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Seasonal and Spatial Changes in the Structure of Mixohaline Benthic Communities

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Abstract

Lagoon Zyusanko is a small mixohaline lake situated at the west side of Tsugaru Peninsula in northwestern Aomori Prefecture. Surveys of the bottom fauna of the lagoon were carried out from August 1974 to July 1975. As for the results, 16 species of macro benthic animals were collected. Of these, *Corbicula japonica*, *Heteromastus similis* and Nemertinea A predominated all the year round. *Notomastus latericeus* in summer and *Prionospio japonicus* from fall through spring were numerically dominant. *Cyathura muromiensis* commonly occurred at all seasons.

Community types and their seasonal and spatial changes were determined by a cluster analysis of cored samples. There are consequentially 8 community types of cluster groups from A to H. These communities are categorized as follows:

Cluster group A; *Corbicula japonica* community occurred at all seasons.
Cluster group B; *Heteromastus similis* community found only in summer.
Cluster group C; *C. japonica* - *H. similis* community found only in summer.
Cluster group D; *H. similis* - Nemertinea A community appeared only in summer.
Cluster group E; *Prionospio japonicus* - *H. similis* - *C. japonica* community occurred from fall to spring.
Cluster group F; *H. similis* - *P. japonicus* - Nemertinea A community found from fall to spring.
Cluster group G; *H. similis* - *P. japonicus* community occurred from fall to spring.
Cluster group H; *Notomastus latericeus* community found in warmer seasons.

Seasonal and spatial changes of communities in Zyusanko except *C. japonica* and *N. latericeus* communities were found between summer and the other seasons, i.e. seasonal and spatial changes at the community level in Zyusanko were clearly controlled by fluctuations in population densities of *Prionospio japonicus*. Seasonal aspects of communities and correspondence between types and chlorinity of interstitial water are discussed here.

Fresh-water ecologists are well aware of seasonality in benthic communities due to the importance of insect emergence.[1~3] However, seasonality in marine benthic communities is less well understood. Although seasonality in both reproduction and larval settling is known to occur in many marine benthic species,[4,5] seasonal changes in the structure of entire benthic communities have so far seldom been described. Seasonal variation has not been found in the soft bottom communities of Buzzards Bay, Massachusetts[5], of Shimizu Harbour and

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Orido Bay, Shizuoka Prefecture[6], and in the maritime coastal regions on the Seto Inland Sea, southwestern Japan[7]. It may be safely stated that seasonal variation is a rare feature of benthic community structure.

On the contrary, a considerable number of investigations pointed out that seasonal changes in the structure at the community level had been cleary controlled by the fluctuations in population densities of numerically dominant species.[8~12] Furthermore, numbers of species and of individuals and biomass increase from spring to summer, and decrease from summer to fall.[13,14] Yamamoto[15] reported that these values reached a maximum during the period from August to November and a minimum from February to April. On the other hand, Holland et al.[12] described that the total faunal depletion occurred during summer, an initial recolonization during early fall, a secondary one during late fall, and that growth and structural development occurred during winter and spring, reflecting the successful recruitment of four species reproduced in fall.

Since most temperate-zone invertebrates are reproductively active only seasonally,[16,17] it is possible to hypothesize that the structure of communities numerically dominated by certain of these organisms will vary seasonally, depending upon their recruitment and mortality trends.

The object of this study was to demonstrate and evaluate quantitative temporal and spatial changes in the structure of mixohaline benthic communities on the basis of the surveys performed in 1974 and 1975.

Materials and Methods

Area and stations studied

Lagoon Zyusanko (Fig. 1) is located at the west side of Tsugaru Peninsula in northwestern Aomori Prefecture. Surface chlorinity in neighborhood of the mouth of the lagoon varies seasonally from about 6.5 ‰ in warmer seasons to about 0.5 ‰ in winter (Fig. 2). Its hydrographical peculiarities are mainly caused by an inflow of fresh water of rivers. The bottom sediments vary from coarse sand in regions shallower than 1.5 m depth to fine sand in regions deeper than 2 m.[18]

The positions of fixed stations for the present study are illustrated in Figure 1.

Sampling

During from August 1974 to July 1975, five replicate samples were taken by means of a cylindrical coring device with 176 cm^2 in sampling area at each station. Core contents were washed through a sieve with 1-mm mesh and all animals retained on the mesh were preserved in buffered 10 % formalin solution. Bottom water for a laboratory analysis of chlorinity were collected 25 cc in volume from the upper 2 cm of the sediment surfce. Sedimentary interstitial water in the 2 cm surface layer of sediment was extracted by using a centrifuge. The chlorinity was determined by the method of Fajans.

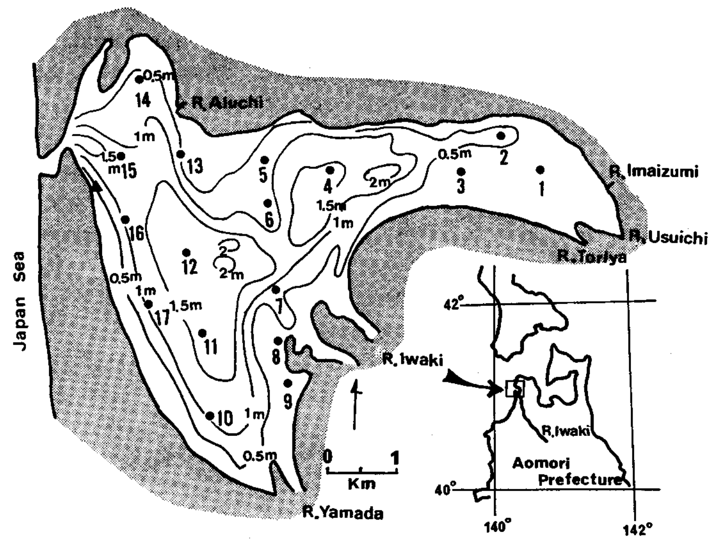

Fig. 1. Map of Lagoon Zyusanko with noted sampling sites. The lines indicate approximate water depth in meter.

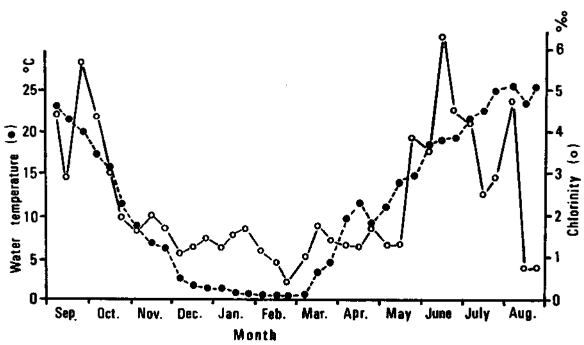

Fig. 2. Surface water temperature and chlorinity observed at the station (triangle in Fig. 1) in the neighbourhood of the mouth of the lagoon.

Results

Chlorinities of bottom water and of interstitial water

The variation in chlorinities of the bottom water is widespread, the values decrease from more than 15 ‰ in the mouth of the lagoon to zero ‰ in the inner parts (Fig. 3). In the warmer seasons, the chlorinities are more than 15 ‰ spread out from the mouth to the middle region of the lagoon, and the values are found less than 1‰ in the inner parts. In winter and spring, more than 15 ‰ of chlorinity are found in the extremely limited area around the mouth and the other greater parts are covered with low chlorinity less than 5 ‰ in winter and with fresh water in spring. This may be caused by the seasonal fluctuation of inflowing water from the rivers. On the contrary, seasonal variations are not found in the regional distribution of the chlorinities of interstitial water. In all seasons, high chlorinities

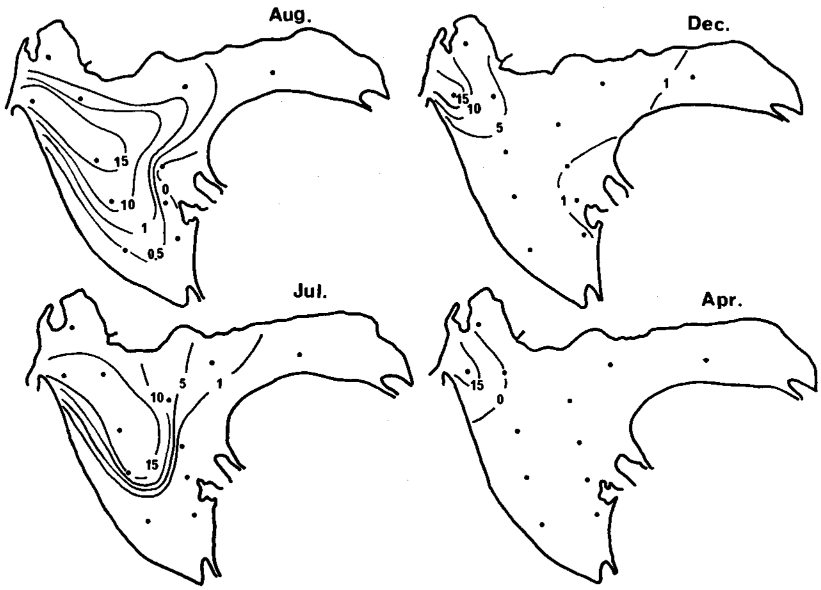

Fig. 3. Seasonal distributions of chlorinity (‰) of bottom water.

more than 5 mg Cl per g of sediment in dry weight are found in the small area showing the deepest water depth, while the values gradually decrease towards shallower water (Fig. 4).

Seasonal and spatial distribution of species

Table 1 shows numerical dominance expressed as a percentage of total number of individuals. *Corbicula japonica* predominated all the year round and *Heteromastus similis, Prionospio japonicus* and Nemertinea A were predominant species. *Cyathura muromiensis* at all seasons and *Notomastus latericeus* in summer commonly occurred. These six species might be principal members of benthic communities in Lagoon Zyusanko. Spatial and seasonal distributions of these species are shown in Figure 5.

Corbicula japonica was markedly numerically dominant at Stations 5, 6 and 16, and predominated at other stations, but was lacking from the majority of samples taken in the middle region including Stations 11, 12 and 13. On the contrary, Nemertinea A was common in the same middle region just mentioned. *Heteromastus similis* developed widely in the lagoon, particularly the stations showing its high density were concentrated on the western offshore. *Cyathura muromiensis* was low in density but was found in every place except the middle region and the region adjacent to the mouth of Iwaki River (Fig. 5). The faunal density of these 4 species showed no clear pattern of seasonal and spatial changes. On the other hand, *Prionospio japonicus* was seasonal in its occurrence, namely, this species was abundant from October to April, showing a spatial distribution similar to that of *Heteromastus similis* but its density remarkably dropped during the warmer portion of the summer months. *Notomastus latericeus* had the most restricted distribution, and, as can be seen in Figure 5, it was only found in area adjacent to the mouth of Iwaki River and was numerically dominant from the summer to the fall.

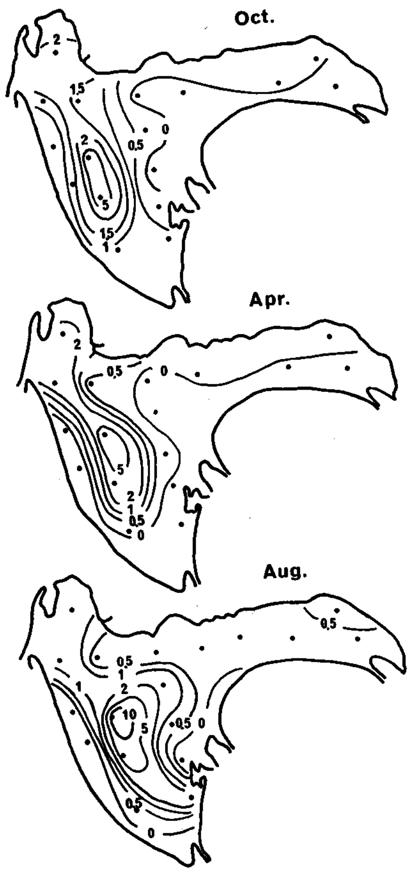

Fig. 4. Seasonal distributions of chlorinity (mg-Cl/g-sediment in dry weight) of interstitial water.

Analysis of spatial structure

As indicated above, seasonal and spatial changes in the number of individuals are recognized in Lagoon Zyusanko. To analyze the spatial structure of the benthic communities, Morisita's community similarity index[19] was applied for comparing to compornents of the benthic animals among sampling stations. The resultant matrix of overlap values for all possible pairs of stations was arranged as a trellis diagram (Fig. 6). The weighted-pair grouping method of cluster analysis was employed on the matrix of correlation values[20] and results are presented as a dendrogram (Fig. 7). To exaggerate differences within each cluster group, an inverted logarithmic scale was used for the correlation values.

Four cluster groups are evident in the dendrogram of August, each of which included samples that were correlated above an r values of 0.80. Cluster group D was weakly correlated with Cluster group B, and Cluster groups C, D and H were not correlated with one another. Two cluster groups in October, four cluster groups in April and in July are evident in the dendrogram. The locations of these cluster groups over the study sites are indicated in Figure 8 and these communities are categorized as follows:

1. Cluster group A community which is composed principally of *Corbicula japonica* and inhabits the narrow region in north shallow water of the lagoon at all seasons.
2. Cluster group B community which is composed principally of *Heteromastus simils* and inhabits the shallower coasts only in summer.

Table 1. *Seasonal changes of composition (%) of benthic fauna in Lagoon Zyusanko.*

Species	Aug.	Oct.	Dec.	Apr.	Jul.
Corbicula japonica	72.8	67.0	93.4	33.7	42.7
Mya arenaria oonogai	0.1	—	—	—	—
Gastropoda	—	—	—	0.8	—
Cyathura muromiensis	3.8	1.2	0.5	2.6	3.4
Gammaridae A,B,C	0.2	0.4	0.1	—	0.1
Chironomidae	—	—	—	—	0.2
Prionospio japonicus	0.8	17.1	2.4	27.6	4.3
Heteromastus similis	10.6	10.5	2.6	28.5	34.7
Notomastus, latericeus	6.6	2.2	—	—	5.1
Sigambra sp.	0.7	0.1	0.1	0.2	0.5
Neanthes diversicolor	0.8	0.6	0.3	1.0	2.0
Nemertinea A, B	3.4	0.9	0.6	5.6	6.7
Sipunculidae	0.3	—	—	—	0.3

3. Cluster group C community which is composed principally of *C. japonica* and *H. similis*, and found only in summer, widespread in distribution.

Cyathura muromiensis may be found with these communities above mentioned.

4. Cluster group D community which is composed principally *H. similis* and Nemertinea A, and found only in summer.
5. Cluster group E community which is composed principally of *Prionospio japonicus*, *H. similis* and *C. japonica*, and its distribution corresponds with that of (3). This community appears from fall through spring.
6. Cluster group F community which is composed principally of *H. similis*, *P. japonicus* and Nemertinea A, and occurs from fall through spring.

Communities of (4) and (6) typically occupy the substratum at greater depth of the middle regions.

7. Cluster group G community which is composed principally *H. similis* and *P. japonicus*, and mostly found in spring at the inner part of the lagoon.
8. Cluster group H community which is composed principally of *Notomastus latericeus* and is confined to the estuary of Iwaki River.

Seasonal and spatial changes of communities in Zyusanko except communities of (1) and (8) took place between summer and the other seasons. *P. japonicus* was one of the principal species which organized communities appearing from fall through spring, i.e. seasonal and spatial changes at the community level in Zyusanko were clearly controlled by fluctuations in population densities of *P. japonicus*.

Discussion

Benthic communities in Lagoon Zyusanko are characterized by temporal and spatial changes in their component populations. For example, *Prionospio japonicus* shows a density range of more than 3 orders of magnitude (0 in warmer seasons to 390/m^2 in April at Station 17). Frankenberg and Leiper[8)] reported that *Spiophanes bombyx* showed a density range of more than 3 orders of magnitude on the Georgia Continental Shelf and that it was not surprising to find such orderof-magnitude difference as 3 orders of magnitude in densities. They added that density variation, rather constancy, was typical of numerically dominant species in the same water above mentioned. In Lagoon Zyusanko, however, 3 numerically

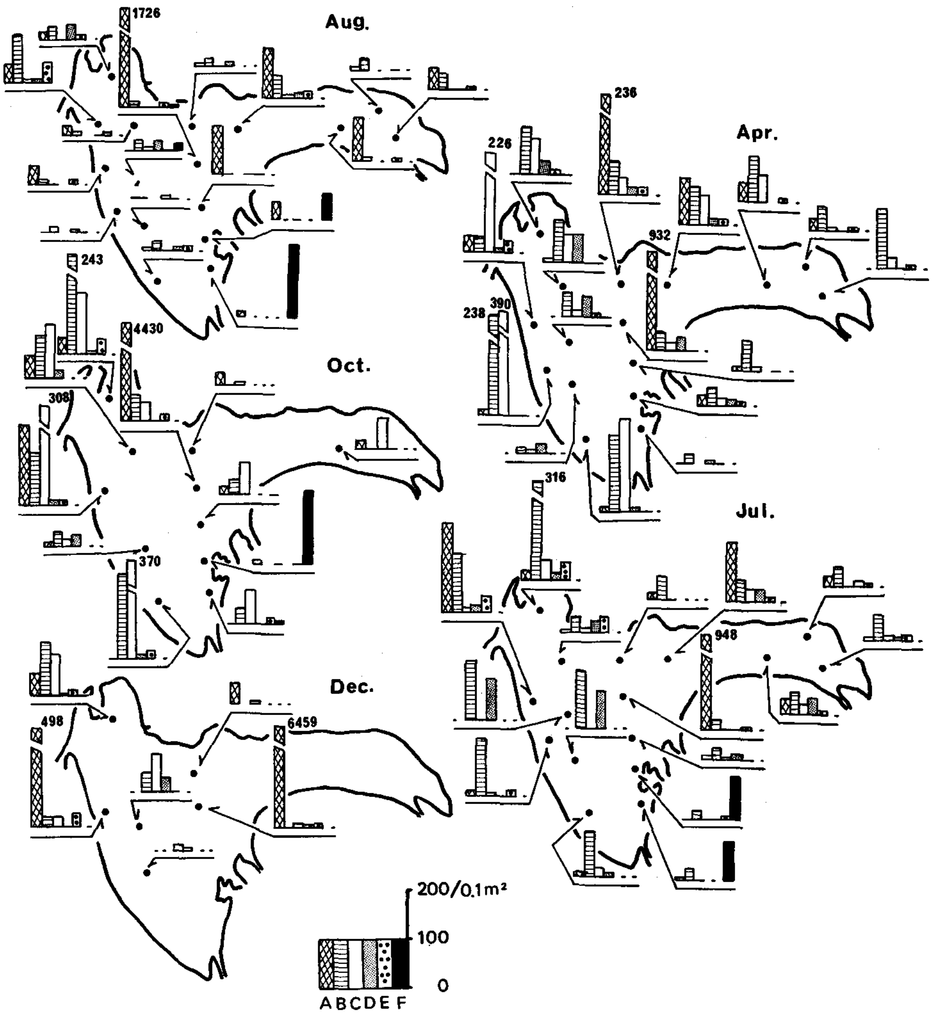

Fig. 5. Map showing the distribution of six common species. A: *Corbicula japonica* B: *Heteromastus similis* C: *Prionospio japonicus* D: Nemertinea A E: *Cyathura muromiensis* F: *Notomastus latericeus*

dominant species, *Heteromastus similis*, *Cyathura muromiensis* and Nemertinea A did not show temporal and spatial changes in densities. But *Corbicula japonica* appears abundant from October to December at Station 6. Reproductive swarming was described in *C. japonica*[21], and may also be involved in its density peak from fall to winter at Station 6. *P. japonicus* is one of the common associate of the

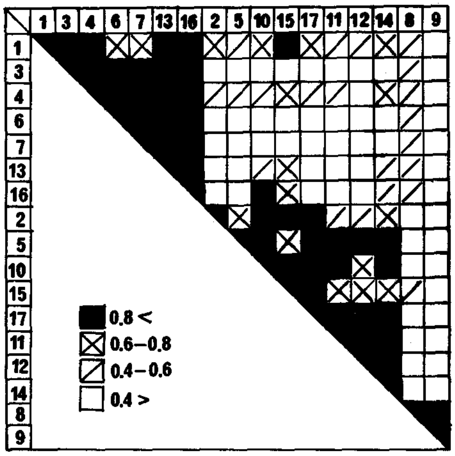

Fig. 6. Trellis diagram showing similarity index (Morisita's index) between pairs of samples collected in August 1974. The four symbolic intervals are chosen for equal area in the diagram.

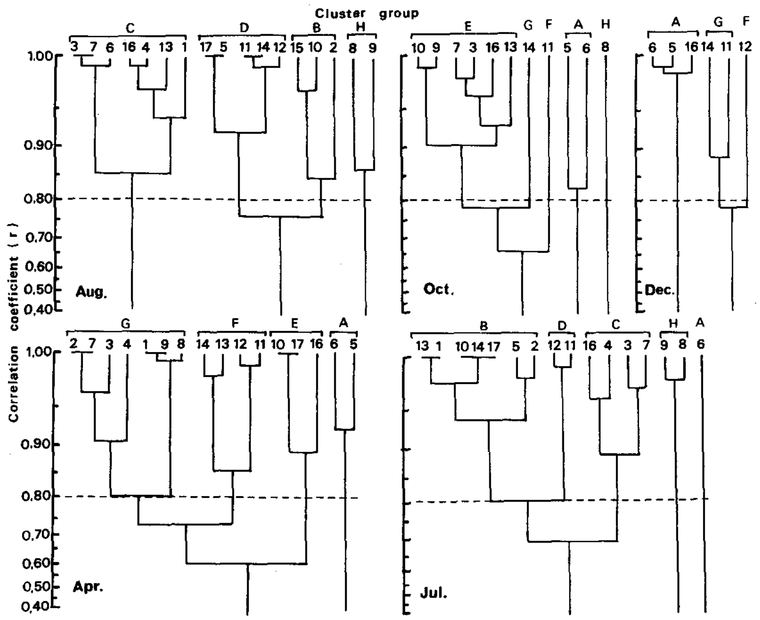

Fig. 7. Plot of results of the cluster analysis as a dendrogram. Numbers listed across the top of the dendrogram correspond to numbers assigned to each core sample in Fig. 1.

mesohaline communities[22] and showed high densities in spring in mesohaline Lake Hinuma[23], but no seasonal changes in density was observed owing to his investigation in a single season. It may be said, however, that in the distribution of *P. japonicus* there is a recurring seasonal density pattern which seems abundant from fall through spring. Figure 5 gives average densities calculated from 5 replicate samples, and therefore do not represent variability between replicates.

Replicate samples usually differed from one another. Sometimes the differences are substantial but usually replicates varied less from one another than from samples taken at other times or other sampling stations[8]. Variation between replicates

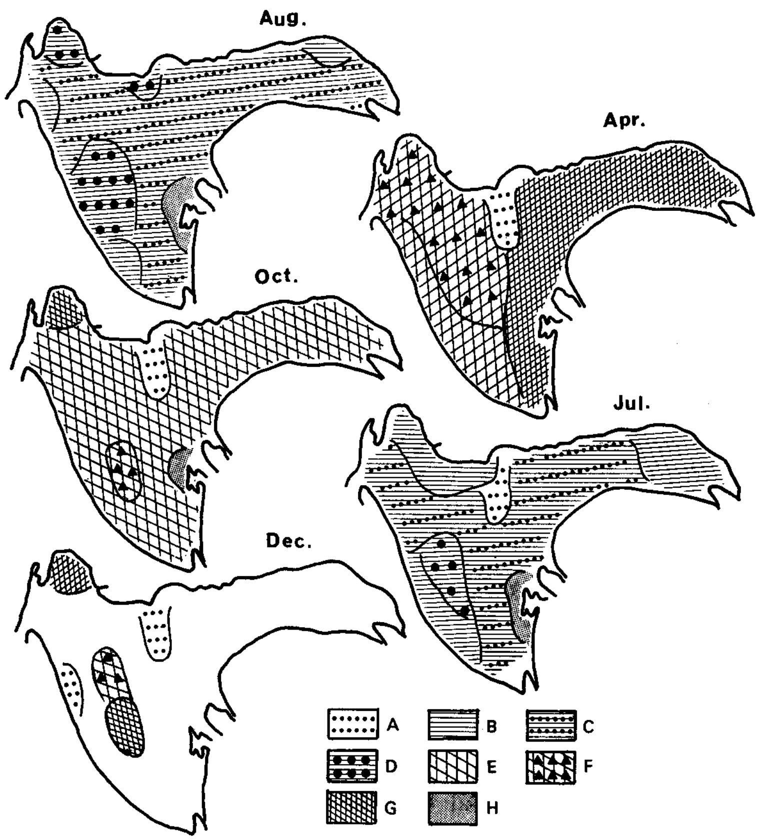

Fig. 8. Seasonal and spatial distributions of benthic communities in Lagoon Zyusanko. A: *Corbicula japonica* community B: *Heteromastus similis* community C: *C. japonica-H. similis* community D: *H. similis*-Nemertinea A Community E: *Prionospio japonicus-H. similis-C. japonica* community F: *H. similis-P. japonicus* -Nemertinea A community G: *H. similis-P. japonicus* community H: *Notomastus latericeus* community

and its significance to benthic sampling problems will be the subject of another paper.

The quantified seasonal changes in community structure are demonstrably associated with net population changes in specific species population. Dynamics events (e.g. recruitment and mortality) occurring at the population level are thus related to seasonal changes in structure observed at the community level[10]. Two communities of Cluster group A predominated by *C. japonica* and Cluster group H predominated by *Notomastus latericeus* did not show seasonal and spatial changes except Cluster group A in August and Cluster group H in April, respectively. Numerically dominant species, *C. japonica* and *N. latericeus* in these two comm-

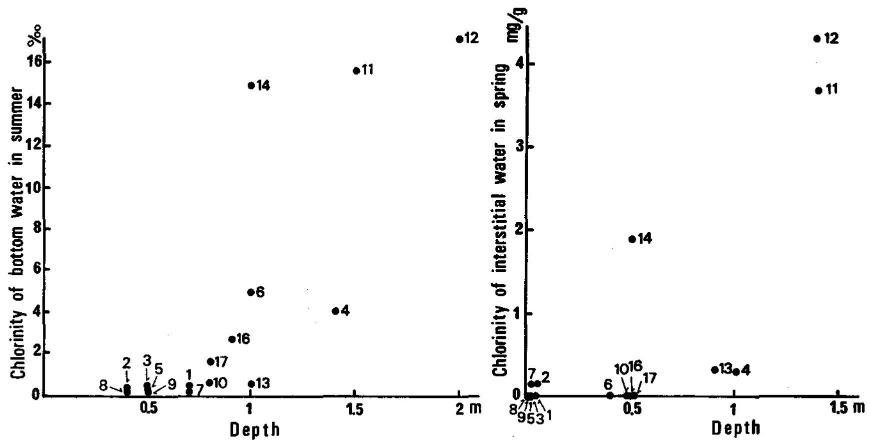

Fig. 9. Environmental situations of sampling stations in Lagoon Zyusanko. The left figure shows the relation between bottom chlorinity and water depth, and the right figure indicates the relation between interstitial chlorinity and water depth.

unities maintained a relatively stable density throughout the year. In summer the communities of Cluster group B predominated by *H. similis*, C predominated by *C. japonica* and *H. similis*, and D predominated by *H. similis* and Nemertinea A show seasonal and spatial changes in community structure. These 3 communities just mentioned were transformed into the communities of Cluster groups E, F and G of which *P. japonicus* was one of the principal components in the communities, from fall through spring. The seasonal and spatial changes described above in the community structure correspond with the annual population density fluctuations of *P. japonicus*. Miyadi et al.[24)] and Kikuchi[25)] reported that the lack of dissolved oxygen limited the faunal composition and lowered the productivity of benthic fauna in brackish water Lake Nakaumi.

According to Tamura[26)], however, bottom water in Zyusanko in summer showed high oxygen content. Therefore the bottom water did not show anaerobic conditoins, probably influenced by wind or current because of the shallow depth. The Venice System classification of brackish water, particularly the designation of euhaline, polyhaline, mesohaline, and oligohaline, has been widely used to relate these schemes to the distribution of benthic community patterns.[27~30)] Yamamoto[31)] studied the macro-benthic communities of brackish water lakes in northern Honshu and concluded that a serial change of community patterns accompanied with the gradient of chlorinity conditions. On the other hand, from the comparison of the benthic coenocline of Chesapeake Bay and Brisbane Estuary, Boesch[32)] concluded that the benthic community patterns on these two water regions showed no correlations between benthic community patterns and chlorinity designation schemes such as the Venice System.

The distribution of estuarine organisms appeared to be regulated by the boundary conditions of the minimum salinity throughout the year rather than by average conditions.[32,33]

Oglesby[34] studying three nereid polychaetes occurring in the different salinity in the San Francisco Bay suggested that ecological distribution of these animals were directly determined by their osmoregulatory abilities. Bottom water deeper than 1 m depth in summer in Zyusanko were under strong influence of sea water. On the contrary, bottom chlorinity in spring was approximately zero at all stations except St. 15 in the entrance (Fig. 3). Thus at St. 12 the chlorinity showed the widest range such as 17.16 ‰ in bottom water during the year, and at Sts. 7, 8 and 9 it showed the narrowest range such as 0.15 ‰ (Fig. 9). Whereas the chlorinity of interstitial water showed little seasonal change (Fig. 4). Fig. 9 indicates interstitial chlorinities at each station in spring (April) when bottom chlorinities were almost zero. Sts. 11, 12 and 14 indicate high chlorinities, and St. 13 follows them. Sts. 2, 4 and 7 show a slight chlorinities, less than 0.3 mg-Cl per gram sediment in dry weight. Sts. 10, 16 and 17 also showing almost zero in interstitial chlorinities are slightly influenced by sea water in bottom water in summer (Fig. 9), and the other stations except St. 6 are scarcely influenced by sea water in bottom water all the year round. Particularly Sts. 8 and 9 in the estuary of Iwaki River showed fresh water in the whole year.

Groups of the stations classified by the characteristics of bottom and interstitial chlorinities in April, just above mentioned, correspond roughly with those of the stations included in each Cluster group in April. In another seasons similar trends are shown. Thus, it can be considered that chlorinity often limits the distribution of the benthic fauna in Lagoon Zyusanko, especially chlorinities of interstitial water are major limiting factors more than those of bottom water for the structure and the distribution patterns of benthic cmmunities.

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