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EFFECTS OF THE POLLUTION ON THE BENTHIC MACROFAUNA IN MASAN BAY, KOREA

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馬山灣의 海洋汚染이 底棲動物群集에 미치는 影響

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Abstract: Distribution of soft-bottom macrobenthos in Masan Bay was studied in terms of seasonal changes in species composition, abundance, and diversity from August, 1980 to May, 1981.

Of the 65 species of benthic macrofauna observed, polychaete was the most dominant taxonomic group with 34 species, which accounted for 72% of the total number of benthic animals. Species richness and numerical abundance seemed to decrease from the outer bay stations to the inner-most bay station, where certain zoological groups such as crustaceans and echinoderms were eliminated.

Based on the ecological indices calculated, the inner basins of the Masan Bay apparently receive high input levels of organic material derived from land drainage, domestic wastes, and industrial complex installed in Masan city and nearby urban area. Particularly, at two inner bay stations of the Masan Bay, these levels seemed to approach the limit of the degradative capacity of the muddy bottom ecosystem, and have significantly affected the characteristics and distribution of the benthic macrofauna.

要約 : 1980년 8월부터 1981년 5월까지 경남 마산만과 그 인접해역의 저서동물의 군집생태학적 연구를 실시하였다.

모두 5개 조사 정점에서 improved van Veen grab으로 계절별로 채집한 저서동물은 총 65종이었으며, 그 중 다모환충류가 34종으로 가장 많았고, 개체수 분석에서도 전체 개체수 608개체의 72%에 달하여 種數나 個體數에 있어서 우점 동물 분류군으로 나타났다.

출현종의 수 및 개체수는 마산만 외해에서부터 내만으로 들어갈수록 감소하고 있었으며, 특히 마산만의 안쪽에 위치하고 있는 정점인 경우 비교적 많은 산소량을 요구하는 갑각류 및 극피동물과 같은 일부 동물 group들이 전혀 출현하고 있지 않았다.

출현된 저서동물군들에 대한 종다양도 지수, 우점도 지수, 기타 생태학적 제 지수의 분석으로 미루어볼 때 마산만 내만의 경우는 인근 육지로 부터 흘러들어오는 담수의 유입, 도시하수 및 산업폐수 등에 기인하는 유기물 오염이 이 해역 저서 생물상의 분포 및 특성에 심각한 영향을 미치고 있으며 마산만의 泥底 底棲生物 生態系를 파괴하고 있는 것으로 나타났다.

INTRODUCTION

With increasing industrial development in the vicinity of Masan city, domestic and industrial wastes have been major causes of marine pollution problems in Masan Bay, including red tides which occur very frequently in this coastal area.

The area has been previously studied in terms of water quality (Do *et al.*, 1981; Lee *et al.*, 1981) and of phytoplankton community (Yoo and Lee, 1976, 1979, 1980a, 1980b; Park, 1980, 1982; Lee *et al.*, 1981), but no studies dealing with the benthic fauna have been reported.

In recent years, there has been increasing concern on organic pollution of Masan Bay arising from domestic and industrial effluents. The excessive discharge of organic waste into the natural environment makes Masan Bay and the adjacent areas remain under the eutrophic conditions.

In the review on the macrobenthic succession in relation to organic enrichment and pollution of the marine environment, Pearson and Rosenberg(1978) have tried to focus attention on changes in physical environmental and biological parameters brought about by increased organic enrichment and the consequent changes in sedimentary and biological structure. If organic enrichment is of a certain magnitude it will superimpose its own gradient on the environment and induce modifications of the distribution of organisms initially controlled by, for example, salinity and temperature. Faunal community structure along such gradients does not show distinct difference rather the communities integrate continuously.

It is the purpose of this paper to assess the benthic community by quantitative evaluation of the macrobenthic soft-bottom community in Masan Bay and to relate to it to the degree of pollution.

STUDY AREA

Masan Bay is located in the southeastern part of the Korean Peninsula (Fig. 1). The bay is approximately 8.5km long south-northerly with 1.8km of maximal width and 15km² of surface area. The mean tidal range is

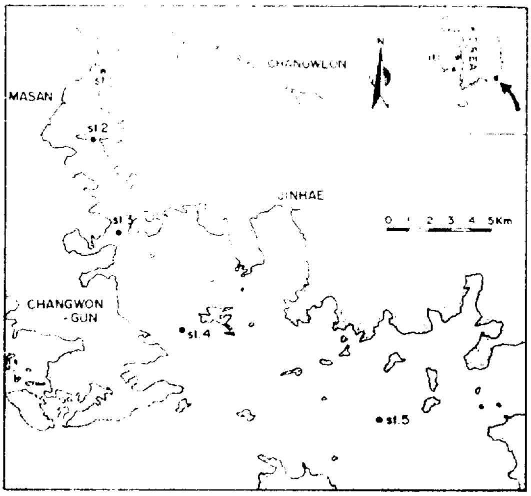

Fig. 1. The study area and Masan Bay.

2.0m. Prevailing winds are generally southwest. The monthly bottom water temperature and salinity during 1979—1980 were in the range of 2.3—20.9°C (14.1°C in average) and 29.08—34.10‰ (32.51‰ in average), respectively. Dissolved oxygen concentrations in the bottom waters were between 0—7.87ml/l (4.03ml/l in average) and anoxic conditions were found in summer in Masan Bay(Lee *et al.*, 1980). This phenomenon is related to the topographic configuration of the bay, which is characterized by semi-closed bay mouth and leads to the partial stagnation of the bay water due to the narrow channel.

It is well known that Masan Bay, the area of frequently occurring red tides, is heavily contaminated by organic pollution due to the domestic wastes and industrial activities especially including pulp mills, textile industry, food and drink manufacturing factories, and by the heavy metals from the Changweon industrial complex (Do *et al.*, 1981). Lee and Lee(1983) reported from the analysis of heavy metals in sediments in Jinhae Bay that the concentrations of Cd, Cr, Cu, Pb, and Zn decreased gradually with increasing distance from the head of Masan Bay, indicating pollutant transport from industrial and municipal waste waters.

METHODS AND MATERIALS

Duplicate grab samples of the sediment were taken using a 0.1m² Improved van Veen grab at three month intervals from August, 1980 to May, 1981. Five stations were selected in the study area along an environmental gradient towards the offshore, of which two outer bay stations were chosen for the faunal comparison (Fig. 1).

Grab samples were washed on a 1mm mesh sieve and the residues preserved in 4% formaldehyde and returned to the laboratory for examination. In the laboratory the samples were sorted from the residues, identified, and enumerated. Surface sediment samples (about 100g) were analysed for grain size, using sieves for the coarse fractions and pipette analysis for the fine fractions.

Benthic community structure was analyzed by species diversity indices (Shannon and Weaver, 1963; Margalef, 1951) and dominance index (Hulburt, 1963). The diversity index (Shannon-Weaver, 1963) was calculated as

$$\bar{H}=-\sum_{i=1}^{S}\frac{ni}{N}\log_2\frac{ni}{N}$$

where ni/N=proportion of the abundance of ith species, S=number of species, and N= number of individuals. Margalef's species diversity index was measured as

$$d=\frac{S-1}{\ln N}$$

where S=number of species, and N=number of individuals. Hulburt's dominance index (1963), the ratio of the concentration of two most abundant species to the total number of individuals of a sample, was calculated as

$$\delta_2=\frac{100\times(n_1+n_2)}{N}$$

where N= total number of individuals present in the sample, n_1=number of individuals of the first rank dominant species, and n_2 number of individuals of the second ranked species in dominance.

RESULTS AND DISCUSSION

Grain size distribution

The ternary classification method for grain size analysis of sand, silt, and clay was used for the presentation of the sediment type (Folk, 1954). According to this classification the study area was generally categorized as silty bottom. Only the station 5 contains a little more sandy fractions than in the other four stations as shown in Fig. 2.

Three stations located in the Masan Bay (stations 1, 2, and 3) are generally characterized by a putrid mud. Particularly, sediment at stations 1 and 2 appeared to be almost completely decomposed and nearly black with a easily-observable quantity of H_2S. At station 3, however, many bioclastic elements of molluscan bivalves, gastropods, and some scaphopods were mixed in the mud, probably due to the rapid bottom current. Stations 4 and 5, being located in the outer bay, showed in some degree a typical subtidal muddy bottom but the station 4 appeared to be already under some influence

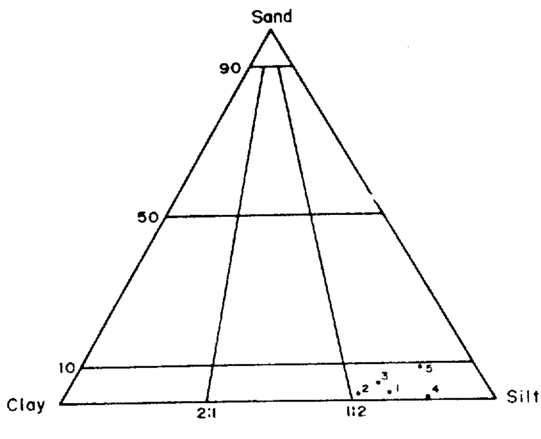

Fig. 2. Ternary diagram of sediment granulometry in the study area in August, 1980.

of the Masan Bay waters. Only the station 5 remains fairly undisturbed and can be considered as the control station for the representative benthic community of the muddy bottom of the area.

COMPOSITION OF THE FAUNA

The figure 3 showing simultaneously the number of species and individuals along sampling stations demonstrated clearly that two stations (Station 1 and 2), located in the inner part of the Masan Bay, were defined by low species richness and numerical abundance and then separated from the other three stations. The latter category may be redivided into two sections; the section comprising the stations 3 and 4 shows relatively low number of species but high quantitative abundance of the fauna. Finally the station 5, situated in the outer bay and influenced by the open water circulation, shows that the fauna are most diverse with a certain degree of numerical abundance.

The macrobenthic fauna consisted of 65 species, of which 52% were polychaetes, 37% mollusks, 6% crustaceans, and 3% sipunculids. Of these, 24 species were observed only once, and 21 were represented by five or more individuals (Table 1). A total of 608 individuals are sampled during the study period, and polychaetes were the most dominant faunal group with 440 individuals accounting for 72% of the total number of benthic animals. The mollusks and crustaceans are represented by only 23% and 3%, respectively (Fig. 4). However, in a study of subtidal benthic community in Ulsan Bay located in the eastern coast of Korea, Yi *et al.* (1982) found a total of 127 species comprising 3,810 individuals during the same study period using the same sampling gear and volume. This qualitative and quantitative impoverishment of the fauna in Masan Bay and the adjacent area may be due to the fact that certain areas, particularly located in the Masan Bay, were already heavily affected by the organic pollution, and so could not evolve the development and the

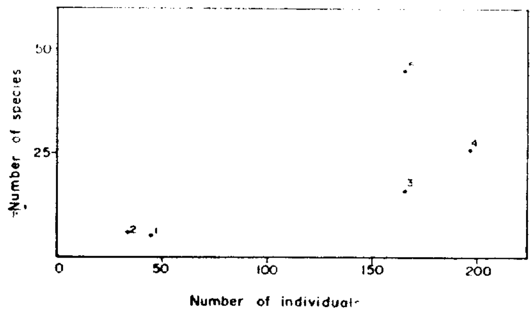

Fig. 3. Species richness and quantitative abundance in the study area during the study period (times eliminated).

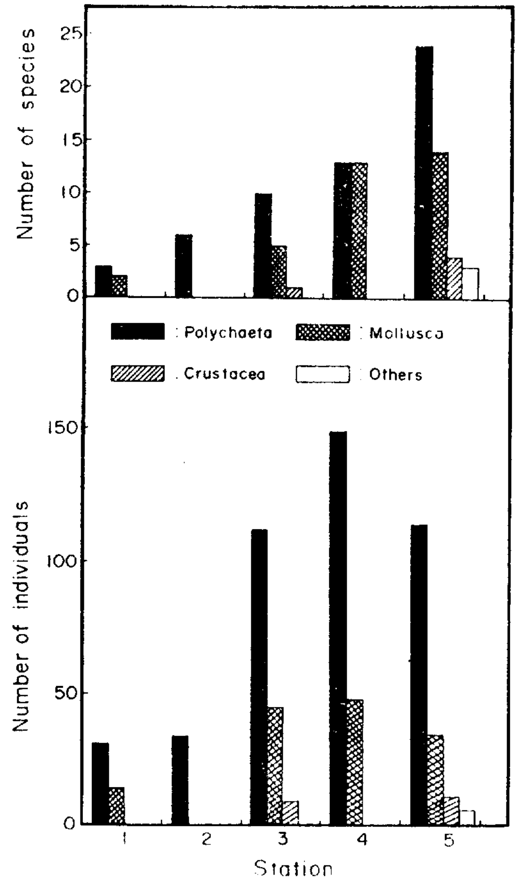

Fig. 4. Spatial changes in numbers of species(upper) and individuals(lower) for different faunal groups during August, 1980 - May, 1981.

Table 1. Numerical abundance of macrozoobenthos in the study area during August, 1980—May, 1981 (Unit : individuals/0.2m²)

Species \ Date / Station	August, 1980					Subtotal	November, 1980					Subtotal	February, 1981					Subtotal	May, 1981					Subtotal	Total
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5		1	2	3	4	5		
Nemertinea																	1	1							1
Polychaeta																									
Amphisamytha japonica										1		1					1	1							2
Ancistrosyllis hanaokai																				2		4		6	6
Autolytus sp.															1			1							1
Capitella sp.													3					3		1	1			2	5
Capitelllidae indet.							1					1											1	1	2
Chone sp.															6			6			1			1	7
Cossura coasta																	1	1							1
Diopatra sugokai											1	1													1
Glycera sp.					1	1																			1
G. decipiens											2	2			6	1		7		1			2	3	12
Haploscoloplos elongatus																							1	1	1
Laonome tridentata																							1	1	1
Lumbrineris longifolia				2		2				7		7				3	1	4				7		7	20
L. sp.																					7			7	7
Magelona japonica					1	1					6	6											3	3	10
Nectoneanthes latipoda									1	1		2			2			2		2	9	1		12	16
Nephtys sp.					5	5					3	3			1	2		3			10	13	8	31	42
Nereidae indet.					2	2																			2
Notomastus sp.																1		1							1
Ophelina aulogaster																							1	1	1
Ophioglycera sp.					1	1				5	9	14				2		2			2	2	6	10	27
Paraonis sp.										1		1													1
Prionospio sp.																1		1							1
Paraprionospio pinnata								1		20		21		6	64	29		99		19		42	2	63	183
Perinereis nuntia																					1			1	1
Pista sp.					1	1																			1
Polynoidae indet.																							1	1	1
Sabellidae indet.																	1	1							1
Schistocomus sp.											1	1													1
Spionidae indet.											1	1				1	1	2							3
Spiochaetopterus sp.																			27	2			1	30	30
Spio sp.											1	1													1
Sternaspis scutata					3	3					10	10					10	10					22	22	45
Tharyx sp.										1	2	3				2		2							5
Sipuncula																									
Golfingia sp.					1	1																			1
Sipunculidae indet.					1	1					1	1					1	1					1	1	4
Gastropoda																									
Allopeas cf. *pyrgula*				2		2																			2
Amphisa columbiana					1	1																			1
Opisthobranchia indet. 1										2		2													2
Opisthobranchia indet. 2										1		1													1
Cingulina cingulata					3	3																			3

—to be continued—

—continued—

Zeuxis caelatus					1	1				2		2													3
Gastropoda indet. 1											1	1											4	4	5
Gastropoda indet. 2	1					1																			1
Bivalvia																									
Acila (A.) divaricata					2	2					1	1													3
Axinopsida subquadrata				2		2					1	1													3
Cycladicama cumingii					1	1					2	2													3
Felaniella usta				3		3																			3
Macoma tokyoensis				3	2	5				7		7				2	1	3			1			1	16
Nitidotellina nitidula											2	2											1	1	3
Nucula cf. *nucula*				1		1																			1
Nuclanacea sp.																							1	1	1
Raetellops pulchela									4		1	5	13					13			13	2	1	16	34
Tellinidae indet.																					5			5	5
Theora fragilis															14			14			7	9		16	30
Thyasira (T.) tokunagai					1	1					1	1													2
Veneridae indet.				2		2																			2
Yoldia sp.				1		1									1			1							2
Bivalve indet. 1				9	3	12					1	1													13
Scaphopoda																									
Dentalium octangulatum					3	3																			3
Crustacea																									
Alpheus japonicus																							2	2	2
Diogenes edwardsii																	2	2							2
Paradorippe granulata																							1	1	1
Pinnixa rathbuni															3		6	9			6			6	15
Total number of individuals	1			25	33	59	1	1	5	48	47	102	16	6	98	44	26	190	27	27	63	80	60	257	608
Number of species	1			9	14	25	1	1	2	11	19	29	2	1	9	10	11	25	1	6	12	8	19	30	65

growth of the benthic community. Especially two stations of the inner bay area were often under the anoxic conditions. It is important to note that some zoological groups such as echinoderms, crustaceans, and other minor groups were eliminated in this area (Fig. 4)

The faunal diversity varies a little with season in the stations of the inner bay area; Station 1 is almost constantly oligospecific or azoic throughout the year. Stations 2 and 3 show somewhat relatively high species richness in November 1980 and February 1981, but at stations 4 and 5 no seasonal difference in species richness was found (Fig. 5). This phenomenon was not practised for the number of individuals, but it is clear that the stations of the inner bay area showed pronounced seasonal difference with the comparison of the two outer bay stations, which are characterized by slightly different faunal abundance (Fig. 6). However, seasonal variations of the faunal diversity and abundance were relatively lower in summer when the low oxygen containing water masses are developed especially in this smaller bay environment with limited bottom water circulation.

In faunal composition two stations of the inner bay, stations 1 and 2, comprise only less than 10 species composed of three species of polychaetes and two species of mollusks. It is interesting to note that crustaceans and echinoderms were absent in this inner part of the bay

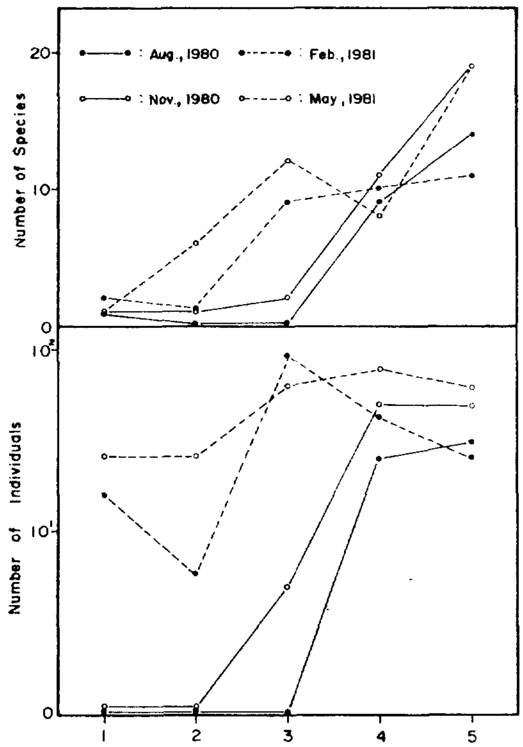

Fig. 5. Seasonal variation of species richness (upper) and numerical abundance (lower) during the study period.

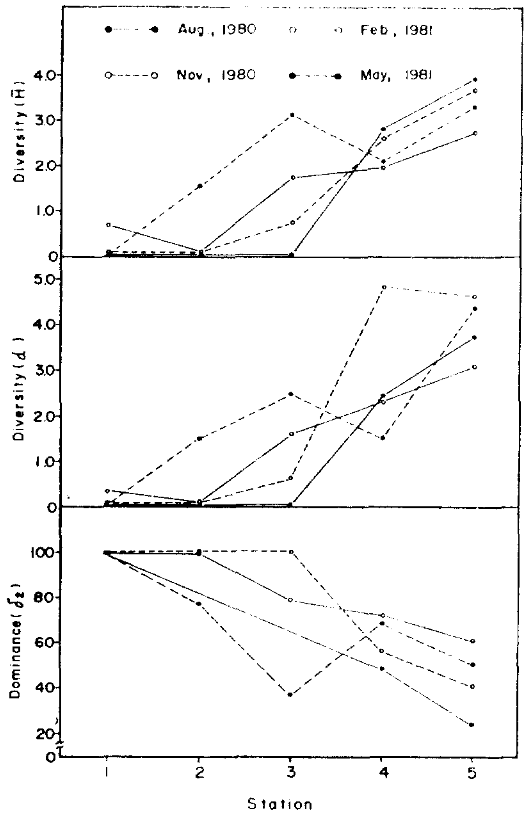

Fig. 6. Seasonal changes in diversity indices ($\bar{H}$ and d) and dominance index (δ_2) during August, 1980—May, 1981.

and this fact may suggest that they are sensitive to the environmental alteration by the organic pollution.

DOMINANT SPECIES

The most dominant species was the tiny spionid polychaete *Paraprionospio pinnata*, representing 30% of the total individuals. Five other dominant species were three polychaetes (*Nephtys* sp,. *Spiochaetopterus* sp., *Sternaspis scutata*) and two bivalves (*Raetellops pulchella* and *Theora fragilis*). But their quantitative abundances amounted to only 5%~7% of the total individuals, respectively.

A spionid polychaete *Paraprionospio pinnata* was numerically the most dominant in all the station except station 1 where this species was absent; this polychaete was found with highest abundance at station 4 and then diminished gradually towards the inner part of the Masan Bay. This trend may be interpreted as the absence of this species at station 1 suggests the maximal pollution effect here, judging from the fact that this species has been generally reported as an indicator species of organic pollution or eutrophicated waters containing low oxygen content (Kikuchi, 1978; Kitamori, 1963).

Therefore, it is possible to hypothesize that the highest value of numerical abundance at station 4 (320 individuals/m^2) resulted from the maximal survival concentration of organic content for this species during the survey period. Accordingly the station 4 was affected by the organic enrichment even though located in the outer bay and it should be noted that this species was also represented even at station 5 but with the abundance of only 10 individuals/m^2.

Three following polychaetes are fairly well represented in the survey area, and their ecological significances seem to be different; the presence of *Spiochaetopterus* sp., a small chaetopterid polychaete, was noteworthy because of the important abundance at stations 1 and 2. In these two stations of the inner part of the Masan Bay, colour of the surface mud turned to black and it smelt odour of hydrogen sulfide. This small tubicolous chaetopterid, still unidentified and new to Korea, is remarkable in its presence and abundance with a density of 135 individuals per m^2 in the polluted silty bottom. In the estuarine environment of the Hampton Roads area, Virginia, Boesch (1973) observed that *Spiochaetopterus oculatus* with *P. pinnata* was, to a certain extent, more abundant on mud and muddy sand, and the abundances of both species were noticeably seasonal only on sand, where *S. oculatus* was more abundant in August and *P. pinnata* in February.

On the other hand, another polychaete *Nephtys* sp. was completely absent in the inner bay stations but moderately abundant at stations 3, 4, and 5. These species were more abundantly found in the outer bay stations towards the offshore station. A cosmopolitan sternaspid polychaete, *Sternaspis scutata* was present only at station 5 with a maximal density of 110 individuals/m^2. Huh *et al.* (1981) found more than 300 individuals/m^2 in the central part of Deukryang Bay, being the most dominant species. Yi *et al.* (1982) reported density of 100 individuals/m^2 but $4\sim24/m^2$ in the shallow waters of the vicinity of Busan City (Lee, 1976). This species is common in sandy mud-substrates usually in shallow subtidal regions (Yi, 1975; Lee, 1976; Yi *et al.*, 1982) but seems to be somewhat sensitive to the environmental perturbation under the organic pollution.

Two other dominant species were pelecypods, *Raetellops pulchella* and *Theora fragilis*, which were generally well-represented in the Masan Bay stations under the organic pollution state. However, their densities were not significantly important. Habe (1956) reported that *R. pulchella* showed high embayment degree together with *Paraprionospio pinnata*, and Kikuchi & Tanaka (1976) pointed out that life cycle of *Theora fragilis* is opportunistic and its natural population is composed of many overlapped cohorts of different recruitment time and survival rates. Moreover Kikuchi (1976) demonstrated a correlation between the pollution degree and the relative dominance of three opportunistic species *Theora fragilis*, *Raetellops pulchella*, and a spionid polychaete *P. pinnata* in eastern half of Seto Inland Sea, Japan.

Poore and Kudenov (1978) reported in the benthic study of the Port Melbourne, Australia, that *Theora fragilis* was a deposit feeding tellinacean and was probably more successful in sediments rich in organic matter. Population densities were higher in summer months and lower in colder winter months but the rate of winter mortality varied with station.

However, Kikuchi and Tanaka (1978) observed in Tomoe Cove, Amakusa, southern Japan, that this species increased its number in early spring and reached maximum in April and kept high level until the end of the summer, then decreased drastically In early winter, population began to increase again.

COMMUNITY STRUCTURE

Differences in diversity may be resulted, to some extent, from differences in environmental heterogeneity (Simpson, 1964), environmental stability (Sanders, 1968), or the degree of biological competition (Dobzhansky, 1950). To understand the environmental stability, two

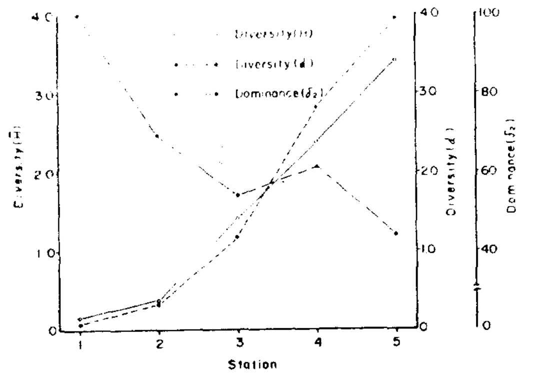

Fig. 7. Changes in mean diversity indices ($\bar{H}$ and d) and dominance index (δ_2) during the study period.

measurements of community diversity were examined; Shannon-Weaver's diversity index ($\bar{H}$) and Margalef's index of diversity(d). These two diversity indices and their seasonal variation along the five sampling stations are shown in Fig. 6.

In general, the diversity indices of the stations located in Masan Bay were more fluctuated seasonally than those of outer part of the bay with little seasonal variation. The seasonal variation in benthic diversity at station 3 was noticeable and the reason seemed to be due to the bottom currents caused by the geographical topography.

If the time factor was eliminated to simplify spatial distribution trend, stations surveyed were grouped into the four zones; particularly two stations, 1 and 2, showed less than 0.5 bits in diversity indices, which are quite different from the other stations, as previously demonstrated in the analysis of the numbers of species and individuals. However, it is noteworthy that the sample taken in May of the station 2 was relatively high. For other three stations increases were clearly observed towards offshore, and diversity values reached maximum at station 5.

Dominance index values showed an inverse relationship to diversity indices (Fig. 7), and the inner bay stations 1 and 2 recorded higher dominance values, while this index value decreased towards offshore station 5.

CONCLUSIONS

A quantitative macrobenthic study was carried out in Masan Bay and the adjacent sea areas from grab samples collected in every three months from August, 1980 to May, 1981. The distribution of soft-bottom macrobenthos was examined in terms of seasonal changes in species composition, abundance, and diversity.

From forty van-Veen grab samples a total of 65 species representing 608 benthic animals were observed during the survey period. These data showed lower species richness and quantitative abundance than those of other similar habitats in Korean coasts.

The numbers of species and individuals were observed to decrease from the outer-bay station 5 towards the innermost bay station 1 throughout the study period. In general, the inner bay stations showed not only a low numerical abundance but also a very low specific richness. This qualitative and quantitative impoverishment lowered the two diversity indices. The high specific richness, shown at the offshore station, positively affects to the diversity, and dominance index has on the whole inverse relationship to the interstational trend of diversity values(Fig. 7).

The various ecological indices showed that the inner basins of the Masan Bay apparently receive high inputs of organic materials from domestic and industrial wastes. Particularly, these levels at two inner bay stations seemed to approach the limit of the degradative capacity of the muddy bottom ecosystem, and have significantly affected the characteristics and distribution of the benthic macrofauna. Furthermore the summer stagnation of the bottom waters under poor circulatory conditions probably causes an increase in the actual amount of organic materials reaching the sediments, as suggested in the benthic study of some Shetland fjords in Scotland (Pearson and Stanley, 1977), then rapid elimination of the benthic macrofauna might have taken place in these basins.

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