The Journal of the Korean Society of Oceanography
Vol. 29, No. 3, pp. 304-318, September 1994

Macrobenthos Community in Keum-Mankyung-Dongjin Estuaries and its Adjacent Coastal Region, Korea

JIN-WOO CHOI* AND CHUL-HWAN KOH
Department of Oceanography, Seoul National University, Seoul 151-742, Korea

한국 서해의 금강-만경-동진 하구역과 주변 연안역의 저서동물군집

최진우* · 고철환
서울대학교 해양학과

Macrobenthic fauna in three Keum-Mankyung-Dongjin Estuaries and their nieghbouring coastal region in the west coast of Korea were sampled at 39 stations with van Veen grab to describe the distribution patterns of macrobenthos. Total 61 taxa from 10 faunal taxonomic groups and 5,636 individuals were collected. Abundance, species number, and faunal composition varied among three estuaries and coastal region. Dominant species from estuaries were similar to each other, but different from those of coastal region. Dominant species in estuarine regions were *Prionospio cirrifera, Potamocorbula amurensis, Nephtys californiensis, Glycera chirori,* and *Glycinde* sp. Those from coastal area were *Mactra chinensis, Magelona japonica, Owenia fusiformis, Anaitides koreana,* and *Nephtys polybranchia.* Two most dominant species in estuaries, *Potamocorbula amurensis* and *Prionospio cirrifera,* were not found elsewhere in Korean waters. The patchy distribution of dominant species and low species richness were reflected in the low species diversity. Filter feeders were a major component in estuaries. High proportion of carnivores and low percentage of subsurface deposit feeders seemed to be a typical trophic composition in the study area. The distribution pattern of macrobenthos was related with the salinity and sediment types.

본 연구는 한국서해의 금강, 만경강 및 동진강 하구역과 그 외곽의 연안역에서의 저서동물군집의 분포양상을 파악하기 위해 van Veen grab을 사용하여 조하대 하구역의 39개 정점에서 저서생물을 채집하였다. 채집된 저서동물은 10개 동물분류군, 총 61종이며 개체수는 5,636였다. 각 하구역별로 출현종수와 개체수가 달랐지만 외곽의 연안역과 비교하면 3개 하구역은 종조성과 우점종에 있어서는 서로 유사하였다. 하구역에서의 우점종으로는 *Prionospio cirrifera, Potamocorbula amurensis, Nephtys californiensis, Glycera chirori, Glycinde* sp.등이었고, 연안역의 우점종으로는 *Mactra chinensis, Magelona japonica, Owenia fusiformis, Anitides koreana, Nephtys polybranchia* 등으로서 하구역과는 매우 달랐다. 이들 중에서 이매패류인 *Potamocorbula amurensis*와 다모류의 *Prionospio cirrifera*는 이곳 하구역에서 처음 발견되었고 다른 종들에 비해 극히 우점하여 본 조사하구역의 저서동물군집을 대표하는 종이다. 종다양성지수값은 하구역에서 대체로 낮았는데 이는 우점종의 밀집분포와 전반적인 출현종수의 빈약에 기인한 것이다. 식성군조성에 있어서는 하구역에 여과식자와 육식자의 비율이 높은 반면 표층하퇴적물식자의 비중은 낮았다. 이러한 식성군조성은 본 하구역의 전형적인 특징으로 파악되었다. 집괴분석 결과 하구역의 저서동물군집은 일차적으로 염분의 구배에 의해서, 소규모적인 분포양상은 퇴적상에 의해 결정되는 것으로 나타났다.

본 연구는 문교부 학술진흥재단의 지원(과제번호 BSRI 93-552)에 의해 수행되었음.
*Present address: Biological Oceanography Division, KORDI, Ansan, P.O.Box 29, Ansan 425-600, Korea

INTRODUCTION

The invertebrate community of soft-bottom in estuaries is often recommended as a subject for baseline studies and impact assessments for several reasons. The community is diverse, different feeding types are represented, most species are relatively immobile (and hence unable to evade impact), and some are long-lived and persistent (Boesch *et al.*, 1976). The macrobenthic faunal communities in estuaries are organized and changed by various environmental factors, e.g. salinity (Sanders *et al.*, 1965; Ristich *et al.*, 1977; Jones *et al.*, 1986; Bae and Yoon, 1989), sedimentation rate (Schaffner *et al.*, 1987; Sun and Dong, 1985), grain-size gradient (Gambi and Giangrande, 1986), and disturbances from dredging, chemical pollution and organic enrichment (Gaston and Nasci, 1988; Probert, 1984).

Some ecological studies on the macrobenthos were carried out in the coastal areas of Korea, but few studies were attempted to investigate estuarine macrobenthic communities (Bae and Yoon, 1989, An and Koh, 1992). The Keum Estuary and its adjacent two estuaries, the Mankyung and Dongjin Estuary, and their outer coastal region, are shallow, polyhaline, and have a very complex bathymetry. However this estuarine system will be a unique one in Korea in terms of well developed sand flat in contrast to the mud flats common found in the west coast of Korea. There have been some geological, geochemical and biological studies on plankton, but informations on the benthos in sand flat and subtidal region of the Keum-Mankyung-Dongjin Estuaries were few (An and Koh, 1988). Thus a preliminary servey on the intertidal and subtidal macrobenthos was conducted in summer of 1988. The aims of this study are (1) to describe community patterns in space, and (2) to relate these patterns with salinity and sedimentary variables.

STUDY AREA

Keum, Mankyung and Dongjin Estuaries located on the western coast of Korea are shallow and macrotidal estuaries (Fig. 1). The tide at the mouth of Keum River is semi-diurnal type with a mean range of 4.3 m, and the maximum tidal current velocity reaches 2 m·sec^{-1}. The average spring- and neap-tidal range are estimated as 5.7 m and 2.8 m, respectively. This great tidal fluctuation in the estuary controls the residence time of fresh water as well as the dynamics of fine sediments. Periodic resuspensions and depositions of bottom sediments occurrs along with the spring- and neap-tidal cycle.

The annual fresh water discharge is estimated as about 6×10^9 m^3·yr^{-1}, most of which is concentrated in the summer rainy season. The discharge of the suspended materials through Keum River amounts about 1.3×10^6 ton·yr^{-1} (Schubel *et al.*, 1984). Among them, 65 percent of terrestrial sediments transported into Keum Estuary deposits in the river mouth in summer, and the strong northwestern wind in winter causes the bottom sediments to resuspend and transport them into seaward and southward (Choi, 1993; Park *et al.*, 1986).

Daily salinity variation during tidal cycle in Keum Estuary is in the range from 7.6‰ to 25.3‰, and seasonal salnity variation is from 5‰ in rainy season to 21.3‰ in dry season. In the river mouth of Mankyung and Dongjin River, salinity showed great seasonal fluctuation; it was 0.7‰ in July, 16.6 ‰ in October, 26.0‰ in April, and increased to 28.8‰ in December, which causes the seasonal variation in salinity to reach up to 28.1‰ (Shim *et al.*, 1991; Cho and Shim, 1992). The annual seawater temperature changed from 5.8℃ in winter to 27.6℃ in summer (Shim *et al.*, 1991).

MATERIALS AND METHODS

The study area included three estuaries, the Keum Estuary, the Mankyung Estuary, and the Dongjin Estuary and their outer coastal region (Fig. 1). Macrobenthic fauna were collected at 39 stations during 3 day cruise from June 29 to July 1, 1988. At each station duplicate samples were taken by using a van Veen grab sampler covering 0.1 m^2, and were screened through a sieve with 1.0 mm mesh size. The remained fauna on the

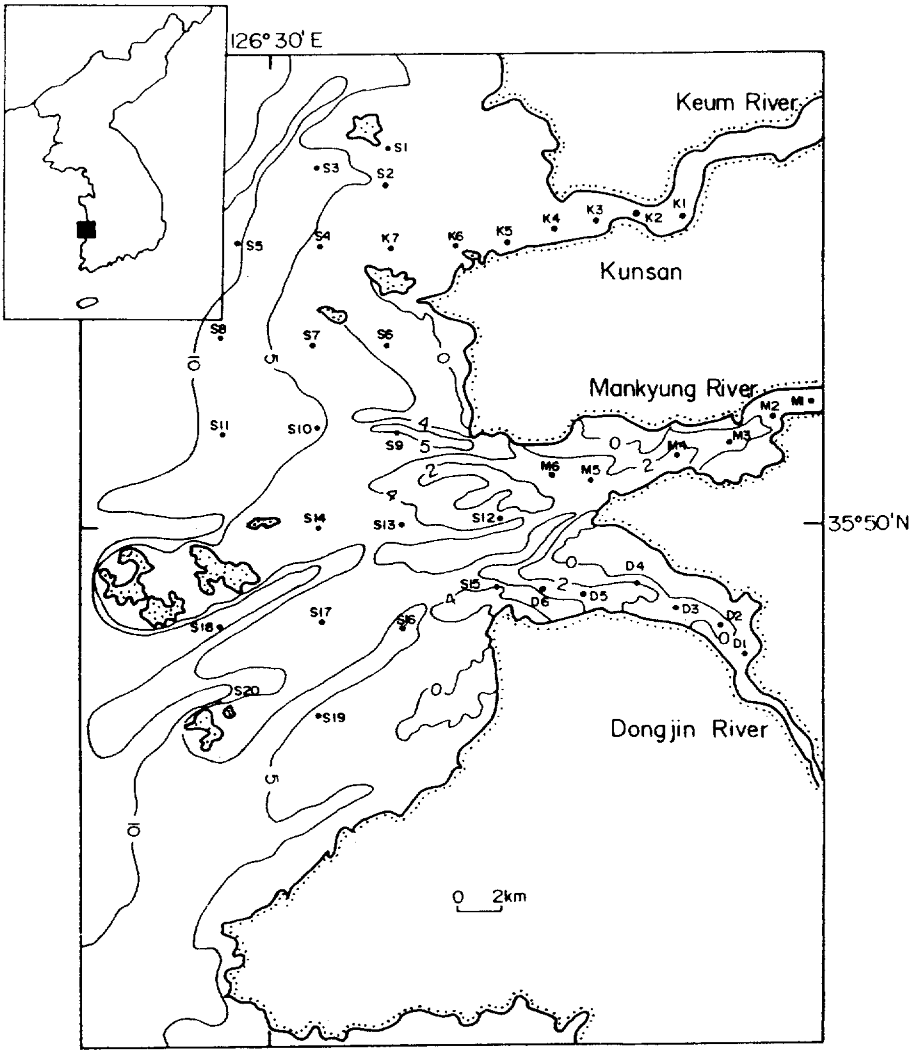

Fig. 1. A map showing the sampling sites and bathymetry of the Keum-Mankyung-Dongin Estuarine system, west coast of Korea.

sieve were fixed with 10% formalin solution neutralized by seawater.

In the laboratory the fauna were sorted into major taxonomic groups and polychaetes and mollusks were identified into as species level as possible, and counted. Species diversity was calculated using Shannon-Wiener's index (H') and evenness by Pielou's index (J), and dominance by McNaughton's index. The trophic composition of macrobenthic community was calculated using fauna data identified to species or genus level. Crustaceans and some mollusks were excluded in the analysis. To display the faunal affinity along the estuaries, a cluster analysis by the Jaccard's similarity index and weighted group average linkage was performed. In order to recognize site groups and species groups, from log-transformed abundance data of 18 dominant species, a cluster analysis using the group average sorting strategy with the Bray-Curtis dissimilarity coefficient was performed.

Table 1. The sedimentary facies of surface sediments observed in the estuaries and coastal region off Kunsan, Korea

St.	Sediment Type	St.	Sediment Type
K1	SILT	S1	SANDY SILT
K2	MEDIUM SAND	S2	SILTY SAND
K3	SILT	S3	SANDY SILT
K4	MEDIUM SAND	S4	SILTY SAND
K5	SANDY SILT	S5	SILTY SAND
K6	SILTY SAND	S6	SILTY SAND
K7	COARSE SAND	S7	FINE SAND
M1	SILT	S8	FINE SAND
M2	SILTY SAND	S9	FINE SAND
M3	SANDY SILT	S10	SILTY SAND
M4	FINE SAND	S11	FINE SAND
M5	SILTY SAND	S12	FINE SAND
M6	FINE SAND	S13	SILTY SAND
D1	SILT	S14	SANDY SILT
D2	FINE SAND	S15	SANDY SILT
D3	SILTY SAND	S16	FINE SAND
D4	FINE SAND	S17	FINE SAND
D5	SILTY SAND	S18	SILT
D6	SILTY SAND	S19	SILTY SAND
		S20	SILTY SAND

RESULTS

Estuarine environments

The sedimentary facies of surface sediments in the study area were dominated by sand and silty sand (Table 1). The inner part of three estuaries, silt and sandy silt facies were largely found, while near the river mouthes sand predominated. In Keum Estuary, the bottom of central channel region was composed of sandy sediments, but along the shallow river side, the bottom was covered mainly with silty sediments. Keum River has some patches of silty sediment with more than 50% of silt in the middle area, i.e. at st. K3 and K6, but Mankyung River and Dongjin River showed gradual decrease in silt portion toward the river mouth.

The bottom water temperature of Keum Estuary was in the range from 23℃ to 25℃, and those of Mankyung River and Dongjin River was from 22℃ in the river mouth to 27℃ in the inner part. Salinity of bottom water of Keum Estuary changed from 23‰ in the inner part to 31‰ in the outer coastal region, but those of Mankyung and Dongjin Estuaries increased from 26‰ in the inner part of estuary to 31‰ in the coastal region. Most estuarial stations remained below 28‰ during high tides (Fig. 2). The slight difference in the temperature and salinity between Keum and Mankyung-

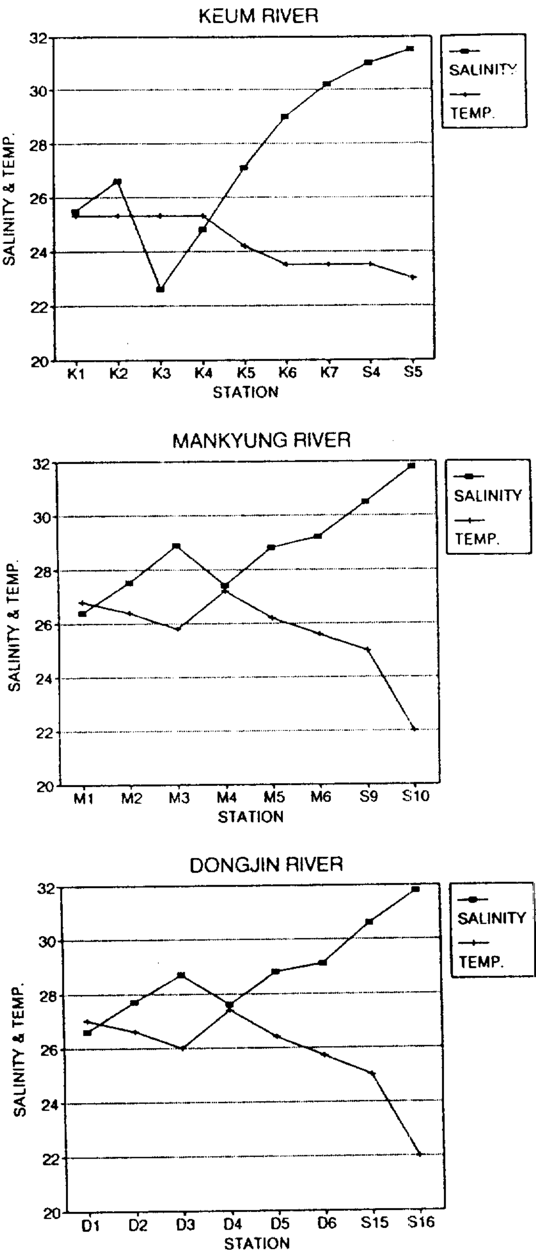

Fig. 2. Bottom salinity and temperature changes along three estuaries measured by a T-S bridge at high tide in July.1988.

Table 2. Macrobenthic fauna occurred in Keum Estuary (Unit: indiv./0.2 m^2)

Species/Station	K1	K2	K3	K4	K5	K6	K7	Sum
Anthozoa						1		1
Nemertea			12			3		15
Bivalvia								0
Culterensis sp.			2					2
Musculus senhausia			158	1				159
Potamocorbula amurensis			169		55	228		452
Gastropoda			4					4
Isopoda			4					4
Amphipoda		2	28	2	16	4	12	64
Decapoda		1	24	3	1	3		32
Polychaeta								0
Anaitides koreana			6	1	24	3		34
Armandia lanceolata						1		1
Brada villosa						1		1
Capitella capitata			18		12	9		39
Diopatra sukogai						1		1
Eteone longa	1			1				2
Glycera chirori						5		5
Glycinde sp.			18		4	5		27
Haploscoloplos elongatus						15		15
Heteromastus sp.			14			20		34
Lagis bocki			6			4		10
Mediomastus sp.					3		2	5
Neanthes japonica	1		2					3
Nectoneanthes oxypoda		1	10		3			14
Nephtys californiensis	1							1
Nephtys polybranchia			2			4		6
Nephtys schmitti			2					2
Polynoella sp.					1			1
Prionospio cirrifera	167	160	10	120	4	18		479
Paraprionospio pinnata					4		4	8
Pseudopoldora kempi	3		152		220			375
Sigambra sp.					4	1		5
Tharyx sp.						2		2
Hesionidae indet.							4	4
Number of Species	5	4	19	6	13	19	4	35
Total indiv. No.	173	164	641	128	351	328	22	1807

Dongin Estuaries would be due to the difference in the river scale such as water depth, the amount of freshwater runoff between them. Based on the observed salinity range, the estuaries of present study were classified as a polyhaline estuarine system (18~30‰), but it may be mesohaline (18~5‰) or oligohaline (lower than 5‰) estuary in rainy summer.

Macrobenthic fauna

Macrobenthic fauna collected in the whole study area comprised a total of 61 taxa from 10 taxonomic groups and were counted as 5,636 individuals. The faunal density at each station was ranged from 30 ind·m^{-2} to 4,425 ind·m^{-2}, and the average density was 723 ind·m^{-2}. The benthic fauna occurred in estuaries and coastal area are described individually in the following:

Keum Estuary

Macrobenthic infauna occurred in the Keum Estuary comprised 35 taxa included in 8 faunal

Table 3. Macrobenthic fauna occurred in Mankyung Estuary (unit: indiv./0.2 m^2)

Species—Station	M1	M2	M3	M4	M5	M6	Sum
Nemertea		5		1			6
Bivalvia							
Potamocorbula amurensis	4	752	158	12	5	11	942
Gastropoda			1				1
Amphipoda	6		1	22	5	3	37
Cumacea					2	1	3
Decapoda	4	1	1	3	1	3	13
Polychaeta							
Anaitides koreana	8						8
Armandia lanceolata						1	1
Capitella capitata			1				1
Eteone longa	4						4
Glycera chirori				1			1
Glycinde sp.	4	4	20	18	5	5	56
Haploscoloplos elongatus			1		2	2	5
Heteromastus sp.			7				7
Mediomastus sp.		3					3
Neanthes japonica	1		1				2
Nectoneanthes oxypoda		14		1			15
Nephtys californiensis	31	102	3	10	6	11	163
Nephtys oligobranchia	2		1				3
Owenia fusiformis						1	1
Prionospio cirrifera	38	8	10				56
Paraprionospio pinnata						6	
Pseudopoldora kempi		1					1
Nereidae indet.	2						2
Polynoidae indet.	1						1
Number of Species	13	8	12	8	7	10	24
Total indiv. No.	110	885	205	68	26	44	1332

groups and a total of 1,807 individuls were collected (Table 2). Among them, 24 taxa were from polychaetes which were main contributors in species richness and abundance of each station. No fauna in echinoderms or chordates was found in Keum Estuary. Station K3, K5, and K6 contained more than 10 species and were a rather richer fauna composition than the rest ones.

Most dominant species was a spionid, *Prionospio cirrifera*, occupied 26.5% of total individuals, and followed by *Potamocorbula amurensis* (25.0%), *Pseudopolydora kempi* (20.8%), and *Musculus senhousia* (8.8%) (Table 6).

The maximum density was up to 3,205 ind·m^{-2} at Station K3, and the lowest one was shown at station K7. The mean density was 1,290 ind·m^{-2}. A bivalve species, *Potamocorbula amurensis*, showed its maximum population density of 1,140 ind·m^{-2} at station K6.

Mankyung Estuary

A total of 1,332 specimen from 24 taxa in 7 faunal groups was collected in Mankyung Estuary (Table 3). 18 taxa were from polychaete worms. No echinoderms was found in this estuary. A bivalve, *Potamocorbula amurensis*, was the most abundant species which occupied 70.7% of total individuals. It showed very high density of 3,760 ind·m^{-2} at station M2 ,where the highest denisty in the study area reaching 4,425 ind·m^{-2} was found. Other dominant species in this estuary were *Nephtys californiensis* (12.2%), *Glycinde* sp.(4.2%), and *Prionospio cirrifera* (4.2%) (Table 6). The macrobenthic community in Mankyung Estuary had a rather poorer faunal comosition than that of Keum

Table 4. Macrobenthic fauna occurred in Dongjin Estuary (unit: indiv./0.2 m^2)

Species/Station	D1	D2	D3	D4	D5	D6	Sum
Anthozoa					1	3	4
Bivalvia							
Potamocorbula amurensis	155	16			1		172
Unidentified spp.			4	3		8	15
Isopoda			1				1
Amphipoda		5		1	8	1	15
Cumacea			1				1
Decapoda							
Orithyia sinica		2					2
Unidentified spp.			2				2
Polychaeta							
Eteone longa	16	1	1			1	19
Glycera chirori	30	34	37	4	3	21	129
Heteromastus sp.	8					3	11
Lagis bocki	1						1
Nephtys californiensis	53	55	14	2	15	12	151
Nephtys oligobranchia	5						5
Prionospio cirrifera	28	29	149	16	1	17	240
Pseudopoldora kempi	4	1			1		6
Number of Species	9	8	8	5	7	8	16
Total indiv. No.	300	143	209	26	30	66	774

Estuary. The overall fauna density was 1,110 ind·m^{-2}.

Dongjin Estuary

A total of 774 individuals from 16 taxa in 7 faunal groups were collected (Table 4). This was the poorest faunal composition among three estuaries. Among faunal groups, polychaetes were the most dominant, and comprised a half of total species number.

Dominant species were *Prionospio cirrifera* (31.0%), *Potamocorbula amurensis* (22.2%), *Nephtys californiensis* (19.5%), *Glycera chirori* (16.7%) (Table 6). These four species accounted for 89% of total fauna abundance. The highest density of 1,500 ind·m^{-2} was found at station D1, and the inner part of the river (st. D1 to st. D3) sustained a rather higher density of benthic fauna. The mean density was 645 ind·m^{-2}, which was a rather lower than those of other two estuaries.

Coastal area

The outer region of three estuaries, where 20 sampling stations were allocated, had more diverse faunal composition than estuaries. A total of 1,710 individuals from 53 taxa in 10 faunal groups was counted (Table 5). From the station basis, the species number of coastal region was in the range from 18 taxa to 4 taxa, which was similar or slightly higher than that of estuaries.

Polychaete worms comprised 41 taxa from total 53 taxa, and were the most dominant faunal group in both species richness and abundance. Dominant species in the coastal area were different from those in estuaries (Table 6); they were *Mactra chinensis* (10.0%), *Magelona japonica* (8.8%), *Owenia fusiformis* (8.0%), *Anaitides koreana* (6.5%), *Nepthys polybranchia* (5.8%), and *Prionospio japonicus* (5.5%). Macrofaunal density in this coastal area was changed from 30 ind·m^{-2} at st. S17 to 1,710 ind·m^{-2} at st. S12, and the mean fauna density was 430 ind·m^{-2}.

Trophic composition

In Keum Estuary, the proportion of surface deposit feeders (SDF) was very high along overall estuarine area, and at station K3 and K6 filter

Table 5. Macrobenthic fauna occurred in the coastal region off Keum Estuary (Unit: indiv./0.2 m²)

Species—St.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	Sum
Anthozoa		1																1	2		
Nemertea			1	2	4			8							2					2	19
Bivalvia																					
Potamocorbula amurensis															1						1
Mactra chinensis		8				18			124	3			2						4	12	171
Unidentified spp.					1		3	1								2		4	5		16
Gastropoda																					
Neverita dudima										1											1
Unidentified spp.			1	1			7														9
Amphipoda	10		2		6	4	4	1	8		1	52	17	1	23			4	10		143
Isopoda	8																	1	1		10
Cumacea									2												2
Decapoda	2			1	1	1		1	4			2	2			6		4	2	2	28
Holothuroidea		2		1								2	1			2		1			9
Polychaeta																					
Aglaophamus sinensis					2			1													3
Anaitides koreana	2	3	1	5		7	2		1			85	1	2				2			111
Armandia lanceolata						12									4						16
Aricidea jeffreysii	38				6			27										9	2		82
Aricidea sp.				2				1													3
Axiothella rubrocincta																		2			2
Chaetozone spinosa					4																4
Chaetozone sp.																			1		1
Diopatra sukogai									1									1			2
Eteone longa						1									4						5
Glycera chrori		2			1							1	1		1			4			10
Glycinde sp.	28	6	2	13				7			3	1	1		17			3			81
Haploscoloplos elongatus						2		2							1			1			6
Heteromastus sp.	10		1				28	3					26		3			15			86
Lagis bocki				1																	1
Lumbrineris cruzensis																		2			2
Lumbrineris heteropoda															1						1
Lumbrineris longifolia	8																				8
Magelona japonica	8		5		14			96		2	15	2			1	4	1		1	2	151
Marphysa sanguinea	2																				2
Mediomastus sp.		22			4	4				28										4	62
Nectoneanthes oxypoda												26									26
Nephtys californiensis	2		2	2	6	12	13		6	4	2	11		9	8		3		4	2	86
Nephtys polybranchia	6	16	4	17	8			32			4				1			6	2	4	100
Notomastus sp.								1													1
Owenia fusiformis		2	3	5	3	3		1				115	3		1				2		138
Paralacydonia paradoxa					1																1
Paraprionospio pinnat				24							8	14							1		47
Polydora ligni												25									25
Prionospio cirrifera	6	2	6		16		12					4			22	4	1	4	9	2	88
P. japonicus				10				24	2	29			22	8							95
Sigambra sp.			1					8					1					3	5		18
Scolelepsis foliosa					1														1		2
Spiophanes bombyx																			1		1
Sternaspis scutata	4	1		6				2		2	2							7	2		26
Tharyx sp.								3			2										5
Travisia sp.															1						
Hesionidae indet																				2	2
Nereidae indet.	2																1				3
Polynoidae indet.												2									2
Sabellidae indet.	2																				2
Number of Species	16	11	12	14	16	10	7	18	8	7	8	14	11	4	16	5	4	18	18	9	53
Total indiv. No.	138	65	29	90	78	64	69	219	148	69	37	342	77	20	91	18	6	73	54	32	1719

Table 6. Dominant species of three estuaries and coastal region of the study area in July 1988

Region	Species	%	Feeding type
Keum Estuary	*Prionospio cirrifera*	26.5	SDF
	Potamocorbula amurensis	25.0	FF
	Pseudopolydora kempi	20.8	SDF
	Musculus senhausia	8.8	FF
Mankyung Estuary	*Potamocorbula amurensis*	70.7	FF
	Nephtys californiensis	12.2	C
	Prionospio cirrifera	4.2	SDF
	Glycinde sp.	4.2	C
Dongjin Estuary	*Prionospio cirrifera*	31.0	SDF
	Potamocorbula amurensis	22.2	FF
	Nephtys californiensis	19.5	C
	Glycera chirori	16.7	C
Coastal region	*Mactra chinensis*	10.0	FF
	Magelona japonica	8.8	SDF
	Owenia fusiformis	8.0	FF
	Anaitides koreana	6.5	C
	Nephtys polybranchia	5.8	C
	Prionospio japonicus	5.5	SDF
	Prionospio cirrifera	5.1	SDF
	Nephtys californiensis	5.0	C
	Heteromastus sp.	5.0	SSDF

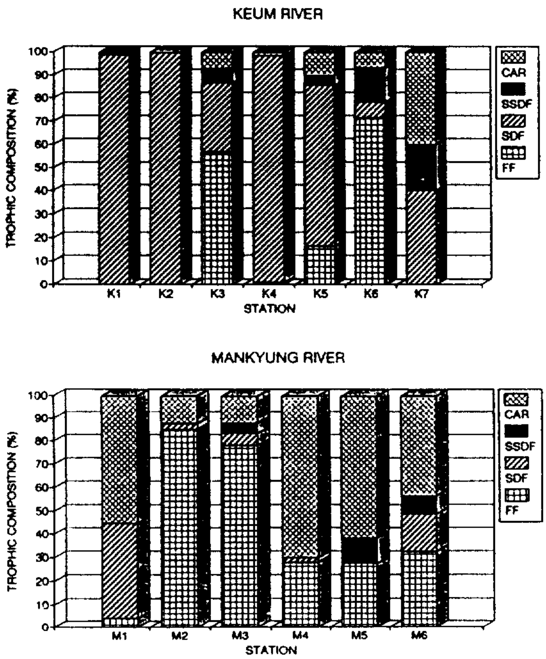

Fig. 3. The trophic composition of macrobenthic fauna in three estuaries and their coastal region. (CAR: carnivores, SSDF: subsurface deposit feeders, SDF: surface deposit feeders, FF: filter feeders).

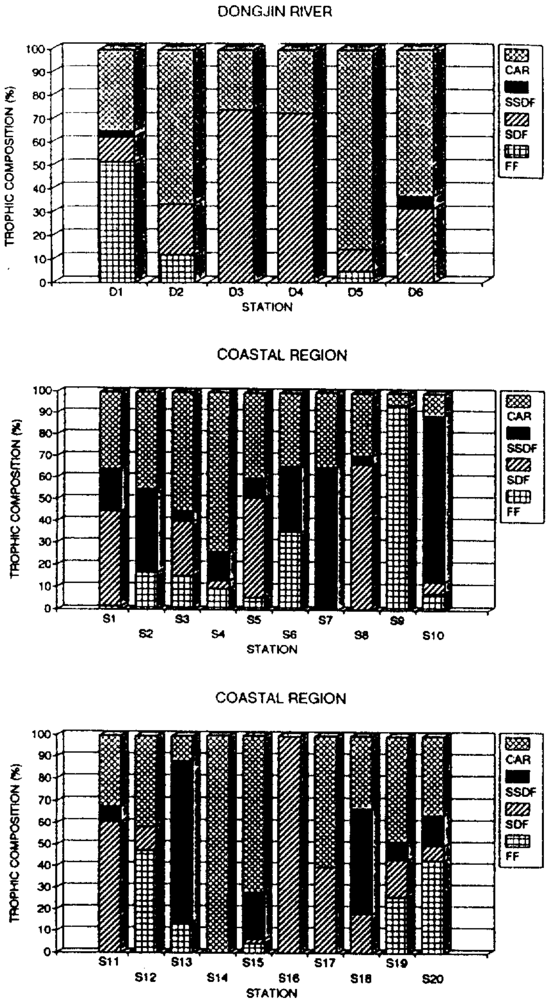

Fig. 3. Continued.

feeders (FF) predominated (Fig. 3). Subsurface deposit feeders (SSDF) and carnivores (CAR) showed relatively high proportion only in the river mouth with maximum value of 20% and 40%, respectively.

In Mankyung Estuary, SDF was confined to the inner area, and the proportion of filter feeders and carnivores was higher than that in Keum Estuary and they gradually replaced SDF toward the river mouth (Fig. 3). In Dongjin Estuary, filter feeders were confined to the inner part and CAR and SDF were major trophic component of this estuarine community, especially at station D3 and D4 (Fig. 3).

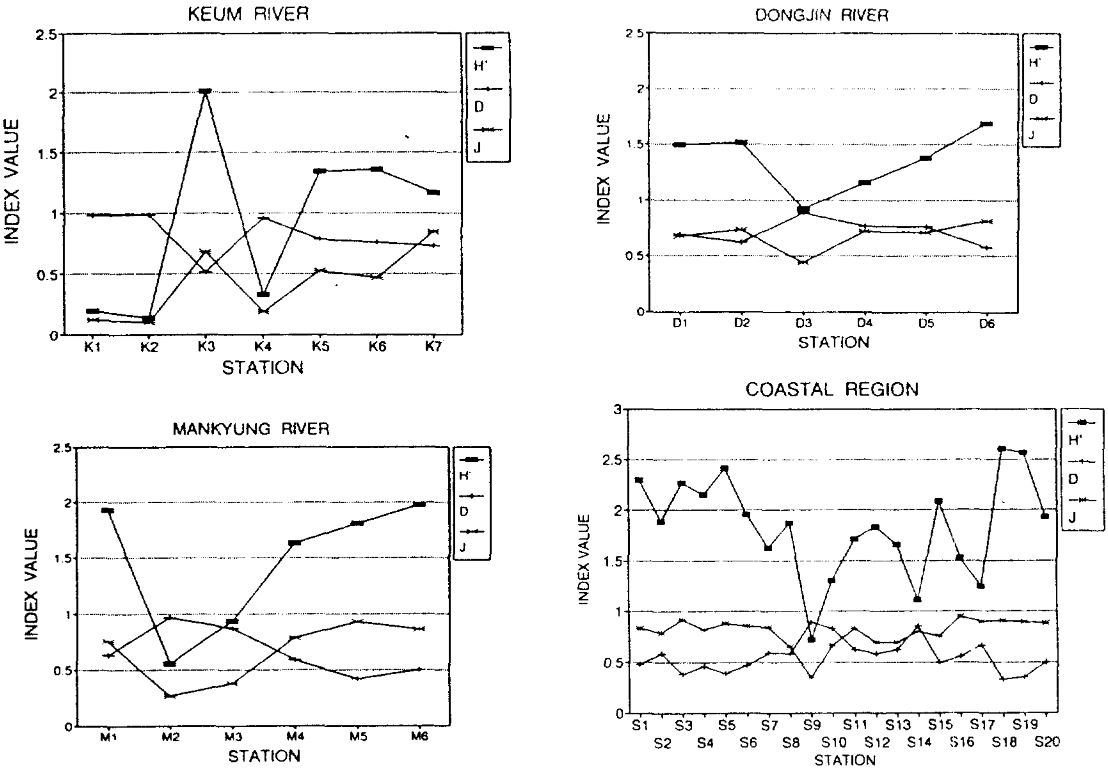

Fig. 4. The community index values along three estuaries and in the coastal region. (H': Shannon-Wiener's diversity index, D: McNaughton's dominance index, J: Pielou's evenness index).

In the coastal region, four feeding types showed a mosaic distributional pattern according to the sediment types (Fig. 3). CAR occurred at all stations, but showed their high proportion at 13 stations mainly composed of mixed sediment types. SSDF which was mainly ristricted to the inner part of estuaries of fine sediment, showed their dominance at six stations: at one station with both sand and silt, 4 stations of silty sand. SDF predominated at seven stations. 5 stations of sand and at both silty sand and sandy silt. FF occurred abundantly at 4 stations. 2 at sand and 2 at silty sand.

The mixed sediment types such as silty sand or sandy silt sustained more diverse feeding types and evener trophic composition than sand or silt. This trend was also seen in three estuaries even though less uniform distribution among feeding types was found.

Ecological indices

The overall species composition is well indicated in the species diversity index (H') and evenness index (J) or dominance index (D). In three estuaries, the overall diversity index value (H') was very low and high dominance index value was shown (Fig. 4). At station K1, K2 and K4, the species diversity index was less than 0.4 and most abundant two species occupied more than 90% of all individuals. At stations M2 and D3, the H' value was less than 1.0. The maximum value of H' was 2.0 at station K3 where 19 taxa were collected. These low species diversity values may be due to the few species number and high dominance of a few species within the communities. In the coastal region, diversity values were higher than those of estuaries, and H' value was over 2.5 and only at station S9, it was less than 1.0 (Fig. 4). This

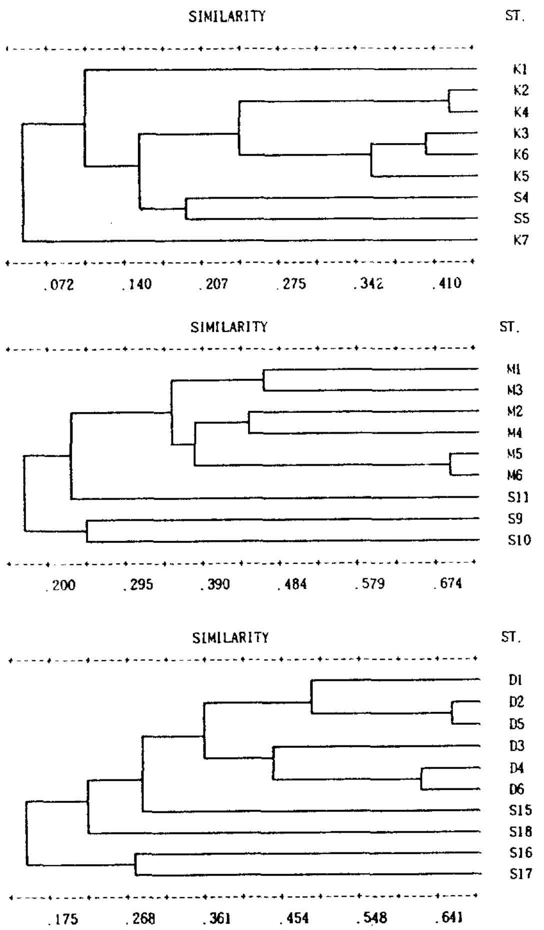

Fig. 5. A dendrogram showing the faunal affinities between stations along each estuary. The estuarine stations (K1-K7, M1-M6, D1-D6) were agglomerated and separated from coastal stations (S4-S 18).

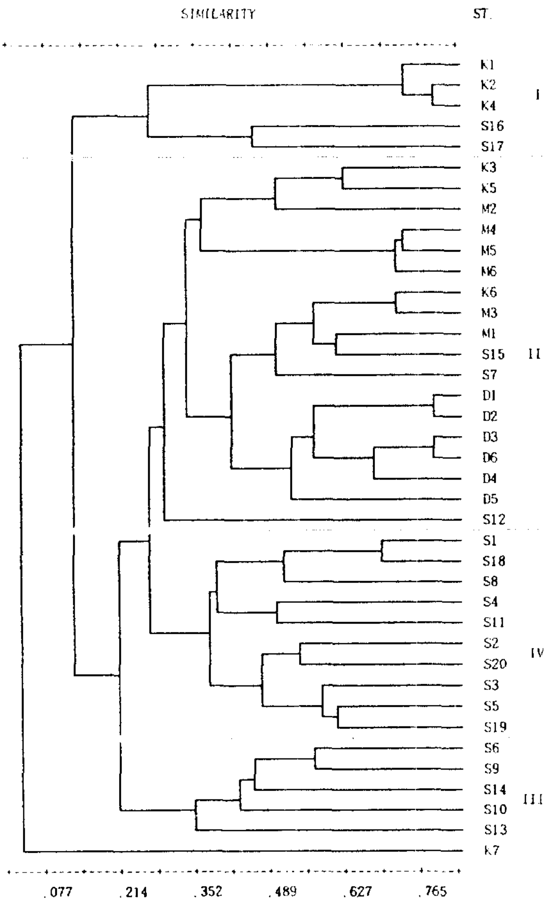

Fig. 6. A dendrogram from the cluster analysis on the whole study area using the abundance data of dominant species by the Bray-Curtis index and weighted group average linkage. Four station groups (I to IV) were emerged.

may be mainly due to the high evenness value over 0.7 and lower dominance compared to those of estuaries.

Faunal affinity

In order to relate the spatial distribution of benthic fauna to the salinity gradient of estuaries, the cluster analysis using Jaccard's index and by weighted pair group average linkage was performed at each estuary along a transect line from the inner part of estuary to the outer coastal area.

The dendrograms resulted from cluster analyses showed that the inner part stations were separated from those in the coastal region (Fig. 5). The species composition of estuaries was different from that of their outer coastal region. Along each estuarine system, the faunal composition was changed gradually from the inner part through the river mouth toward the outer coastal region. The low similarity values between stations of river mouth and coastal region also reflected that a sharp gradient of faunal change existed in the river mouth of each estuary.

Based on the faunal affinity in the whole study area, 4 station groups were largely clustered as seen in the dendrogram (Fig. 6), and also 4 faunal

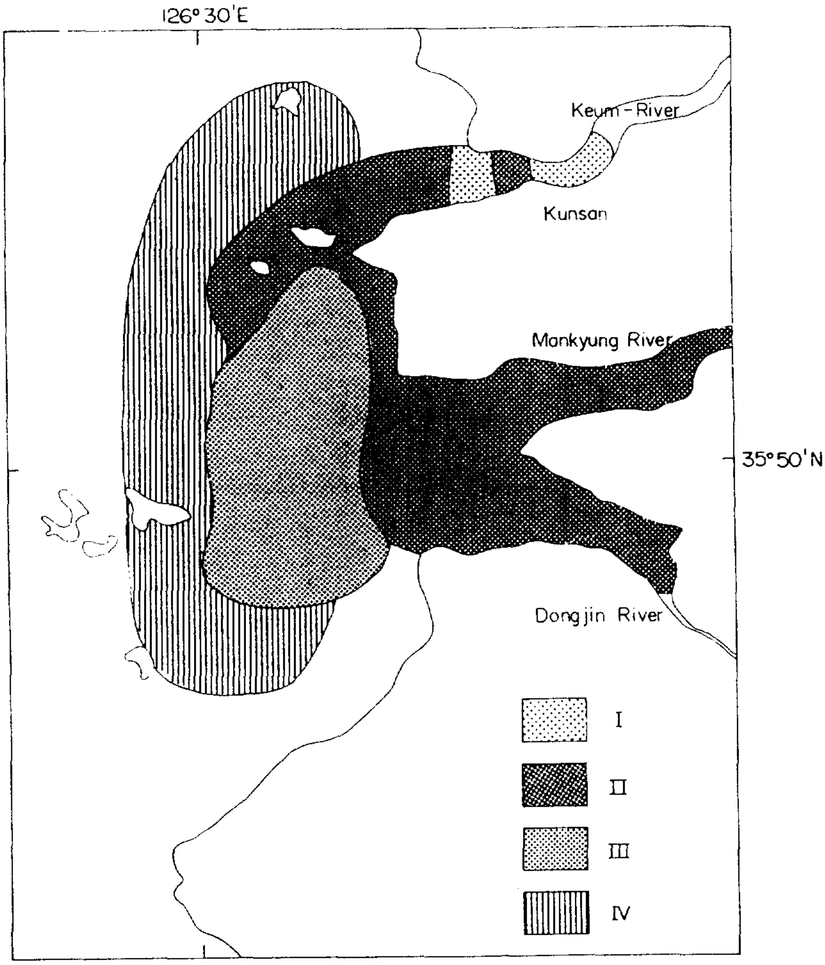

Fig. 7. Spatial distribution of station groups (I-IV) classified by cluster analysis.

groups were emerged although not shown in a figure. For the station groups, this preliminary clustering was adjusted and some stations were reallocated on the regional basis (Fig. 7). Station group I located in the inner part of Keum Estuary was composed of 3 stations, and station group II composed of 19 stations occupied nearly three estuaries. Station group III and IV cover the coastal region off the estuaries, and the former consisted of inner 7 stations and the latter, outer 10 stations.

To see the characteristic species at each station group, the mean abundance of 18 dominant species in four species groups was counted (Table 7). Station group I was solely dominated by a spionid polychaete, *Prionospio cirrifera*. Station group II was occupied by species group A, especially *Potamocorbula amurensis*, and *Prionospio cirrifera* and *Nephtys californiensis* in species group D. Station group III was represented by species group D, especially *Magelona japonica*, and station group IV by species group B, mainly a bivalve *Mactra chinensis*. Species group A is completely restricted in their distribution in estuarine systems while species group B occurred mainly in the open coastal region. Species group C and D showed their high abundance near the river mouths except two species, *P. cirrifera* and *N. californiensis*. These two species appeared more in estuaries and their abundance gradually decreased toward open coastal region.

Table 7. The mean abundance of dominant species in each species group within station groups (unit: indiv./0.2 m²)

Species groups/ station groups	I	II	III	IV
Group A				
Musculus senhausia	*	8	0	0
Potamocorbula amurensis	0	82	0	0
Pseudopolydora kempi	1	3	0	0
Nectoneanthes oxypoda	*	20	0	0
Group B				
Mactra chinensis	0	0	2	21
Mediomastus sp.	0	*	3	5
Prionospio japonicus	0	0	3	9
Group C				
Anaitides koreana	*	7	1	2
Owenia fusiformis	0	6	2	1
Paraprionospio pinnata	0	81	3	0
Group D				
Aricidea jeffreysii	0	0	8	0
Magelona japonica	0	*	14	1
Glycera chirori	0	7	1	*
Nephtys californiensis	*	18	2	5
Prionospio cirrifera	149	19	5	1
Glycinde sp.	0	4	3	4
Nephtys polybranchia	0	1	10	0
Heteromastus sp.	0	1	10	0

*: present but less than 1.0 indiv./0.2 m².

DISCUSSION

Species composition

The dominant species in the estuaries were different from those of the open coastal region. *Prionospio cirrifera* is a small spionid and its distribution is not yet reported in Korean waters. *Potamocorbula amurensis*, a small bivalve species occurred only in the brackish waters. This bivalve species was first found in this study area in Korea and its distribution seems to be confined to this study area. Dominant species in Keum Estuary such as *Pseudopolydora kempi* and *Musculus senhausia* were considered as opportunistic species which occur at highly organically enriched sediments in the river mouth (Shin *et al*., 1992a; Hong *et al*., 1982). The occurrence of these opportunistic species suggest that the Keum Estuary is under the enrichment of organic matters discharged from Kunsan city and upstream of Keum River. The dominant polychaete species in the coastal area, such as *Magelona japonica*, *Owenia fusiformis*, *Anaitides koreana*, and *Nephtys polybranchia*, are all identical to those occurred in the offshore region of the present study area (Lee and Chin, 1989; Choi and Koh, 1992).

The species richness at each sampling station was very low; the maximum value was 19 taxa at station K3 and K6 in Keum Estuary and only 4 taxa were found at station K2, K7 and S17. This low value in species richness is comparable to that of polychaete community at sand and mud sediments off Kunsan, Korea (Choi and Koh, 1992), but very low compared with 124 polychaete species in southern Kyonggi Bay where sandy sediment prevails (Shin *et al*., 1992b). This low species richness may be partly due to the homogeneous sediment of fine sand in estuaries and also partly due to the salinity gradient dropped down from 31‰ to 22‰ even at high tide. Shim *et al*. (1991) reported that the salinity at the river mouth of Mankyung Estuary decresed to less than 18‰ and 28‰ in May and December, respectively. Thus the low species diversity in estuaries suggests that salinity gradient should prevent the invasion of marine benthic fauna into estuarine environment and cause the poor faunal composition.

The overall density of macrobenthic fauna in this study area was estimated as 720 ind·m⁻². This value is a rather higher than that of offshore benthic community off Kunsan, which was collected in Feb. 1985, estimated as 290 ind·m⁻² (Choi and Koh, 1992), and also higher than those reported as 368 ind·m⁻² in southern Kyonggi Bay (Shin *et al*., 1992b). The numerical dominance of polychaete worms in the macrobenthic community was 55% in the range of 6.8~100%. This dominance value of polychaetes is similar to that of polychaete community off Kunsan (52%) and southern Kyonggi Bay (57%), but low compared to those in muddy dominant areas where about 90% of total abundance was from polychaetes.

Trophic composition

The proportion of feeding types of macrobenthic fauna reflects the habitat conditions. Thus in the muddy habitat, subsurface deposit feeders might be major component and in the sandy habitat, sessile filter feeders predominate (Choi and Koh, 1992). Woodin (1976) classified three functional groups of infauna; (1) non-tubicolous motile, deposit feeders, (2) filter feeding bivalves, and (3) tube-builders of various trophic types. The dominance of filter feeders in estuaries was due to the high abundance of a filter feeding bivalve, *Potamocorbula amurensis*, which is assigned to the second category of Woodin's functional groups. The high proportion of carnivores in the trophic composition is a distinctive feature in the shallow sand prevailing coastal regions (Maurer and Leathem, 1981). The carnivores in the study area were all small sized worms which could efficiently handle their small preys. Dominant spionid worms in estuaries, *Prionospio cirrifera* and other species were assigned to the surface deposit feeders (SDF), but this species can aslo be classified into the filter feeder because they switch their feeding mode from SDF to filter feeders when high particulate flux exists or current velocity increases (Taghon *et al*., 1980; Dauer *et al*., 1981). Two most dominant species in estuaries, *Potamocorbula amurensis* and *Prionospio cirrifera*, showed an alternative patchy distribution, especially in Keum Estuary, and this distributional pattern can be partly explained by the competition on the food and habitat between infauna within the same functional group.

REFERENCES

An, S. and C.-H. Koh. 1992. Environmental and distribution of benthic animals on the Mankyung-Dongjin tidal falt, west coast of Korea. *J. Oceanol. Soc. Korea*, **27**: 78-90 (in Korean).

Bae, K.S. and I.B. Yoon. 1989. Study on the environmental characteristics and dynamics of benthic macroinvertebrates in Naktong Estuary. Korean *J. Limnol.*, **22**: 11-27.

Cho, B.C. and J.H. Shim. 1992. Significance of estuarine mixing in distribution of bacterial abundance and production in the estuarine system of the Mankyung River and Dongjin River, Korea. *J. Oceanol. Soc. Korea*, **27**: 154-163.

Choi, J.Y. 1993. Seasonal variations of suspended matters in the Keum estuary and its adjacent coastal area. *J. Oceanol. Soc. Korea*. **28**: 272-280 (in Korean).

Choi, J-W. and C-H. Koh. 1992. The distribution and feeding guilds of the polychaete community in the west coast off Kunsan, Korea. *J. Oceanol. Soc. Korea*. **27**: 197-209.

Chung, J.Y. and I.K. Bhang. 1984. Circulation dynamics of the Keum River estuary. II. Fluid dynamic characteristics. *J. Oceanol. Soc. Korea*, **19**: 141-152.

Dauer, D.M., C.A. Maybury and R.M. Ewing. 1981. Feeding behaviour and general ecology of several spionid polychaetes from the Chesapeake Bay. *J. Exp. Mar. Biol. Ecol.*, **54**: 21-38.

Gambi, M.C. and A. Giandrande. 1986. Distribution of soft-bottom polychaetes in two coastal areas of the Tyrrhenian Sea (Italy): structural analysis. *Estuar. Coast. Shelf Sci.*, **23**: 847-862.

Gaston, G.R. and J.C. Nasci. 1988. Trophic structure of macrobenthic communities in the Calcasieu Estuary, Louisiana. *Estuaries*, **11**: 201-211.

Hong, S.Y., U.J. Han, and E.I. Paik. 1982. Marine macrobenthos distribution and the substrate conditions of Suyeong Bay. Publ. Inst. Mar. Sci. Nat. Fish. Univ. Busan, **14**: 1-21.

Jones, A.R., C.J. Waston-Russell and A. Murray. 1986. Spatial patterns in the macrobenthic communities of the Hawkesbury Estuary, New South Wales. Aust. J. Mar. Freshw. Res., **37**: 521-543.

Lee, J-H. and P. Chin. 1989. Quantitative importance and species composition of polychaetes in the benthic community of the Yellow Sea. Bull. Korean Fish. Soc., **22**: 189-195 (in Korean).

Livingston, R.J., 1976. Diurnal and seasonal fluctuations of organisms in a North Florida Estuary. Estuar. Cosat. Shelf Sci., **4**: 373-400.

Maurer, D., L. Watling, W. Leathem, and P. Kinner. 1979. Seasonal changes in feeding types of estuarine benthic invertebrates from Delaware Bay. *J. Exp. Mar. Biol. Ecol.* **36**: 125-155.

Maurer, D.M. and W. Leathem. 1981. Polychaete feeding guilds from Georges Bank, USA. Mar. Biol., **62**: 161-171.

Park, Y.A., S.C. Kim and J.H. Choi. 1986. The distribution and transportation of fine-grained sediments on the inner continental shelf off the Keum River estuary, Korea. Cont. Shelf Res., **5**: 499-519.

Probert, P.K., 1984. Disturbance, sediment stability, and trophic structure of soft-bottom communities. *J. Mar. Res.*, **42**: 893-921.

Ristich, S.S., M. Crandall, and J. Fortier, 1977. Benthic and epibenthic macroinvertebrates of the Hudson River. I. Distribution, natural history and community structure. *Estuar. Coast. Shelf Sci.*, **5**: 253-266.

Sanders, H.L., P.C. Mangelsdorf, Jr., and G.R. Hampson. 1965. Salinity and faunal distribution in the Pocasset River, massachusetts. Limnol. & Oceanogr., **10**: R216-R229.

Schaffner, L.C., R.J. Diaz, C.R. Olsen and I.L. Larsen. 1987. Faunal characteristics and sediment accumulation processes in the James River estuary, Virginia.

Estuar. Coast. Shelf Sci., **25**: 211-226.

Schubel, J. R., H. T. Shen, M. J. Park. 1984. A comparison of some characteristic sediment processes of estuaries entering the Yellow Sea. In: Proc. Korea-U.S. Seminar and Workshop on Marine Geology and Physical Processes of the Yellow Sea, edited by Y. A. Park, O. H. Pilkey and S. W. Kim, 286-308.

Shim, J. H., Y-K. Shin, and H-G. Yeo. 1991. Abiotic environment and primary producer of estuarine pelagic ecosystem in the lower water of the Mangyung river and the Dongjin river. I. Environmental characteristics and phytoplankton community structure. *J. Oceanol. Soc. Korea*, **26**: 155-168 (in Korean).

Shin, H-C., -S. Choi, and C-H. Koh, 1992a. Seasonal and spatial variation of polychaetous community in Youngil Bay, southeastern Korea. *J. Oceanol. Soc. Korea*, **27**: 46-54 (in Korean).

Shin, H-C., S-G. Kang, and C-H. Koh, 1992b. Benthic polychaete community in the southern area of Kyeonggi Bay, Korea (in Korean).

Sun, S. and Y. Dong, 1985. Ecological control of polychaete distributions in the Changjiang estuary and adjacent waters. Cont. Shelf Res., **4**: 215-225.

Taghon, G. L., A. R. M. Nowell and P. A. Jumars, 1980. Induction of suspension feeding in spionid polychaetes by high particulate fluxes. Science, **210**: 562-564.

Woodin, S. A., 1976. Adult-larval interactions in dense infaunal assemblages: Patterns of abundance. *J. Mar. Res.*, **34**: 25-41.

Accepted September 2, 1994