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# Community structures of the benthic macrofaunal assemblages in Kyonggi Bay and Han Estuary, Korea

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The species composition and distribution patterns of the subtidal benthic faunal assemblage in Sokmo and Yomha Channels and Kyonggi Bay were studied in spring and fall of 1989 and correlated to some environmental variables: temperature, salinity and substrate type. For both seasons, a total of 7,779 organisms were counted belonging to 244 species. Of these, 3,647 organisms in 185 species were counted for spring (March 1989) and 4,132 in 189 species for fall (September 1989). The oyster, *Crassostrea gigas* and the tellinidean bivalve, *Moerella rutilla* were the two most abundant species in the spring, constituting 17.22% and 6.47% of the total abundance respectively. While in the fall, the barnacle, *Balanus reticulatus* and macrura, *Ogyrides orientalis* dominated comprising 13.72% and 6.87 % of the total number of individuals. Community structure analysis revealed good correlations with the variations of salinity in Yomha and Sokmo Channels and sedimentary facies in Kyonggi Bay, Korea.

## INTRODUCTION

The impact of man on estuarine habitat and its vicinity for the last 25 years has been enormous all over the world. In Korea, one of the impacted estuaries is Han Estuary and nearby Kyonggi Bay, located in the middle part of the Korean Peninsula and eastern part of the Yellow Sea. It is a major source of aquatic resources and utilized for recreation, particularly in the summer by the people living around the area.

However, during the last two decades the country has undergone rapid industrialization, and, as a result, the quality of the water in Han Estuary and Kyonggi Bay has deteriorated (IDCC, 1993; Kim, 1994; NMP, 1987, 1988) and the structure of its planktonic faunal and floral communities has been altered (KOACA, 1994; IDCC, 1993).

Cognizant of the present state of Han Estuary and Kyonggi Bay, the Seoul City Government in 1984 to 1986 embarked on a program to further develop the Han River and its nearby areas, to maximize its use as a resource and to restore it to its original state. However, the studies of the impact on the macrobenthic fauna in this area have not received much attention except the work of Shin *et al.* (1989), in contrast to the relatively considerable studies conducted on the plankton community of the area (Choi and Shim, 1986a, 1986b, 1986c; Chung and Park, 1988; Kwon, 1990; Lee, 1993).

Here we present the results of our studies on the characteristics and the seasonal variations in the community structures of benthic macrofaunal assemblages in Han Estuary and Kyonggi Bay as affected by salinity, and the types of substrates.

## MATERIALS AND METHODS

### *Characteristics of the study area*

The study area, Han Estuary and Kyonggi Bay (37° 25' N, 126° 06' E and 37° 43' N, 126° 38' E) is a typical estuary characterized by a well-developed tidal flats and two channels namely: Yomha and Sokmo Channels (Fig. 1). Through these two channels, the Han River, one of the major rivers in Korea, supplies a large volume of freshwater to Kyonggi Bay, forming a typical estuarine en-

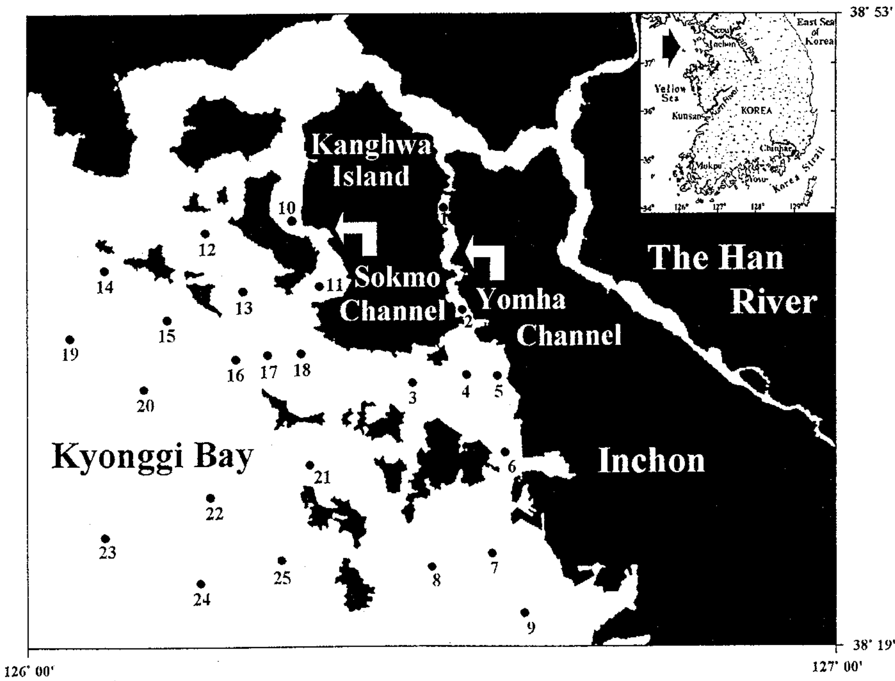


Fig. 1. Locations of benthic sampling sites in the Han Estuary and Kyonggi Bay, Korea.

vironment within the mouth of the river.

*Sampling stations*

Twenty-five sampling sites were established from the shallow coastal to deeper offshore areas of Kyonggi Bay and within the two channels of Han River. Of the 25 stations, two are located in Yomha Channel and another two in Sokmo Channel with the rest of the stations distributed in the greater part of Kyonggi Bay (Fig. 1).

*Samplings*

Samplings were conducted in early spring (March) and mid-fall (September), 1989. Collection of samples was done using a 40 l semi-quantitative rectangle dredge (Type Charcot, mouth 17×32 cm). After collection, samples were preserved in 10% formalin then filtered through a screen (mesh size: 1.0 mm). Sediment samples were also collected for analysis. Surface and bottom temperature and salinity at each station were determined using a portable T-S Bridge.

The preserved samples collected at each station were washed several times with tap water, sorted, then identified to the species level whenever possible using a dissecting microscope (Olympus, ISZH-141). The number of individuals per species were counted and their abundances recorded.

For the sediment grain size analysis, a subsample of each sediment sample was taken. An aliquot was extracted, and then sieved through a series of nested screens according to Wentworth (1922) and Folk (1968). Granulometric parameters were calculated based on the equations of Folk and Ward (1957).

## MATERIALS AND METHODS

*Statistical analysis of the data*

The Pearson's product-moment correlation was applied (SAS, Statistical Package) to determine the correlation among the environmental parameters measured here while Cluster Analysis was used to analyze sedimentological data to define clearly the types of sediments among stations. On the other hand, to understand the benthic faunal community

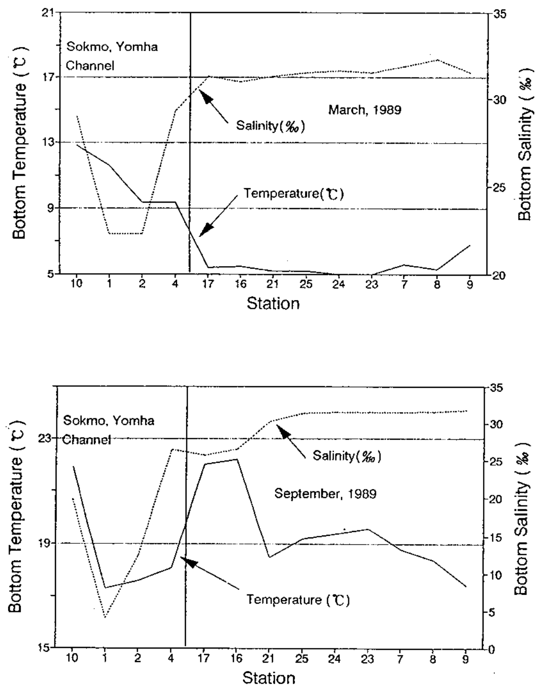


Fig. 2. Bottom temperature and salinity fluctuation in the study area in March and September 1989.

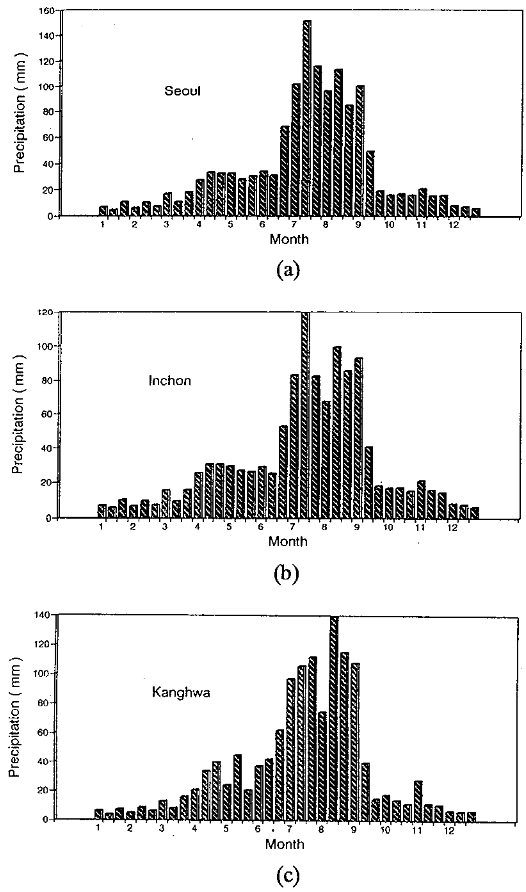


Fig. 3. 10-day normals of precipitation for 1961-1990 ((a), (b), and (c)). Data taken from Korea Meteorological Agency, 1991).

structure of the study area, indices on species richness (Margalef, 1958), evenness (Pielou, 1975) and diversity H' (Shannon and Wiener, 1949) were computed based on the species identified and its abundance. Diversity and other indices were calculated on the biologically truncated station groups (Hong and Yoo, 1996; Yoo, 1992), because, Diversity, H' is often biased when sample size is less than 200 individuals (Paul and Thompson, 1982; Sanders, 1968). Also, the following comparisons among environmental variables were performed on the same station groups.

## RESULTS AND DISCUSSION

### *Physical characteristics of Kyonggi Bay and Han Estuary*

Of the various physical parameters, bottom temperature, bottom salinity, mean phi values and compositional variables of sediments were determined from correlation analysls to describe the physical environment of the study areas. Without giving much attention to the abrupt decrease of the bottom temperature at Station 1, 2 and 4 in September at the inner part of Yomha Channel, temperatures for both seasons showed a decreasing trend from the inner part of the two channels to the outside of Kyonggi Bay. Whereas, salinity showing a marked decrease at Stations 1 and 2 in March and Station 1 in September, followed a reverse trend, increasing toward the outside of Kyonggi Bay (Fig. 2). The mean bottom temperature and salinity range for March were $6.83\pm2.66$°C and $29.78\pm2.60$‰ while in September $20.03\pm1.91$°C and $25.73\pm6.94$‰, respectively. Difference between temperature and salinity means represented and typified their seasonal patterns.

The spatio-temporal changes in temperature and salinity are mainly due to freshwater inputs from the Han River. Station 10 located in Sokmo Channel was expected to have lower salinities since it received greater amount of freshwater than Yomha Channel but we recorded higher salinities in the area. This increase in salt content to a level above that of Yomha Channel could be attributed to the bigger width and depth of Sokmo Channel causing high rate of freshwater influx and wide fluctuations in salinity in consonance with tidal rhythm. Furthermore, the mean bottom currents and net discharges of Sokmo Channel (6.90 cm/s, 0.04 $m^2$/s) are lower compared to Yomha (24.64 cm/s, 1.26 $m^2$/s) and Kyodong (6.75 cm/s, 1.78 $m^2$/s) (Kim, 1990).

The amount of precipitation the study area received should also be considered to influence changes in faunal structure. In Fig. 3 is the 10-day normal precipitation during the dry and wet seasons (1961-1990) in Seoul (4.9-48.6 mm in dry season and 68.2-152.0 mm in wet season), Inchon (5.3-40.8 mm and 53.0-119.8 mm) and Kanghwa (3.9-42.1 mm and 62.4-139.6 mm), the synoptic stations for Kyonggi Bay areas. High precipitations in the area occur in late June to early September and low in mid-September to mid-June. This also contributes to the freshwater inputs of the area thus lowering surface salinities.

Four types of surficial sedimentary facies are recognized from Kyonggi Bay and Han Estuary, namely, pebble and gravel facies, sand and mixture facies, silt facies and mud facies. Yomha and Sokmo Channels, where tidal currents are strong, have pebble and gravel facies, while the intertidal zones have mud facies, and the outer part of Kyonggi Bay have sand facies. Gravel and silt are spuriously distributed on the intertidal areas of the channels where local geographical configurations and changes in tidal currents predominate.

Results of the Cluster Analysis are presented in Table 1. Stations were grouped into 2; Group A and B. Group A is composed of stations having a sediment type of some gravel and sand but higher in silt content, except Station 6 which had a distinct sedimentary facies composed of 2% gravel, 5% sand and 74% silt in March. The number of stations having sediment with higher silt contents was reduced to six in September. Station 6 showed some variations but continually remained a unique facies (4% in gravel, 50% in sand and 36% in silt). In contrast, the stations of Group B are those having sediments with high sand contents (76-94%) in March and expanded to include 7 other stations in September (Table 1).

Obviously, the sedimentary facies in Kyonggi Bay and Han Estuary exhibit seasonal variations among stations. Jang (1989) observed that the dis-

Table 1. Reallocated groups from cluster analysis of the sediment characteristics (March and September 1989). Group A are mud facies and Group B are sand facies.

Group A

| Group A in March 1989 | | | | | | | | | | | | | | Group A in September 1989 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 68% < silt < 78% 1% < sand < 12% with some gravel | | 75% < silt < 81% 1% < sand < 5% with high clay content | | | | | | | 47% < silt < 68% 14% < sand < 38% with some | | 45% < silt < 51% 36% < sand < 42% | | silt 74% sand 5% gravel 2% | 73% < silt < 77% 3% < sand < 11% with some gravel | | | 42% < silt < 83% 10% < sand < 52% | | | silt 36% sand 50% gravel 4% |
| St. 1 | St. 11 | St. 2 | St. 3 | St. 4 | St. 10 | St. 12 | St. 14 | St. 18 | St. 25 | St. 7 | St. 19 | St. 22 | St. 6 | St. 1 | St. 3 | St. 4 | St. 2 | St. 12 | St. 5 | St. 6 |
| (g)sM | (g)sM | Z | Z | Z | Z | Z | Z | Z | (g)sM | (g)sM | sZ | sZ | (g)sM | (g)sM | (g)sM | (g)sM | gM | zS | Z | (g)mS |

Group B

| Group B in March 1989 | | | | | | | | | | | Group B in September 1989 | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12% < silt < 19% 76% < sand < 83% | | | | | | | 89% < sand < 94% | | | | 10% < silt < 23% 72% < sand < 86% | | | | | | | | | | | | 1% < silt < 7% 91% < sand < 98% | | | | |
| St. 5 | St. 8 | St. 9 | St. 16 | St. 20 | St. 21 | St. 23 | St. 13 | St. 17 | St. 15 | St. 24 | St. 7 | St. 8 | St. 25 | St. 11 | St. 23 | St. 13 | St. 15 | St. 16 | St. 17 | St. 18 | St. 19 | St. 20 | St. 9 | St. 10 | St. 21 | St. 22 | St. 24 |
| mS | zS | zS | zS | zS | zS | mS | (g)mS | S | (g)S | S | (g)mS | (g)mS | zS | zS | (g)mS | mS | mS | mS | zS | zS | (g)S | S | (g)S | S | S | | |

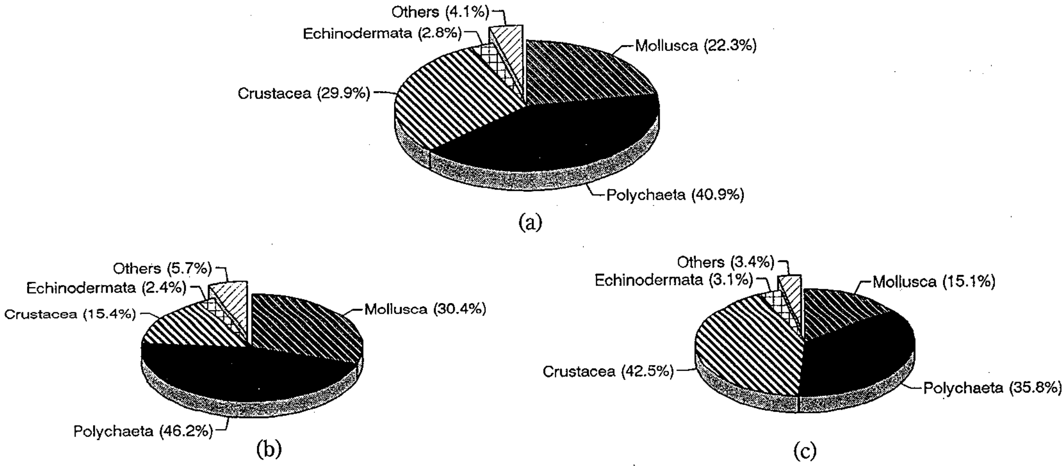


Fig. 4. Percentage (abundance) of major taxa. (b) March 1989, (c) September 1989, and (a) March and Septerber combined total.

tributional patterns of sedimentary facies, particularly sand facies are mainly affected by the amount of river discharges and suspended sediment loads from the Han River which differed markedly between dry and wet seasons.

*Faunal Composition*

A total of 7,779 organisms belonging to 244 species were collected for both seasons. Of the total organisms, 3,647 in 185 species were counted in March. Polychaetes (46.2%), molluscs (30.4%) and crustaceans (15.4%) were the predominant taxa. In September, 189 species and an additional 485 organisms were found compared to the March data. Crustaceans (42.5%) replaced polychaetes (35.8%) as the most dominant faunal group followed by molluscs (15.1%) (Fig. 4). Specieswise, in March polychaetes had the most number (74 species or 40%), next were the crustaceans (42 species or 22.7%) and molluscs (35 species or 19.5%). In September, polychaetes remained the dominant group (34.9%) followed closely by crustaceans at 30.2% then molluscs (20.1%). Other taxa present, such as echinoderms, had a low species number (Fig. 5).

*Dominant species*

In Table 2 and 3 are the lists of the first 30 dominant species of the total 185 identified in March and 189 in September with their corresponding percentage abundance. The oyster, *Crassostrea gigas* had the highest number of individual counts (628 ind.) followed by the tellinidean bivalve, *Moerella rutila* (236 ind.) with combined percentage abundance of 23.69%. In terms of distributional patterns, *C. gigas* was restricted in the areas at Yomha Channel and *M. rutila* in the Kyonggi Bay. Other top 10 ranked species were mainly polychaetes followed by crustaceans.

In fall, the barnacle, *Balanus reticulatus* dominated (567 ind. or 13.7%), followed by *Ogyrides orientalis* with 284 ind. or 6.9%. In March, these two species ranked 23rd and 18th respectively. *B. reticulatus* mainly occurred at Sokmo and Yomha Channels while *O. orientalis* were found in the outer parts of the channels which are influenced by freshwater influx and Kyonggi Bay. The other top 10 ranked species were crustaceans and polychaetes.

*Benthic faunal community structure in relation to some environmental factors*

In Table 4 are the five ecological indices used to characterize the community structure of macrofaunal assemblages in Kyonggi Bay and Han Estuary. Group II (especially Subgroup II-A) has consistently higher diversity values than Group I. The

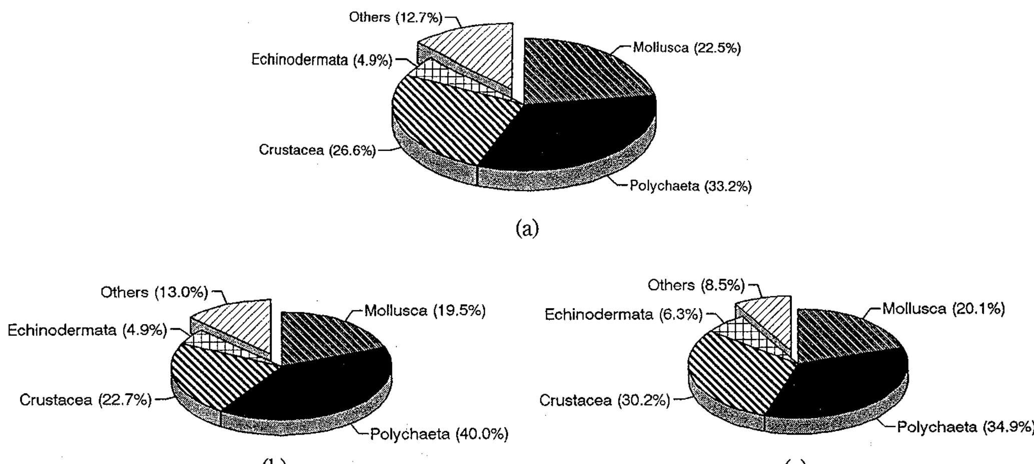


Fig. 5. Percentage (species) of major taxa. (b) March 1989, (c) September 1989, and (a) March and Septerber combined total.

lowest diversity in Group II was found in II-C. The stations of Subgroup II-A had the highest index values for both seasons.

From the results above, it can be deduced that the species diversity and richness from Sokmo and Yomha Channels are increasing towards the outer part of Kyonggi Bay. The Subgroups II-A and II-B maintained higher diversity values for both seasons.

Table 2. List of the 30 dominant species arranged according to their abundance for all stations in March 1989

| Rank | Species | Total No. of individuals | (%) | Cumulative(%) |
|---|---|---|---|---|
| 1 | *Crassostrea gigas* | 628 | 17.22 | 17.22 |
| 2 | *Moerella rutila* | 236 | 6.47 | 23.69 |
| 3 | *Sternaspis scutata* | 171 | 4.69 | 28.38 |
| 4 | *Anaitides koreana* | 151 | 4.14 | 32.52 |
| 5 | *Heteromastus filiformis* | 127 | 3.48 | 36.00 |
| 6 | *Glycera chiori* | 112 | 3.07 | 39.07 |
| 7 | *Nephtys* sp. | 104 | 2.85 | 41.92 |
| 8 | *Mediomastus californiensis* | 91 | 2.50 | 44.42 |
| 9 | *Lumbrineris nipponica* | 87 | 2.39 | 46.81 |
| 10 | *Notomastus* sp. | 74 | 2.03 | 48.83 |
| 11 | Haustoriidae sp. | 71 | 1.95 | 50.78 |
| 11 | Phoxocephalidae sp. | 71 | 1.95 | 52.73 |
| 13 | *Tharyx* sp. A. | 70 | 1.92 | 54.65 |
| 13 | *Glycinde gurjanovae* | 70 | 1.92 | 56.57 |
| 15 | *Prionospio paradisea* | 58 | 1.59 | 58.16 |
| 16 | *Cirolana japonensis* | 49 | 1.34 | 59.50 |
| 17 | Anthuridae sp. | 45 | 1.23 | 60.73 |
| 18 | *Ogyrides orientalis* | 43 | 1.18 | 61.91 |
| 18 | *Nephtys californiensis* | 43 | 1.18 | 63.09 |
| 20 | *Diopatra sugokai* | 42 | 1.15 | 64.24 |
| 21 | *Anthopleura* sp. | 35 | 0.96 | 65.20 |
| 22 | *Magelona japonica* | 34 | 0.93 | 66.14 |
| 23 | *Balanus reticulatus* | 33 | 0.90 | 67.04 |
| 24 | *Ampelisca* sp. | 30 | 0.82 | 67.86 |
| 24 | *Typhlocarcinops canaliculata* | 30 | 0.82 | 68.69 |
| 26 | *Philline argentata* | 28 | 0.77 | 69.45 |
| 26 | *Loimia medusa* | 28 | 0.77 | 70.22 |
| 28 | *Nemertinea* sp. 2 | 27 | 0.74 | 70.96 |
| 28 | *Cycladicama cumingii* | 27 | 0.74 | 71.70 |
| 30 | *Modiolus elongatus* | 26 | 0.71 | 72.42 |

The low evenness value of Subgroup II-A in September could be due to the dominance of *Tharyx* sp. A, *Mediomastus californiensis* and *Balanus reticulatus*.

Comparisons of environmental factors were carried out by examining the averages and deviations among the biologically established groups (Table 5). Primarily, Group I and II were compared. As a result, bottom salinity appeared to be the most important factor differentiating these two groups. In both of the seasons, Group I always showed lower salinity than Group II (24.40±2.97‰ and 30.51±1.30‰ in March and 12.13±6.50‰ and 27.68±4.06‰ in September). In addition, they differed weakly in sorting value in March and weakly in granulometric parameters in September. However, most variables other than salinity could be ignored because of their similar mean values with large variances. The following analyses were performed again on the Subgroup, II-A, II-B and II-C. Each of the seasons displayed major distinction in sedimentological variables (contents, mean phi) and others showed negligible differences. The stations of Subgroup II-A were mainly composed of sand and mud-mixed facies and mean phi of 4.92±1.51 in March and 4.68±0.94 in September.

Also, those of Subgroup II-B were composed of sand facies and had similar averages to each other season in mean phi (3.32 in March and 2.78 in September). Even though the environmental factors varied between two seasons, the stations of Subgroup II-C were separated peculiarly by their distinctive biological qualities. First in March, Subgroup II-C was muddier than any other group. The silt contents were 80.85±0.43% and mean phi values were 6.01±0.13. Bottom salinities and depths were slightly lower than in the other groups. On the other hand, Subgroup II-C in September was found to be totally different from the other groups, spatially and seasonally. It was chiefly composed of stations with

Table 3. List of the 30 dominant species arranged according to their abundance for all stations in September 1989

| Rank | Species | Total No. of individuals | (%) | Cumulative(%) |
|---|---|---|---|---|
| 1 | *Balanus reticulatus* | 567 | 13.72 | 13.72 |
| 2 | *Ogyrides orientalis* | 284 | 6.87 | 20.60 |
| 3 | *Crassostrea gigas* | 269 | 6.51 | 27.11 |
| 4 | *Tharyx* sp. A. | 261 | 6.32 | 33.42 |
| 5 | *Haustoriidae* sp. | 240 | 5.81 | 39.23 |
| 6 | *Glycera chiori* | 186 | 4.50 | 43.73 |
| 7 | *Moerella rutila* | 180 | 4.36 | 48.09 |
| 8 | *Mediomastus californiensis* | 159 | 3.85 | 51.94 |
| 9 | *Corophium* sp. | 148 | 3.58 | 55.52 |
| 10 | *Sternapsis scutata* | 116 | 2.81 | 58.33 |
| 11 | Phoxocephalidae sp. | 108 | 2.61 | 60.94 |
| 12 | Nemertinea sp. 2 | 73 | 1.77 | 62.71 |
| 13 | *Mysis sp. (unid.)* | 59 | 1.43 | 64.13 |
| 14 | *Magelona japonica* | 57 | 1.38 | 65.51 |
| 15 | *Comanthus japonica* | 56 | 1.36 | 66.87 |
| 15 | *Scoloplos armiger* | 56 | 1.36 | 68.22 |
| 17 | *Prionospio paradisea* | 55 | 1.33 | 69.55 |
| 18 | *Cycladicama cumingii* | 52 | 1.26 | 70.81 |
| 19 | *Heteromastus filiformis* | 51 | 1.23 | 72.05 |
| 20 | *Lumbrineris nipponica* | 48 | 1.16 | 73.21 |
| 21 | *Nephtys californiensis* | 42 | 1.02 | 74.23 |
| 22 | *Amphioplus megapomus* | 39 | 0.94 | 75.17 |
| 23 | *Lygdamis giardi* | 38 | 0.92 | 76.09 |
| 23 | *Diopatra sugokai* | 38 | 0.92 | 77.01 |
| 25 | *Cirriformia tentacaculata* | 37 | 0.90 | 77.90 |
| 26 | *Glycinde gurjanovae* | 30 | 0.73 | 78.63 |
| 27 | *Ericthonius* sp. | 28 | 0.68 | 79.31 |
| 28 | *Glycera onomichiensis* | 27 | 0.65 | 79.96 |
| 29 | Oedicerotidae sp. | 25 | 0.61 | 80.57 |
| 29 | *Modiolus elongatus* | 25 | 0.61 | 81.17 |

prominent sand facies which had been sand and mixed facies in March, and characterized biologically by their low abundances. Based only on the abiotic environments, the poor biocoenosis is attributed to the extreme sedimentary facies in both seasons (1.61% of sand contents in March and 87.28% in September).

In former times, Kyonggi Bay was poorly investigated in terms of benthic macro-invertebrates. However, Shin *et al.* (1989) has recently studied in Kyonggi Bay and revealed that this area is different in several ecological parameters (e.g., number of species, mean density) from those in the other coastal waters of Korea. They exemplified that Garorim Bay (Lee *et al.*, 1983), which lies adjacent to this study area, was characterized by a high number of species (340 species), even though benthic organisms were collected by biological dredge and the sampling volume was limited to 15 l. In this study, sampling volume was approximately 40 l, however, the number of species was lower (244 species) than that of Garorim Bay. Thus, it can be said that Kyonggi Bay is characterized by low richness and diversity, even though diversity was not compared with other areas.

The result of the analysis of community structure and environment in Kyonggi Bay and Han Estuary could be compared with those of Bae and Yoon (1988, 1989a, 1989b), Yoon and Bae (1984) and Yoon *et al.* (1987) who studied in Naktong estuary from April 1983 to September 1987. Among the studies, Bae and Yoon (1989a) said that species diversity ranged from 0 to 2.55 in upper reaches and from 0.95 to 3.56 in lower parts of the estuary. In

Table 4. Numbers of species, abundance, species richness, species diversity, and evenness for each station group in March and September 1989

March 1989

| Ecological indices | Site Groups | | | |
|---|---|---|---|---|
| | Group I | Group II | | |
| | | Subgroup II-A | Subgroup II-B | Subgroup II-C |
| Numbers of Species(S) | 46 | 144 | 78 | 26 |
| Abundance(A) | 90 | 1733 | 819 | 188 |
| Species Richness(SR) | 6.61 | 19.18 | 11.48 | 4.77 |
| Species Diversity(H') | 1.61 | 4.12 | 3.01 | 1.96 |
| Evenness(J') | 0.40 | 0.82 | 0.69 | 0.60 |

*Group I: St. 1, 2 and 5.
Group II: Subgroup A, B and C.
A-4, 6, 7, 9, 11, 12, 13, 14, 22, 24, 25
B-8, 15, 16, 19, 20, 21, 23
C-3, 10, 18

September 1989

| Ecological indices | Site Groups | | | |
|---|---|---|---|---|
| | Group I | Group II | | |
| | | Subgroup II-A | Subgroup II-B | Subgroup II-C |
| Numbers of Species(S) | 31 | 121 | 102 | 19 |
| Abundance(A) | 850 | 1625 | 1584 | 73 |
| Species Richness(SR) | 4.45 | 16.23 | 13.71 | 4.20 |
| Species Diversity(H') | 1.98 | 3.34 | 3.21 | 2.39 |
| Evenness(J') | 0.58 | 0.70 | 0.69 | 0.81 |

*Group I: St. 1, 2 and 10.
Group II: Subgroup A, B and C.
A-3, 4, 5, 6, 7, 25
B-8, 9, 12, 15, 16, 17, 18, 19, 20, 23, 24
C-11, 13, 21, 22

seasonal comparisons, diversity indices were hightened from spring to autumn and lowered in winter. However, diversity indices changed severely during the rainy season. Bae and Yoon (1989a) stated that there was a stable community structure in spring and autumn. The physiological pressures were increased by the variation of salinity and sedimentation of the substratum during the rainy season. Additionally, they described that some of the infauna and most epifauna must have been swept out or migrated to the open sea during the rainy season. As a result, they regarded salinity as the most important factor and described that the variation of salinity ruled the ecological characteristics and composition of the macrobenthic community in Naktong estuary (Bae and Yoon, 1989b). They also suggested the importance of abrupt sedimentation during the rainy season.

At this time, the lower richness and diversity can be explained by the "Stability-Time Hypothesis" of Sanders (1968). He has shown, by comparing with various other environments, that lower diversity was caused by the fluctuating physical characteristics in estuarine environments. In this study, the lowest diversity was recorded from Yomha and Sokmo channel area (Group I). The other area (Group II) had relatively high values of species richness and diversity. It seemed that diversity soundly indicated the influences from the fluvial source in the two channels. Meanwhile, the diversity of the outer part of Kyonggi Bay seemed rather to be affected by substratum type. High diversities were found in intermediate environments of sedimentary facies (mixed facies) and those two extreme sedimentary facies (genuine mud and sand facies) sustained low diversities.

The benthic faunal community structure in Han Estuary and Kyonggi Bay showed a distinct spatial

Table 5. Comparisons of environmental factors of each clustered station group in March and September 1989 (±S. D.)

March 1989

| Group | Depth(m) | Bottom salinity(‰) | Sand(‰) | Silt(‰) | Clay(‰) | Mean(ϕ) | Sort. Coeff. |
|---|---|---|---|---|---|---|---|
| Group-I | 5.20(±0.28) | 24.40(±2.97) | 27.93(±37.53) | 56.90(±31.84) | 15.07(±5.65) | 4.65(±2.17) | 2.15(±0.40) |
| Group-II | 7.05(±4.98) | 30.51(±1.30) | 46.25(±37.23) | 42.82(±30.45) | 10.78(±6.75) | 4.43(±1.54) | 1.70(±0.44) |
| Group II | | | | | | | |
| Subgroup II-A | 6.58(±4.87) | 30.41(±1.54) | 34.47(±33.97) | 51.93(±27.59) | 13.29(±6.31) | 4.92(±1.51) | 1.84(±0.45) |
| Subgroup II-B | 10.54(±3.53) | 31.10(±0.66) | 77.55(±14.50) | 17.36(±11.50) | 5.09(±3.05) | 3.32(±0.59) | 1.49(±0.41) |
| Subgroup II-C | 2.67(±2.36) | 29.27(±0.21) | 1.61(± 0.91) | 80.85(± 0.43) | 17.53(±0.77) | 6.01(±0.31) | 1.85(±0.02) |

*Group I: St. 1, 2 and 5.
Group II: Subgroup A, B, and C.
A-4, 6, 7, 9, 11, 12, 13, 14, 22, 24, 25
B-8, 15, 16, 19, 20, 21, 23
C-3, 10, 18

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| Group | Depth(m) | Bottom salinity(‰) | Sand(‰) | Silt(‰) | Clay(‰) | Mean(ϕ) | Sort. Coeff. |
|---|---|---|---|---|---|---|---|
| Group-I | 6.67(±2.36) | 12.13(±6.50 | 43.52(±35.96) | 44.72(±29.05) | 11.68(±6.82) | 4.39(±1.64) | 1.83(±0.52) |
| Group-II | 7.90(±6.34) | 27.68(±4.06) | 69.73(±27.13) | 24.14(±23.75) | 5.78(±3.78) | 3.28(±1.19) | 1.54(±0.60) |
| Group II | | | | | | | |
| Subgroup II-A | 6.17(±4.34) | 29.10(±2.31) | 37.46(±29.05) | 52.16(±25.88) | 9.27(±4.48) | 4.68(±0.94) | 1.87(±0.63) |
| Subgroup II-B | 7.53(±7.23) | 27.11(±4.65) | 80.96(±11.12) | 14.37(±9.81) | 4.66(±2.06) | 2.78(±0.82) | 1.47(±0.52) |
| Subgroup II-C | 11.50(±4.61) | 27.10(±3.82) | 87.28(± 6.36) | 8.95(±4.45) | 3.64(±2.63) | 2.56(±0.41) | 1.25(±0.56) |

*Group I: St. 1, 2 and 10.
Group II: Subgroup A, B, and C.
A-3, 4, 5, 6, 7, 25
B-8, 9, 12, 15, 16, 17, 18, 19, 20, 23, 24
C-11, 13, 21, 22

gradient along the environmental factors, wherein, stations affected by freshwater inputs and sedimentological characteristics are distinguishable from each other. Hence, this study will reaffirm the importance of abiotic factors in the shallow subtidal habitats of these estuarine and bay systems. The salinity distributions and sedimentary facies of Han Estuary and Kyonggi Bay are very much influenced by the tidal currents, geographical configurations and seasons. From this, the influences which are enhanced by the increased river discharges during the rainy seasons can be the causes of cyclic seasonal variations and the reclamation of the coasts that are actively carried out in and around this area would be responsible for the probable linear trend in temporal variations.

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