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A Study on the Polychaete Community in Kwangyang Bay, Southern Coast of Korea

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光陽灣의 多毛類群集에 관한 硏究

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Abstract: This study was conducted to interpret the relations between the polychaete community and its environments in Kwangyang Bay during July, 1982. The type of sediments in the study area varies from sand to clay and the organic content obtained by ignition was in the ranges of 0.3% to 15.4%. The polychaetes which occurred at 25 stations comprised 70 species representing 63 genera and had an average density of 490 animals/m^2. The most abundant species were *Lagis bocki* (20%), *Lumbrineris longifolia* (15%), *Chone teres* (7%) and *Sternaspis scutata* (5%). The polychaete populations show the highest density in muddy sand sediments and have a tendency to decrease their abundance in finer sediments such as mud and clay. The individual numbers of each feeding type show the same tendency. Kwangyang Bay consists of three distinct characteristic communities, representing different physical and biological factors: delta community, muddy flat community and channel community. Delta community has very poor organisms and seems to be determined by physical factors such as tidal current, and by sediment conditions and by the food availability. Muddy flat community shows more diverse and higher abundance than delta community, but seems to be impoverished by the stress of oxygen deficiency in sediments. Channel community has the highest density in the study area and comprises more various feeding types. This is probably due to the supply of allochthonous materials from the Seomjin River and offshore as food, the heterogeneous sediments and some biological interactions within habitats.

要約: 본 연구의 목적은 潮下帶 軟性底質에 서식하는 多毛類 群集을 중심으로 이들의 종조성, 종다양성, 지역별 분포의 특징 및 食餌型 등과 환경과의 관계를 논의코저함이다. 대상지는 光陽灣으로 만내의 25개 조사지점을 선정, 1982년 7월에 조사가 실시되었다. 출현 다모류는 총 63속 70종으로 개체수의 견지에서 중요 출현종은 *Lagis bocki* (20%), *Lumbrineris longifolia* (15%), *Chone teres* (7%), *Sternaspis scutata* (5%) 등이다. 퇴적물상에 따른 多毛類의 출현개체수는 泥沙質에서 가장 높으며 泥質퇴적상으로 갈수록 감소하는 경향을 보인다. 食餌型에 따른 출현개체수로는 表層下堆積物食者가 광양만 전체에 걸쳐 우세하게 나타나고(58.4%), 表層堆積物食者(21.4%), 肉食者(11.1%), 濾過食者(9.1%) 순으로 그 출현빈도가 감소한다. 光陽灣의 다모류군집은 현존량, 우점종, 종다양성 및 식이형조성 등의 결과에 의해 沙質환경의 델타군집, 泥質환경의 內灣군집 및 泥沙質환경인 水路군집 등 3개 군집으로 대별된다. 各 多毛類 群集에 영향을 주는 환경요인을 보면 델타지역의 다모류群集은 沙質퇴적상과 강한 潮流에 의한 퇴적물의 不安定性, 낮은 有機物含量에 의한 먹이부족 등이며, 內灣지역의 다모류군집은 퇴적물내 溶存酸素의 부족에 의해, 水路지역의 다모류군집은 외부로부터의

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먹이공급, 底質의 다양한 粒度組成, 種간경쟁, 捕食, 管棲多毛類에 의한 퇴적물의 安定性 등에 의해 영향을 받고 있다. 특히 理·化學的 환경조건이 유사한 곳에서는 生物學的인 相互作用이 다모류 群集構造에 중요한 요인이 되고있다.

INTRODUCTION

The polychaetes which inhabit in the soft bottom have been known as an important benthic animal group in respect of their numerical abundance and species richness in the soft bottom community (Sanders 1958, Young and Rhoads 1971, Yi 1975, Lee 1976). The distribution pattern of polychaetes would be determined primarily by environmental factors such as the composition of grain size or the organic content in sediments (Sanders 1958). The food supplied in the habitats would determine the composition of feeding types which reflects the feeding strategies of benthic fauna (Levinton 1972, Jumars and Fauchald 1977). There will be also biological competition between polychaete worms inhabiting in the same space, when they have the same feeding strategies and require the same kind of food. We should therefore consider the biological interactions, such as interspecific competition (Woodin 1976), predation (Virnstein 1977) and trophic amensalism (Rhoads and Young 1970), as environmental factors which control the community structure of this benthic animal.

Studies on the benthic fauna of the Korean coasts and estuaries have mainly focused on distribution patterns in relation to the degree of industrial pollution (Lee 1976, Hong *et al.* 1983, Yi *et al.* 1982, etc.). They did not give a comprehensive interpretation on the construction processes of communities and the structural differences which could be understood through interactions of environmental complexity.

This paper is aimed at understanding the relationship between the polychaete community and its environmental conditions which would play the main role in constructing and controlling the community structure. We have considered physical conditions and some sediment properties, e.g., the composition of grain size and the content of organic matter in sediments, as significant environmental factors. Some biological parameters such as density, species composition, species diversity and the feeding type of polychaete were investigated.

STUDY AREA

This study was conducted at 25 stations in Kwangyang Bay (Fig. 1) in July, 1982. Kwangyang Bay is a semi-enclosed estuarine bay which receives fresh water from the Seomjin River and has a well developed sandy delta in the northern part. The bay has three main channels with the depths of 20~30m. The study area consists of several regions, each of

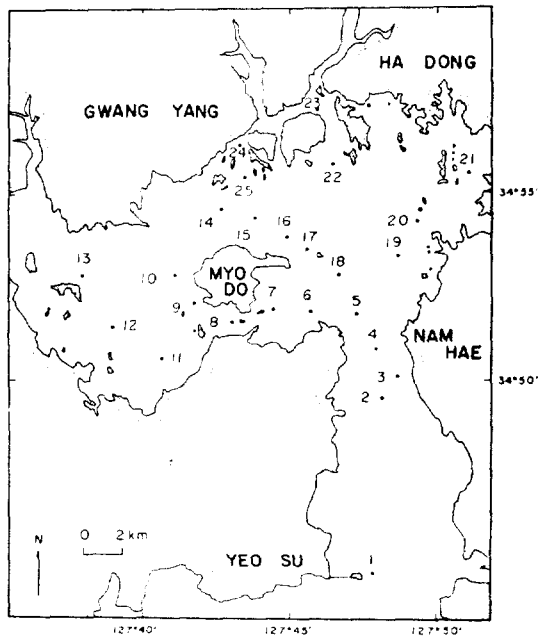

Fig. 1. A map showing sampling stations in the study area.

which shows characteristic pattern in environmental conditions such as salinity, tidal range, tidal current velocity and sediment facies. The tidal type of this area is a mesotidal in the range of 290 cm to 335 cm. Noryang Strait has the highest tidal current velocity up to 130 cm/sec in contrast to the western region with its maximum velocity of 25 cm/sec. The difference of sedimentary environments such as bottom topography and current velocity results in distinct sedimentary facies (Park et al. 1984). Under the influence of river discharge during summer season the salinity of study area ranges from 16.5‰ in the delta region up to 30‰ in the inner bay.

METHODS

The samples were collected using a Van Veen type bottom sampler (sampling area 0.1m^2) at 25 stations. Duplicate samples were taken at each station. The sediments were sieved through a 1 mm mesh sieve and the retained animals was fixed in 10% formalin solution. The polychaetes were sorted in the laboratory and were identified to species level (Paik 1982, Imajima and Hartman 1964, etc.), and those with complete body or head part were counted as one individual for the estimation of density in each station. Shannon-Weaver's function was used to calculate species diversity index, $H'=-\Sigma(ni/N)\ \log_2\ (ni/N)$. Dominance index was obtained from Simpson's formula, $C=\Sigma(p_i)^2$ and evenness index from Pielou's, $J'=H'/\log\ S$.

The feeding modes of polychaetes in the study area could be categorized into four groups: subsurface deposit feeder, surface deposit feeder, filter feeder and carnivores. All the polychaetes occurred in the study area were classified into these four categories based on the literatures describing the feeding modes of polychaetes (Jumars and Fauchaid 1977, Fauchald and Jumars 1979). Direct observation on the gut contents of polychaetes was also performed to confirm the feeding types in the study area.

Sediment samples were also collected for the particle size analysis and organic content determinations. The salt and organic matter in the sediments were removed to prevent the aggregation of clay particles. Sand fractions were determined by sieve analysis and silt clay fractions by pipetting. Mean grain size(Mz) and sorting coefficient(σ_I) were calculated from the graphic technique computation using Folk's equation and sediments were classified by the ternary diagram. The organic content of sediments was estimated as the loss in weight of dried material (100°C, 24 h) after combustion (550°C, 4h).

RESULTS

Bottom sediment

The bottom sediments of Kwangyang Bay showed six types and each sediment type had distinct characters in sorting value and organic content (Table 1). For example, sandy sediment had the lowest organic content and was moderately sorted, while muddy sand sediment showed an intermediate value in organic content and the worst sorting condition (except St. 18) probably due to the high energy of tidal current.

On the basis of these results the study area could be divided into 3 regions: delta region of sandy sediments, inner bay region of muddy sediments and channel region of mixed sediments. Each region could be represented by the following characteristics of sediment conditions. The lowest organic content and sorting values were shown in the delta region, the highest organic content and intermediate sorting values in the inner bay, and intermediate organic content and the highest sorting values in the channel region of the bay. The sorting value at St. 18 in the channel region was 1.78 ϕ and this value is exceptionally low compared with

Table 1. Sediment properties: grain size composition, mean grain size(Mz), sorting value (σ_I), sediment types and organic content at each station in July, 1982.

Stations	Grain size composition (%)			$Mz(\phi)$	$\sigma_I(\phi)$	Sediment types	Organic contents (%)
	sand($4\phi<$)	silt($4-8\phi$)	clay($>8\phi$)				
1	7.2	45.4	47.4	8.1	2.71	mud	7.0
2	6.5	47.8	45.7	7.7	2.28	〃	7.9
3	69.5	12.3	18.2	2.5	4.00	muddy sand	6.9
4	6.1	41.2	52.7	8.4	2.62	mud	15.7
5	62.4	18.2	19.4	4.1	3.71	muddy sand	4.2
6	6.3	26.9	66.8	9.1	2.43	clay	10.9
7	16.8	15.7	67.5	8.0	3.21	sandy clay	10.1
8	49.4	20.7	29.9	5.0	4.02	sandy mud	6.5
9	5.6	16.7	77.7	9.7	2.33	clay	11.1
10	4.7	37.8	57.5	8.6	2.63	mud	11.2
11	1.9	25.2	72.9	9.9	2.11	clay	8.0
12	6.7	21.9	71.4	9.2	2.87	〃	8.1
13	0.6	34.1	65.3	9.1	2.29	mud	14.5
14	71.9	14.8	14.2	5.0	3.39	muddy sand	4.6
15	67.1	13.4	19.5	4.1	3.97	〃	3.6
16	56.8	22.0	21.2	5.0	3.07	〃	7.4
17	48.0	23.9	28.1	5.6	3.45	sandy mud	5.3
18	86.1	6.6	7.3	2.7	1.78	muddy sand	4.4
19	54.5	15.9	29.6	5.3	3.68	〃	6.0
20	34.6	34.8	30.6	4.6	2.70	sandy mud	7.1
21	62.7	12.0	25.3	3.2	4.88	muddy sand	10.1
22	94.0	3.4	2.6	1.4	1.36	sand	1.0
23	99.1	0.9	—	1.2	0.62	〃	0.4
24	99.4	0.6	—	0.5	0.95	〃	0.5
25	99.7	0.3	—	1.0	0.43	〃	0.3

other stations in this region. This is partially due to the high densities of *Lagis bocki* and *Lygdamis giardi* which build their tubes with sand particles.

Polychaete Community

The polychaetes which occurred at 25 stations comprised 70 species representing 63 genera and had an average density of 490 animals/m^2, but they show regional differences in species composition and abundance (Table 2). For examples, in the north channel of Myodo (St. 14, 15, 18, etc.) and Noryang channel (St. 19, 20, 21) occurred more than 20 species, but in the delta region there occurred only one or two species. The highest values in both species number and density are shown at St. 18, the lowest value at St. 23 and 24. The most abundant species in the study area were *Lagis bocki*(20%), *Lumbrineris longifolia*(15%), *Chone teres*(7%), and *Sternaspis scutata*(5%). These 4 species comprise 47% of the total individuals collected from all stations. Each species had its distributional range. *Lumbrineris longifolia*, which occurred at 19 stations, shows the broadest distributional range. The occurrence of such species as *Lagis bocki*, *Chone teres*, *Lygdamis giardi* are restricted in some regions in spite of their importance in abundance (Fig. 2).

The study area could be classified into 3 regions in respect of the species richness, abundance and dominant species of polychaetes: delta region, inner bay region and channel

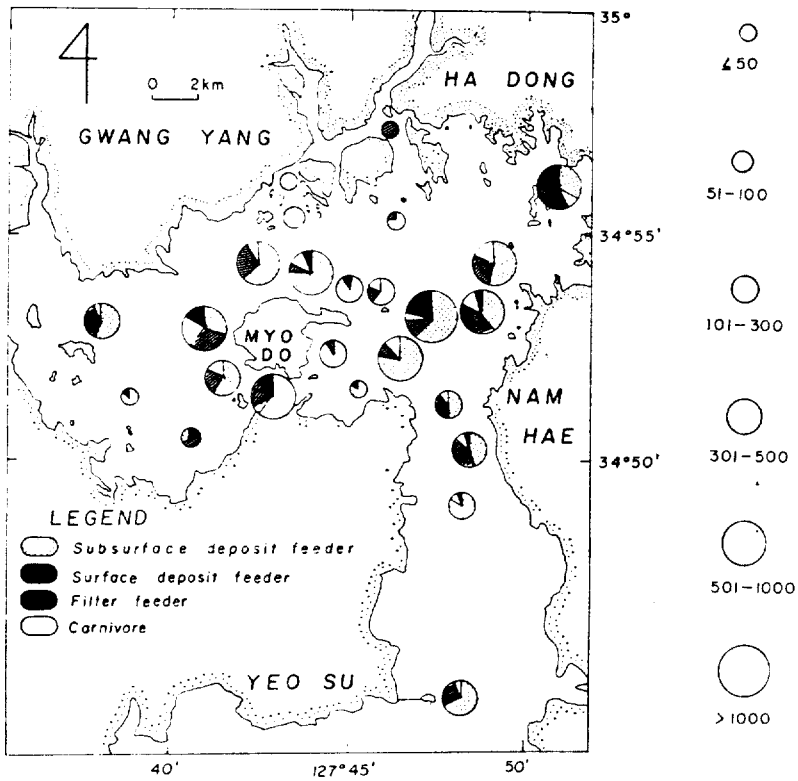

Fig. 2. Spatial pattern of distribution in abundance of polychaetes. Total numerical abundance for each station is represented relatively and abundance of dominant species is shown proportionally in each circle.

region. Delta region is mainly inhabited by *Armandia lanceolata* and *Nepthys* sp. and shows a very impoverished community with low diversity and abundance. The inner bay is dominated with *Lumbrineris longifolia*, but this region could be divided into two sub-regions in terms of their species number and abundance. One sub-region including St. 9, 10 and 13 shows high values of the species number and abundance, the other sub-region composed of St. 11 and 12 has very low values. The channel region is characterized by its great abundance and species number. There is significance in dividing this region into three sub-regions which have their characteristic species and their species compositions. The dominant species in the north and south channel of Myodo were *Lagis bocki* and *Glycera chirrori* respectively. *Terebellides stroemi*, *Lumbrineris longifolia* and *Chone teres* were the predominant species in the Noryang channel, among these *T. stroemi* is rocognized as a typical species occurring in this sub-region.

We should mention the fact that the channel region community exhibited distinctive composition of dominant species in a relatively small area (Table 3). The most dominant species inhabiting at St. 14 are *Sternaspis scutata* and *Amphisamytha japonica*, but these species occur at St. 15 in lower concentration. St. 15, in which the density of *Sternaspis scutata* and *Amphisamytha japonica* is low, is represented with the species *Lagis bocki* and *Lumbrineris longifolia*. There are also an inverse relation between St. 5 and St. 18 in respect of the densities of inverse relation between St. 5 and St. 18 in respect of the densities of domin-

Table 2. The number of species, numerical abundance of polychaetes, species diversity(H′), dominance(C) and evenness(E) at each station.

Station	No. of species	Density	H′	C	E	Station	No. of species	Density	H′	C	E
1	12	445	2.52	0.27	0.68	14	21	740	3.59	0.11	0.82
2	8	160	2.22	0.34	0.74	15	19	780	2.78	0.26	0.65
3	17	490	3.91	0.08	0.94	16	7	265	1.37	0.58	0.49
4	20	330	3.53	0.14	0.79	17	6	130	2.29	0.24	0.89
5	18	980	2.39	0.40	0.57	18	33	2,985	2.61	0.35	0.51
6	5	40	2.16	0.25	0.93	19	26	870	4.00	0.09	0.83
7	7	310	1.51	0.48	0.54	20	20	755	3.74	0.10	0.87
8	25	655	3.74	0.12	0.81	21	25	640	3.90	0.10	0.83
9	16	375	3.13	0.20	0.76	22	2	20	0.81	0.63	0.81
10	33	605	4.07	0.11	0.81	23	1	10	—	1.00	—
11	5	80	2.16	0.25	0.92	24	1	10	—	1.00	—
12	4	50	1.92	0.28	0.96	25	1	70	—	1.00	—
13	17	395	3.30	0.14	0.81						

Table 3. The distribution of dominant species and feeding types in three regions of the study area

Regions		Delta	Inner bay			Channel									Other Stations						Total individual number
			Southern	Northern		South	North channel of Myodo						Noryang Channel								
Stations		22 23 24 25	11 12	9 10 13		8	14 15 16 17 18 5						19 20 21			1 2 3 4 6 7						
Dominant species	*Lagis bocki*	— — — —	— —	— — —		—	95 360 200 — 1,700 20						5 — —			— — 10 — — —						2,425(20.0%)
	Lumbrineris longifolia	— — — —	10 10	145 55 90		—	85 140 20 30 10 570						65 140 120			10 10 20 100 — 200						1,830(15.0%)
	Chone teres	— — — —	— —	5 165 —		115	— 45 — — 290 —						5 — 125			— — 40 10 — —						800 (6.6%)
	Sternaspis scutata	— — — —	— —	5 10 90		—	150 — 20 50 — —						25 20 5			10 90 30 50 10 5						570 (4.7%)
	Nephtys sp.	15 — — —	10 —	15 30 10		—	60 10 — — 165 40						85 10 15			20 10 60 10 — —						565 (4.7%)
	Terebellides stroemi	— — — —	30 —	10 30 20		—	35 5 5 20 25 20						150 90 40			— — 20 15 — —						515 (4.3%)
Feeding types	Subsurface deposit feeder	15 — 10 70	30 40	235 165 225		45	445 600 240 80 1,980 730						380 400 250			310 130 210 210 35 290						7,125(58.4%)
	Surface deposit feeder	5 10 — —	50 —	85 195 150		125	220 60 25 30 280 100						365 220 210			120 10 190 90 5 5						2,610(21.4%)
	Filter feeder	— — — —	— —	5 165 —		115	— 50 — — 590 —						10 — 125			— — 40 10 — —						1,110 (9.1%)
	Carnivore	— — — —	— 10	50 70 20		370	75 65 — 20 140 110						110 130 55			20 20 60 20 — 15						1,360(11.1%)

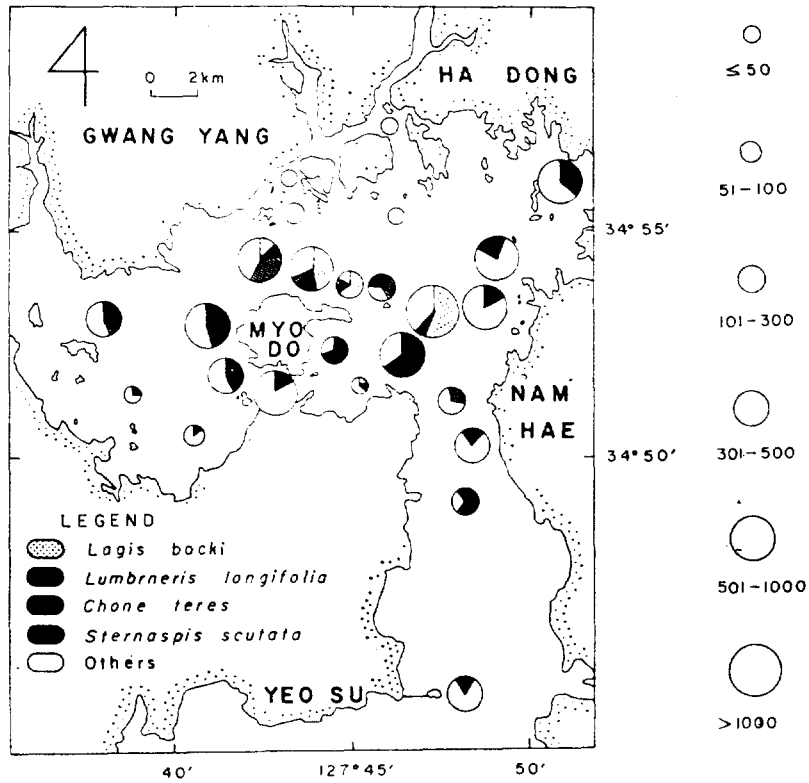

Fig. 3. Relative abundance for each feeding type of polychaetes in Kwangyang Bay.

ant species, though these two stations adjoin each other. *Lumbrineris longifolia* shows high density of 570/m² at St. 5 where that of *Lagis bocki* is 20/m², while the density of *Lagis bocki* at St. 18 is up to 1700/m² in contrast to the low value (10/m²) of *Lumbrineris longifolia*.

The species diversity shows different values from region to region (Table 2). The lowest values are found in the delta region (0~0.81); the highest values occur in the northern part of the inner bay (3.13~4.07) and in the Noryang channel region (3.74~4.00). The values of the species diversity have a tendency to increase gradually from the delta region to the inner bay and the channel region. The diversity indices show a relationship with sorting coefficients (σ_I). Stations with high diversity in the channel region have high values of sorting coefficicients. In the stations with low values of σ_I, low diversity indices have appeared. As exceptions, there are some stations in the north channel of Myodo where their low diversities are shown, though sorting coefficients in most of the channel region are high.

All polychaetes occurred in the study area were classified into four feeding types according to their feeding strategies, and individual number of each feeding type was calculated (Table 3). Subsurface deposit feeders which burrow and feed on the detritus in the sediment comprise 58.4% of total polychaetes. Surface deposit feeders which feed close to the sediment-water interface occupy 21.4%. Filter feeders and carnivores accounting for a small fraction of total individual number were dominant at a few stations. Filter feeders represented by the species *Chone teres* and *Lygdamis giardi* occurred with high density at stations 8, 10, 18 and 21, carnivores were dominant only at St. 8 located in the south

Table 4. Organic content, individual number of each feeding type and total density in each sediment type. All values are arithmatic mean at each sediment type. SSDF: Subsurface deposit feeder; SDF: Surface deposit feeder; FF: Filter feeder; C: Carnivore.

Sediment type	Organic content (%)	SSDF	SDF	FF	C	Total density
Clay	0.93	85	35	1	15	136
Mud	11.26	208	113	33	26	388
Sandy clay	10.10	290	5	—	15	310
Sandy mud	6.30	175	125	38	173	513
Muddy sand	5.90	604	181	102	77	971
Sand	0.55	24	4	—	—	28

channel of Myodo. The feeding types occurred in the study area are different from region to region (Fig. 3). In the delta region and stations 6, 7, 11, 12 and 16, the subsurface deposit feeders were mainly dominated, but various feeding types were found in the channel region. Filter feeders and surface deposit feeders, which are sessile animals and have their sandy or muddy tubes, occurred with high density where subsurface deposit feeders were relatively scarce.

Numerical abundance and the type of feeding modes of polychaetes seems to be determined by their habitat conditions such as sediment type and organic content in sediments. The average density of polycaetes occurring in muddy sand sediments show the highest value (971/m^2), it decreased in clay sediments (136/m^2) and the lowest value (28/m^2) is shown in sandy sediments habitat (Table 4). We conclude from this result that the mixed sediment could be more populated than the sandy or fine sediment. All feeding types except carnivores showed the highest abundance in muddy sand sediments. Contents of organic matter in each sediment type are negatitively correlated with the densities of polychaetes in it when the sediment is rich in organic matter. But this relation is inversed in the case of sandy sediment where the organic content is extremely low.

DISCSUSION

Kwangyang Bay was divided into three regions which are represented by delta region, inner bay region and channel region. Each region has its characteristic sedimentary facies: sandy facies in delta region, muddy facies in inner bay and mixed facies in channel region. The polychaete community in each region shows also distinctive structure in relation to its habitat conditions such as sedimentary facies and other physical factors. We will discuss the relationship between the structure of polychaete community and its environments.

Delta region, shallow sand flat habitat

This region shows sandy facies and the abundance of polychaete worms is very low (Table 3). The feeding type of dominant species in this region belongs to the deposit feeder. No filter feeding polychaete are occurred. According to Sanders (1958), Rhoads and Young (1970), filter feeders should be abundant in the sandy sediment due to the continuous supply of foods when the velocity of the current is moderate (e.g. below 15cm/sec). But Wildish and Kristmanson (1979) indicated that filter feeders in the sandy sediment would have a very low density if the velocity of the current is beyond 25cm/sec, because this strong current creates the unstable, constantly moving substrate and inhibits the ingestion of food materials. From the facts of the absence of filter feeders and the low density of deposit feeders in this delta

region, we could conclude that the abundance of polychaetes would be greatly influenced by the environmental factors such as rapid tidal current (35~45cm/sec) and unstable sediments. We should also regard the content of organic matter in sediment as a limiting factor in this region. *Armandia lanceolata* and *Nepthys* sp. which were dominant in this delta region have low density of below 70 ind./m^2. But they showed high density in the intertidal sandy sediment of Yongho Bay located at southeastern coast of Korea, which has a high organic content of 4.7% to 12.2% (Yi, 1975).

Inner bay region, muddy flat habitat

This region was divided into two sub-regions for their structural differences of the polychaete community. We suppose that these differences could be attributed to the degree of oxygen supply. There are no marked differences in sediment properties and tidal current velocity. According to Sanders (1958), the density of benthic animals should be low if the sediment contains extremely high proportion of clay particles. In the fine sediment occurs the depletion of oxygen and therefore animals inhabiting in it would be depressed and excluded. The sub-region which contains the stations located near the pathway of water circulation can be supplied with more oxygen and so this sub-region would have a higher density of polychaetes.

Channel region, current influenced habitat

The channel region which is characterized by deeper water, strong tidal current and mixed sediments shows large polychaete populations in contrast to any other regions in Kwangyang Bay. This region was divided into three sub-regions: Noryang channel, north channel and south channel of Myodo.

The Noryang channel showed high diversity of species and high density. This sub-region is predominantly inhabited by tube builders which are represented as surface deposit feeders. The high diversity and high density of polychaetes in this channel region could be explained by the stable state of sediments achieved by those tube building animals. Young and Rhoads (1971) stated that the bottom sediment, though lain under the influence of the strong current, could be densely populated if the sediment is stabilized by biological activities. The sediment facies represented as a mixed type in this sub-region also contribute to this rich and diverse polychaetes community. Lee *et al.* (1983) reported that benthic animals were rich in abundance and diverse in Garolim Bay where the heterogeneous sediment was shown.

Each station in the north channel of Myodo is populated by its characteristic species with extremely high density. Dominant species such as *Lagis bocki*, *Lumbrineris longifolia*, *Sternaspis scutata* and *Nepthys* sp., which are named subsurface deposit feeder, show high population density in each preferential habitat of this sub-region. *Chone teres* and *Lygdamis giardi*, which are classified as the filter feeder for their feeding modes, have the same tendency as above mentioned species. The neighboring two stations such as St. 5 and St. 18 show an inverse relation between their dominant species, *Lagis bocki* and *Lumbrineris longifolia*, namely these two stations show an inverse pattern of dominant species in spite of their similar habitat conditions. We could consider this as a result of a biological interaction. *Lagis bocki* is a tube builder. According to Woodin (1676), tube builders would restrict the amount of infaunal space by their tube building activities and therefore exclude other species. It seems that the low dedsity of *Lumbrineris longifolia* at St. 18 has resulted from the high activities of a large population of *Lagis bocki*. On the other hand, *Lumbrineris longifolia*, although this species is considered as subsurface deposit feeder on the basis of its gut content, is known as carnivore

(Fauchald and Jumars, 1979). The distribution and abundance of other species at St. 5 might be greatly influenced by this predatory character of the species *Lumbrineris longifolia*.

The south channel of Myodo represented by St. 8 shows high diversity value ($H'=3.74$) and is predominantly inhabited by the species *Glycera chirrori*, which occupies a small portion in the density of other stations. The species *Lumbrineris longifolia* and *Nepthys* sp. occurred with low densities at this station, even though they show high densities over all Kwangyang Bay. It is probably due to the carnivorous character of *Glycera chirrori* that the high diversity of polychaetes at St. 8 and the low densities of *Lumbrineris longifolia* and *Nepthys* sp. at this station are shown.

The channel region generally shows higher densities of polychaetes compared with other regions in the study area. According to Park *et al.* (1984) and Kim (1984), considerable amounts of allochthonous suspended materials, mainly consisted of silt or clay particle size, are supplied from the Seomjin River and offshore into over all the channel region. These suspended materials contain a high content of organic matters and therefore may play an important role in supplying foods for benthic animals such as filter feeders and deposit feeders in this region.

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