kuwano)	·		·	
Helenina anderseni (Warren)	·		·	
Neoconorbina stachi (Asano)	·		·	
Rosalina australis (Parr)	·		·	
R. bradyi (Cushman)	6		·	
R. columbiensis (Cushman)	·		·	
R. vilardeboana d'Orbigny	6		·	
R. sp. (fragment)	·		·	
Valvulineria hamanakoensis (Ishiwada)	4		2	
Glabratella cf. *globosa* (Sidebottom)	·		·	
G. cf. *chasteri* (Heron-Allen & Earland)	·		·	
G. milletti (Wright)	·		·	
G. nakamurai (Asano)	·		·	
G. opercularis (d'Orbigny)	6		·	
G. cf. *patelliformis* (Brady)	·		·	
G. subopercularis (Asano)	6		·	
G. sp.	·		·	
Spirillina cf. *vivipara* Ehrenberg	·		·	
Patellina corrugata Williamson	·		·	
Ammonia beccarii (Linné) forma 1	3		11	8
A. beccarii (Linné) forma 2	14		14	8
A. beccarii (Linné) forma 3	·		·	
A. japonica (Hada)	6		2	
A. ketienziensis (Ishizaki)	6		·	
A. spp. (fragments)	·		1	
Pararotalia? *minuta* (Takayanagi)	8		3	
P. nipponica (Asano)	2		·	
P.? *takayanagii* Matoba n. sp.	·		·	
Elphidium advenum (Cushman)	9		·	
E. clavatum Cushman	1	17	·	
E. crispum (Linné)	1		4	
E. hanzawai Asano	·		·	
E. reticulosum Cushman	·		·	
E. jenseni (Cushman)	3		·	
E. kusiroense Asano	2		·	
E. cf. *kusiroense* Asano	7		4	
E. cf. *reticulosum* Cushman	3		·	
E. subarcticum Cushman	13	17	7	
E. subarcticum Cushman var.	2		4	
E. subgranulosum Asano	3		2	
E. sp.	3		·	
E. spp. (fragments)	·		·	
"*Elphidium*" *subincertum* Asano	4		6	
"*E.*" *somaense* Takayanagi	7		9	
Eponides? sp.	·		·	
"*Eponides*" *orientalis* Asano	·		·	
Poroeponides cribrorepandus Asano & Uchio	·		·	
P. lateralis (Terquem)	·		·	
Cibicides aknerianus (d'Orbigny)	·		·	
C. lobatulus (Walker & Jacob)	2		·	
C. pseudoungerianus (Cushman)	·		·	
C. spp. (fragments)	3		·	
Caribeanella ugiensis (Matsunaga)	·		·	
Dyocibicides perforata Cushman & Valentine	·		·	
Cymbaloporetta bradyi (Cushman)	·		·	
Fursenkoina complanata (Egger)	·		·	
Nonionella stella Cushman & Moyer	·		·	
Pseudononion japonicum Asano	3		·	
Anomalina sp.	·		·	
A.? *pauperata* (Balkwill & Wright)	·		·	
Hanzawaia nipponica Asano	9		·	
Cerobertina sp.	·		·	
Number of Benthonic Forms	47	6	22	5
Ratio of Agglutinated Foraminifera (%)	16	34	44	75
Ratio of Calcareous, Porcelaneous Foram. (%)	4	17	9	·
Ratio of Calcareous, Hyaline Foram. (%)	81	49	55	25
Ratio of Living Population to Total ($L/T \times 100$) (%)	1.5		5.4	
Planktonic Population: actually counted	2		·	
Planktonic Population: in 10cc of surface sediment*	37		·	
Planktonic Population: ratio to total ($Pl/(Pl+Ben)$) (%)	5		·	

* calculated for equal sample from actual count

Table 3. Occurrence of the total and living benthonic

Facies and Subfacies		B1		C1		B1		C1		B1		A		C2						B2				A															
Station Number		Ms 2		Ms 3		Ms 4		Ms 5		Ms 6		Ms 7		Ms 8		Ms 9		Ms 10		Ms11a		Ms11b		Ms12		Ms13		Ms14		Ms15		Ms16		Ms17		Ms18		Ms19	
Depth (m)		0.9		1.2		1.7		2.2		2.2		2.5		2.2		1.8		2.7		3.2		3.2		2.7		12.5		2.4		3.5		5.2		2.4		0.8		1.2	
Total(T:living and dead) and Living(L)		T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L
Benthonic Population	in10cc of surface sediment*	5500	96	3680	192	2750	256	1190	216	3590	176	3580	304	1080	296	792	116	1640	344	2350	216	1820	80	8510	144	2220	120	9250	224	18900	384	6980	352	4920	368	5460	544	13200	640
	actually counted	343	6	230	12	343	32	298	54	244	11	448	38	271	74	198	29	205	43	294	27	227	10	219	9	278	15	289	7	286	6	218	11	307	22	342	34	206	10
AGGLUTINATED FORAMINIFERA																																							
Reophax nana Rhumbler		%	%	-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
R. gracilis (Kiaer)		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-		-		-		-		-	
R. scottii Chaster		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Miliammina fusca (Brady)		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Haplophragmoides canariensis (d'Orbigny)		-		-		-		-		-		-		-		-		.5		-		-		-		-		-		-		-		-		-		-	
H. hancocki Cushman & McCulloch		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
H. sp.		-		-		-		-		-		-		-		-		-		.3		-		-		-		-		-		-		-		.3		.5	
H. spp. (fragments)		-		-		-		-		-		-		-		-		-		.3		-		-		-		-		-		-		-		-		-	
Ammobaculites exiguus Cushman & Bronnimann		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		.3		-		-	
Ammoscalaria pseudospiralis (Williamson)		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Spiroplectammina biformis (Parker & Jones)		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
S. typica Lacroix		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Textularia candeiana d'Orbigny		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		.3		-		.5	
T. earlandi Parker		-		-		-		.3	2	-		.5		-		.5		-		1		.4		-		.4		-		-		-		.7		-		-	
T. sp.		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Tiphotrocha sp.		-		-		-		-		-		-		.4		-		-		-		-		-		-		-		-		.5		-		.3		-	
T. kellettae (Thalmann)		-		-		-		.3		-		.5		-		-		.5		.7		-		.5		2		.3		-		-		-		.3		-	
Trochammina discorbis Earland		.3		-		-		-		-		-		-		-		.5		.3		-		-		-		-		-		-		-		-		-	
T. hadai Uchio		4		17	8	9	3	21	9	7	9	3		24	8	38	17	17	14	11	31	7	10	3		.4		1		.7		.9	9	1		2		4	10
T. inflata (Montagu)		.3		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
T. cf. *japonica* Ishiwada		9		22	67	13	19	12	33	8	9	5	16	34	73	24	52	36	60	9	50	15	60	3		1		2	14	.4		2	9	4	18	4	32	1	10
T. pacifica Cushman		-		-		-		-		-		-		-		-		-		-		-		.5		-		-		-		.5		-		-		-	
T. sp.		-		-		-		.3		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Gaudryina matusimai Asano		-		-		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-	
G. sp.		-		-		-		-		.4		-		-		-		-		-		-		-		-		-		.4		-		-		-		-	
Eggerella propinqua (Brady)		.3	17	-		-		-		-		-		-		-		-		.7		-		2		.7		-		-		-		-		-		-	
E. scabra (Williamson)		3	17	3		3	6	2		9	9	3	3	10	7	11	10	17	5	6		19	20	6		.4		2		2		3	9	4	13	2		1	
Goesella iizukae Takayanagi		.3		1		.6		-		-		-		-		.5		-		-		.4		-		-		-		-		-		-		-		-	
CALCAREOUS PORCELANEOUS FORAMINIFERA																																							
Cyclogyra planorbis (Schultze)		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-		.3		-	
Wiesnerella auriculata (Egger)		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-		-		-	
Quinqueloculina cf. *curta* Cushman		.9		-		-		-		-		-		-		-		-		-		-		-		3		-		1		.5		.3		.3		-	
Q. elongata Natland		-		-		-		-		-		-		-		-		-		-		.4		.5		1		.3		1		1		-		.6	3	-	
Q. fukushimaensis Takayanagi		-		-		-		.3		-		-		-		-		-		-		-		-		1		.7		2		.5		-		.3		-	
Q. cf. *lamarckiana* d'Orbigny		-		-		-		-		-		-		-		-		-		-		-		-		.7		-		-		-		-		-		-	
Q. costata d'Orbigny		-		-		-		-		.4		.2	3	-		-		-		-		-		-		.7		-		-		-		-		-		-	
Q. rhodiensis Parker		-		.4		-		.7		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Q. seminulum (Linné)		.3		-		-		-		-		-		-		-		-		-		-		-		.7		-		-		-		-		-		-	
Q. vulgaris d'Orbigny		-		-		-		-		-		-		-		-		-		-		-		.5		.4		-		-		-		-		-		-	
Q. yabei Asano		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		.4		-		-		-		-	
Q. sp. 1		.3		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Q. sp. 2		-		-		-		-		-		-		-		-		-		-		-		-		.7		-		.7		-		-		.6		-	
Q. sp. 3		.3		-		-		-		-		-		-		-		-		-		-		.9	11	.7	7	-		.7		-		-		-		-	
Q. sp. 4		-		-		-		-		-		-		-		-		-		-		-		.9	11	-		-		.4		-		-		-		-	
Q. sp. 5		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-		-		-	
Q. sp. 6		-		-		-		-		-		-		-		-		-		-		-		-		.7		-		-		-		-		-		-	
Q. sp. 7		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Q. spp. (fragments)		.6		-		-		-		-		.2		-		-		-		.3		-		1		-		-		.7		-		.7		.9		.5	
Massilina inaequaris Cushman		.3		-		-		-		-		-		-		-		-		-		-		-		1		-		-		.9		-		-		-	
M. milletti (Wiesner)		-		-		-		-		-		-		-		-		-		-		-		-		.7		-		-		-		-		-		-	
M. secans (d'Orbigny)		-		-		-		-		-		-		-		-		-		-		-		-		-		.3		-		-		-		-		-	
M. sp.		-		-		-		-		-		-		-		-		-		.3		-		-		.4		.3		1		.5		-		-		-	
Siphonaperta macbeathi Vella		-		-		-		-		-		.2		-		-		-		-		-		-		-		-		.4		.5	9	-		-		-	
Pyrgo ezo Asano		.3		-		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-	
Triloculina brevidentata Cushman		-		-		-		-		-		-		-		-		-		-		-		.5		.4		-		-		-		-		-		-	
T. laevigata d'Orbigny		-		.4		-		.3		-		.5		-		-		-		-		.4		-		1		1		.7		-		2		.9		-	
T. rotunda d'Orbigny		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-		-		-	
T. terquemiana (Brady)		-		-		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-	
T. cf. *terquemiana* (Brady)		-		-		-		-		-		-		-		-		-		-		-		-		1	13	-		-		-		-		-		-	
T. trigonula (Lamarck)		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
T. sp.		-		-		-		-		-		-		-		-		-		-		-		2	11	1	7	-		.7		-		-		-		-	
Miliolinella circularis (Bornemann)		-		-		-		-		-		-		-		-		-		-		-		.5		1		-		2		-		-		.3		-	
M. oblonga (Montagu)		-		-		-		-		-		-		-		-		-		-		-		-		1		-		-		.5		-		-		-	
M. sublineata (Brady)		-		-		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-	
M.? cf. *sidebottomi* (Martinotti)		.6	17	-		-		-		-		-		-		-		.5		.3		1		.9		.7		-		.7		.9		1	5	.6		-	
M.? sp.		-		-		-		-		-		-		-		-		-		-		-		-		.7		-		.4		.9		-		-		-	
CALCAREOUS HYALINE FORAMINIFERA																																							
Dentalina ittai Loeblich & Tappan		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
Lagena laevis (Montagu)		-		-		-		-		-		-		-		-		-		-		-		-		-		-		.4		-		.3		-		-	
L. cf. *perlucida* (Montagu)		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	
L. distoma Parker & Jones		-		-		-		-		-		.2		-		-		-		-		-		-		-		-		-		.5		-		-		-	
L. semilineata Wright		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		.5	9	-		-		-	
Oolina costata (Williamson)		-		-		-		-		-		-		-		-		-		-		-		.5		-		-		-		-		-		-		-	
O. melo d'Orbigny		-		-		-		-		-		-		-		-		-		-		-		-		-		.3		-		-		-		-		-	
O. sp.		-		-		-		-		-		-		-		-		-		-		.4		-		-		-		-		.5		-		-		-	
Fissurina annectens (Burrows & Holland)		-		-		.3		-		.4		.2		-		-		-		.3		-		-		-		.7		-		-		.3		-		-	
F. cucurbitasema Loeblich & Tappan vars.		-		-		-		-		-		-		-		-		-		1		-		.5		.4		-		.4		-		-		.3	3	-	
F. cucurbitasema bispinata Ujiié		-		.4		-		-		-		-		-		-		-		-		-		.9		.4		-		-		-		-		.3		-	
F. sp. 1		-		-		-		-		-		.2		-		-		-		-		-		-		-		-		-		-		-		-		-	
F. sp. 2		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		.3		-		-	
F. sp. 3		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-	

Foraminifera, each in percent of the total and living populations.

				B1	C1	B1			C1			C2	C4				C3	C2	B2	A	B2	C2		C3	C2	B1	A
Ms 20	Ms 21	Ms 22	Ms 23	Ms 24	Ms 25	Ms 26	Ms 27	Ms 28	Ms 29	Ms 30	Ms 31	Ms 32	Ms 33	Ms 34	Ms 35	Ms 36	Ms 37	Ms 38	Ms 39	Ms 40	Ms 43	Ms 44	Ms 45	Ms 46	Ms 47	Ms 55	Ms 56
8.7	5.7	4.4	2.5	0.7	1.5	0.9	1.2	1.8	1.3	0.9	1.3	1.3	0.4	0.4	0.5	1.3	1.5	2.0	2.7	2.2	2.5	2.2	1.3	0.9	2.0	1.5	1.7
T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L	T / L
526 / 44	11300 / 736	16700 / 512	1340 / 20	4300 / 688	3630 / 224	2350 / 304	442 / 104	2420 / 272	1280 / 244	4430 / 368	1650 / 384	936 / 172	612 / 238	53 / 8	179 / 80	264 / 76	1380 / 956	1680 / 256	1700 / 208	5090 / 352	1720 / 112	1670 / 328	1700 / 152	3580 / 160	720 / 66	1110 / 20	5670 / 224
263 / 22	353 / 23	292 / 8	334 / 5	269 / 43	227 / 14	299 / 38	221 / 52	304 / 34	321 / 61	277 / 23	206 / 48	234 / 43	306 / 118	53 / 9	179 / 80	264 / 76	345 / 239	210 / 32	213 / 26	204 / 11	215 / 14	209 / 41	213 / 19	224 / 10	360 / 33	278 / 5	318 / 14
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.4	-	-	1 / 20	-	-	.3 / 3	5	-	.3	.4	-	-	.3 / 1	-	-	-	-	.5	1	-	.5	-	-	-	.3	-	.3
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.9 / 5	.3	-	-	-	-	-	-	-	-	-	-	.4	-	-	-	-	-	-	.5	-	-	-	-	-	-	-	-
7 / 20	-	-	2	-	.4	.3	.5	-	.3	-	-	.4	.3	-	-	-	-	-	.5	-	.9	1	-	-	-	.4	.3
1	.6	-	8	15 / 33	25	8 / 11	8 / 4	6 / 12	26 / 16	13 / 4	29 / 17	30 / 28	10 / 4	13 / 25	16 / 1	34 / 16	24 / 21	27 / 6	15 / 4	.7	9	36 / 20	43 / 11	55	26 / 3	5	2 / 14
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.4	2 / 4	.3	5	.7 / 2	3	2	5 / 4	5 / 3	4 / 7	8 / 13	2 / 2	3	-	2	-	-	-	15 / 3	9 / 19	7 / 18	10 / 7	6	1	2	3 / 6	9	5
-	-	-	1 / 20	.4	.9	.3	-	-	.6	1	-	3	2	4	2	3	.9	-	.5	-	.5	1	.9	4	.8	.4	-
.3 / 9	-	-	.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.3 / 7
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F. sp. 4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.6	-	-
F. sp. 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.4
F. sp. 6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Parafissurina sp. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.4
P. sp. 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Buliminella elegantissima (d'Orbigny)	.9 17	-	-	-	-	.2	.4	-	-	.3	.4	-	1	3	.7	.5	.3	.6 3	-	.4
Bolivina pseudoplicata Heron-Allen & Earland	.3	-	-	-	-	.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
B. robusta Brady	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.3	-	-
B. cf. *seminuda* Cushman	.3	-	-	-	-	.2	-	-	-	.3	-	-	.7	.7	-	.5	-	.6	-	.8
B. striatula Cushman	-	-	-	.7 4	-	.5	-	-	-	2 4	.4	.9	.4	.7	.7	-	.7	.3 3	-	1 5
B. cf. *tokiokai* Uchio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.4	-	-	-	-	.4
B. sp.aff. *B. durrandii* Millett	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.4
Bulimina marginata d'Orbigny	-	-	-	-	-	-	-	-	-	-	-	-	.4	-	-	-	-	-	-	-
Chrysalidinella dimorpha (Brady)	.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Reussella pacifica Cushman & McCulloch	-	-	-	-	-	-	-	-	-	-	-	-	-	.3	-	-	-	-	-	-
Uvigerinella glabra (Millett)	-	.4	-	1 2	.8	2 3	.4	.5	-	1	4	.9	-	.3	.4	.5	2 9	.9	.5 10	-
Buccella frigida (Cushman)	6	2	2	3	4	3	3	.5	2 2	12	10	5	4	9	4	5	5	3 3	1	2
B.? *makiyamae* Chiji	.6	.2	.3	.7	-	.2	-	-	-	.6	-	.5	-	-	.7	1	.3	.6	4	4 5
Epistominella naraensis (Kuwano)	-	-	.3	-	-	-	-	-	-	-	-	.5	-	-	-	-	-	-	-	1 5
Helenina anderseni (Warren)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neoconorbina stachi (Asano)	-	-	-	-	-	-	-	-	-	-	-	-	.7 7	-	.7	-	-	-	.5	.4
Rosalina australis (Parr)	-	-	-	-	-	-	-	-	-	-	-	-	.7	.3	-	-	-	-	2	-
R. bradyi (Cushman)	.6	-	.3	.3	.8 9	.7	-	-	-	1	-	3	1	.7	4	5	.3	.9	2 20	.4
R. columbiensis (Cushman)	-	-	-	-	-	-	-	-	-	-	-	-	3 13	-	-	-	-	-	.5	-
R. vilardeboana d'Orbigny	.6	-	-	-	-	1	-	-	-	.7	-	3 11	2 13	2	3 33	1	.3	2 3	-	4 14
R. sp. (fragment)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.3	-	-	-
Valvulineria hamanakoensis (Ishiwada)	4	2	.9	.7	2	1	2	2	2 5	.7	.4	-	.4	.3	.4	.5	.3	1 3	1	-
Glabratella cf. *globosa* (Sidebottom)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. cf. *chasteri* (Heron-Allen & Earland)	-	-	-	-	-	.7	.4	-	-	-	-	-	2	-	-	.5	-	.3	-	2
G. milletti (Wright)	-	-	-	-	-	-	-	-	-	.3	-	.5	-	.3	-	.9	-	-	-	1
G. nakamurai (Asano)	-	-	-	-	-	-	-	-	-	-	-	.5	-	-	.7	.9	-	.3	-	-
G. opercularis (d'Orbigny)	.6	-	.3	-	-	-	-	-	-	-	-	.5	1	1	-	-	-	-	.5	-
G. cf. *patelliformis* (Brady)	-	-	-	-	-	-	-	-	-	-	-	-	.4	-	-	-	-	-	1	-
G. subopercularis (Asano)	.6	-	-	-	-	-	-	-	-	.3	-	-	-	.7	.7	-	-	.3	-	-
G. sp.	-	-	-	-	-	-	-	-	-	.7	-	-	-	.3	1	-	.3	-	-	-
Spirillina cf. *vivipara* Ehrenberg	-	-	-	-	-	-	-	-	-	-	-	-	.4	-	-	-	-	-	-	-
Patellina corrugata Williamson	-	-	-	-	-	-	-	-	-	-	-	-	.4	-	-	-	-	-	-	-
Ammonia beccarii (Linné) forma 1	3	11 8	4 6	.7	-	1	-	-	-	-	-	-	-	-	-	-	2 5	4	4 20	.4
A. beccarii (Linné) forma 2	14	14 8	12 6	10 19	20	5	18 8	15 14	14 9	13 12	8	8	.4	7	4 16	5 9	9	4	2 10	1 5
A. beccarii (Linné) forma 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
A. japonica (Hada)	.6	2	11 31	-	1	2 5	-	-	.5	.3	7 10	3	8 13	1 14	2	2	3 13	5 21	-	.8 9
A. ketienziensis (Ishizaki)	.6	-	.6	-	-	-	-	-	-	.3	-	.5	2	-	2	2	-	1 3	4	.8
A. spp. (fragments)	-	1	-	-	-	.2	.4	-	2	1	-	-	-	-	-	-	-	-	-	-
Pararotalia? minuta (Takayanagi)	8	.9	1	4	4	6	-	-	-	8	3	10	8	20	13	10	10 5	12	7 10	9 5
P. nipponica (Asano)	2	-	.9	1	.4	.7	-	-	-	-	-	2	4	1	5	12	3	3 3	31	4 5
P.? *takayanagii* Matoba, n. sp.	-	-	-	-	.4	.5	-	-	-	-	-	-	.7	.3	-	-	-	-	-	.8
Elphidium advenum (Cushman)	.9	-	1	-	.8	.9	-	-	-	.7	-	.9	-	-	1	1	-	-	2	-
E. clavatum Cushman	1 17	-	-	-	-	.2	-	-	-	.3	.4	.5	-	-	-	.5	.3	.3	-	.8
E. crispum (Linné)	1	.4	-	.3	.4	.5	-	-	1	-	-	5	2	1	3	4	2	1	8	-
E. hanzawai Asano	-	-	-	-	-	-	-	-	-	-	-	.5	-	-	-	-	-	-	-	-
E. reticulosum Cushman	-	-	.3	.3	.8	.7	-	1	-	1	2	.5	-	1	-	.5	.3	.3	-	-
E. jenseni (Cushman)	.3	-	-	-	.8	-	-	-	-	2	.4	.9	1	1	1 16	-	.3	.3	.5	.4
E. kusiroense Asano	2	-	.9 3	1	1	.5	.4	1 3	1	2	2	-	2	3	2	3	1	3	-	1
E. cf. *kusiroense* Asano	2	4	5	2 2	3	1	.4	1	-	2	6	4 11	-	3	6	.9	4 5	3	2	2
E. cf. *reticulosum* Cushman	.3	-	-	-	.8	.5	-	-	1 2	.3	-	.3	-	-	1	-	1	-	-	.4
E. subarcticum Cushman	13 17	7	19 25	18 26	27 55	38 66	2 3	-	-	6 4	4	5	7 13	10 43	7 33	9 27	22 27	18 12	12 10	14 9
E. subarcticum Cushman var.	2	.4	7	3	.8	7	.4	-	-	1	.9	2	1	1	1	1	6	3	1	3 5
E. subgranulosum Asano	3	2	4	5 2	-	1	2 1	4 3	2 2	3 4	2	2	2	5	1	.5	1	3	.5	1
E. sp.	.3	-	.3	.7	-	.2	-	-	-	-	-	-	-	-	.4	.5	-	-	-	-
E. spp. (fragments)	-	-	-	-	-	.5	-	-	-	1	.9	1	.4	1 14	1	-	1	.3	-	-
"*Elphidium*" *subincertum* Asano	4	6	2	1 2	4	3 3	.7	1	1	.7	.4	-	.4	2	1	.9	3	.9	-	.8
"*E.*" *somaense* Takayanagi	7	.9	.3	2	2 9	5 3	.4	-	2	5	1	7	11	7	5	7	4	10 6	1	2 5
Eponides? sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
"*Eponides*" *orientalis* Asano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Poroeponides cribrorepandus Asano & Uchio	-	-	-	-	-	-	-	-	-	-	-	.5	.7	-	.4	.5	-	-	-	-
P. lateralis (Terquem)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cibicides aknerianus (d'Orbigny)	-	-	-	-	-	-	-	-	-	-	-	-	.7 7	.3	-	-	-	-	-	-
C. lobatulus (Walker & Jacob)	2	-	.3	.7	1	.9	.4	-	-	.3	-	.9	.7	2	3	6 9	3	.9	4	2
C. pseudoungerianus (Cushman)	-	-	-	-	-	-	-	-	-	-	-	-	.7	-	.7	-	-	-	-	.4
C. spp (fragments)	.3	-	-	-	-	-	-	-	-	-	-	-	.7	.7	.7	-	-	.3	-	.8
Caribeanella ogiensis (Matsunaga)	-	-	-	-	-	-	-	-	-	-	-	-	-	.3	-	-	-	-	-	-
Dyocibicides perforata Cushman & Valentine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cymbaloporetta bradyi (Cushman)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fursenkoina complanata (Egger)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nonionella stella Cushman & Moyer	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	.5	.3 5	.3	-	.4
Pseudononion japonicum Asano	.3	-	-	-	-	.2	-	-	-	-	.9	-	-	.7	1	1	-	.6	-	-
Anomalina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	.3 3	-	-
A.? *pauperata* (Balkwill & Wright)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hanzawaia nipponica Asano	.9	-	-	-	-	-	-	-	-	.3	-	-	-	.7	-	-	-	-	.5	-
Cerobertina sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Number of Benthonic Forms	47 6	22 5	28 8	30 10	26 6	43 8	18 6	14 6	17 8	42 6	29 4	46 7	68 10	45 4	57 4	50 9	40 10	51 14	30 8	53 14
Ratio of Agglutinated Foraminifera (%)	16 34	44 75	26 28	36 44	23 27	12 18	68 88	74 79	72 79	29 80	43 90	14 11	5 -	6 14	4 -	6 36	10 32	9 32	7 20	13 23
Ratio of Calcareous, Porcelaneous Foram. (%)	4 17	.9 -	- -	1 -	- -	1 3	- -	- -	.5 -	1 -	2 -	8 33	22 33	3 -	15 -	6 9	4 5	5 3	.5 -	27 9
Ratio of Calcareous, Hyaline Foram. (%)	81 49	55 25	74 72	62 56	77 73	87 79	32 12	26 21	28 21	70 20	55 10	78 56	74 67	91 86	81 100	87 55	86 63	87 65	93 80	60 68
Ratio of Living Population to Total ($L/_{L+D}$) (%)	1.5	5.4	8.7	16.8	2.5	7.1	27.3	14.6	20.5	8.9	4.4	4.1	4.7	2.1	2.1	5.0	7.2	8.8	4.9	8.4
Planktonic Population: actually counted	2	-	-	-	-	-	-	-	-	1	-	1	2	2	3	2	4	3	-	6
Planktonic Population: in 10cc of surface sediment*	32	-	-	-	-	-	-	-	-	8	-	16	16	64	192	64	64	48	-	12
Planktonic Population: ratio to total ($Pl/_{Pl+Ben}$) (%)	.5	-	-	-	-	-	-	-	-	.3	-	.5	.1	.7	1.0	.7	1.3	.9	-	2.2

* calculated for equal sample from actual count

58	11	37	6	57	4	26	9	19	5	29	10	28	12	38	8	20	7	33	8	13	6	14	3	16	14	10	5	9	6	11	4	7	4	16	6	29	9	58	4	35	5	17	5	13	3	13	3	22	5	34	2	44	8
5	4	.7	-	26	40	27	74	55	57	22	58	24	44	18	41	68	75	45	49	66	71	82	86	32	37	66	75	63	49	61	82	81	91	73	73	47	69	9	27	34	50	74	76	81	89	89	60	64	79	23	-	12	21
6	9	10	-	5	-	2	-	.4	-	.7	-	3	-	2	-	.6	-	.4	-	2	-	.4	-	10	9	-	-	5	9	5	-	-	-	.5	-	.9	-	11	-	5	7	1	-	.5	-	.4	-	.8	-	1	-	4	7
30	87	89	100	70	60	71	26	44	43	77	42	73	56	79	59	31	25	55	51	42	29	18	14	58	54	34	25	32	42	34	18	19	9	27	27	52	31	80	73	60	43	24	24	17	11	10	40	36	21	76	100	84	72
6.0		2.7		1.5		16.0		6.2		12.7		23.5		11.2		19.0		8.3		23.3		18.4		38.6		15.1		44.7		28.8		69.3		15.7		12.2		3.9		6.5		19.6		8.9		4.5		9.2		1.8		4.4	
5		-		2		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		1		1		1	
160		-		8		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		2		4		16	
1.4		-		.6		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		-		.3		.4		.3	