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방조제 건설 이후 천수만 지역의 저서생물 군집 변화 연구

Community Structures of Macrobenthos after the Construction of Sea-Wall in Chonsu Bay, Korea.

1996년 9월

한 국 해 양 연 구 소

제 출 문

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본 보고서를 ' 방조제 건설 이후 천수만 지역의 저서생물 군집 변화 연구 '의 보고서로 제출합니다.

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연구책임자 : 이 재 학

연 구 원 : 박 홍 식

Community Structures of Macrobenthos after the Construction of Sea-Wall in Chonsu Bay, Korea

JAE-HAC LEE and HEUNG-SIK PARK

Biological Oceanography Division, Korea Ocean Research and Development Institute
P.O.Box 29, Ansan, 425-600 Seoul, Korea

Based on 53 quantitative samples collected in April (23 stations) and August (30 stations) of 1993, species composition, distribution and abundance of benthic invertebrates in Chonsu Bay were determined. The bottom sediments were composed of mud, coarse sand and pebbles along the channels. A total of 273 species (177 in April and 200 in August) were identified. Mean density was 480 ind./m^2 in April and 1,126 ind./m^2 in August. The number of species was different between April and August, and between regions as well. The number of individuals, however, increased greatly in August due to larval recruitment throughout the study area. *Theora fragilis*(Bivalvia), *Lumbrineris longifolia, Neptys oligobranchia* (Polychaete) were dominant species during the sampling period, but densities changed greatly in all regions. While in the summer, the large number of juveniles have been recruited , irrespective of sediment facies, in all area including the defaunated area. But, as time goes by, successful settlement has been a rare event over years and locality. Benthic communities in Chonsu Bay have been supported unstable conditions, because it underwent significant stress effects caused by several environmental factors(related to construction of sea-wall, especially) regionally.

INTRODUCTION

Coastal zone, which is economically important region as a spawning and nursery ground, has been exploited for living marine resources for a long time. However, it has been deteriorated abruptly due to rapid industrialization and coastal development such as reclamation and sea-wall construction, causing many environmental and ecological problems. Topographic changes in coastal area, especially in the western coast of Korea, influenced tidal current patterns resulting in the changes of sediment facies. Benthic communities of dermersal fishes and benthic diatoms, and particulate organic matters in the sediment are influenced directly and indirectly by the grain size composition of sediment(Sanders *et al.*, 1962; Holland & Polgar, 1976; Flint & Holland, 1980). If the sediment facies changes abruptly, total marine ecosystems will be disturbed and damaged through food webs.

Some studies revealed that marine ecosystems in Chonsu Bay have been seriously changed since sea-wall construction in 1984, for example, changes of phytoplankton (Shim *et al.*, 1988; Shim & Yeo, 1988; Shim and Shin, 1989), zooplankton(Yoon, 1988; Shin, 1989), and fish eggs and larvae(Lee & Seok, 1984; Shim *et al.*, 1988). Studies on macrobenthos are very limited in Chonsu Bay (KORDI, 1978; Je *et al.*, 1991; Shim *et al.*, 1988).

In coastal zone, continuous monitoring is important to compare present ecosystem with the past one. Especially, Chonsu Bay is suitable area for investigating the effects of coastal development on the coastal marine ecosystem. The presence or absence of particular biota may be due to fluctuations in environmental factors such as temperature, salinity, and dissolved oxygen; variations in sediment texture or depth; biological factors such as recruitment cycles, predation and competition (Long & Chapman, 1985). So, if we understand marine ecological processes in the specific area, past data will be used as basic data to predict the changes in the marine ecosystem after coastal zone development.

The purpose of this study is to investigate species composition, distribution and abundance of benthic invertebrates and the effect of benthic communities influenced by the change of environmental factors after the construction of sea-wall in Chonsu Bay.

STUDY AREA

Chonsu Bay is a semi-enclosed bay, opening to the Yellow Sea (Fig.1). The bay is composed of two channels with both sides from north to south direction, and north-west part are composed of the sand dune exposed extensively during ebb tides.

The tide is predominantly semi-diurnal, which affects physical processes in the region.

The mean tidal range is about 4.71m. Maximum current velocity at the mouth of the bay was 3.4 knots at flood tide and 3.1 knots at ebb tide(O.H.A. 1991-1992). Current velocity decreased toward inner bay (1.51 m/sec on Gojeong-ri, located in the mouth and 0.26 m/sec on Kanwoldo, located near the sea-wall)(Shim *et al.*, 1988; Lee, 1988), but mean current velocity(1.0 - 1.75 m/sec) before the sea-wall construction was faster than that of present(KORDI, 1974).

The monthly mean water temperature varied from the minimum of about 5.℃ in February to the maximum of about 26℃ in August. The temperature varied between the surface and bottom layer was almost about 1.0℃.

There is no industry complex around here, but some sewage from local villages discharges. Freshwater inflows from the lake to the bay intermittently for controlling of water level. So, at this time, marine ecosystems near the sea-wall are affected.

Before the construction of sea-wall, lavel culture had been prevailed. But, after that, it disappeared because of decreasing the tidal current velocity. A cockle, *Fulvia mutica*, had been abundant until a few years ago, but it is very rare now due to changing sediment composition.

MATERIALS AND METHODS

Macrobenthos and sediment samples were collected at 53 stations (23 stations in April and 30 stations in August, respectively) (Fig. 1). Three 0.1 m^2 van Veen grab samples were collected at each station. The sediments were sieved through a 1.0mm mesh screen to collect macrobenthos. Animals retained on the screen were fixed in buffered 10% formalin, sorted to major phylogenetic group, and preserved in 70% ethanol solution later. Specimens were identified to the species level, if possible, and counted.

Grain size composition was determined by wet sieving and pipette analysis (Folk and Ward, 1957). Organic contents of sediment were measured by determining the loss in weight of dried sediment at 550℃ for 2 hours and cabon, nitrogen, and surfur content in sediment were measured using CHN Analyser.

Salinity and temperature were measured with CTD(SBE-19). Dissolved oxygen was measured only in August, 1993.

Shannon-Wiener diversity H'(Shannon & Wiener, 1963), Richness (Margalef, 1958) and

Dominance index were analyzed to define community structure and spatial variability. Dominance ranking of the leading species in each faunal assemblage was calculated using the Le Bris Index (Le Bris, 1988). Hierarchical classification(Bray & Curtis, 1957) and Pearson's Correlation were performed with transformed individuals numbers and environmental data to determine similarity between each station. Abundance data were log-transformed becaused of the large variation between individuals.

RESULTS

Sediment facies

Analysis of sediment showed heterogenous substrates. The middle region and adjacent to the sea-wall located in the northern part were composed of mud(mean phi is more than 7). Sand dune located in the northwestern region and adjacent to the outlet were composed by muddy sand (less than 4φ)(Fig. 2). The channels were composed of bioclastic elements, shell debris, cobble and pebbles. The mouth of the bay was composed of coarse sediment, sand (more than $4\ \varphi$) and rock bed locally.

Faunal composition

A total of 273 species (177 spp. in April and 200 spp. in August) representing 10 phyla (Hydrozoa and Bryozoa were not identified) were identified. Polychaetes, comprised 33.3% (91 species) of the fauna, crustaceans 28.6%(78 species), mollusks 27.2% (74 species), echinoderms 4.4%(12 species) and minor taxa 5.6% (15 species) including cnidarian, platyhelminthes, sipunculid, nemertinea, brachiopod and chordates (Table, 1). The number of species in regional groups during each sampling period ranged from 1(Stn B, S15) to 64(Stn S12) in April and 7 (Stn T21) to 88(Stn T22) in August, respectively. Species numbers were higher in the middle part of the bay, decreasing gradually toward both direction of the mouth and sea-wall in April. But, it was higher in the mouth part than in the middle part in August (Fig. 3).

Faunal Density

A total of 11,048 individuals were collected in April. Polychaetes(55.0%), mollusks (20.8%) and crustaceans (20.4%) were most dominant and the remainder comprised 2.2%.

In August, 33,779 individuals were collected. Polychaetes (43.1%), mollusks(39.5%) and crustaceans (13.2%) were also most dominant(Table 1).

The density in each region ranged from 3 ind./m^2 (Stn S15) to 1,521 ind./m^2 (Stn S7) in April, and from 43 ind./m^2 (Stn T10) to 2,782 ind./m^2 (Stn T22) in August. Mean values were 480 ± 387 ind./m^2 and 1,126 ± 690 ind./m^2, respectively. The mean densities of regional groups were higher in the middle part of the bay, and decreasing greatly toward the bank and the mouth of the bay in April. However, mean densities were generally higher in August than in April. Especially, it increased greatly in the defaunated area, adjacent to bank and the mouth of bay (Fig. 4).

Species Dominance

Dominance ranking of the dominant species showed that each assemblage was dominated by a small number of species, polychaetes, *Lumbrineris longifolia* (69.0 ind./m^2 mean density), *Nephtys oligobranchia* (66.7 ind./m^2), mollusks, *Theora fragilis*(92.7 ind./m^2) and amphipods (Aoridae unid., *Eriopisella sechelensis*) in both seasons, although the density are different greatly between seasons. These dominant species were recruited throughout the study area in August, and some species, *Philine argentata* (27.4 ind./m^2) in Gastropod, *Sternaspis scutata* (73.6 ind./m^2) in Polychaete and *Moerella jedoensis* (38.9 ind./m^2) in Bivalve, were also recruited in great quantities (Table 2).

Community structure

Mean diversities were 2.28±0.50 and 2.63±0.49 in each season, respectively. Southwestern part(Stn S12) and middle part(Stn C, S6) of inner bay showed higher diversity in April. But, in August, the area adjacent to the mouth of the bay(Stn T22), southern part(Stn H) and northern part(Stn A) represented higher values. The area adjacent to the sea-wall represented the lowest value (less than 2.0) in summer, although its mean value was higher than any other stations in April (Fig. 5).

The Pearson's correlation values indicated some significant correlation($P=<0.05$) between biological and environmental data. The number of species and density seemed to be related to sediment, but not correlated with any other environmental variables in April. On the other hand, in August, biological data were not correlated with any other environmental variables(Table 3).

In hierarchical classification on stations, four major clusters and 4 isolated points(Stn s14, s11, s15 and B) were separated in April(Fig. 6). Group I contained some stations located in northern part, except stations adjacent to the sea-wall, mainly defined by mud. Low number of species(14 to 23) and density(139 to 637 ind./m^2) were found in these groups. This group was not represented by any characteristic species. Most of species were composed of wide-spread species (Assemblage I, in Table 4). Group II contained all stations, seven stations, located in the southern part of the bay. Most of the species which were collected in Chonsu Bay were found in this area, where showed the most diverse assemblages. Group III included the middle of the bay, except for sand dune locating in northwestern part, defined by heterogenous sediment locally, where showed relatively high number of species(14 to 61) and density(135 to 1016 ind./m^2). Group IV included only two stations(Stn S9 and S13), which composed of muddy-sand. This group contained isolated species such as *Musculus senhousia* and *Ruditapes philippinarum*.

In r-mode hierarchical classification, five major clusters (species lists in Table 4) were separated(Fig. 6), divided generally by the sedimentary gradient(Table 4). Assemblage I containd ubiquitous species, *T. fragilis*, *E. sechelensis*, *Glycinde* sp. and so on, which were mainly sampled at the stations composed of fine sediment. Assemblage II contained characteristics species, Aoridae unid., *Nitidotellina minuta*, *S. scutata* and so on, which were sampled at the stations composed of muddy and mixed bottoms included areas adjacent to the sea-wall. Assemblage III contained isolated species which lived densely on restricted area. Assemblage IV contained rare species (less than 6 in mean density), *Dorisca* cf. *nana*, *Tambalagamia fauvelli*, *Raphidopus ciliatus* and *Ampharete arctica*, sampled at the stations which are located in the northern parts of the bay and composed of gravelly-mud sediment. Assemblage V contained amphipods (*Gammaropsis utinomi*, *Photis longicaudata*, *Byblis japonicus*, *Melita* sp) which lived in muddy-sand and sandy-mud types.

But in August, hierarchical classification by q-mode (sampling unit) showed some different results when it was compared with April, which were separated by four major clusters and 5 isolated points(Stn H, T3, T4, T10 and T21)(Fig. 7). Particularly, most of the isolated points contained several stations located on intertidal zone and channels. Group I contained the stations located in the northern part of the bay, adjacent to the channels connected to the outer sea, and composed of strange species(*Mytilus edulis galloprovincialis*, *Corophium* sp.) which were collected in group Ⅰ region. Group Ⅱ contained two stations(Stn A , T7) located in the northern part and southeastern part of the bay defined by gravelly mud, respectively. The highest number of species(44 to 88) and density(934 to 2,782 ind./m^2) were found in this region. Group Ⅲ contained stations located near the sea-wall(Stn B, D, T5, T6, T8, T9, and T12). Most of the stations belong to group Ⅲ showed relatively low number of species(11 to 31) and density(515 to 1,795 ind./m^2). This group was composed of ubiquitous species. Group Ⅳ containd stations located in the middle part defined by heterogenous sediment.

In r-mode hierarchical classification showed five major clusters(species lists showed in Table 5)(Fig. 7). Assemblage Ⅰ contained dominance species, *T. fragilis* and *L. longifolia*, that were sampled in most of the stations with fine sediment facies. Assemblage Ⅱ contained the isolated species, *M. edulis galloprovincials*, *Ophioplus megapomus* and so on, that sampled in sand and gravelly mud sediment located in the northern parts of the bay. Assemblage Ⅲ were composed of 10 species, *Terebellides horikoshii*, *Gammaropsis utinomi*, *A. arctica* and so on, that were found in northern part and the middle parts, defined by mixed sediment. Assemblage Ⅳ contained characteristic species, *S. scutata*, *A. misakiensis*, *Chaetozone spinosa*, that were found in the middle parts. Assemblage Ⅴ contained ubiquitous species, *P. argentata*, *R. ciliatus*, *Protankyra bidentata* and so on, that preferred to mud sediment.

Relationship to sediment type

Significant variation in the number of species and mean densities was dependent on sediment type(Fig. 8). While the heterogenous bottom that mixed with cobble, gravel, mud, shell fragment and biogenic materials showed the highest number of species, the lowest values occured on coarse sediment and intermediate values occured in muddy-sand. The trend of number of species per sediment type represented higher in August than in April.

Mean densities were also influenced by sediment facies. For instance, sand and gravelly-mud types increased in August, but in coarse sediment, sandy-gravel and gravelly muddy-sand types, did not changed in both seasons (Fig. 8).

Seasonal changes

The number of species at 8 stations(Stn A ~H) which were sampled continuously during both seasons have increased mostly , except to Stn C and G, in August (Fig. 9 A). Station B located near the sea-wall always contained the lowest number of species. It increased greatly at station C located between sand bar and channel in April(62 spp.).

Abundance increased at ststions E and F in August especially(Fig. 9 B). Most of the stations showed similar densities except station C in April, however, revealed great fluctuation in the middle part and F, and the mouth part of bay in August. Amoug them, stn E appeared the greatest seasonal fluctuations. Stn B showed defaunated condition in April, but recruited newly in August althrough it had small quantities as compared with other station.

Densities of dominant species(*T. fragilis, L. longifolia, N. oligobranchia* and *S. scutata*) changed greatly during the sampling period (Fig. 10). A dominant species, *T. fragilis,* was found in the middle of the bay with high mud composition. *L. longifolia* also recruited to the inner bay in summer, but was little observed in the mouth of the bay. *N. oligobranchia* increased in stn C and G during the summer. *S. scutata* also increased in density in stn F. These species, except *S. scutata*, decreased greatly in all stations in spring.

DISCUSSION

Results of sediment analysis showed distinct regional differences in substrate patterns, similar to results by Shim *et al.*(1988). These differences were due to variation in wave strength, current activity and topographical conditions. At the mouth of the bay relatively greater tidal current scoured the substrate. But in the northern areas, adjacent to sea-wall, reduced wave and current action allowed the settling of suspended materials. But coarse sediments were predominant near the outlets, caused by irregular freshwater outfalls.

Grain size is an important environmental factor in benthic community. In addition to grain size, organic content, microbial content, food supply and trophic interactions are also important. But no single factor has been able to explain patterns (Snelgrove &

Butman, 1994). In fact, all factors are influenced by the near-bed flow regime, and they could influence infaunal distributions directly or indirectly via several compelling mechanisms. Larval supply and particle flux are also determined by the boundary-layer flow, which may not be important determinant of species distributions and composition of sediment facies. Increased appreciation for the role of boundary-layer flow and sediment transport in benthic ecology, an understanding of the ways in which infaunal organisms interact with sediments and the near-bed regime is undergoing a transformation(Miller *et al.*, 1992; Snelgrove & Butman, 1994; Taghon & Greene 1992). For instance Chonsu Bay has similar patterns refered to above, because of influence by tidal current cycle. Shim *et al.*(1988) suggested that sediment facies were affected by the tidal current in Chonsu Bay.

Macrobenthos sampled in both seasons comprised of 313 species. Althrough differences in area and methodology make exact comparisons between surveys difficult (Coleman *et al.*, 1978), the number of species was higher in this area than any other coastal areas of Korea, for example, 87 species in Kyeonggi Bay (Shin *et al.*, 1992), 287 species in Chinhae Bay (Lim, 1993), but abundance per species was very low. KORDI(1978) carried out investigation in Gojeong-ri power plant located in adjacent to the mouth of bay partly (identified 21 sp.), and Shim *et al.* (1988) identified benthic animals on class level except three dominant species, *Pisidia* sp. (Crustacea), *Theora lata* (Bivalvia), *Polydora* sp. (Polychaeta).

Juveniles came into Chonsu Bay with various sediment facies from outer sea by periodical tidal current. Dobb and Vozarik(1983) suggested that water turbulance suspended benthic infauna and dispersed both larvae and adults. Tidal current determines the nature of bottom substrate to a large degree and it influences on the stability of the sediment and food supply for benthic organisms (Widish and Kristmanson, 1979). So, we snggest that tidal current in Chonsu Bay plays an important role in dispersal of macrobenthos. Although species composition was spatially different, macrobenthos recruited newly were collected at all stations in summer. But, stable settlement was localized. In fact, the population range of each species is influenced somewhat differently by the polyfactorial gradient changes in environmental conditions (Tenore, 1972). Macrobenthos in Chonsu Bay were also influenced by several environmental factors, and physical and topographical conditions. For example, species composition in northern areas appeared to change seasonally. Substrate of this area has been changed to mud since sea-wall construction, and weakened currents and irregular freshwater discharge through the outlet may influence importantly on benthic community. Many abundant species were eliminated from shallow bottoms due to abrupt changes of salinity (Tenore, 1972; Boesch *et al.*, 1976), and an excessive outfalls of particulate organic debris and dissolved organic matter from freshwater resulting in hypoxia. The recovery of macrobenthic assemblages from hypoxia should be largely dependent on the relationship between timing of the return to normal conditions and species life histories. Faunal colonization in newly open space will depend on a combination of water exchange, proximity of reproducing organisms with opportunistic life-history characteristics, and larval availability(Llanso, 1991). Opportunistic species often colonize benthic habitats rapidly after defaunation as a result of physical disturbance or pollution abatement(Arbugov, 1982; Ferraro *et al.*, 1991; McCall, 1977; Pearson & Rosenberg, 1978; Santos & Simon, 1980). Actually, although less quantity, the opportunistic species, *T. fragilis, L. longifolia,* were recruited adjacent to the sea-wall especially.

The areas around the mouth of the bay also were under bad environmental conditions. Sediments were disturbed and resuspended periodically due to tidal current. In fact, community structure of marine soft-bottom habitats can be shaped by natural physical and biological disturbances which affect substratum stability (Gray, 1974; Ong and Krishnan, 1995). Thouzeau *et al.*(1991) suggested that sediment instability (in sand dune) or inappropriate substrate (pebbles and cobbles) might account for the low bivalve densities. This gradient can be defined as the changes in the sand level of the beach profile as well as grain size and sorting coefficients (Rhoads; 1974; Thouzeau *et al.*, 1991). Sediment heterogeneity and porosity, as well as the functional importance of polychaete tubes and cobbles (in providing spatial refuges from predators and suitable microhabitats for invertebrates, especially the juveniles), may partly explain biogenic bottom richness. So, in these areas, inhabited sessile filter feeder, for example Hydrozoa, Brachiopoda, Bryozoa, and a small amount of polychaetes.

As compared with these areas, the middle area may have stable benthic ecosystem relatively. Sediment facies were mostly sandy-mud, and mixed sediments were found along the channels. In these type, more diverse benthic animals inhabit. Althrough the exact biological significance of sorting is not understood, sorting should, at least in theory, affect diversity. Poorly sorted sediments in channels have a wide range in particle size and should therefore offer a wide range of niches, leading to a high species diversity(Coleman *et al.*, 1978).

The results of the community structure by cluster analysis in Chonsu Bay showed that stations located in the middle area had high similarity in both seasons, but northern areas and the mouth of bay, which were connected with outer sea, had high similarity only in summer. Recruitment influenced on the community structure seasonally. Especially, the occurrence of ubiquitous species(*T. fragilis, L. longifolia*) affected faunal similarity between stations. We suggested from the results about community structure in both seasons that mony benthic animals including ubiquitous species had recruited around the bay in summer, but most of animals recruited in both side of the bay did not grow any longer and may be died, and animals which recruited in the middle of bay had grown continuously.

Correlation provides an important preliminary to an understanding of the physical control community structure and function (Warwick & Uncles, 1980). Correlations between sediment type and faunal community have been considered for the static pattern of sediment granulometry, not for the dynamic physical environment in which the animals live(Widish and Kristmanson, 1979). Many studies about infaunal invertebrate distributions have correlated with sediment grain size, leading to the generalization of distinct associations between animals and specific sediment types. But there is, in fact, little evidence that sedimentary grain size alone is the primary determinant of infaunal species distributions(Snelgrove & Butman, 1994). It is difficult to evaluate the significance of animal-sediment associations because the mechanism determining distribution of organisms is poorly understood (Miller & Sternberg, 1988). As results, one particular environmental factor might have not influenced all benthic community, but sediment type have to be an important parts in benthic macrofaunal assemblages in Chonsu Bay.

A dominant species, *T. fragilis* showed that recruitment occured quantitatively in summer in most of study areas. But recrutment was probably more successful in mud substrate rich in organic matter. Most of dominant species such as, *L. longifolia, N.oligobranchia,* and *S. scutata* have been similar patterns in this area(Fig. 10).

Many species showed that patterns of dominance changed with time and area. Although dominant species in Chonsu Bay got low proportion in total density of the community, they played a major role in the community. In fact, more diverse communities contained species with high reproductive potentials. Thus it may be possible to predict the species diversity of highly diverse communities after catastrophe. The dominant species in such a community are much more difficult to predict (Poore & Kudenov, 1978). But most of dominant species in this area were composed of 'opportunistic species' and other species fluctuated according to time and area. In conclusion, we suggest that benthic community has been maintained under unstable conditions since the construction of sea-wall. But these results are infered based on the data only in two seasons. Field studies on environmental impacts are necessary at appropriate time and space intervals and for sufficient duration (Gray, 1981). But, according to these results, benthic communities in Chonsu Bay was affected by changed current system and sedimentary facies due to the sea-wall construction, irregular freshwater discharge, and input of a lot of organic matter from neighbouring fish farms.

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Table 1. Total number of species, density (ind./ m^2), number of species, percentage composition and frequency occurrence(%) of all taxonomic groups during each sampling period of macrobenthos in Chonsu Bay.(Sp.: Number of species, (%): percentage composition, Den.: Density)

	Total No. sp.		April, 1993					August, 1993				
Taxa.	Sp.	(%)	Sp.	(%)	Den.	(%)	Freq. Occurrence	Sp.	(%)	Den.	(%)	Freq. Occurrence
Cnidaria	5	1.8	3	1.7	17	0.1	21.7	5	2.5	40	0.1	26.7
Platyhelminthes	1	0.4		0.0		0.0	0.0	1	0.5	73	0.2	36.7
Sipunculida	3	1.1	2	1.1	46	0.4	21.7	2	1.0	20	0.1	16.7
Nemertina	4	1.5	4	2.3	79	0.7	56.5	4	2.0	205	0.6	70.0
Brachiopoda	1	0.4	1	0.6	102	0.9	13.0		0.0		0.0	0.0
Mollusks												
Polyplacophora	1	0.4	1	0.6	23	0.2	8.7	1	0.5	17	0.0	10.0
Gastropoda	29	10.6	10	5.6	99	0.9	60.9	18	9.0	788	2.3	90.0
Bivalvia	43	15.8	30	16.9	2,181	19.7	87.0	22	11.0	12,570	37.2	96.7
Cephalopoda	1	0.4	1	0.6	3	0.0	4.3		0.0		0.0	0.0
Annelid												
Polychaeta	91	33.3	63	35.6	6,079	55.0	91.3	84	42.0	14,566	43.1	100.0
Arthropoda												
Crustacea	78	28.6	48	27.1	2,251	20.4	87.0	54	27.0	4,457	13.2	96.7
Echinodermata												
Crinoidea	1	0.4	1	0.6	3	0.0	4.3		0.0		0.0	0.0
Asteroidea	2	0.7	2	1.1	17	0.1	17.4	2	1.0	89	0.3	13.3
Ophiuroidea	7	2.6	5	2.8	79	0.7	34.8	4	2.0	436	1.3	53.3
Echinoidea	2	0.7	2	1.1	10	0.1	13.0	2	1.0	69	0.2	30.0
Holothuroidea	3	1.1	3	1.7	54	0.5	30.4	1	0.5	449	1.3	53.3
Chordata	1	0.4	1	0.6	7	0.1	8.7		0.0		0.0	0.0
Total	273		177		11,048			200		33,779		

Table 2. Dominance ranking(Le Bris index) in density(ind./m^2) of macrobenthos during each sampling period. (Po: Polychaeta, Bi: Bivalvia, Ga: Gastropoda, Cr: Crustacea, Ho: Holothuroidea)

Rank	Species	Taxa.	Mean density (ind./m^2±std)	Total Density	% of total Density	Freq(%) of Occurence
April, 1993						
1	*Lumbrineris longifolia*	Po	69.04±100.39	897	8.12	56.52
2	*Sigambra tentaculata*	Po	18.28± 21.38	238	2.15	56.52
3	*Nephtys oligobranchia*	Po	65.74± 85.21	855	7.74	56.52
4	*Theora fragilis*	Bi	92.66±114.05	1,112	10.07	52.17
5	Aoridae unid.	Cr	56.53± 54.35	452	4.09	34.78
6	*Eriopisella sechelensis*	Cr	15.77± 16.14	142	1.28	39.13
7	*Amphareta arctica*	Po	17.75± 23.83	231	2.09	56.52
8	*Prionospio krusadensis*	Po	53.26± 71.41	746	6.75	60.87
9	*Ampelisca* sp.	Cr	13.66± 8.35	96	0.87	30.43
10	*Glycinde* sp.	Po	28.61± 21.35	429	3.88	65.22
11	*Dorisca* cf. *nana*	Bi	13.20± 11.42	79	0.72	26.09
12	*Glycera chirori*	Po	14.52± 11.48	218	1.97	65.22
13	*Heteromastus* sp.	Po	29.30± 40.59	234	2.12	34.78
14	*Eteone longa*	Po	9.24± 6.04	46	0.42	21.74
15	*Sternaspis scutata*	Po	22.37± 16.30	201	1.82	39.13
August, 1993						
1	*Theora fragilis*	Bi	432.60±451.87	9,517	28.18	73.33
2	*Lumbrineris longifolia*	Po	206.32±274.26	4,333	12.83	70.00
3	*Philine argentata*	Ga	27.65± 18.02	581	1.72	70.00
4	*Nephtys oligobranchia*	Po	10.46± 7.79	251	0.74	80.00
5	*Raphidopus ciliatus*	Cr	23.10± 21.65	508	1.50	73.33
6	*Sternaspis scutata*	Po	73.43± 18.08	881	2.61	40.00
7	*Glycinde* sp.	Po	27.09± 19.40	515	1.52	63.33
8	*Heteromastus* sp.	Po	16.07± 17.09	241	0.71	50.00
9	*Moerella jedoensis*	Bi	38.81± 36.66	660	1.95	56.67
10	*Glycera chirori*	Po	12.21± 10.40	281	0.83	76.67
11	*Amphareta arctica*	Po	61.74±126.52	865	2.56	46.67
12	*Arcidea* sp.	Po	21.15± 35.64	360	1.06	56.67
13	*Sigambra tentaculata*	Po	19.11± 17.09	363	1.07	63.33
14	*Tharyx* sp.	Po	21.65± 23.96	347	1.03	53.33
15	*Protankyra bidentata*	Ho	28.05± 41.58	449	1.33	53.33

Table 3. Pearson's correlation coefficients matrix(5% of significant level) between abiotic and biotic variables in Chonsu Bay. (Temp.: Bottom water temperature, Sal.: Bottom salinity, D.O.: Bottom dissolved oxygen, Sand: Sand proportion of surface sediment, Phi: Mean phi of surface sediment, O.C.: Organic content of surface sediment, Sp.: Number of species, Ind.: Individuals, Div.: Diversity index, Ric.: Richness index, N: Nitrogen content of surface sediment, S: Sulfur content of surface sediment)

	Temp.	Sal.	D.O.	Sand	Phi (φ)	O.C.	Sp.	Ind.	Div.	Ric.	N	S
Temp.		0.98		0.29	-0.60	-0.48	0.60	0.67	-0.64	-0.39	-0.29	0.00
Sal.	0.37			0.42	-0.62	-0.46	0.62	0.67	-0.59	-0.51	-0.26	0.03
D.O.	-0.30	-0.26										
Sand	0.29	0.13	-0.04		-0.31	-0.18	0.35	0.36	-0.18	-0.33	-0.13	-0.02
Phi(φ)	0.33	0.08	-0.17	0.19		0.27	-0.42	-0.43	0.18	0.24	0.21	0.03
O.C.	-0.35	-0.43	0.79	-0.09	-0.14		-0.32	-0.34	-0.04	0.12	0.94	0.68
Sp.	0.03	0.33	-0.42	0.17	-0.29	-0.41		0.89	-0.39	-0.20	-0.27	-0.15
Ind.	0.26	0.69	-0.17	0.11	-0.29	-0.29	0.46		-0.39	-0.28	-0.27	-0.21
Div.	0.36	-0.54	0.39	0.12	0.09	0.18	-0.42	-0.37		0.16	-0.16	-0.30
Ric.	-0.34	-0.43	0.45	-0.08	-0.13	-0.02	-0.15	-0.29	0.54		-0.10	-0.19
N	-0.04	0.01	-0.22	0.04	0.86	-0.21	-0.12	-0.40	-0.12	0.01		0.86
S	0.62	0.41	-0.21	0.22	-0.01	-0.29	0.33	0.25	0.13	-0.26	-0.10	

Upper triangle: April, 1993; lower triangle: August, 1993

Table 4. Distribution by density intervals(mean value) of the main macrobenthos sampled in April, 1993. (Bi: Bivalvia, Po: Polychaeta, Cr: Crustacea, Bc: Brachiopoda; Mean density : ind./m^2; (#)< 16 ind./m^2; (##) 17 to 32 ind./m^2; (###) 33 to 75 ind./m^2; (####) 76 to 218 ind./m^2 (#####) >218 ind./m^2)

No.	Species	Taxa.	Mean Density	Sand	Gravelly Sandymud	Gravelly Mud	Muddy-sand	Sandy-mud	Mud
Assemblage I									
1	*Theora fragilis*	Bi	92.66		#####	###	####	#####	#####
2	*Eriopisella sechelensis*	Cr	15.77	#		##		##	##
3	*Glycinde* sp.	Po	28.61	##	####	####	#	####	###
4	*Sigambra tentaculata*	Po	18.28	#	##	##	#	#	####
5	*Moerella jedoensis*	Bi	14.85	#	##	##	###	##	###
6	*Nephtys oligobranchia*	Po	65.74	###	#####	####	####	#	#
7	*Prionospio krusadensis*	Po	53.26	####	#	#####	#	####	####
8	*Lumbrineris longifolia*	Po	69.04	##	#####	####	#	#####	#
9	*Arcidea* sp.	Po	35.31	#	###	#####	#	###	#
10	*Glycera chirori*	Po	14.52	###	####	###	###	##	#
Assemblage II									
11	Aoridae unid.	Cr	56.53	###	#####	####	##	#	
12	*Nitidotellina minuta*	Bi	14.16	##	##	###	##	#	#
13	*Paralacydonia paradoxa*	Po	8.81	#	#	##	###	#	
14	*Magelona japonica*	Po	9.17	##	#	##	##	#	
15	*Sternaspis scutata*	Po	22.37	##	##	#	#	###	###
16	*Abrina lunella*	Bi	10.33	##	###	#	##	#	#
17	*Raeta pulchella*	Bi	6.60	##	#	#	#	#	#
Assemblage III									
18	*Lumbrineris japonica*	Po	37.72	##	#		###		####
19	*Musculus senhousia*	Bi	69.30		####				
20	*Ruditapes philippinarum*	Bi	79.20		#####			#	
21	*Corophium* sp	Cr	13.86	##	#		#	#	##
22	*Pisidia serratifrons*	Cr	52.80				#		###
23	Cumacea unid.	Cr	9.08	##	#	##	##	#	#
24	*Coptothyris grayi*	Bc	34.09	#		#			###
25	*Xenophthalmus pinnotheroides*	Cr	23.10	##			###	#	
26	*Owenia fusiformis*	Po	15.84	#		#	###		
Assemblage IV									
27	*Heteromastus* sp.	Po	29.30		#	#	#	####	##
28	*Dorisca* cf. *nana*	Bi	13.20	##	##	###		#	#
29	*Tambalagamia fauvelli*	Po	14.52		###	###		#	
30	*Raphidopus ciliatus*	Cr	22.54				#	##	#
Assemblage V									
31	*Amphareta arctica*	Po	17.75		####	###	#	###	#
32	*Gammaropsis utinomi*	Cr	13.56		#	###	###	#	#
33	*Photis longicaudata*	Cr	27.82	###	####	###	#		#
34	*Byblis japonicus*	Cr	17.82	#		##	#		###
35	*Thelepus* sp.	Po	11.55	#		#	#		##
36	*Melita* sp.	Cr	19.80		##			###	#
37	*Limaria hakodatensis*	Bi	72.60						###
38	*Ampelisca* sp.	Cr	13.66		###	##	#	#	#
39	*Anatides koreana*	Po	9.54		#	#	#	##	##

Table 5. Distribution by density intervals(mean value) of the main macrobenthos sampled in August, 1993. (Ga: Gastropoda, Bi: Bivalvia, Po: Polychaeta, Cr: Crustacea, Op : Ophiuroidea, Ho: Holothuroidea ; Mean density: ind./m^2; (#)<16 ind./m^2; (##) 17 to 32 ind./m^2; (###) 33 to 75 ind./m^2; (####) 76 to 218 ind./m^2, (#####) >218 ind./m^2)

No.	Species	Taxa.	Mean Density	Sand	Gravelly Sandymud	Gravelly Mud	Muddy-sand	Sandy-mud	Mud
Assemblage I									
1	*Theora fragilis*	Bi	432.60		##	#	###	#####	#####
2	*Lumbrineris longifolia*	Po	206.32	##	#####	#####	#####	#####	####
Assemblage II									
3	*Mytilus edulis gall.*	Bi	674.29	#####				###	
4	*Corophium* sp.	Cr	127.88	#####	##	####			
5	*Ophioplus megapomus*	Op	42.40	###	#	#####			
6	*Clymenella* sp.	Po	28.74		#	#####		#	#
7	Syllidae unid.	Po	21.45	####	####	####			
Assemblage III									
8	*Terebellides horikoshii*	Po	55.21		#####	#####	###	###	##
9	*Ampelisca* sp.	Cr	32.01		####	#####	##	#	#
10	*Gammaropsis utinomi*	Cr	82.96		#####	#####	#	#	
11	*Praxillella affinis*	Po	64.68		####	#####	###	#	
12	*Amphicteis gunneri*	Po	47.03		####	#####	#	#	#
13	*Glycera chirori*	Po	12.74	###	####	###	###	##	##
14	*Melita* sp.	Cr	21.45	####	####		##	##	#
15	*Amphareta arctica*	Po	66.50	##	###	#####		###	#
16	*Amaoana* sp.	Po	28.38		###	#####	###	###	#
17	*Anatides koreana*	Po	19.80		###	####	###	##	###
Assemblage IV									
18	*Sternaspis scutata*	Po	73.43		#		##	####	####
19	*Ampelisca misakiensis*	Cr	70.39				####	####	
20	*Chitinimandibulum* sp.	Cr	23.93		#	#	####	##	#
21	*Eriopisella sechellensis*	Cr	22.51		#		#	###	###
22	*Moerella jedoensis*	Bi	38.81		#	##	###	####	####
23	*Chaetozone spinosa*	Po	47.16					##	####
24	*Prionospio krusadensis*	Po	30.00		#			###	####
25	*Tharyx* sp.	Po	23.10		#	####		##	####
26	*Heteromastus* Sp.	Po	17.19		#	###	##	##	###
Assemblage V									
27	*Philine argentata*	Ga	29.04		###	##	#	####	####
28	*Glycinde* sp.	Po	28.61		####	#	#	####	###
29	*Raphidopus ciliatus*	Cr	24.19	####	##	###	###	###	####
30	*Protankyra bidentata*	Ho	28.05	#			#	####	###
31	*Sigambra tentaculata*	Po	19.11	#	#	###	#	###	###
32	*Arcidea* sp.	Po	21.15		#	#	##	####	#
33	*Harmothoe* sp.	Po	25.51	#####	##	###		##	#
34	*Nephtys oligobranchia*	Po	11.39	##	##	####	##	##	##

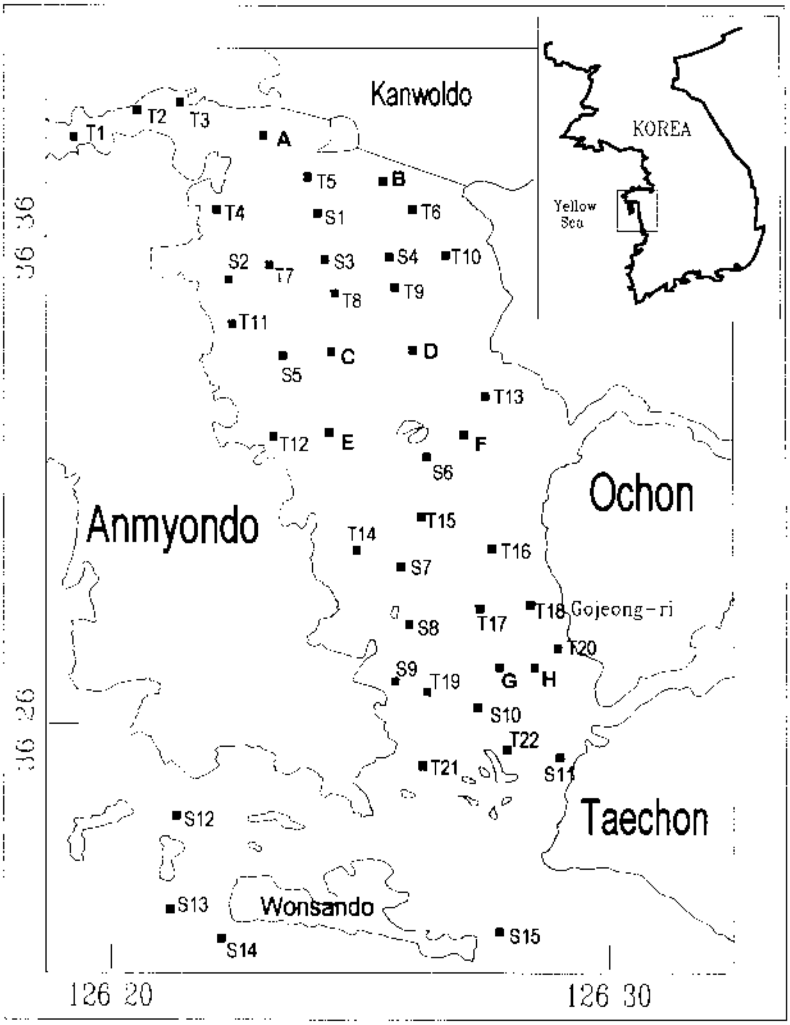

Fig. 1 A map of the study area showing sampling stations. Stn S1~S15: investigation in April, 1993, Stn T1~T22: in August, 1993, Stn A~H: investigations in both April and August.

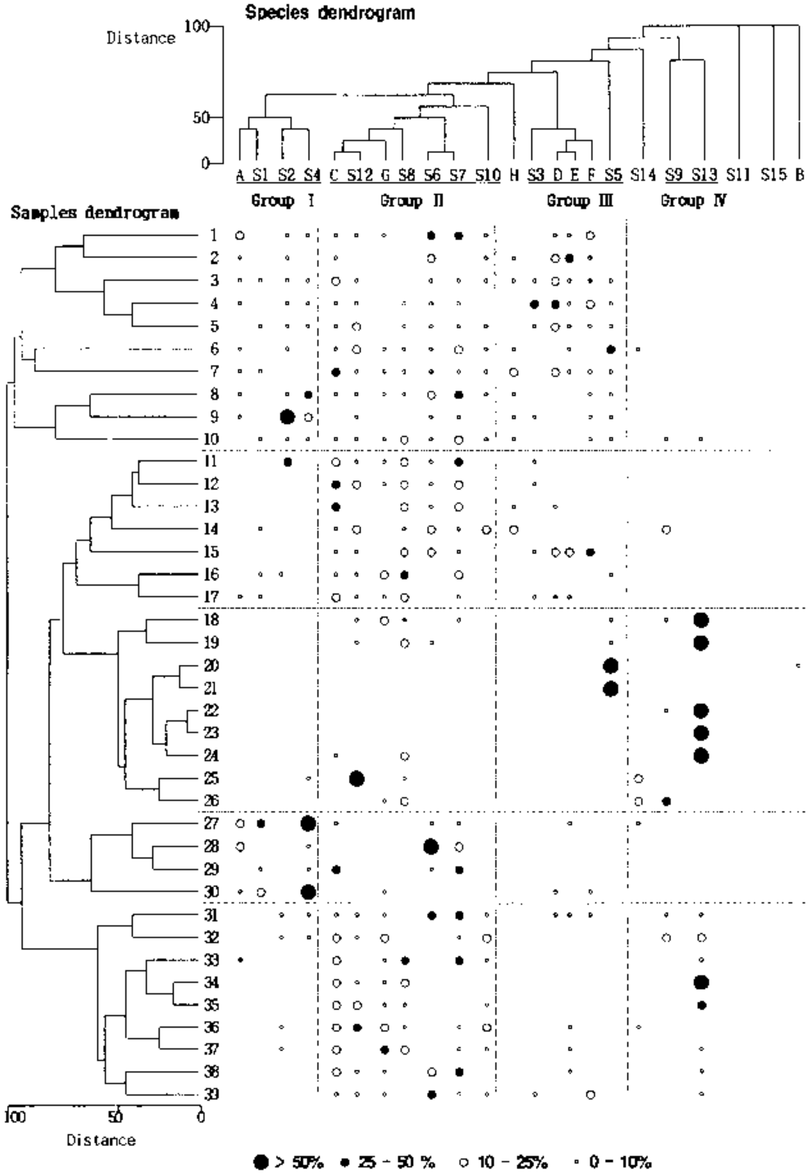

Fig. 6 Condensed two-way co-incidence table clustering aggregate samples along upper abscissa ordinate and species(1 to 39 described in Table 4) along left-hand investigated in April, 1993. Scales of cluster diagram show percent dissimilarity. Cells are coded to represent percent composition of species within sample groups(bottom abscissa).

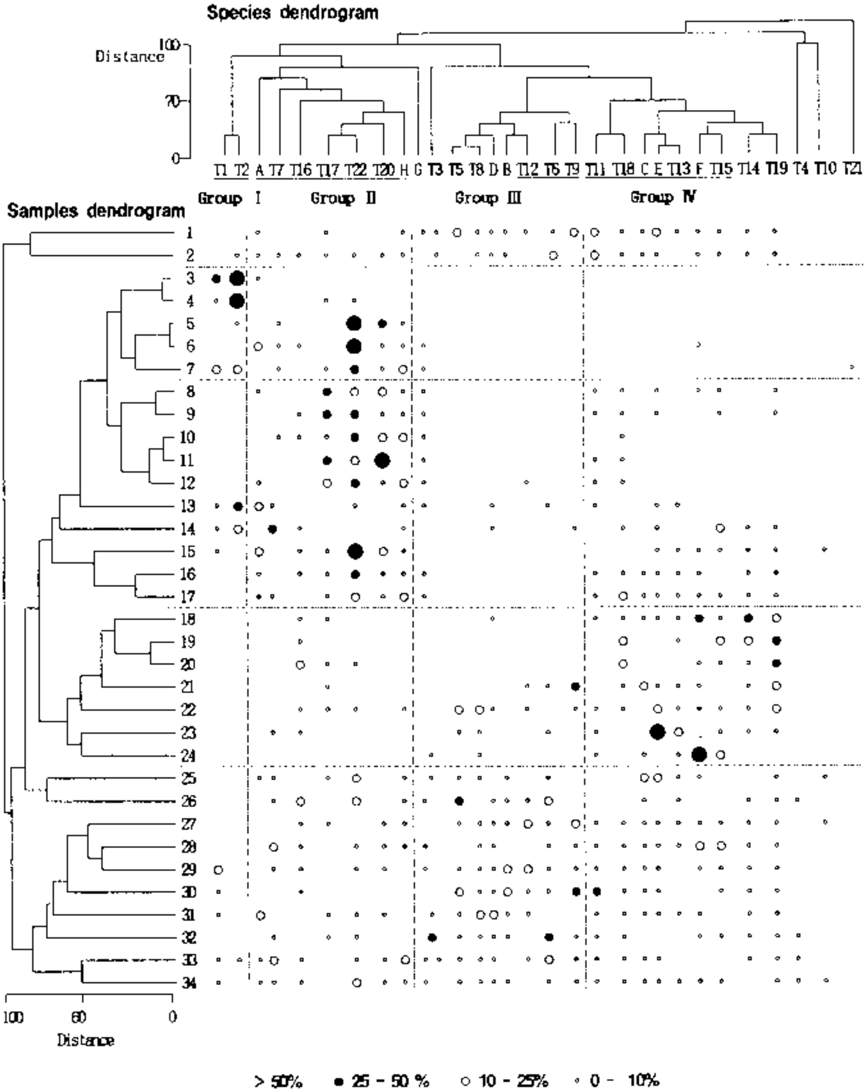

Fig. 7 Condensed two-way co-incidense table clustering aggregate samples along upper abscissa ordinate and species(1 to 34 described in Table 5) along left-hand investigated in August, 1993. Scales of cluster diagram show percent dissimilarity. Cells are coded to represent percent composition of species within sample groups(bottom abscissa).

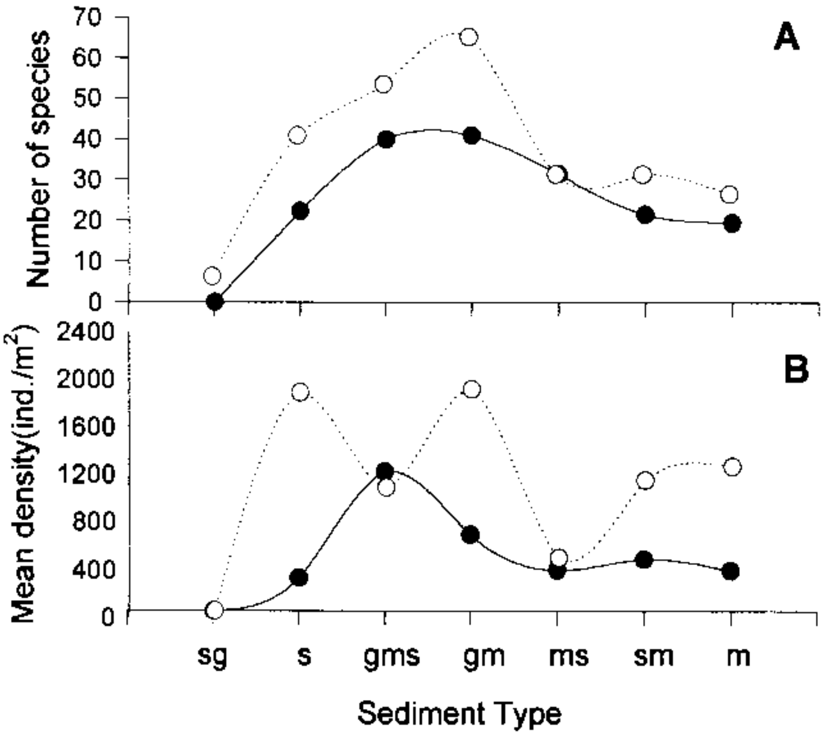

Fig. 8 Number of species(A) and mean density(ind./m^2)(B) of all taxonomic groups of macrobenthos combined, in relation to sediment type. —●— : April, 1993, ···○··· : August, 1993, **sg**: Sandy gravel, s: Sand, **gms**: Gravelly-muddy sand, **gm**: Gravelly mud, ms: Muddysand, sm: Sandy mud, m: Mud

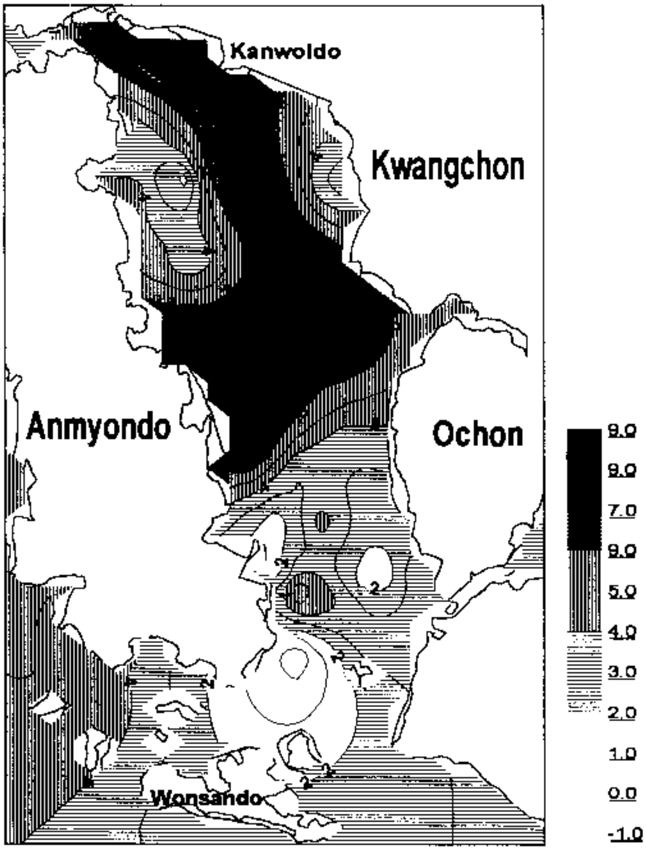

Fig. 2 Geographical distribution of sediment types mapped according to mean phi(φ) data.

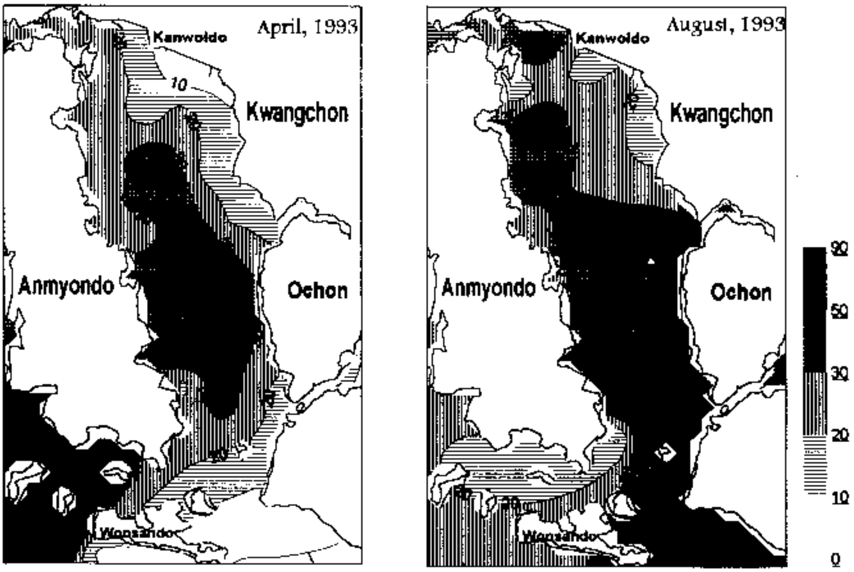

Fig. 3 Geographical distribution of number of species in April (Left) and August (Right), 1993, respectively.

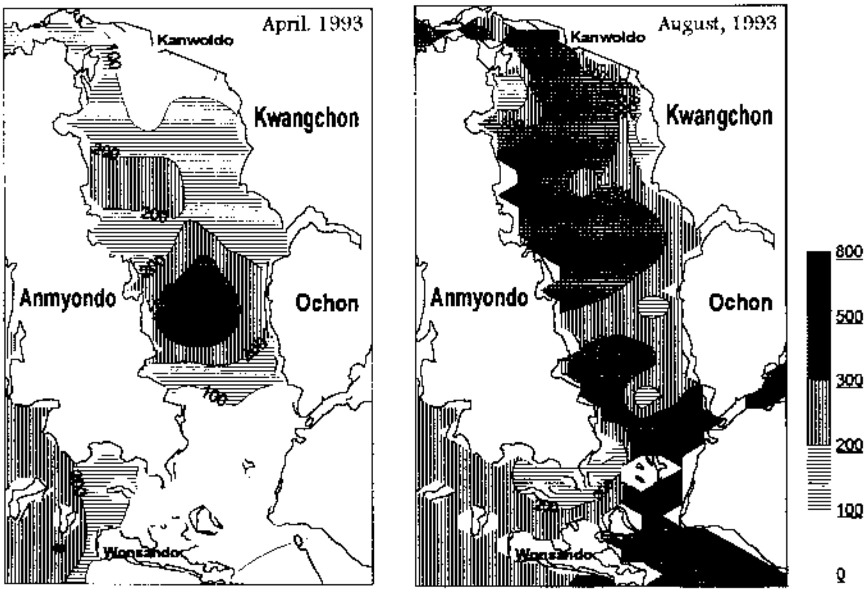

Fig. 4 Geographical distribution of Macrobenthos density(ind./m^2) in April (Left) and August (Right), 1993, respectively.

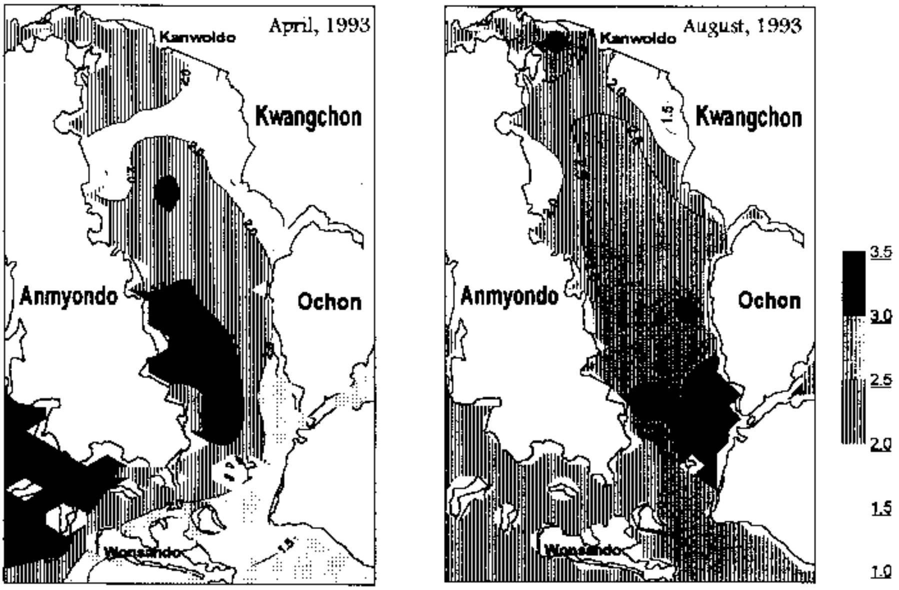

Fig. 5 Geographical distribution of Diversity index(H') in April (Left) and August (Right), 1993, respectively..

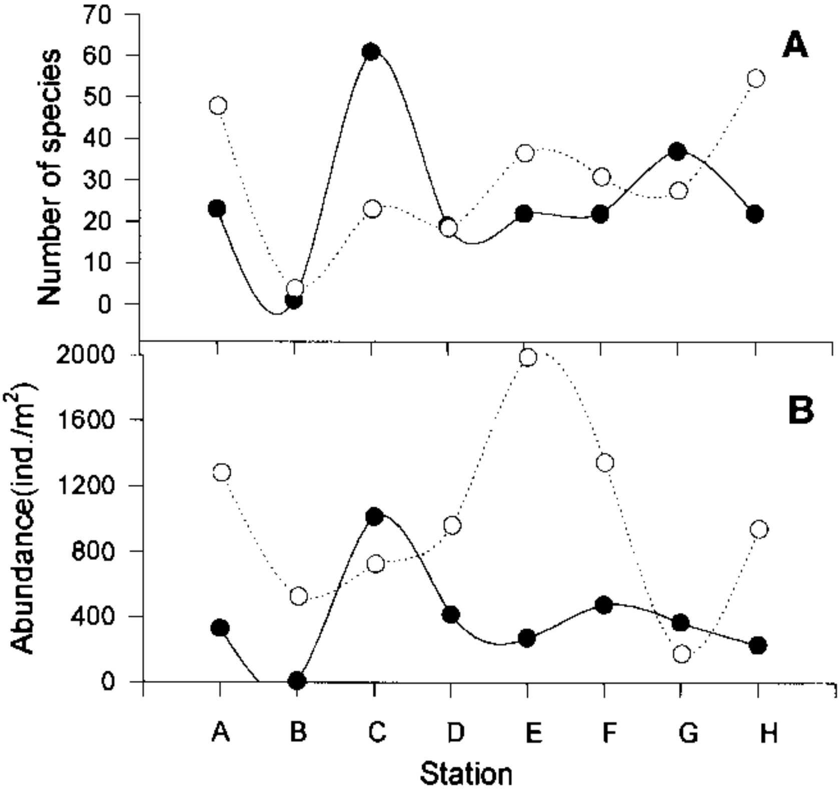

Fig. 9 Spacial changes to number of species(A) and mean density(ind./m^2)(B) of macrobenthos combined. —●— : April, 1993, ···○··· : August, 1993,

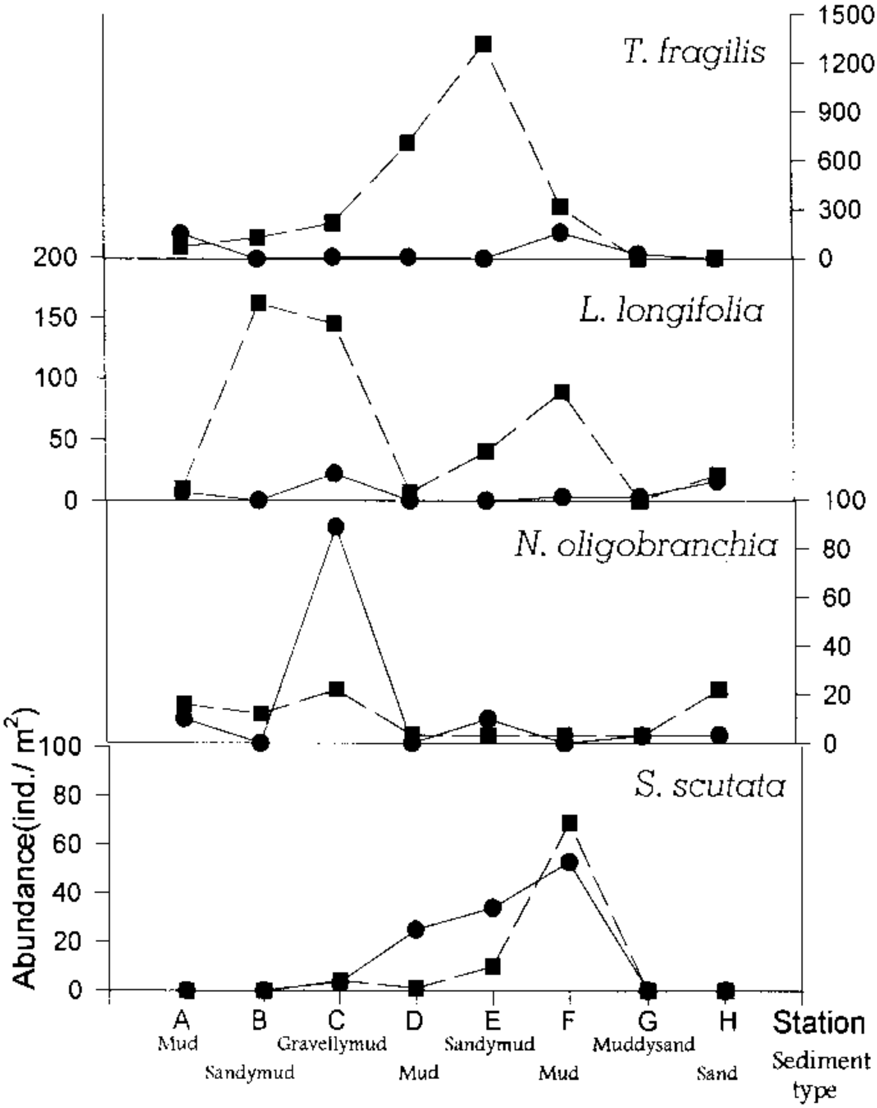

Fig. 10 Spacial changes to 4 dominance species. —●— : April, 1993, ···■··· : August, 1993.