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Seasonal Variations in Species Composition and Abundance of Fish and Decapods in an Eelgrass (*Zostera marina*) Bed of Jindong Bay

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Abstract : *The objectives of this study to determine seasonal changes in species composition and abundance of fish and decapod assemblage, and the relationships between environmental factors and their abundance in an eelgrass bed of Jindong Bay. A total of 26 fish species and 29 decapod species were collected by a small beam trawl from an eelgrass bed in Jindong Bay in 2002. The dominant fish species were Hexagrammos otakii, Pholis neulosa and P. fangi and these accounted for 48.4 % in the total number of individuals. Dominant decapod taxa were Palaemon macrodactylus, Charybdis japonica, Pagurus minutus and C. bimaculata. These were primarily small species or early juveniles of larger species. Species composition and abundance varied greatly showing a peak in the number of individuals in April and May, and peak biomass in fish in July and decapods in August. Catch rate was low in winter months both in fish and in decapod. Seasonal changes in the abundance of fishes and decapods corresponded with eelgrass biomass and abundance of food organisms indirectly.*

Key Words : *Fish, Decapods, Hexagrammos otakii, Pholis neulosa, Pholis fangi, Palaemon macrodactylus, Charybdis japonica, Pagurus minutus, Charybdis bimaculata, Eelgrass biomass, Jindong Bay*

1. Introduction

Zostera marina (eelgrass) is the most common seagrass species in temperate coastal areas, and increases habitat complexity and provides living space and shelter for marine animals (Klumpp et al., 1989; Connolly et al., 1999; Hemminga and Duarte, 2000). Many fish and decapod species use eelgrass beds as feeding and nursery grounds, including many economically important fishes (Nelson, 1981; Edgar and Shaw, 1995; Huh and Kwak, 1997a; Huh and An, 1997; Guidetti and Bussotti, 2000). Some studies have been made on eelgrass bed in Korea to determine seasonal variation in species composition and abundance of fishes in Kwangyang Bay, Hamduck around Cheju Island and Angol Bay (Huh and Kwak, 1997a; Go and Cho, 1997; Lee et al., 2000) and feeding habits of particular fish species (*Acanthogobius flavimanus*, *Platycephalus indicus*, *Liparis tanakai* and *Pleuronectes yokohamae*) in the Southern sea, Korea (Huh and Kwak, 1999; Kwak and Huh, 2002; 2003a; 2003b).

Large eelgrass beds are developed in Jindong Bay, southern Korea, and provide a habitat for variety of invertebrates and small fish, which in turn are the potential food of large fishes. Although some ecological studies on fish in the eelgrass bed have been conducted in the Bay, their interest in the studies is confined to feeding habits of some fish species (Kwak and Huh, 2004; Kwak et al., 2004; Kwak et al., 2005).

The objective of this study was to examine the seasonal variation in species composition and abundance of fishes and decapods inhabiting an eelgrass bed of Jindong Bay, Korea and to determine the relationships between environmental factors and fish and decapod abundance.

2. Materials and Methods

The eelgrass bed of Jindong Bay (Fig. 1) is forming subtidal bands (500~700 m wide) in the shallow water (< 3 m), and forming patches for about 4 km along the shore.

Fish and decapod samples were collected monthly by 5-m beam trawl (1.9-cm mesh wing and body, 0.6-cm mesh liner). Four 6-min tows in each sampling time were carried out during the day in an eelgrass bed throughout 2002. Specimens were preserved immediately in 10 % formalin after capture and later transferred to 70 % isopropanol. These samples were identified according to Masuda et al. (1984), Kim (1973), NFDRI (2001) and Kim et al. (2005) and weighed to the nearest gram in wet weight.

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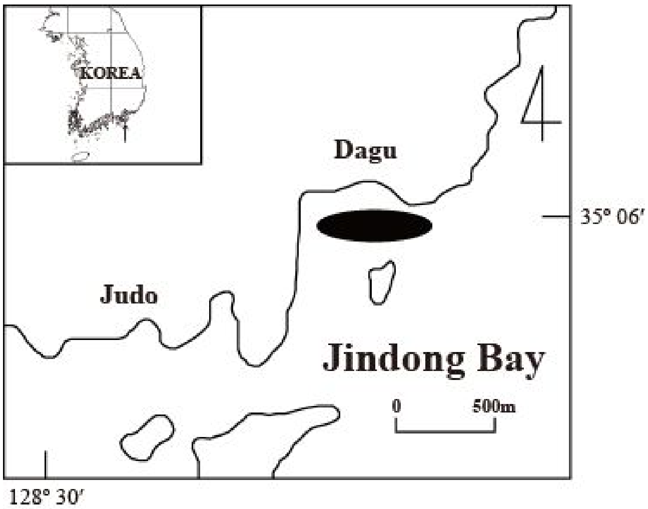

Fig. 1. Map of study sites in Jindong Bay, Korea. Black area is eelgrass bed.

Specimens were measured to the nearest millimeter (fish, standard length SL; shrimp, carapace length CL; crabs, carapace width CW). Crabs were separated on the basis of sex.

Surface water temperature (by thermometer) and salinity (by salinometer) were monitored monthly on each sampling occasion. The eelgrass biomass was estimated from all plant bodies taken in a sea bottom of 0.01 m^2. The plants were separated into the above- and below-ground parts, dried at 80 ℃ for 24h then weighed to the nearest gram.

The fish and decapod data was analyzed to obtain the following community variables. Diversity H' (Shannon and Weaver, 1949) was calculated as:

$$H' = \sum\left[\frac{n_i}{N}\times\log\left(\frac{n_i}{N}\right)\right] \qquad (1)$$

where n is the number of individuals of each i species in a sample and N is the total number of individuals.

Association of fish and decapod species, Pianka's similarity index (Pianka, 1973), A_{ij} was calculated as:

$$A_{ij} = \frac{\sum(P_{ih}\times P_{jh})}{\sqrt{\sum P_{ih}^2\times\sum P_{jh}^2}} \qquad (2)$$

where A_{ij} is the similarity of species j on species i; P_{ih} is the proportion of individuals of a species i in a particular month h; P_{jh} is the proportion of individuals of a species j in a particular month h. Values for the similarity index may vary between 0, if no similarity occurs, and 1 for complete similarity. The Pianka's similarity index was subjected to an average linkage cluster analysis.

A one-way ANOVA with orthogonal design was used to analyze variations in fish abundance and environmental factors with season. The relationships between fish and decapod abundance and eelgrass biomass were analyzed using Pearson's correlation coefficient.

3. Results

3.1 Water temperature, salinity, and eelgrass biomass

Water temperature at the study site ranged from 7.4 ℃ to 27.7 ℃ and varied significantly with months (one way ANOVA, df=11, F=13.77, $p < 0.05$). The peak of water temperature was around July, a decline in October and a minimum during winter (Fig. 2A). Salinity ranged from 28.7 ‰ to 34.2 ‰ and did not vary

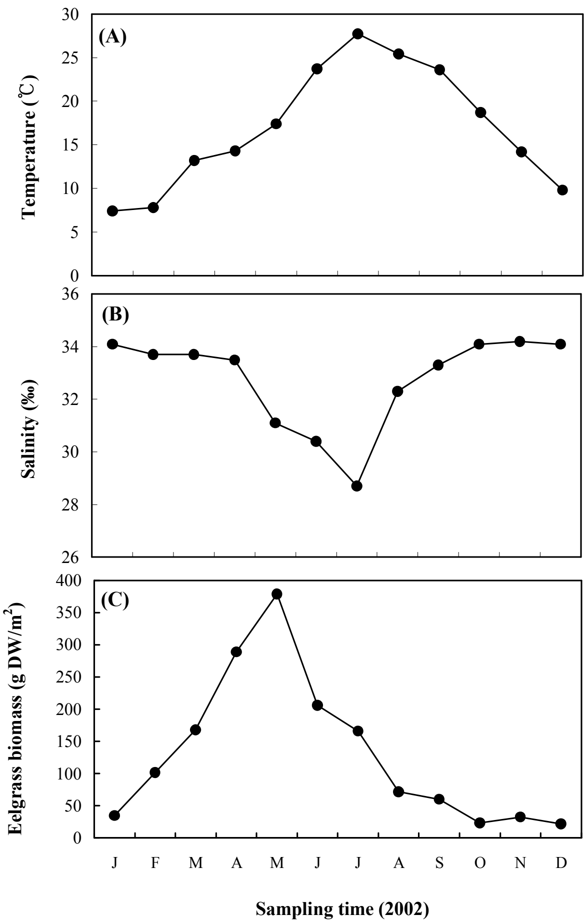

Fig. 2. Monthly variations of water temperature, salinity and eelgrass biomass in an eelgrass bed of Jindong Bay in 2002.

significantly among months (one way ANOVA, df=11, F=2.11, $p > 0.05$) with display a similar pattern except in July when it dropped (about 28 ‰) (Fig. 2B). The average eelgrass biomass ranged from 21.8 g DW/m^2 to 378.7 g DW/m^2 and varied significantly with months (ANOVA, $p < 0.05$). The peak of eelgrass biomass was around May, and a sharp decline in June and a minimum in December (Fig. 2C).

3.2 Fish and decapod species composition

A total of 2,143 fish belonging to 26 species were collected (Table 1). Numerically dominant fish were *Hexagrammos otakii* (17.9 %), *Pholis nebulosa* (15.6 %), *P. fangi* (14.9 %), *Acanthopagrus schlegeli* (9.4 %), *Lateolobrax japonicus* (9.3 %), *Leiognathus nuchalis* (5.3 %) *Acentropagrus pflaumi* (4.6 %), *A. flavimanus* (4.2 %), and *Pseudoblennius cottoides* (4.0 %), together accounting for 85.3 % of the catch and 80.9 % of biomass. The dominant fish species were primarily small fish species or young juveniles. Only about 10 % exceeded 5 cm SL.

A total of 2,039 decapods, belonging to 29 species (15 shrimp, 2 hermit crab and 12 crab species) were collected (Table 2). Numerically dominant species were *Palaemon macrodactylus* (19.4 %), *Charybdis japonica* (15.2 %), *Pagurus minutus* (8.9 %), *C. bimaculata* (8.4 %), *Alpheus digitalis* (7.0 %), *Hemigrapsus penicillatus* (6.5 %), *Crangon affinis* (6.2 %), and *C. uritai* (5.8 %). These made up 77.3 % of numbers of individuals and 85.0 % of total biomass. Most individuals were relatively small: 0.2 to 1.8 cm CL for shrimps and 0.2 to 7.2 cm CW for crabs.

3.3 Seasonal variation in abundance of fish and decapods

The number of fish species (5~17 species) varied with seasons (one-way ANOVA, df=11, F=4.85, $p < 0.05$). Fish species was

Table 1. Abundance and standard length of fish collected by a beam trawl in an eelgrass bed of Jindong Bay in order of decreasing number of individuals

Species	N	Percentage	B	Percentage	Standard length range (cm)
Hexagrammos otakii	384	17.9	6,184.7	42.6	4.5~16.3
Pholis nebulosa	334	15.6	426.5	2.9	4.1~18.6
Pholis fangi	319	14.9	362.0	2.5	3.7~15.8
Acanthopagrus schlegeli	202	9.4	1,396.3	9.6	2.9~10.2
Lateolabrax japonicus	200	9.3	1,054.1	7.3	2.1~11.1
Leiognathus nuchalis	114	5.3	288.2	2.0	2.5~6.9
Acentrogobius pflaumi	99	4.6	194.1	1.3	2.2~5.9
Acanthogobius flavimanus	91	4.2	1,736.5	12.0	4.2~13.1
Pseudoblennius cottoides	86	4.0	96.4	0.7	2.3~7.2
Repomucenus valenciennei	71	3.3	553.3	3.8	2.6~9.8
Silago japonicus	51	2.4	1,117.2	7.7	3.7~10.6
Hippocampus japonica	35	1.6	43.0	0.3	1.2~7.6
Rudaris ercodes	29	1.4	48.3	0.3	2.2~5.3
Takifugu niphobles	25	1.2	535.2	3.7	6.2~10.3
Pseudoblennius percoides	24	1.1	88.0	0.6	3.6~7.1
Syngnathus schlegeli	18	0.8	59.4	0.4	9.5~21.3
Sebastes inermis	17	0.8	33.1	0.2	1.6~4.9
Sebastes longispinis	13	0.6	17.8	0.1	1.5~4.5
Sebastes schlegeli	10	0.5	19.4	0.1	1.5~5.6
Pleuronectes yokohamae	6	0.3	148.1	1.0	6.8~9.7
Hypodytes rubrippins	5	0.2	26.4	0.2	2.3~4.2
Clupea pallasii	4	0.2	4.2	0.0	7.3~12.2
Zoarces gilli	2	0.1	18.5	0.1	7.3~8.1
Ditrema temmincki	2	0.1	65.6	0.5	8.3~8.5
Sardinella zunasi	1	<0.1	1.0	<0.1	7.6
Chaenogobius heptacanthus	1	<0.1	0.7	<0.1	2.5
Total	2,143	100	14,518.0	100	

N: Number of individuals, B: Biomass(g)

Table 2. Abundance and standard length of decapods collected by a beam trawl in an eelgrass bed of Jindong Bay in order of decreasing number of individuals

Species	N	Percentage	B	Percentage	Range of CL[a] and CW[b]	
Penaeiodea						
Penaeidae						
Trachysalambria curvirostris	86	4.2	155	1.5	0.7~1.7	
Marsupenaeus japonicus	12	0.6	19.9	0.2	1.1~1.5	
Metapenaeus joyneri	7	0.3	54.5	0.5	0.8~1.3	
Caridea						
Palaemon macrodactylus	395	19.4	128.9	1.3	0.3~1.2	
Alpheus digitalis	142	7	63.6	0.6	0.2~1.8	
Crangon affinis	127	6.2	73.6	0.7	0.4~1.3	
Crangon uritai	119	5.8	70.8	0.7	0.2~1.1	
Latreutes anoplonyx	61	3	18.6	0.2	0.3~1.3	
Palaemon ortmanni	41	2	55.1	0.5	0.4~1.4	
Eualus leptognathus	38	1.9	15.4	0.1	0.2~1.3	
Crangon hakodatei	18	0.9	32.8	0.3	0.5~1.3	
Palaemon gravieri	15	0.7	0.8	<0.1	0.4~1.2	
Heptacarpus pandaloides	13	0.6	0.3	<0.1	0.3~1.6	
Tozeuma tomentosum	10	0.5	3.2	<0.1	0.5~0.9	
Lysmata vittata	4	0.2	0.1	<0.1	1.1~1.3	
(Subtotal)	1,088	53.4	692.6	6.7		
Anomura						
Pagurus minutus	181	8.9	101.8	1		
Upogebia major	58	2.8	172.6	1.7		
(Subtotal)	239	11.7	274.4	2.7		
Brachyura					Female	Male
Charybdis japonica	310	15.2	5,507.7	53.5	0.7~6.8	1.4~7.2
Charybdis bimaculata	171	8.4	2,737.9	26.6	0.8~6.2	1.1~5.9
Hemigrapsus penicillatus	132	6.5	65.3	0.6	0.2~1.3	0.1~0.9
Pugettia quadridens	47	2.3	69.8	0.7	0.5~1.1	0.6~1.3
Portunus trituberculatus	17	0.8	413.4	4.0	1.1~1.3	1.2~1.4
Telmessus acutidens	10	0.5	326	3.2	0.7~4.6	0.8~5.2
Gaetice depressus	7	0.3	24.1	0.2	1.3~1.6	1.6~1.8
Sphaerozius nitidus	7	0.3	5.6	0.1	1.2~1.3	1.1~1.4
Tritodynamia rathbuni	6	0.3	6.5	0.1	0.2~0.8	0.2~0.4
Portunus sanguinolentus	3	0.1	156.4	1.5	0.3~0.6	0.8~0.9
Hemigrapsus sinensis	1	<0.1	1.7	<0.1	0.3	
Carcinoplax vestita	1	<0.1	6.7	0.1		0.7
(Subtotal)	712	34.9	9,321.1	90.6		
Total	2,039	100	10,288.1	100		

N : Number of individuals, B: Biomass(g)
[a]CL:Carapace length in shrimps
[b]CW:Carapace width in crabs

abundant in April and May (Fig. 3A). Number of individuals varied significantly with seasons (one-way ANOVA, df=11, F=11.13, $p < 0.05$, Fig. 3B). A large number of fish were collected from April to July when *H. otakii, P. nebulosa. P. fangi, L. japonicus,* and *A. schlegeli* were abundantly occurred. Fish numbers was low in January and February (Appendix 1). The fish biomass differed substantially between different seasons (one-way ANOVA, df=11, F=6.65, $p < 0.05$, Fig. 3C). Higher biomass was in July and August when big-sized *H. otakii, A. schlegeli, L. japonicus, A. flavimanus*, and *Sillago japonicus* were present (Appendix 2). The range of diversity index was 0.72~2.32, and higher value was in May and August (Fig. 3D).

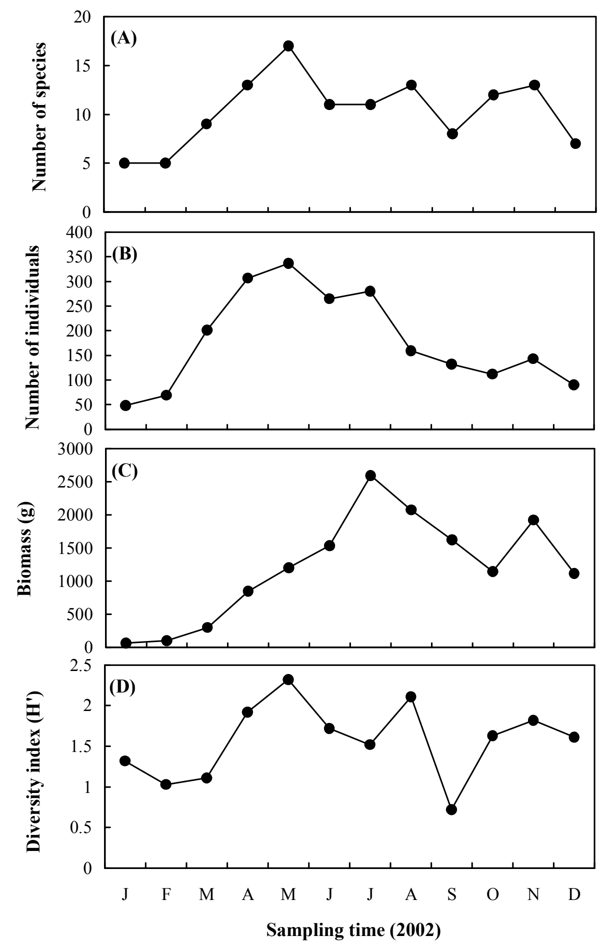

Fig. 3. Monthly variations in (A) number of species, (B) number of individuals, (C) biomass, and (D) diversity index of fishes collected by a beam trawl in an eelgrass bed in Jindong Bay in 2002.

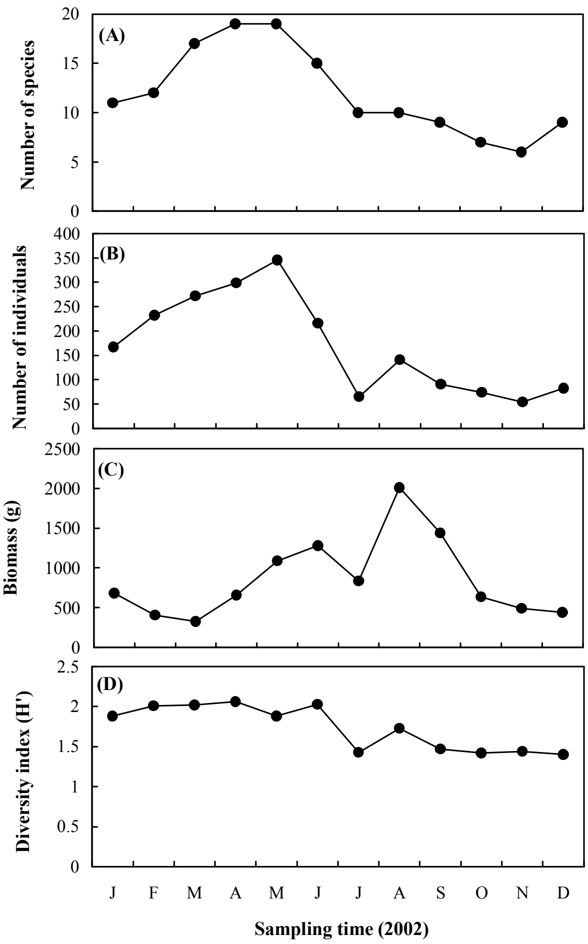

Fig. 4. Monthly variations in (A) number of species, (B) number of individuals, (C) biomass, and (D) diversity index of decapods collected by a beam trawl in an eelgrass bed in Jindong Bay in 2002.

The one-way ANOVA revealed that the number of decapod species (df=11, F=17.86, $p < 0.05$), number of decapod individuals (df=11, F=8.88, $p < 0.05$), and decapod biomass (df=3, F=8.45, $p < 0.05$) differed significantly between seasons. Number of decapod species was more than 14 species from March to June, and number of decapod individuals was the highest in May which were dominated *P. macrodactylus, C. japonica, Trachysalambria curvirostris*, and *A. digitalis* (Fig. 4A, 4B). The biomass of decapods was high in August and September (Fig. 4C), when an abundance of large *C. japonicus* and *C. bimaculata* were found (Appendix 2). The study area had similar value of diversity regardless of month, suggesting that the number and relative abundances of decapods were similar over study periods (Fig. 4D).

The dendrogram shows three clusters which identify the fish species (Fig. 5). The group 1 was composed of *P. fangi*, *P. nebulosa*, *H. otakii*, *A. flavimanus*, *L. japonicus*, *A. pflaumi*, *Hippocampus japonica*, *A. schlegeli*, and *Silago japonicus* with occurring predominantly over study periods. This group can be further divided into two subgroups: subgroup 1 contains *P. fangi*, *P. nebulosa* and *H. otakii*, with large numbers from March to May when eelgrass biomass was large in the study area, while subgroup 2 composed of *A. flavimanus*, *L. japonicus*, *A. pflaumi*, *H. japonica*, *A. schlegeli*, and *S. japonicus* with peak numbers from June to August. The group 2 was composed of *L. nuchalis*, *Rudaris ercode*, *Takifugu niphobles*, *Repomucenus valenciennei*, *Ditrema temmincki*, and *Pleuronectes yokohamae* which were peak numbers from September to November. These periods were coincided with the period of small eelgrass biomass. The group 3

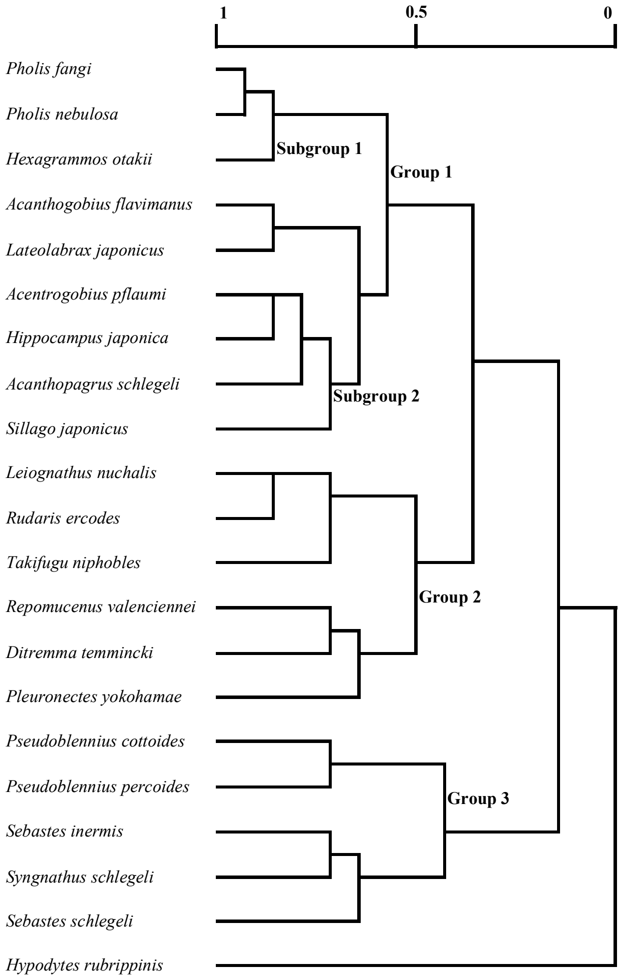

Fig. 5. Dendrogram illustrating the species associations of fishes collected by a beam trawl in an eelgrass bed in Jindong Bay in 2002.

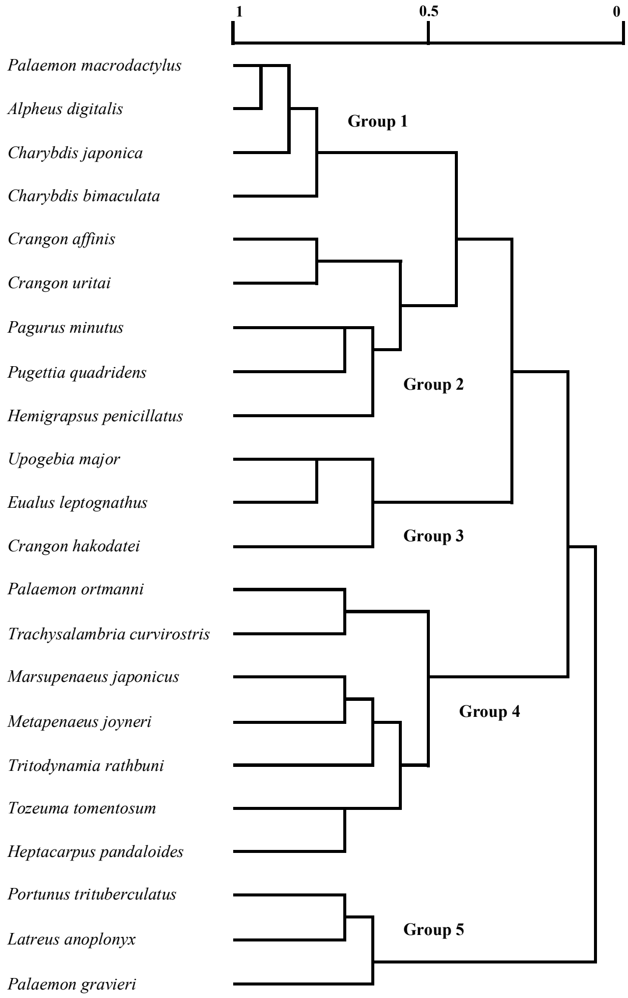

Fig. 6. Dendrogram illustrating the species associations of dacapods collected by a beam trawl in an eelgrass bed in Jindong Bay in 2002.

was composed of *Sebastes schlegeli*, *Syngnathus schlegeli*, *S. inermis*, *Pseudoblennius cottoides* and *P. percoides*. This group was high numbers from March to June when water temperature was increased. while, individuals were few in other periods.

The dendrogram shows five clusters which identify the decapods species (Fig. 6). The group 1, consisting of *P. macrodactylus*, *A. digitalis*, *C. japonica*, and *C. bimaculata*, occurred predominantly over the study period in the study area, being comparatively large in number of individuals in May and June, when the eelgrass biomass was large. This group also occurred predominantly over the study period. The group 2 was composed of *C. affinis*, *C. uritai*, *P. minutus*, *Pugetiia quadridens*, and *H. penicillatus*, which occurred with large number in March and April when water temperature was being increased. The group 3 consists of *Upogebia major*, *Eualus leptognathus*, and *C. hakodatei*, which occurred in February and March. The group 4 was composed of *P. ortmanni*, *Trachysalambria curvirostris*, *Marsupenaeus japonicus*, *Metapenaeus joyneri*, *Tritodynamia rathbuni*, *Tozenuma tomentosum*, and *Heptarcarpus pandaloides* with occurrence from March to June, and the group 5 was composed of *Portunus trituberculatus*, *Latreus anoplonyx*, and *P. gravieri* with occurrence from August to October when eelgrass biomass and water temperature were decreased.

3.4 Relationships between abundance and environment factors

Water temperature, salinity and eelgrass biomass variations corresponded closely with seasonal variation of the abundance of

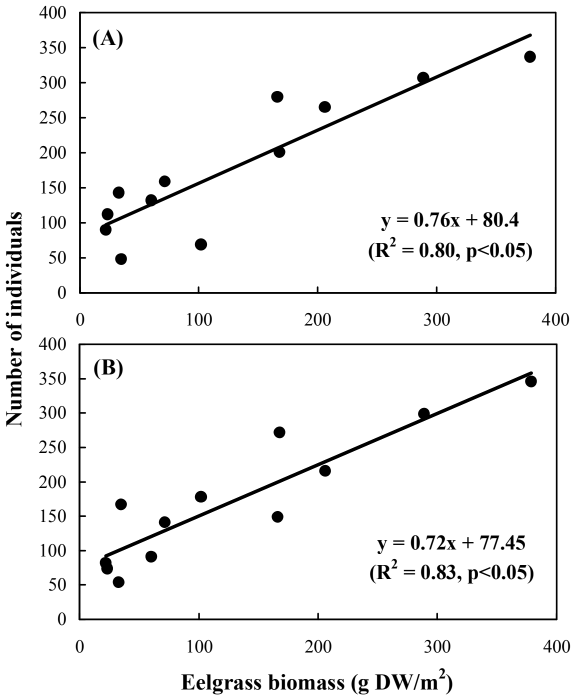

Fig. 7. Relationships between number of individuals of fishes (A) and decapod (B) and eelgrass biomass in an eelgrass bed.

fishes and decapods over the study period. There are only signigicant relationships between water temperature and salinity and abundance of fish ($p < 0.05$). However, number of individuals of both fish (r^2=0.80, $p < 0.05$) and decapods (r^2=0.83, $p < 0.05$) were correlated with eelgrass biomass (Fig. 7).

4. Discussion

A total of 26 fish species was recorded from an eelgrass bed of Jindong Bay and of these *H. otakii*, *P. neulosa*, *P. fangi*, *A. schlegeli*, *L. japonicus*, *L. nuchalis*, *A. pflaumi*, *A. flavimanus*, and *P. cottoides* were numerically dominant. Most of fish species are of commercial and recreational importance. For example *H. otakii, A. schlegeli* and *L. japonicus* are valued as live fish in the Southern area, Korea, and *P. nebulosa* and *P. fangi* harvested as a food fish (Kim and Kang, 1993; Kim et al., 2005).

Broad-scale surveys of fish communities in the eelgrass beds from other regions of Korea suggest a similar community structure. Very similar species composition of fish showed in Myoungjuri eelgrass bed where close to present study area (Baeck et al., 2005). Comparing with other regions, *H. otakii*, *P. fangi*, *P. cottoides*, and *P. nebulosa* also dominated the fish community in Kwangyang Bay (Huh and Kwak, 1997a), *A. schlegeli*, *P. nebulosa* in Angol Bay (Lee et al., 2000), and *H. otakii*, *P. nebulosa* in Hamduck around Cheju Island (Go and Cho, 1997). Kikuchi (1966; 1974) reported that the genera *Hexagrammos*, *Pseudoblennius*, *Pholis* were also dominant fish groups in the eelgrass beds of Tomioka Bay, Japan. Although there are some difference in dominant species among regions, it seems that the seagrass habitats of Northwestern Pacific show similar fish and decapod species composition.

The 29 decapod species collected from an eelgrass bed of Jindong Bay were mostly shrimps. *P. macrodactylus* and *A. digitalis* were the dominant species followed by *C. affinis* and *C. uritai*. Studies of the eelgrass bed of Kwangyang Bay showed that *C. affinis*, *C. uritai*, *A. digitalis*, and genera *Palaemon* were dominant in that order (Huh and An, 1997). Compared with eelgrass beds of temperate regions in worldwide, the genera *Alpheus* and *Crangon* were common groups in Tomioka Bay, Japan (Kikuchi, 1966), and *Crangon* and *Palaemon* were also dominated the decapod communities of seagrass beds in Western Port Bay, Australia (Howard, 1984; Connolly et al., 1999). Caridean shrimps in particular were in high abundance, as well as the genera *Palaemon*, *Crangon*, and *Alpheus*. These taxonomical groups were abundant in seagrass beds regardless of locations and sampling gear used.

Fish collected from the Jindong Bay eelgrass bed appeared to be dominated by small fish and juveniles of most species. This indicated that an eelgrass bed of Jindong Bay function as nursery areas. Such conclusions are in general agreement with other studies of seagrass beds (Huh and Kwak, 1997a; Go and Cho, 1997; Rozas and Minello, 1998; Lee et al., 2000; Nagelkerken et al., 2002). A significantly greater abundance of decapod juveniles than that of adults in our study site at Jindong Bay confirmed that also these species were likely to be dependent on seagrass beds for shelter and survival during the early life cycle stages (Coles and Lee Long, 1985; Turnbull and Mellors, 1990; Haywood et al., 1995; Vance et al., 1996; Huh and An, 1997).

Seasonal variation in both species composition and abundance appear to be considerable for fish and decapod communities utilizing eelgrass bed. In Jindong Bay, number of individuals was highest in May. These peaks in abundance corresponded closely with peak eelgrass biomass and prey availability. Seasonal variation of eelgrass biomass in Jindong Bay was marked. When eelgrass biomass increased from March, the number of fish and decapod individuals also increased, and numbers declined with decreases in eelgrass biomass from September. Higher diversity indices of fish have been recorded corresponding with increased species number, abundance and eelgrass biomass. However, the biomass of both fishes and decapods were relatively high when eelgrass standing crops were low. It seems that larger individuals were abundant due to low eelgrass density and can be captured easily by fishing gear. Several other studies have demonstrated a positive correlation between faunal richness and abundance and the aboveground biomass of seagrass beds (Nelson 1981; Leber, 1985; Bell and Pollard, 1989; Heck and Weinstein, 1989; Huh and Kwak, 1997a; Connolly et al., 1999). Other studies have shown similar patterns of variable faunal abundance in fish communities of eelgrass beds, Korea. For example, the fish abundance increased with increasing eelgrass biomass and water temperature in Angol Bay (Lee et al., 2000), and similarly in Hamduck off Cheju Island (Go and Cho, 1997). Huh (1986) have demonstrated that seasonal variation of fish abundance in Hansilpo, Chungmu was correlated positively with water temperature. Features of eelgrass beds such as shoot density and length can influence faunal abundance, and this has been shown best with decapods. The density of caridean shrimps was significantly associated with eelgrass biomass and living-space in an eelgrass bed of Kwangyang Bay (Huh and An, 1997).

Dominant species showed distinct seasonal occurrence patterns. The seasonal abundance of many species can be attributed to their reproductive habits. For example, the increase in abundance of pholidae species including *P. nebulosa* and *P. fangi* recorded during the winter and spring was consistent and coincides with their spawning season (Kang et al., 1996; Hwang and Lee, 2001). Panaeid shrimp such as *T. curvirostris* and *M. japonicus* mainly occurred their adult individuals during spawning seasons (Minagawa et al., 2000; Oh et al., 2003). Similarly, other species including *A. schlegeli*, *L. japonicus*, *L. nuchalis*, *A. pflaumi*, *A. flavimanus* and *R. valenciennei* occurred as juveniles in large numbers around spawning season. It appears that these species rely on eelgrass bed as a nursery ground. Whereas, the consistent occurrence of some species such caridian shrimps, hermit crabs and *Charybdis* crabs in this area suggest that these species undergo their whole life-cycle in this zone.

Prey availability may also be an important factor influencing faunal abundance in an eelgrass bed. High seagrass standing crop provides good shelter and food resources for small organisms such as epiphytic epifauna (Amphipods, Isopods, Tanaids etc.) (Klumpp et al., 1989; Klumpp and Kwak, 2005). Small fishes such as dominant fish species (e.g. *H. otakii, P. nebulosa, P. fangi, A. schlegeli,* and *L. japonicus*) in Jindong Bay fed mainly on small amphipods and isopods (Kwak unpublished data). The seasonal abundance of epiphytic epifauna coincided with these groups of dominant fishes during the study period. These common fish changed diets from gammarid amphipods and copepods to decapods such as caridean shrimps and crabs as they increased in size (Kwak and Huh, 2004; Kwak et al., 2004; Kwak et al., 2005). Other studies of feeding habits of fishes have reported similar correlated temporal variation in abundance of epiphytic epifauna and fish occurrence in Korean eelgrass beds (Huh and Kwak, 1997b; 1998; Kwak et al., 2005). Huh and Kwak (1997a) demonstrated that the abundance of dominant fishes in an eelgrass bed of Kwangyang Bay was positively correlated with eelgrass biomass and prey availability. Hence we suggest that the high abundance of epiphytic epifauna and caridean shrimps were responsible for the maintenance of fish abundance through predator-prey interactions in this eelgrass bed.

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References

[1] Baeck, G. W., S. N. Kwak and S. H. Huh(2005), Seasonal variations in abundance ans species composition of fish in an eelgrass bed in Myoungjuri of Jindong Bay, Korean Journal of Ichthyol, Vol. 17, pp. 8-18.

[2] Bell, J. D. and D. A. Pollard(1989), Ecology of fish assemblages and fisheries associated with seagrasses. pp. 565-597. In: A. W. D. Larkum, A. J. McComb & S. A. Shepherd (eds). Biology of seagrasses: A treatise on the biology of seagrasses with special reference to the Australian region, Elsevier Science Publishers B. V., New York/Amsterdam.

[3] Coles, R. G. and W. J. Lee Long(1985), Juvenile prawn biology and the distribution of seagrass prawn nursery

grounds in the southeastern Gulf of Carpentaria. pp. 55-60. In: P. C. Rothlisberg, B. J. Hill & D. J. Staples (eds). Second Australian National Prawn Seminar NPS2, Cleveland, Australia, CSIRO publishers, Collingwood.

[4] Connolly, R., G. Jenkins and N. Loneragan(1999), Seagrass dynamics and fisheries sustainability. pp. 24-64. In: A. Butler, and P. Jernakoff (eds). Seagrass in Australia: strategic review and development of an R & D plan. CSIRO publishers, Collingwood.

[5] Edgar, G. J. and C. Shaw(1995), The production and trophic ecology of shallow-water fish assemblages in southern Australia. I. Species richness, size-structure and production of fishes in Western Port Bay, Victoria. Journal of Experimental Marine Biology and Ecology, Vol. 194, pp. 53-82

[6] Go, Y. B. and S. H. Cho(1997), Study on the fish community in the seagrass belt around Cheju Island I. Species composition and seasonal variations of fish community, Korean Journal of Ichthyology, Vol. 9, pp. 48-60.

[7] Guidetti, P. and S. Bussotti(2000), Fish fauna of a mixed meadow composed by the seagrasses *Cymodocea nodosa* and *Zostera noltii* in the Western Mediterranean, Oceanologica Acta, Vol. 23, pp. 759-770.

[8] Haywood, M. D. E., D. J. Vance and N. R. Loneragan(1995), Seagrass and algal beds as nursery habitats for tiger prawns (*Penaeus semisulcatus* and *P. esculentus*) in a tropical Australian estuary, Marine Biology, Vol. 122, pp. 213-223.

[9] Heck, K. L. and M. P. Weinstein(1989), Feeding habits of juvenile reef fishes associated with Panamanian seagrass meadows, Bulletin of Marine Science, Vol. 45, pp. 629-636.

[10] Hemminga, M. A. and C. M. Duarte(2000), Seagrass Ecology, Cambridge University Press, p. 231.

[11] Howard, R. K.(1984), The trophic ecology of caridean shrimps in an eelgrass community, Aqautic Botany, Vol. 18, pp. 155-174.

[12] Huh, S. H. and S. N. Kwak(1997a), Species composition and seasonal variations of fishes in eelgrass (*Zostera marina*) bed in Kwangyang Bay, Korean Journal of Ichthyology, Vol. 9, pp. 202-220.

[13] Huh, S. H. and S. N. Kwak(1997b), Feeding habits of *Pholis nebulosa*, Korean Journal of Ichthyology, Vol. 9, pp. 22-29.

[14] Huh, S. H. and S. N. Kwak(1998), Feeding habits of *Lateolabrax japonicus* in the eelgrass *Zostera marina* bed in Kwangyang Bay, Bulletin of Korean Society of Fisheries Technology, Vol. 34, pp. 191-199.

[15] Huh, S. H. and S. N. Kwak(1999), Feeding habits of *Acanthogobius flavimanus* in the eelgrass (*Zostera marina*) bed in Kwanyang Bay, Journal of Korean Fisheries Society, Vol. 32, pp. 10-17.

[16] Huh, S. H. and Y. R. An(1997), Seasonal variation of shrimp (Crustacea: Decapoda) community in the eelgrass (*Zostera marina*) bed in Kwangyang Bay, Korea, Journal of Korean Fisheries Society, Vol. 30, pp. 532-541.

[17] Huh, S. H.(1986), Species composition and seasonal variation in abundance of fishes in eelgrass meadows, Bulletin of Korean Fisheries Society, Vol. 19, pp. 509-517.

[18] Hwang, S. D. and T. W. Lee(2001), Reproduction and early life history of Gunnel, *Pholis fangi* in the Yellow Sea off Korea, Korean Journal of Ichthyology, Vol. 13, pp. 6-18.

[19] Kang, Y. J., Y. H. Kim and W. T. Kim(1996), Age, growth and spawning of *Enedrias nebulosus*, Journal of Korean Fisheries Society, Vol. 29, pp. 191-196.

[20] Kikuchi, T.(1966), An ecological study on animal communities of the *Zostera marina* belt in Tomioka Bay, Amakusa, Kyushu, Publ. Amakusa Mar. Biol. Lab., Vol. 1, 1-106.

[21] Kikuchi, T.(1974), Japanese contributions on consumer ecology in eelgrass (*Zostera marina* L.) beds, with special reference to trophic relationships and resources in inshore fisheries, Aquaculture, Vol. 4, pp. 145-160.

[22] Kim, H. S.(1973), Illustrated encyclopedia of fauna and flora of Korea, Vol. 14, Anomura and Brachyura, p. 694.

[23] Kim, I.S., Y. Choi, C. R. Lee, Y. J. Lee, B. J. Kim and J. H. Kim(2005), Illustrated Book of Korean Fishes, Kyo-Hak, Seoul, p. 615.

[24] Kim, I. S. and Y. J. Kang(1993), Coloured Fishes of Korea. Academy Publishing Co, Seoul, p. 478.

[25] Klumpp, D. W. and S. N. Kwak(2005), Composition and abundance of benthic macrofauna of a tropical seagrass ved in North Queensland, Australia, Pacific Science, Vol. 59, pp. 541-560.

[26] Klumpp, D. W., R. K. Howard and D. A. Pollard(1989), Trophodynamics and nutritional ecology of seagrass communities. pp. 394-437. In: A. W. D. Larkum, A. J. McComb & S. A. Shepherd (eds). Biology of seagrasses: A

treatise on the biology of seagrasses with special reference to the Australian region. Elsevier Science Publishers B. V., New York/Amsterdam.

[27] Kwak, S. N. and S. H. Huh(2002), Feeding habits of *Platycephalus indicus* in eelgrass (*Zostera marina*) beds in Kwangyang Bay, Korean Journal of Ichthyology, Vol. 14, pp. 29-35.

[28] Kwak, S. N. and S. H. Huh(2003a), Feeding habits of juvenile *Liparis tanakai* in eelgrass (*Zostera marina*) beds in Kwangyang Bay, Journal of Korean Fisheries Society, Vol. 36, pp. 372-377.

[29] Kwak, S. N. and S. H. Huh(2003b), Feeding habits of *Limanda yokohamae* in the eelgrass (*Zostera marina*) bed in Kwangyang Bay, Journal of Korean Fisheries Society, Vol. 36, pp. 522-527.

[30] Kwak, S. N. and S. H. Huh(2004), Feeding habits of *Rudarius ercodes* in a *Zostera marina* bed, Journal of Fisheries Science and Technology, Vol. 7, pp. 46-50.

[31] Kwak, S. N., G. W. Baeck and S. H. Huh(2004), Feeding habits of *Sillago japonica* in an eelgrass (*Zostera maina*) bed, Journal of Fisheries Science and Technology, Vol. 7, pp. 84-89.

[32] Kwak, S. N., G. W. Baeck and D. W. Klumpp(2005), Comparative feeding ecology of two sympatric greenling species, *Hexagrammos otakii* and *Hexagrammos agrammus* in eelgrass *Zostera marina* beds, Environmental Biology Fishes, Vol. 74, pp. 129-140

[33] Leber, K. M.(1985), The influence of predatory decapods, refuge, and microhabitat selection on seagrass community, Ecology, Vol. 66, pp. 1951-1964.

[34] Lee, T. W., H. T. Moon, H. B. Hwang, S. H. Huh and D. J. Kim(2000), Seasonal variation in species composition of fishes in the eelgrass beds in Angol Bay of the Southern Coast of Korea, Journal of Korean Fisheries Society, Vol. 33, pp. 439-447.

[35] Masuda, H, K. Amaoka, C. Arago, T. Ueno and T. Yoshino(1984), The Fishes of the Japanese Archipelago: Text and Plates. 437 pp + 370 plates.

[36] Minagawa, M., S. Yasumoto, T. Ariyoshi, T. Umemoto and T. Ueda(2000), Interannual, seasonal, local and body size variations in reproduction of the prawn *Penaeus* (*Marsupenaeus*) *japonicus* (Crustacea: Decapoda: Penaeidae) in the Ariake Sea and Tachibana Bay, Japan, Marine Biology, Vol. 136, pp. 223-231.

[37] Nagelkerken, I., C. M. Roberts, G. vander Velde, M. Dorenbosch, M. C. van Riel, E. Cocheret de la Moriniere and P. H. Nienhuis(2002), How important are mangroves and seagrass beds for coral-reef fish? The nursery hypothesis tested on an island scale, Marine Ecolog. Progress Series, Vol. 244, pp. 299-305.

[38] Nelson, W. G.(1981), The role of predation by decapod crustaceans in seagrass ecosystems. Kieler Meeresforsch, Vol. 5, pp. 529-536.

[39] NFDRI(2001), Shrimps of the Korean Waters, Hanguel, p. 223.

[40] Oh, T. Y., J. H. Choi, H. K. Cha, J. I. Kim, J. L. Koh and J. H. Lee(2003), Maturation and growth of *Trachysalambria curvirostris* in the coastal water of Geomundo, Korea, Bulletin of the Korean Society of Fisheries Technology, Vol. 39, 120-127.

[41] Pianka, E. R.(1973), The structure of lizard communities, Annual Review of Ecology Systematics, Vol. 4, pp. 53-74.

[42] Rozas, L. P. and T. J. Minello(1998), Nekton use of salt marsh, seagrass, and nonvegetated habitats in a South Texas (USA) Estuary, Bulletin of Marine Science, Vol. 63, pp. 481-501.

[43] Shannon, C. E. and W. Weaver(1949), The Mathematical Theory of Communication, Illinois Univ. Press, Urbana.

[44] Turnbell, C. T. and J. E. Mellors(1990), Settlement of juvenile Penaeus esculentus on nursery grounds in Torres Strait. pp. 29-37. In: J.E. Mellors (eds). Torres Strait prawn project: a review of research 1986-1988. Qld Dept Primary Industries Information Series Ql90018, Australia.

[45] Vance, D. J., M. D. E. Haywood, D. S. Heales and D. J. Staples(1996), Temporal and annual variation in abundance of postlarval and juvenile grooved tiger prawn, *Penaeus semisulcatus* (Decapods: Penaeidae), and environmental variation in the Embley River, Australia: a six-year study, Marine Ecology Progress Series, Vol. 135, pp. 43-55.

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Appendix 1. Monthly variations in number of fishes in an eelgrass bed of Jindong Bay in 2002

Species	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Total	
	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W
Hexagrammos otakii					21	52.5	55	427.6	78	670.1	42	383.1	21	529.2	30	732.9	23	507.5	32	744.8	45	1,214.6	37	922.4	384	6,184.7
Pholis nebulosa	23	34.4	25	37.9	96	105.5	97	108.9	57	60.1									11	48.1			25	31.6	334	426.5
Pholis fangi	17	20.8	40	45.1	71	75.6	92	97.5	45	48.5									19	27.3	18	24.6	17	22.6	319	362.0
Acanthopagrus schlegeli							1	52.6	5	104.5	11	83.6	129	696.6	45	252.0	10	179.0	1	28.0					202	1,396.3
Lateolabrax japonicus									11	11.8	110	253.0	59	377.6	20	411.7									200	1,054.1
Leiognathus nuchalis							7	18.3	2	13.8	9	20.7	8	54.4	8	14.0	51	61.2	15	52.5	12	31.4	2	21.9	114	288.2
Acentrogobius pflaumi	6	4.9	1	0.5	3	2.1	13	18.2	4	6.5	62	141.5	2	5.3	4	7.4			3	6.3	1	1.4			99	194.1
Acanthogobius flavimanus							4	73.0			18	538.2	23	310.5	19	229.9	20	424.0	3	89.1	3	52.5	1	19.3	91	1,736.5
Pseudoblennius cottoides					5	1.0	16	17.5	63	73.6	2	4.3													86	96.4
Repomucenus valenciennei					1	0.1					4	20.4			4	23.6			14	72.8	48	436.4			71	553.3
Sillago japonicus											4	54.5	22	484.6	12	283.5	10	272.2	1	17.8	2	4.6			51	1,117.2
Hippocampus japonica							4	5.4	9	8.5	2	3.4	7	11.0	3	3.0	2	3.6	4	3.4	4	4.7			35	43.0
Rudaris ercodes	1	1.0											3	2.5	4	4.1	6	3.8	8	22.4	3	7.2	4	7.3	29	48.3
Takifugu niphobles											1	29.5	5	118.6	3	98.2	10	171.1			2	28.3	4	89.5	25	535.2
Pseudoblennius percoides							10	16.2	14	71.8															24	88.0
Syngnathus schlegeli							6	13.6	11	43.6					1	2.2									18	59.4
Sebastes inermis					1	0.4			10	19.3					6	13.4									17	33.1
Sebastes longispinis									12	16.4											1	1.4			13	17.8
Sebastes schlegeli							1	1.1	9	18.3															10	19.4
Pleuronectes yokohamae			1	11.1	2	56.6															3	80.4			6	148.1
Hypodytes rubrippins	1	1.3	2	6.3	1	8.0			1	10.8															5	26.4
Clupea pallasii									4	4.2															4	4.2
Zoarces gilli									2	18.5															2	18.5
Ditrema temmincki																			1	32.0	1	33.6			2	65.6
Sardinella zunasi													1	1.0											1	1.0
Chaenogobius heptacanthus							1	0.7																	1	0.7
Total	48	62.4	69	100.9	201	301.8	307	850.6	337	1,200.3	265	1,532.2	280	2,591.3	159	2,075.9	132	1,622.4	112	1,144.5	143	1,921.1	90	1,114.6	2,143	14,518.0

N : number of individuals, W : wet weight(g)

Appendix 2. Monthly variations in number of decapods in an eelgrass bed of Jindong Bay in 2002

Species	Jan.		Feb.		Mar.		Apr.		May		Jun		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.		Total	
	N	B	N	B	N	B	N	B	N	B	N	B	N	B	N	B	N	B	N	B	N	B	N	B	N	B
Penaeiodea																										
Penaeidae																										
Trachysalambria curvirostris					9	19.4	12	25.8	39	63.6	25	44.5	1	1.8											86	155.0
Marsupenaeus japonicus					5	9.0	2	2.1	4	7.1			1	1.8											12	19.9
Metapenaeus joyneri							1	8.2	2	17.5	3	21.5	1	7.3											7	54.5
Caridea																										
Palaemon macrodactylus	49	2.9	54	15.1	58	11.6	71	41.9	82	32.8	5	2.0	11	3.9	12	4.3	6	1.4	13	3.5	16	5.1	18	4.3	395	128.9
Alpheus digitalis	6	1.9	7	1.8	8	3.5	26	9.1	33	18.5	28	14.3	5	2.8	12	5.8	2	0.9	3	1.1	4	1.6	8	2.6	142	63.6
Crangon affinis	9	2.1	14	5.9	26	12.7	22	16.1	26	21.1	21	13.7											9	2.2	127	73.6
Crangon uritai	6	1.5	13	3.1	32	17.3	35	27.7	16	12.3	12	7.1											5	1.8	119	70.8
Latreutes anoplonyx															21	4.4	26	8.3	14	5.9					61	18.6
Palaemon ortmanni					9	11.8	13	17.3	11	15.5	8	10.5													41	55.1
Eualus leptognathus			10	4.1	14	5.3	9	3.9	5	2.1															38	15.4
Crangon hakodatei			6	10.2	5	8.5	2	3.8	4	8.4	1	1.9													18	32.8
Palaemon gravieri															4	0.2	7	0.4	4	0.2					15	0.8
Heptacarpus pandaloides									7	0.1	6	0.1													13	0.3
Tozeuma tomentosum							5	1.7	5	1.5															10	3.2
Lysmata vittata	4	0.1																							4	0.1
(Subtotal)	74	8.5	104	40.2	166	99.1	198	157.4	234	200.5	109	115.4	19	17.5	49	14.7	41	11.0	34	10.6	20	6.8	40	10.8	1,088	692.4
Anomura																										
Pagurus minutus	26	10.1	49	30.4	31	17.7	17	10.0	12	3.8	10	3.5	5	4.5	7	5.4	4	3.2	3	2.7	6	4.1	11	6.4	181	101.8
Upogebia major			16	40.5	13	44.9	10	32.1	5	14.5	9	23.6	3	9.6	1	2.9	1	4.6							58	172.6
(Subtotal)	26	10.1	65	70.9	44	62.5	27	42.1	17	18.3	19	27.1	8	14.1	8	8.3	5	7.9	3	2.7	6	4.1	11	6.4	239	274.4
Brachyura																										
Charybdis japonica	23	227.7	16	190.4	4	48.8	26	252.2	43	481.6	53	736.7	25	512.5	39	986.7	38	1,280.6	28	470.4	11	236.5	4	83.6	310	5,507.7
Charybdis bimaculata	11	95.7	9	81.9	6	63.0	17	161.5	28	274.4	22	239.8	11	246.4	35	885.5	4	134.8	9	151.2	11	236.5	8	167.2	171	2,737.9
Hemigrapsus penicillatus	14	3.2	27	8.4	35	11.6	8	3.1	18	8.1					5	4.9	3	3.3			6	7.2	16	15.5	132	65.3
Pugettia quadridens	9	9.7	11	14.9	9	15.9	18	29.3																	47	69.8
Portunus trituberculatus									4	103.2	6	154.8	2	46.4	5	109.0									17	413.4
Telmessus acutidens	10	326.0																							10	326.0
Gaetice depressus					7	24.1																			7	24.1
Sphaerozius nitidus											7	5.6													7	5.6
Tritodynamia rathbuni							4	4.3	2	2.2															6	6.5
Portunus sanguinolentus																							3	156.4	3	156.4
Hemigrapsus sinensis					1	1.7																			1	1.7
Carcinoplax vestita							1	6.7																	1	6.7
(Subtotal)	67	662.3	63	295.5	62	165.1	74	457.2	95	869.5	88	1,136.9	38	805.3	84	1,986.1	45	1,418.7	37	621.6	28	480.2	31	422.7	712	9,321.1
Total	167	681.0	232	406.6	272	326.6	299	656.7	346	1,088.3	216	1,279.4	65	836.9	141	2,009.1	91	1,437.6	74	634.9	54	491.0	82	439.9	2,039	10,287.9

N : Number of individuals, B: Biomass(g)