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Comparisons of Fish Assemblages Associated with Eelgrass Bed and Adjacent Unvegetated Habitat in Jindong Bay

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Fish assemblages associated with eelgrass beds and unvegetated area were compared based on specimens collected every month in Jindong Bay. The common fish species were *Hexagrammos otakii, Acanthopagrus schlegeli, Lateolabrax japonicus, Pholis nebulosa, P. fangi, Leiognathus nuchalis, Repomucenus valenciennei,* and *Acanthogobius flavimanus. H. otakii, A. schlegeli, P. nebulosa* and *L. japonicus* were higher abundance in an eelgrass bed than unvegetated area, whereas *P. fangi, R. valenciennei* and *A. flavimanus* were higher in unvegetated area. *Sillago japonicus, Hippocampus japonica, Takifugu niphobles, Pseudoblennius percoides, Sebastes inermis, Syngnathus schlegeli, Sebastes schlegeli* were found in an eelgrass bed, but not in unvegetated area. Most of fish species were primarily small fish species or juveniles of fish species in an eelgrass bed, while larger fish species were found in unvegetated area. The eelgrass bed in Jindong Bay seem to play a nursery role for fishes. Seasonal variations in both species composition and abundance were large in two habitats; higher number of species and individuals occurred May 2002, and April 2002 to July 2002, while biomass was the highest in April 2002 and July 2002. Fish numbers as well as biomass were lowest in January 2002. Species richness, number of individuals and biomass of fishes in an eelgrass bed were significantly higher than those of in unvegetated area. These result suggest that differences in fish species richness and abundances are primarily related to habitat structure. Different habitat preferences were evidenced for the juveniles and adult of several fish species.

Key words : fish assemblages, seasonal variation, species composition, eelgrass bed, unvegetated habitat

Introduction

Seagrass beds generally support different fish species, a greater diversity and abundance of fish, and larger numbers of juveniles nearby bare substrate (Bell and Pollard, 1989; Heck *et al.*, 1989; Jenkins *et al.*, 1997; Hemminga and Duarte, 2000). This phenomenon is classically explained by considering the high structural complexity of such seagrass systems, which are able to fulfill the role of nursery areas in providing shelter and food to a great number of littoral fish species (Klumpp *et al.*, 1989; Jenkins and Wheatley, 1998; Guidetti, 2000). Jenkins and Wheatley (1998) and Guidetti *et al.* (2000) invoked some features of seagrass canopies, such as shading, baffling of currents and increased surface area of

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substrata due to foliage, as important reasons determining an increased diversity and abundance of fishes in seagrass habitats. By contrast, some studies found no significant differences in fish species richness or total abundance between seagrass beds and unvegetated sites (Hanekom and Baird, 1984; Heck and Thomas, 1984), but peculiar local factors are invoked to explain these results.

Recent studies on eelgrass bed in Korea have reported seasonal variation in species composition and abundance of fishes in Kwangyang Bay, 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 *Limanda yokohamae*). (Huh and Kwak, 1999; Kwak and Huh, 2002, 2003a, b). Shallow waters with rich eelgrass beds are located in Jindong Bay, southern Korea 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 *et al*., 2003; Kwak and Huh 2004; Kwak *et al*., 2004; Kwak *et al*., 2005).

The aim of the present study was to compare species composition, species richness, and abundance of fishes between an eelgrass bed and adjacent unvegetated area.

Materials and Methods

The study area was located in eelgrass bed and adjacent unvegetated area in Jindong Bay (Fig. 1). An eelgrass bed supports a luxuriant eelgrass, *Zostera marina* which is forming subtidal bands (500～700 m wide) in the shallow water (<3 m). An eelgrass bed extended in patches for about 4 km along the shore.

Fish samples were collected monthly by a 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 in an eelgrass bed and adjacent unvegetated habitat 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), Yoon (2002), and Kim *et al*. (2005) and weighed to the nearest gram in

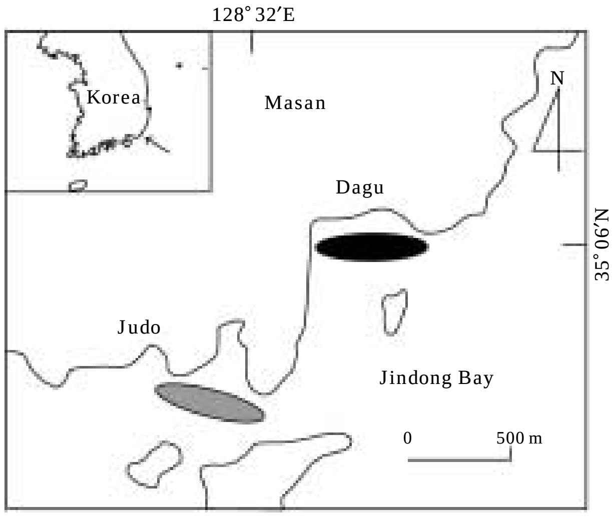

Fig. 1. Location of the study area. (●: Eelgrass bed, ○: Unvegetated habitat)

wet weight and their standard length measured to the nearest millimeter in the laboratory.

Water temperature and salinity were measured at each sampling location. Eelgrass biomass was estimated by removal of all plant matter in a 0.01 m^2 within each station. The plants were separated into the above- and below-ground parts, dried at 80°C for 24 h then weighed to the nearest gram.

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

$$H' = -\Sigma (ni/N) \log (ni/N),$$

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

A two-way ANOVA was used to analyse variations in fish abundance and environmental factors with seasons and habitats. Log transformed data were used to satisfy the equal variance assumption of the model. A Kolmogorove-Smirnov 2-sample test was analysed differences in number of individuals and biomass of fish, and size distribution of common fish species between an eelgrass bed and unvegetated habitat.

Results

Temperature, salinity, and eelgrass biomass

Temperature at the study site ranged from 7.4

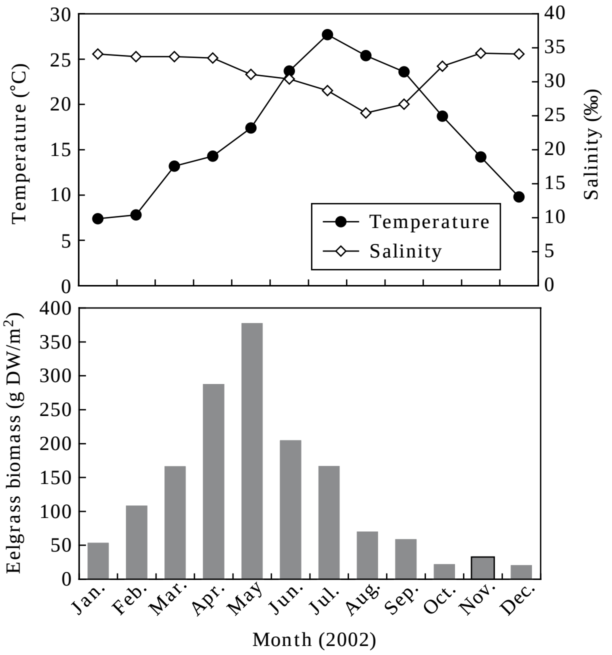

Fig. 2. Monthly variations of temperature, salinity and eelgrass biomass in an eelgrass bed and unvegetated habitat in Jindong Bay.

°C to 27.7°C and varied significantly with months (ANOVA, $p<0.05$), but not with habitats (ANOVA, $p>0.05$). The peak of temperature was around July 2002, a decline in October and a minimum during winter (Fig. 2). Salinity ranged from 25.4‰ to 34.2‰ and did not vary significantly between months and habitats (ANOVA, $p>0.05$) with display a similar pattern except in August 2002 and September 2002 when it dropped (about 25‰) (Fig. 2). 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 2002 and a minimum in December 2002 (Fig. 2).

Species composition

A total of 2,158 fish belonging to 26 species were collected from an eelgrass bed in Jindong Bay (Table 1, 2). Numerically dominant fish were *H. otakii* (17.8%), *A. schlegeli* (12.6%), *L. japonicus* (11.1%), *P. nebulosa* (10.8%), and *P. fangi* (10.1%), together accounting for 72.7% of the catch, and 74.7% of biomass. These were primarily small fish species or early juveniles of larger fish species. Only about 10% exceeded 5 cm SL.

Table 1. Comparisons of number of individuals of fish species between eelgrass bed and unvegetated habitat (The significance level means difference in two habitats)

Species	Habitats				Signi-ficance level
	Eelgrass bed	%	Unve-getat-ed	%	
Hexagrammos otakii	385	17.8	170	17.1	**
Pholis fangi	219	10.1	231	23.3	*
Pholis nebulosa	234	10.8	100	10.1	**
Leiognathus nuchalis	218	10.1	113	11.4	*
Acanthopagrus schlegeli	272	12.6	4	0.4	**
Lateolabrax japonicus	240	11.1	4	0.4	**
Acanthogobius flavimanus	91	4.2	109	11.0	**
Repomucenus valenciennei	71	3.3	114	11.5	**
Acentrogobius pflaumi	99	4.6	78	7.9	**
Pseudoblennius cottoides	86	4.0	17	1.7	**
Silago japonicus	51	2.4			**
Hippocampus japonica	35	1.6			**
Rudaris ercodes	29	1.3	2	0.2	**
Limanda yokohamae	6	0.3	19	1.9	**
Takifugu niphobles	25	1.2			**
Pseudoblennius percoides	24	1.1			**
Sebastes inermis	17	0.8	2	0.2	*
Syngnathus schlegeli	18	0.8			*
Sebastes longispinis	13	0.6			*
Sebastes schlegeli	10	0.5			n.s.
Hypodytes rubrippins	5	0.2	4	0.4	n.s.
Chaenogobius heptacanthus	1	0.0	6	0.6	*
Favonigobius gymnauchen			6	0.6	*
Platycephalus indicus			5	0.5	n.s.
Clupea pallasii	4	0.2			n.s.
Ernogrammus hexagrammus			4	0.4	n.s.
Zoarces gilli	2	0.1			n.s.
Ditrema temmincki	2	0.1			n.s.
Sagamia geneionema			2	0.2	n.s.
Sardinella zunasi	1	0.0			n.s.
Furcina osimae			1	0.1	n.s.
Parablennius yatabei			1	0.1	n.s.
Total	2,158	100	992	100	

$p<0.01$: **, $p<0.05$: *, n.s.: not significant

For fish assemblages in unvegetated habitat, 992 fish belonging to 21 species were collected (Table 1, 2). *Pholis fangi* (23.3), *H. otakii* (17.1%), *R. valenciennei* (11.5%), *L. nuchalis* (11.4%), *A. flavimanus* (11.0%), and *P. nebulosa* (10.1%) were dominated. These are made up 84.4% of number of individuals and 91.3% of total biomass. Although most of fishes species were primarily small fish species or young juveniles, the fish size was larger individuals than those of in an eelgrass bed.

Number of individuals and biomass of fish

Table 2. Comparisons of biomass* of fish species between eelgrass bed and unvegetated habitat (The significance level means difference in two habitats)

Species	Habitats				Significance level
	Eelgrass bed	%	Unvegetated	%	
Hexagrammos otakii	6,154.5	32.4	4,664.9	38.7	*
Pholis nebulosa	2,230.3	11.7	1,757.3	14.6	*
Acanthogobius flavimanus	1,736.5	9.1	1,929.5	16.0	*
Acanthopagrus schlegeli	2,777.1	14.6	284.8	2.4	**
Pholis fangi	1,099.3	5.8	1,673.5	13.9	*
Lateolabrax japonicus	1,359.2	7.2	78.4	0.7	**
Repomucenus valenciennei	553.3	2.9	703.2	5.8	*
Silago japonicus	1,117.2	5.9			**
Leiognathus nuchalis	564.9	3.0	265.0	2.2	**
Takifugu niphobles	535.2	2.8			**
Acentrogobius pflaumi	194.1	1.0	173.2	1.4	*
Limanda yokohamae	148.1	0.8	213.1	1.8	*
Pseudoblennius cottoides	96.4	0.5	172.6	1.4	**
Pseudoblennius percoides	88.0	0.5			**
Platycephalus indicus			71.4	0.6	**
Ditrema temmincki	65.6	0.3			**
Syngnathus schlegeli	59.4	0.3			**
Rudaris ercodes	48.3	0.3	2.1	0.0	**
Sebastes inermis	33.1	0.2	12.8	0.1	**
Hippocampus japonica	43.0	0.2			**
Hypodytes rubrippinis	26.4	0.1	0.8	0.0	**
Sebastes schlegeli	19.4	0.1			**
Zoarces gilli	18.5	0.1			*
Sebastes longispinis	17.8	0.1			*
Sagamia geneionema			12.5	0.1	n.s.
Favonigobius gymnauchen			10.9	0.1	n.s.
Chaenogobius heptacanthus	0.7		4.2	0.0	n.s.
Ernogrammus hexagrammus			4.8	0.0	n.s.
Clupea pallasii	4.2				n.s.
Furcina osimae			3.0	0.0	n.s.
Parablennius yatabei			1.3	0.0	n.s.
Sardinella zunasi	1.0				n.s.
Total	18,991.5	100	12,039.3	100	

$p<0.01$: **, $p<0.05$: *, n.s.: not significant * wet weight (g)

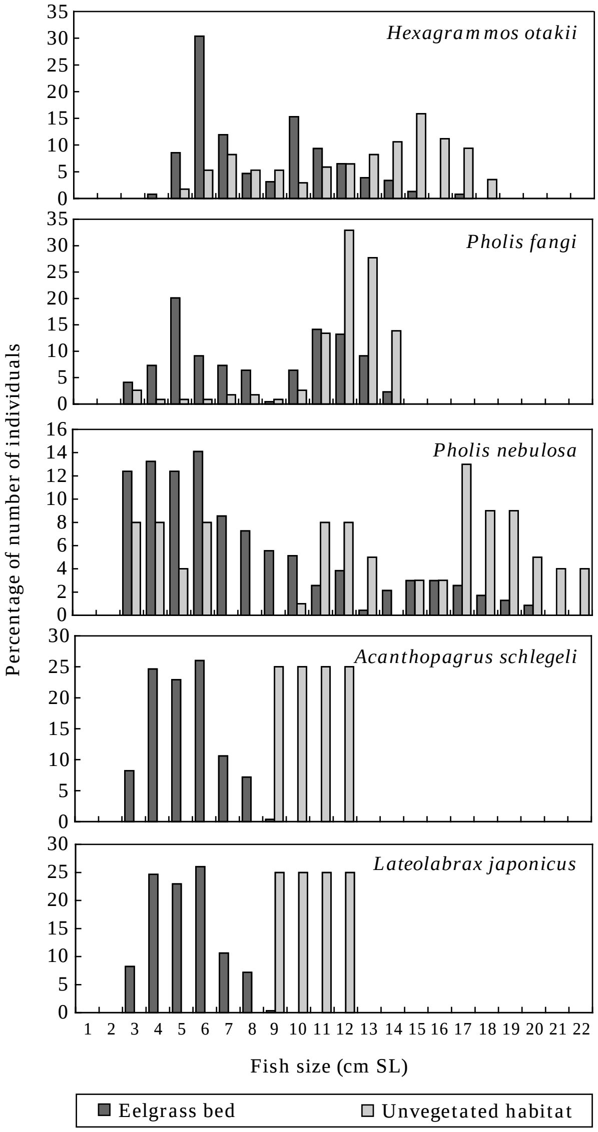

Fig. 3. Size distribution of common fish species collected in an eelgrass bed and unvegetated habitat in Jindong Bay.

species were found to differ significantly between two habitats (see significance level in Table 1, 2). Higher number of individuals of common fish species except *P. fangi* and *L. nuchalis* occurred in an eelgrass bed than unvegetated habitat, while *P. fangi*, *A. flavimanus*, *R. valenciennei*, and *L. yokohamae* were higher in unvegetated habitats. In terms of biomass of fish species, *A. schlegeli*, *L. japonicus* were higher in an eelgrass bed, whereas higher biomass of *P. fangi*, *A. flavimanus*, *R. valenciennei* and *P. cottoides* were occurred in unvegetated habitat. Furthermore *S. japonicus*, *H. japonica*, *T. niphobles*, *P. percoides*, *Sebastes inermis*, *S. schlegeli*, *Sebastes schlegeli* were only collected in an eelgrass bed.

Size distribution of common fish species

The size distributions of common fish species significantly varied with two habitats ($p<0.05$, Fig. 3). Most of smaller individuals was dominated in an eelgrass bed, while larger individuals were found in unvegetated habitat. The size range of *H. otakii* was 4.1 cm to 18.3 cm SL with higher abundance of smaller individuals (< 6 cm

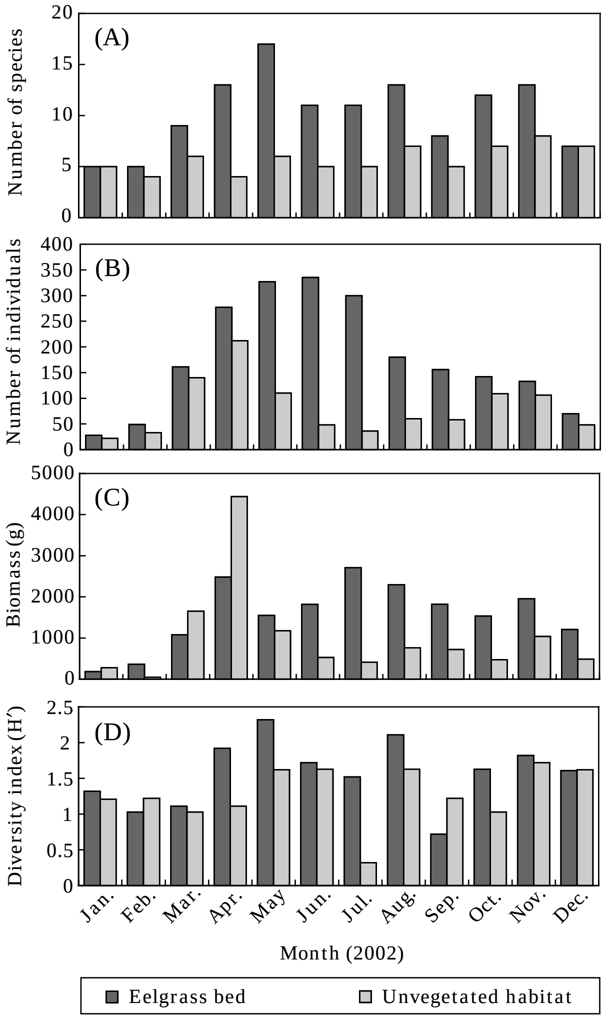

Fig. 4. Monthly variations in (A) number of species, (B) number of individuals, (C) biomass, and (D) diversity index of fish species in an eelgrass bed and unvegetated habitat in Jindong Bay.

SL) in an eelgrass bed, whereas most of *P. fangi* individuals were larger individuals (>12 cm SL) in unvegetated habitat. For *P. nebulosa*, size ranged from 3.5~22.7 cm SL, and larger individuals (>17 cm SL) were predominately found in unvegetated habitat although higher value of smaller individuals were in an eelgrass bed. On the other hand, almost all smaller individuals of *A. schlegeli* and *L. japonicus* were found in an eelgrass bed, but larger individuals were in the unvegetated habitat.

Seasonal variation in abundance of fishes

The number of fish species (4~17 species) varied significantly with seasons and habitats (ANOVA, $p<0.05$). Higher number of fish species occurred in an eelgrass bed than unvegetated habitat with highest value in May 2002 (Fig. 4-a). Number of individuals and biomass of fish species differed substantially between different seasons and habitats (ANOVA, $p<0.05$, Fig. 4-b, c) with the largest number of individuals and biomass occurring in an eelgrass bed. Higher number of fish individuals occurred from May to July 2002 which were dominated *H. otakii*, *A. schlegeli*, *L. japonicus*, and *L. nuchalis*, and lowest numbers occurred in January 2002 in an eelgrass bed (Appendix 1, 2). Fish biomass in an eelgrass bed was higher in April 2002 July 2002, and August 2002 when a few relatively large *P. nebulosa*, *H, otakii*, *S. japonicus*, and *L. japonicus* were present (Appendix 1). However, the highest biomass in April 2002 in unvegetated habitat. Significant seasonal and habitat differences were observed for the diversity index (ANOVA, $p<0.05$, Fig. 4-d) with higher value (0.72~2.32) in an eelgrass bed. The diversity index was highest in May 2002 and August 2002 in an eelgrass bed, while the highest value was in November 2002 in unvegetated habitat.

Discussion

A total of 26 fish species was recorded from an eelgrass bed of Jindong Bay and 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 sea, Korea, and *P. nebulosa* and *P. fangi* harvested as a food fish (Kim and Kang, 1993; Yoon, 2002). Broad-scale surveys of fish communities in the eelgrass beds from other regions of Korea suggest a similar community structure. *Hexagrammos otakii*, *P. fangi*, *P. cottoides*, and *Pholis 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*, and *Pholis* were also dominant fish groups in an eelgrass bed of Tomioka Bay, Japan. On the other hand, 21 fish species collected from unvegetated habitat adjacent eelgrass bed in Jindong Bay, and *P. fangi*, *H. otakii*, *R. valenciennei*, *L. nuchalis*, *A. flavimanus*, and *P. nebulosa* were dominated. These result indicated that several common fish species (e.g. *H. otakii, P. fangi*, and *P. nebulosa*) may use unvegetated area as well as an eelgrass bed. Ferrell and Bell (1991) found that the unvegetated areas adjacent eelgrass beds constituted a specific habitat for a number of species that was distinct from unvegetated areas some distance from seagrass. Also, the number of individuals on sand adjacent to seagrass was significantly higher than sand distant from seagrass. The presence of seagrass may lead to organic enrichment of unvegetated sediments nearby, enriching food production for fishes (Shaw and Jenkins, 1992; Jenkins *et al*., 1997).

Fishes collected from an eelgrass bed in the study area appeared to be dominated by small fish species and juveniles of most species. This indicated that an eelgrass bed in Jindong Bay function as nursery areas. The juvenile stage of a number of commercial fish species such as *H. otakii, P. nebulosa, A. schlegeli*, and *L. japonicus* settled directly in an eelgrass bed. Particularly juveniles of *H. otakii* and *P. nebulosa* are cryptically coloured for life, and may remain in an eelgrass bed. The diet of these species is also dominated by eelgrass-associated biota (Huh and Kwak, 1997b; Kwak *et al*., 2005). Other commercial species such as *A. schlegeli* and *L. japonicus* showed strong preference for eelgrass beds in the juvenile stage. Juveniles of these species feed primarily on small sized epiphytic animals, gammarid amphipods and caprellid amphipods which inhabit in the eelgrass beds (Huh and Kwak, 1998a, b). Such conclusions are in general agreement with other studies of seagrass beds (Huh and Kwak, 1997a; Rozas and Minello, 1998; Lee *et al*., 2000; Im, 2004; Kwak and Klumpp, 2004). A significantly greater abundance of fish juveniles than that of adults in our study site in Jindong Bay confirmed that also these species were likely to be dependent on eelgrass beds for shelter and survival during the early life stages (Brook, 1977; Bell and Pollard, 1989; Edgar and Shaw, 1995). On the other hand, *A. flavimanus, R. valenciennei*, and *L. yokohamae* tended to occur at unvegetated habitats. At least in the case of *A. flavimanus* and *L. yokohamae*, there is an evidence that juveniles may benefit indirectly from eelgrass bed through high abundance of food organisms (Huh and Kwak, 1999; Kwak and Huh, 2003b). Jenkins and Wheatley (1998) demonstrated that eelgrass beds were important habitats for commercial fish species, but some species may show flexible use of unvegetated habitats where sediments are enriched with eelgrass detritus or where eelgrass bed refuge is nearby.

We also found an important differences between fish assemblages associated with each habitat. The species composition on unvegetated habitat were often quite distinct from adjacent vegetated habitat. *Acanthopagrus schlegeli* and *L. japonicus* were predominantly abundant in an eelgrass bed, whereas *A. flavimanus, R. valenciennei*, and *L. yokohamae* were dominant fish species in unvegetated habitat. *Hippocampus japonicus* and *R. ercodes* were also higher in an eelgrass bed. Species richness and abundances of fish species were higher in an eelgrass bed than those in unvegetated habitat. Other studies have shown similar patterns of variable faunal abundance in fish communities of seagrass beds worldwide. For example, the species richness, abundance of fishes were significantly higher in seagrass beds, Victoria, Australia (Jenkins *et al*., 1997; Jenkins and Wheatley, 1998), and a higher species richness and fish density were observed over the *Posidonia* seagrass beds in the Adriatic Sea (Guidetti, 2000). West and King (1996) have demonstrated that shallow vegetated (*Zostera capricorni*) had greatest diversity and higher abundance of fishes in Australian Coastal River during recruitment periods. This results indicated that the major linkage between these fish species and seagrass bed was probably food supply and protection from predators (Klumpp *et al*., 1989; Jenkins and Wheatley, 1998; Guidetti, 2000). Hence we suggest that higher numbers and biomass of fish species in an eelgrass bed are primarily related to habitat structure with increased food availability and greater protection from predators.

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진동만 잘피밭과 인근 잘피가 없는 해역의 어류군집 비교

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진동만 다구리 잘피밭과 인근 잘피가 없는 해역의 어류군집을 비교하기 위해서 2002년 1월부터 12월까지 소형 빔 트롤을 이용하여 어류를 매월 채집하였다. 조사기간 동안 우점하였던 쥐노래미, 감성돔, 농어, 베도라치, 흰베도라치, 주둥치, 문절망둑, 그리고 실양태가 우점하였다. 특히 감성돔과 농어는 잘피밭에서 문절망둑과 실양태는 잘피가 없는 해역에서 많이 출현하였다. 청보리멸, 산호해마, 복섬 및 돌팍망둑, 실고기, 흰꼬리볼락 및 볼락 등은 잘피밭에서만, 양태 및 날개망둑 등은 잘피가 없는 해역에서만 출현하였다. 본 조사해역에서 출현한 어류는 대부분이 소형 어종이거나 대형 어종의 유어들로 구성되어 있어서, 잘피밭이 작은 크기의 어종들에게 좋은 성육장의 역할을 하고 있었다. 어류군집은 뚜렷한 계절변동을 보였는데, 출현 종수는 2002년 5월에, 출현 개체수는 2002년 4월에서 7월 사이에 아주 높았다. 한편 생체량은 2002년 4월과 7월에 가장 높은 수치를 나타내었다. 대체적으로 겨울철에는 출현 종수, 개체수 및 생체량이 모두 낮았다. 잘피밭과 잘피가 없는 인근해역의 어류 군집을 비교해보면, 출현 종수, 개체수 및 생체량이 모두 잘피밭에서 높게 나타났다. 이와 같은 결과는 잘피밭은 잘피가 밀생되어 있어서 먹이 이용 가능성 및 포식자로부터 보호받을 수 있는 서식처의 특성에 의한 것으로 주요 우점종의 체장분포에서도 두 서식처간의 차이가 뚜렷하게 나타났다.

Appendix I. Number of individuals and biomass of fish species in an eelgrass bed in Jindong Bay

Species	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W
Pseudoblennius cottoides					5	1.0	16	17.5	63	73.6	2	4.3												
Acanthopagrus schlegeli							11	578.6	15	313.5	21	159.7	139	750.7	55	308.2	20	358.1	11	308.3				
Rudaris ercodes	1	1.0											3	2.5	4	4.1	6	3.8	8	22.4	3	7.2	4	7.3
Lateolabrax japonicus									21	23.1	120	276.2	69	441.7	30	618.2								
Pseudoblennius percoides							10	16.2	14	71.8														
Zoarces gilli									2	18.5														
Ditrema temmincki																			1	32.0	1	33.6		
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
Limanda yokohamae			1	11.1	2	56.6															3	80.4		
Hypodytes rubrippins	1	1.3	2	6.3	1	8.0			1	10.8														
Sardinella zunasi													1	1.0										
Pholis nebulosa	13	148.2	15	193.5	76	722.0	77	916.3	37	114.3									1	37.1			15	98.9
Takifugu niphobles											1	29.5	5	118.6	3	98.2	10	171.1			2	28.3	4	89.5
Sebastes inermis					1	0.4			10	19.3					6	13.4								
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		
Chaenogobius heptacanthus							1	0.7																
Syngnathus schlegeli							6	13.6	11	43.6					1	2.2								
Repomucenus valenciennei					1	0.1					4	20.4			4	23.6			14	72.8	48	436.4		
Sebastes schlegeli							1	1.1	9	18.3														
Leiognathus nuchalis							7	18.3	2	13.8	59	205.9	8	54.4	8	14.0	65	79.3	55	126.0	12	31.4	2	21.9
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		
Hexagrammos otakii					21	52.5	55	429.1	78	670.9	42	382.2	21	529.2	31	688.2	23	508.3	32	745.7	45	1219.7	37	928.7
Silago japonicus											4	54.5	22	484.6	12	283.5	10	272.2	1	17.8	2	4.6		
Clupea pallasii									4	4.2														
Sebastes longispinis									12	16.4											1	1.4		
Pholis fangi	7	26.5	30	153.3	51	234.9	72	395.3	35	122.4									9	74.9	8	52.9	7	39.1
Total	28	181.9	49	364.7	161	1,077.6	277	2,483.3	327	1,549.5	335	1,815.8	300	2,709.5	180	2,293.9	156	1,820.4	142	1,535.8	133	1,954.5	70	1,204.7

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

Appendix 2. Number of individuals and biomass of fish species in unvegetated habitat in Jindong Bay

Species	Jan.		Feb.		Mar.		Apr.		May		Jun.		Jul.		Aug.		Sep.		Oct.		Nov.		Dec.	
	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W
Pseudoblennius cottoides															16	168.8	1	3.8						
Acanthopagrus schlegeli									4	284.8														
Rudaris ercodes																			2	2.1				
Lateolabrax japonicus													4	78.4										
Acanthogobius flavimanus											18	261	19	260.3	21	445.2	18	428.4	12	153.4	17	263.4	4	117.8
Limanda yokohamae											2	17.8	2	15.9	3	21.3	3	20.7	2	23.4	7	114		
Hypodytes rubrippins			4	0.8																	33	168.9	19	121.6
Pholis nebulosa					16	640.8	24	699.2	8	126.8														
Sebastes inermis															2	12.8								
Chaenogobius heptacanthus	1	0.8			3	2.0																	2	1.4
Ernogrammus hexagrammus			4	4.8																				
Repomucenus valenciennei	4	7.7			3	2.4			45	209.6	2	1.1			2	11.0			9	48.0	33	303.9	16	119.5
Platycephalus indicus	1	9.4																	2	18.2	2	43.8		
Leiognathus nuchalis																	27	36.3	80	212.3	6	16.4		
Acentrogobius pflaumi			16	2.8	2	3.7	12	25.4	15	66.8	12	33.2	8	23.1	8	7.7					4	8.2	1	2.3
Hexagrammos otakii	4	197.2			16	377.9	88	2973.6	22	321.2	14	212.8	3	35.7	8	94.4	9	230.5			4	121.2	2	100.4
Pholis fangi	12	63.2	9	38.7	100	624.4	88	740.8	16	168.8									2	16.2			4	21.4
Favonigobius gymnauchen											4	7.3	1	2.2									1	1.4
Sagamia geneionema					1	5.8					1	6.7											1	3.0
Furcina osimae																								
Parablennius yatabei							1	1.3																
Total	22	278.3	33	47.1	140	1,651.2	212	4,439.0	110	1,178.0	48	525.9	36	413.4	60	761.2	58	719.7	109	473.6	106	1,039.8	48	484.4

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