Fish Aqua Sci 12(3), 219-226, 2009

KOSFAS FISHERIES AND AQUATIC SCIENCES
The Korean Society of Fisheries and Aquatic Science

# Seasonal Variation in the Biomass of Eelgrass (*Zostera marina*) and Epiphytic Algae in Two Eelgrass Beds around Namhae Island in Korea

**Seok Nam KWAK and Sung-Hoi HUH[1]***

*Marine Eco-Technology Institute Co., Ltd. 485-1 Yongdang, Namgu, Busan 608-830, Korea*
*[1]Department of Oceanography, Pukyong University, 599-1 Daeyeon-Dong, Busan 608-737, Korea*

Seasonal variation in the biomass of eelgrass (*Zostera marina*) and epiphytic algae in two eelgrass beds (Dongdae and Aenggang Bay) around Namhae Island was investigated throughout 2005. Shoot density and eelgrass biomass differed across months and locations. Peak shoot density occurred from April to August 2005, whereas eelgrass biomass was higher in July and August 2005. Shoot density as well as eelgrass biomass were higher in Dongdae Bay compared to Aenggang Bay. A total of 21 epiphytic algal species (4 Chlorophyta, 2 Phaeophyta, and 15 Rhodophyta) were collected, and dominant species included *Polysiphonia japonica*, *Lomentaria hakodantensis*, *Symphyocladia latiuscula*, *Champia* sp., and *Heterosiphonia japonica*. Seasonal variation in both the species composition and biomass of epiphytic algae was substantial: peak epiphytic algal biomass occurred in January and December 2005. We also observed high epiphytic algal biomass in the eelgrass bed of Dongdae Bay. Seasonal changes in the biomass of eelgrass and epiphytic algae were primarily influenced by water temperature, whereas those of the epiphytic algal community were also correlated with eelgrass (substrate) morphology and growth, the life cycle of epiphytic algae, and physical characteristics within eelgrass beds. The spatial variation of eelgrass density and biomass were also limited by sediment characteristics.

Key words: Eelgrass, Epiphytic algae, Eelgrass bed, Dongdae Bay, Aenggang Bay, *Polysiphonia japonica*

## Introduction

Seagrasses are among the most productive marine photoautotrophic communities worldwide and are represented by 66 species in six families (Den Hartog and Kuo, 2006). The global ecological importance of seagrasses for high production, food, nursery habitat, and substrate stabilizers in estuaries and coastal areas is well established (Klumpp et al., 1989; Connolly et al., 1999; Hemminga and Duarte, 2000; Nagelkerken et al., 2002). Seagrasses occupy an area of approximately 55 to 70 $km^2$ around the Korean peninsula, and eelgrass (*Zostera marina*) dominates this distribution, occupying about 50 to 60 $km^2$ (Lee and Lee, 2003). Recent studies of eelgrass beds in Korea have examined the production dynamics of eelgrass, macro-invertebrate, and fish communities (Huh and Kwak, 1997; Lee et al., 2000; Yoon, 2006; Hwang, 2007; Park, 2008), with particular focus on the feeding habits of certain fish species (*Liparis tanakai*, *Limanda yokohamae*, *Hexagrammos otakii*, *H. agrammus*, *Pseudoblennius percoides*, and *Hippocampus mohnikei*) along the southern coast of the Korean peninsula (Kwak and Huh, 2003a,b; Kwak et al., 2005, 2008; Huh et al., 2008; Kwak et al., 2008).

The shallow waters around Namhae Island in southern Korea are rich with eelgrass beds that provide habitat for a variety of invertebrates and small fish, which in turn are potential food sources for large fishes. Several ecological studies of eelgrass-associated communities have been conducted in the eelgrass beds around Namhae Island, but their focus has been limited to fish assemblages and the feeding habits of fish species (Hwang, 2007; Huh et al., 2008; Kwak et al., 2008). Fundamental studies involving the eelgrass and epiphytic algae of

*Corresponding author: shhuh@pknu.ac.kr

Namhae Island are lacking, although the seasonal variation of eelgrass and epiphytic algae as well as the marine algal communities of the intertidal zone have been described for the nearby Kwangyang Bay (Huh et al., 1998; Choi and Huh, 2008).

The objectives of this study were to examine seasonal variation in eelgrass and epiphytic algal biomass in two eelgrass beds around Namhae Island in southern Korea and to determine the relationships between environmental factors and the biomass of eelgrass and epiphytic algae. A pilot study indicated that the two target eelgrass beds harbor the highest eelgrass biomass relative to other areas in the coastal waters off Namhae Island. The current research is a fundamental part of a wider study aimed at understanding eelgrass production and growth after recovery from anthropogenic disturbances in temperate Korean seagrass beds.

## Methods

The two study eelgrass beds are located in Dongdae Bay and Aenggang Bay around Namhae Island (Fig. 1), and both support luxuriant eelgrass, *Zostera marina*, communities that form subtidal bands in the shallow waters (<3 m). More specifically, most of Dongdae Bay is covered with eelgrass, and the extensive eelgrass beds in Aenggang Bay form patches for about 1 km along the shore.

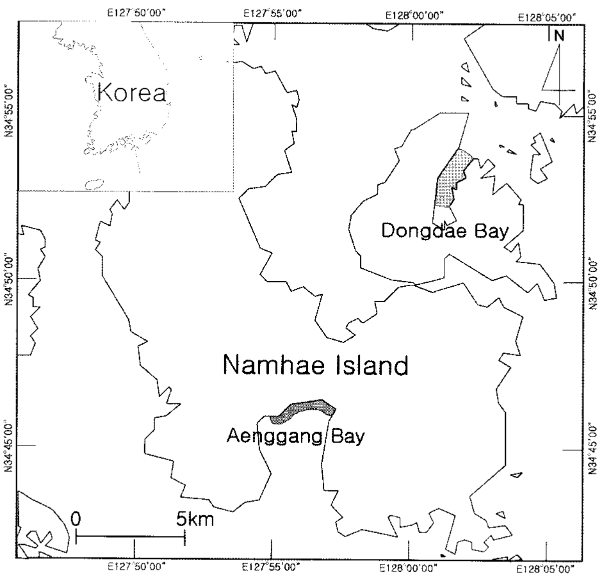


Fig. 1. Location of two eelgrass beds (the black area) around Namhae Island.

The biomass of eelgrass and epiphytic algae were estimated from plant samples collected from a 0.01-$m^2$ area of the sea bottom. Eelgrass shoots were separated into vegetative and reproductive shoots and counted to estimate shoot density. Collection tissues were thoroughly cleaned of epiphytes and sediment and were separated into above- and below-ground parts or epiphytic algae. Shoot height to the nearest 1.0 mm was measured from the meristem to the tip of the longest leaf, and the width of the longest leaf was measured to the nearest 0.1 mm. Epiphytic algal samples were identified according to Kang (1968) and Lee and Kang (1986, 2001) and then dried at 80°C for 24 h along with eelgrass shoots. Subsequently, both plant types were weighed to the nearest gram.

Associations between environmental factors and the biomass of eelgrass and epiphytic algae were investigated concurrently with plant sampling. Temperature and salinity were monitored at each station and on each sampling occasion using a thermometer and a salinometer, respectively. Inorganic nutrient concentrations ($NO_3^-$, $NO_2^-$, $NH_4^+$, and $PO_4^{3-}$) and total suspended materials (TSM) in water samples collected from the study area were measured in the laboratory. The sediment grain size of 1-g sample aliquots were analyzed using a particle size analyzer after drying at 60°C for 24 h. The measured sediment characteristics were median grain size, percentage silt, percentage sand, and percentage gravel. Irradiance data were obtained from the Kyungnam Meteorological Station.

After verification of the normality of data and the homogeneity of variances, two-way analyses of variance (ANOVA) were used to determine if environmental factors, eelgrass density and biomass, and epiphytic algal biomass differed across months and locations. The relationships between eelgrass density, eelgrass biomass, and temperature were analyzed using Pearson's correlation coefficients.

## Results

### Environmental characteristics

Temperature, inorganic nutrient concentrations ($NO_3^-$, $No_2^-$, $NH_4^+$, and $PO_4^{3-}$), and TSM varied significantly among months (ANOVAs, $p < 0.05$) but not between locations (ANOVAs, $p>0.05$; Fig. 2). Salinity did not vary across months (except July 2005) or locations (ANOVAs, $p>0.05$). Sediment characteristics (% sand, % silt, % clay, mean grain size, and sorting) differed significantly between locations, with higher percentages of sand (10.0%) and silt (58.5%) and a larger mean grain size (7.37 Φ) in the eelgrass bed of Dongdae Bay compared to that

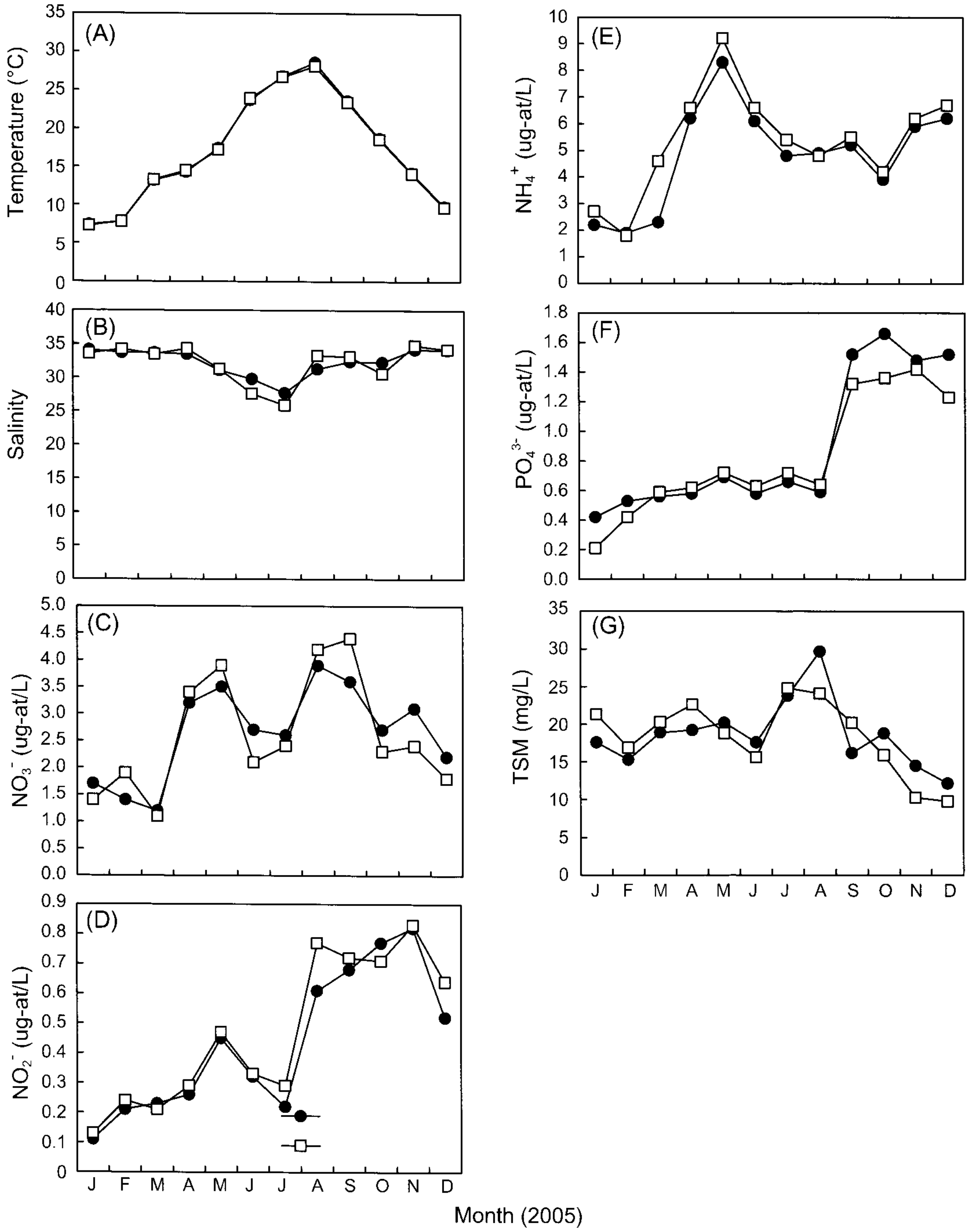


Fig. 2. Monthly variation of (A) temperature, (B) salinity, (C) $NO_3^-$, (D) $NO_2^-$, (E) $NH_4^+$, (F) $PO_4^{3-}$, and (G) TSM in two eelgrass beds around Namhae Island.

Table 1. Charateristics of sediments in two eelgrass beds around Namhae Island

| Locations | Sand (%) | Silt (%) | Clay (%) | Mean grain size (Φ) | Sorting (Φ) | Skweness | Kurtosis |
|---|---|---|---|---|---|---|---|
| Dongdae Bay | 10.02 | 58.45 | 31.53 | 7.37 | 2.05 | -0.16 | 2.14 |
| Aenggang Bay | 5.06 | 55.15 | 39.79 | 7.02 | 2.23 | -0.08 | 2.03 |

of Aenggang Bay (ANOVAs, $p<0.05$). However, we observed a higher percentage of clay in the eelgrass bed of Aenggang Bay (Table 1).

**Seasonal variation in eelgrass shoot density and biomass**

Eelgrass shoot lengths differed significantly across months and locations (ANOVAs, $p<0.05$; Fig. 3-a). Longer shoots occurred in Dongdae Bay relative to Aenggang Bay, with the highest values occurring in July 2005 in both bays (149.6 cm and 129.5 cm, respectively). Leaf widths differed significantly among months, with lower values occurring in November and December 2005; however, the two locations did not vary in eelgrass leaf widths (Fig. 3-b). Total, vegetative, and reproductive shoot density also differed significantly across months and locations (ANOVAs, $p<0.05$; Fig. 4). The total and vegetative shoot densities at Dongdae Bay were higher from May (250 shoots/$m^2$ and 189 shoots/$m^2$, respectively) to August 2005 (271 shoots/$m^2$ and 221 shoots/$m^2$); however, at Aenggang Bay, total shoot density peaked in July 2005 (209 shoot/$m^2$). Reproductive shoots appeared from March to July 2005, with peak densities in April 2005 in both Dongdae Bay (61 shoots/$m^2$) and Aenggang Bay (39 shoots/$m^2$). The two-way ANOVAs revealed that total and above- and below-ground biomass differed significantly among months and locations, with the highest levels occurring in Dongdae Bay (Fig. 5). At this site, total biomass was higher in July (509.6 g DW/$m^2$) and August 2005 (415.9 g DW/$m^2$), whereas the highest values occurred in July 2005 (436.7 g DW/$m^2$) at Aenggang Bay. Peak above- and below-ground biomass occurred in July 2005 at both

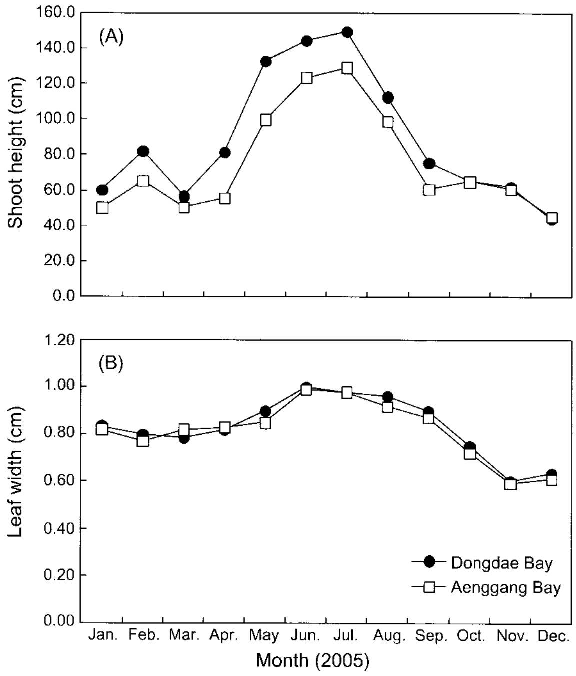


Fig. 3. Monthly variation of (A) shoot height, and (B) leaf width in two eelgrass beds around Namhae Island.

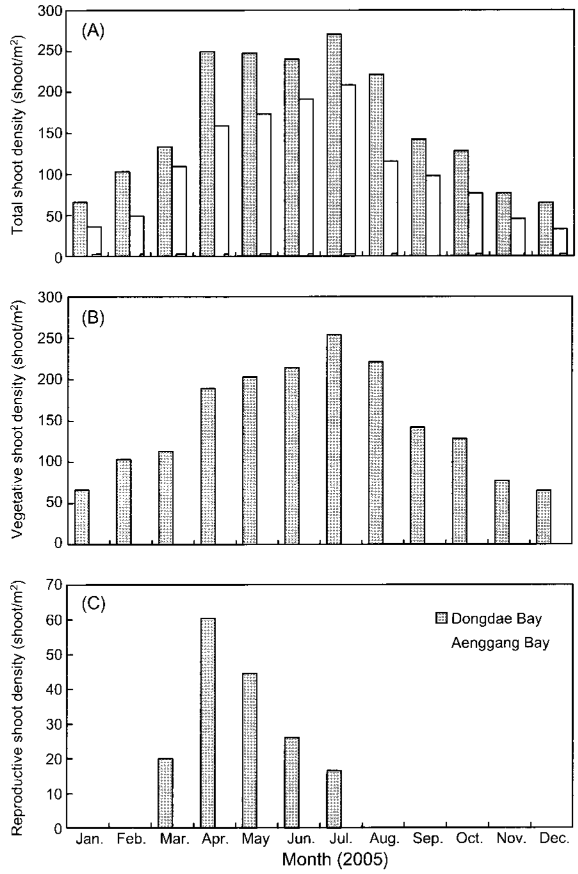


Fig. 4. Monthly variation of (A) total shoot density, (B) vegetative shoot densitym, and (C) reproductive shoot density in two eelgrass beds around Namhae Island.

locations (345.6 and 163.6 g DW/$m^2$, respectively, at Dongdae Bay; 92.5 and 144.2 g DW/$m^2$ at Aenggang Bay).

Variation in water temperature was strongly correlated with seasonal variation in eelgrass density ($r^2=0.822$, $p<0.05$) and biomass ($r^2=0.814$, $p<0.05$) over the study period (Fig. 6).

**Species composition and seasonal variation in epiphytic algae**

A total of 21 epiphytic algae (4 Chlorophyta, 2 Phaeophyta, and 15 Rhodophyta) were collected from Dongdae and Aenggang Bay (Table 2). The species composition of epiphytic algae did not differ between locations. *Polysiphonia japonica*, *Lomentaria hakodantensis*, *Symphyocladia latiuscula*, and *Heterosiphonia japonica* dominated during the entire study period. These species exhibited particularly high biomass from November to February 2005, whereas *Champia* sp., *Calliophyllis rhynchocarpa*, *Laurencia* sp., *Grateoupia* sp., and *Acrosorium*

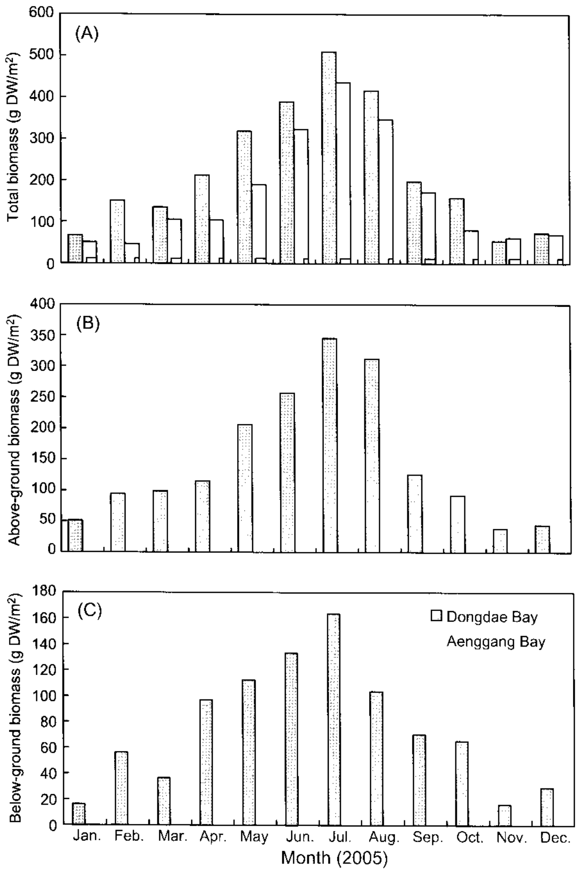


Fig. 5. Monthly variation of (A) total biomass, (B) above-ground biomass, and (C) below-ground biomass in two eelgrass beds aroung Namhae Island.

*flabellatum* were abundant from May to August 2005. In contrast, epiphytic algal biomass varied significantly across months and locations (ANOVAs, $p<0.05$; Fig. 7). Dongdae Bay harbored higher biomass of epiphytic algae compared to Aenggang Bay, with peak values occurring in January (26.2 g DW/m$^2$) and December 2005 (23.5 g DW/m$^2$).

## Discussion

The average total shoot density was >120 shoots/m$^2$ in the study area, which was higher than values observed in eelgrass beds of Kwangyang Bay, Jindong Bay, and the Nakdong River estuary (Huh et al., 1998; Kwak et al., 2006; Park, 2008). In most studies around the Korean peninsula, total shoot density in persistent eelgrass beds ranges from 16 to 276 shoots/m$^2$ (Kim and Choi, 2004; Kaldy and Lee, 2007). Total eelgrass biomass ranged from 54.3 to 509.2 g DW/m$^2$ at Dongdae Bay and from 50.9 to 436.7 g DW/m$^2$ at Aenggang Bay. By comparison, eelgrass biomass ranged from 46.3 to 245.8 g DW/m$^2$ in Kwangyang Bay, from 21.8 to 378.7 g DW/m$^2$ in Jindong Bay, and from 59.1 to 384.2 g DW/m$^2$ in the Nakdong River estuary (Huh et al., 1998; Kwak et al., 2006; Park, 2008). These results indicate that eelgrass biomass at our study sites around Namhae Island is generally higher than is that in other areas. This difference may be attributable to the fact that Dongdae Bay has never been affected by anthropogenic activities, such as pollution. Furthermore, resident fishermen catch a variety of fish in un-baited crab pots. Aenggang Bay also houses several set nets and fishing gear for collecting diverse fisheries resources around eelgrass beds (Hwang, 2007). Several other

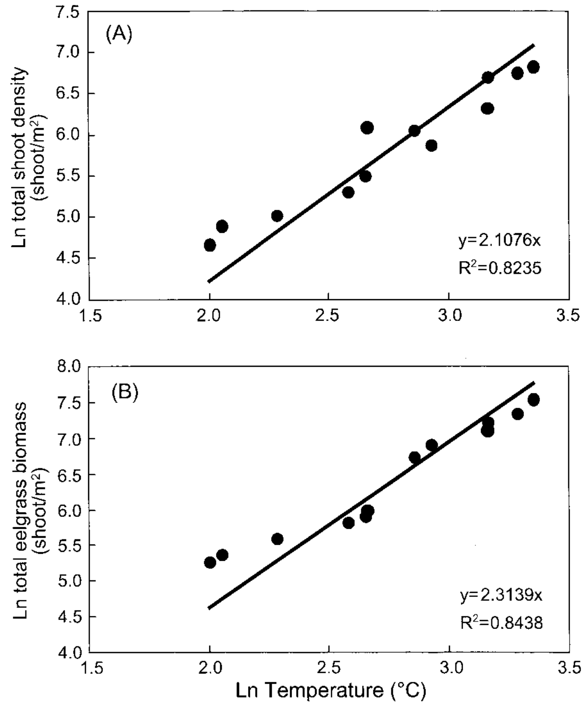


Fig. 6. Relationships between Ln total shoot density (A) and Ln total eelgrass biomass (B) and Ln temperature in an eelgrass bed aroung Namhae Island.

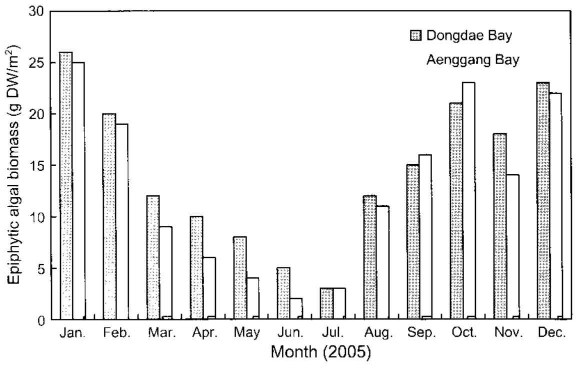


Fig. 7. Monthly variations of epiphytic algae biomass in two eelgrass beds around Namhae Island.

Table 2. Monthly variation in species composition and epiphytic algal biomass in two eelgrass beds around Namhae Island

| Species / Months | Jan. | | Feb. | | Mar. | | Apr. | | May | | Jun. | | Jul. | | Aug. | | Sep. | | Oct. | | Nov. | | Dec. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | A | D | A | D | A | D | A | D | A | D | A | D | A | D | A | D | A | D | A | D | A | D | A |
| Chlorophyta | | | | | | | | | | | | | | | | | | | | | | | | |
| *Ulva pertusa* | ++ | ++ | ++ | + | + | + | + | ++ | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | + | + | + | + | ++ | + | ++ |
| *Codium* sp. | ++ | ++ | ++ | ++ | | + | + | | + | | | | + | + | | | | + | | + | | + | ++ | ++ |
| *Cladophora* sp. | | + | + | + | | | + | + | + | | | | + | | + | + | + | + | | | | + | + | + |
| *Bryopsis plumose* | + | + | + | + | + | + | + | + | | | | | | | | | | | | | | + | + | + |
| Phaeophyta | | | | | | | | | | | | | | | | | | ++ | | | | | | |
| *Sargassum* sp. | +++ | +++ | ++ | + | ++ | + | ++ | + | + | + | + | + | + | + | + | + | + | + | + | ++ | ++ | +++ | +++ | +++ |
| *Colpomenia sinuosa* | ++ | + | | + | | | | | | | | | | + | + | + | + | | | | | + | + | + |
| Rhodophyta | | | | | | | | | | | | | | | | | | ++ | | | | | | |
| *Polysiphonia japonica* | +++ | +++ | +++ | +++ | ++ | ++ | + | + | + | ++ | + | + | + | ++ | + | + | + | + | ++ | ++ | ++ | +++ | +++ | +++ |
| *Lomentaria hakodantensis* | +++ | +++ | +++ | +++ | + | + | + | + | + | + | + | + | + | + | + | ++ | ++ | + | ++ | + | + | +++ | +++ | +++ |
| *Symphyocladia latiuscula* | +++ | +++ | +++ | ++ | + | ++ | + | ++ | ++ | + | ++ | + | + | ++ | + | + | + | | + | + | + | +++ | +++ | +++ |
| *Heterosiphonia japonica* | +++ | +++ | +++ | ++ | + | | | | | | + | ++ | + | + | | + | + | + | + | | + | +++ | +++ | +++ |
| *Champia* sp. | + | | + | | ++ | + | ++ | | ++ | ++ | ++ | ++ | ++ | | ++ | ++ | ++ | | | | | + | | |
| *Calliophyllis rhynchocarpa* | + | + | + | + | + | | + | | ++ | ++ | ++ | + | ++ | ++ | ++ | + | + | | + | | + | + | + | + |
| *Laurencia* sp. | + | + | + | | + | + | + | | ++ | ++ | ++ | +++ | ++ | | ++ | | | | | + | | | | + |
| *Grateoupia* sp. | + | + | | + | ++ | + | ++ | + | ++ | + | ++ | ++ | ++ | ++ | ++ | ++ | ++ | + | + | + | | | + | |
| *Acrosorium flabellatum* | + | + | + | + | + | | + | + | ++ | + | ++ | | ++ | ++ | ++ | +++ | +++ | ++ | | ++ | | + | + | + |
| *Gelidium* sp. | + | + | | + | | + | + | | + | | ++ | + | ++ | | ++ | | | | | | | + | | + |
| *Acrosorium polyneurum* | + | + | + | + | | + | | + | | | + | | | + | + | | | | | + | | + | | |
| *Hypenea* sp. | | + | | | + | + | + | + | + | | + | | | + | + | | | + | + | + | | | | + |
| *Laurencia pinnata* | + | | + | | | + | | + | | | + | + | + | + | + | | | | | | | + | | |
| *Ceramiopsis japonica* | + | + | | + | + | | + | | + | + | | | + | + | + | + | + | + | + | + | + | | + | + |
| *Ceramium kondoi* | + | | + | + | | | | | | + | | | + | | | + | + | + | + | + | + | + | + | + |

D, Dongdae Bay; A, Aenggang Bay; +++, >2 g DW/m$^2$; ++, 0.5~2 g DW/m$^2$; +, <0.5 g DW/m$^2$.

studies have demonstrated a positive correlation between faunal (e.g., fish) richness and the abundance and biomass of seagrass beds worldwide (Klumpp et al., 1989; Huh and Kwak, 1997; Connolly et al., 1999; Hemminga and Duarte 2000).

We observed considerable seasonal variation in both eelgrass density and biomass at our study sites. Both variables were higher from June to August 2005, and these peaks closely corresponded to peak water temperatures. The seasonal variation in water temperature at our study sites was particularly distinct. When water temperature increased in May 2005, eelgrass density and biomass also increased, but both then declined in September 2005 with decreases in water temperature. Previous studies have reported similar patterns of eelgrass biomass and water temperature (Bulthuis, 1987; Adams et al., 1992; Nagelkerken et al., 2002; Park, 2008). For example, Huh et al. (1998) demonstrated that seasonal variation of eelgrass biomass in Kwangyang Bay was positively correlated with water temperature.

Eelgrass density and biomass greatly differed between Dongdae and Aenggang Bay, likely because of differences in sediment characteristics between the two systems. The higher percentages of sand and silt and larger mean grain size in Dongdae Bay coincided with higher eelgrass density and biomass compared to values in Aenggang Bay. Larger proportions of sand and silt improve the circulation of water and air through sediment particles to enhance eelgrass growth, whereas higher percentages of clay may deter growth. These results are further supported by previous studies of seagrass beds (Huh et al., 1998; Hemminga and Duarte, 2000; Nagelkerken et al., 2002).

The majority (70%) of the observed epiphytic algal species belonged to the Division Rhodophyta; e.g., *Polysiphonia japonica*, *Lomentaria hakodantensis*, *Symphyocladia latiuscula*, *Heterosiphonia japonica*, *Champia* sp., *Calliophyllis rhynchocarpa*, *Laurencia* sp., *Grateoupia* sp., and *Acrosorium flabellatum*. *Polysiphonia japonica*, *Lomentaria hakodantensis*, *Champia* sp., *Calliophyllis rhynchocarpa*, and *Laurencia* sp. were also common epiphytic algal species in the nearby Kwangyang Bay, and several of the species occurred in the intertidal zone of the bay (Huh et al., 1998; Choi and Huh, 2008). The differences in epiphytic algal biomass between Dongdae and Aenggang Bay were likely caused by substantial differences in shoot length, leaf width, density, and biomass, even though the species composition of epiphytic algae was similar. Seasonal variation in both the species composition and biomass of epiphytic algal communities was considerable in both Dongdae and Aenggang Bay. Epiphytic algal biomass peaked in January and December 2005, closely corresponding to variations in water temperature. In contrast to seasonal variation in eelgrass biomass, water temperature declines in September 2005 coincided with increases in epiphytic algae biomass. Seasonal variation in epiphytic algal biomass at our study sites was negatively correlated with water temperature. Other studies have documented similar patterns of algal biomass in coastal waters, including eelgrass beds (Song, 1986; Huh et al., 1998).

Eelgrass morphology and growth as a substrate, the life cycle of epiphytic algae, grazing, and currents may also be important factors affecting epiphytic algal communities in eelgrass beds. For example, strong currents in eelgrass beds can damage the complex system of eelgrass and epiphytic algae by affecting eelgrass growth and survival. In addition, the low epiphytic algal biomass from March to May 2005, despite lower water temperatures, may have been caused by increased grazing by epiphytic benthic macrofauna, e.g., gammarid and caprellid amphipods (Kwak and Huh, unpublished data). For example, Morgan and Kitting (1984) noted that small amphipods and mollusks were particularly abundant on epiphytic algae in seagrass beds. Epiphytic algae, especially common species such as *Polysiphonia japonica* and *Lomentaria hakodantensis*, may also be affected by inherent algal life cycle differences as well as the size (shoot length and leaf width) of the eelgrass substrate. Such changes in the eelgrass community may have led to the seasonal variation in species composition and biomass of epiphytic algae from September to November 2005, despite lower water temperature. Hemminga and Duarte (2000) demonstrated that seagrass substrates are extremely important to epiphytic algal communities, whereas higher epiphytic algal biomass may affect seagrass growth and development due to lower seagrass photosynthetic function. In fact, epiphytic algal communities are often used to indicate environmental changes in seagrass beds (May, 1982). Thus, in our study system, eelgrasses may have been maintained through persistent photosynthetic ability associated with fast growth and development, perhaps indicating that epiphytic algae were confined to the upper portions of eelgrass shoots.

## Aknowledgements

We are grateful to Ha Won Kim and Jeong Yun Kim, Department of Oceanography, Pukyong National University for assistance with sampling and data analysis. We also thank Dr. David W Klumpp (AIMS) for his constructive comments in structure of English.

## References

Adams, J.B., W.T. Knoop and G.C. Bate. 1992. The distribution of estuarine macrophytes in relation to freshwater. Bot. Mar., 35, 215-226.

Bulthuis, D.A. 1987. Effects of temperature on photosynthesis and growth of seagrass. Aquat. Bot., 27, 27-40.

Choi, C.G. and S.H. Huh. 2008. Composition of marine algal community at the intertidal zone in Gwangyang Bay, South Sea, Korea. J. Kor. Fish. Soc., 41, 201-207.

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

Den Hartog, C. and J. Kuo. 2006. Taxanomy and biogeography of seagrasses. Seagrass: biology, ecology and conservation. In: Larkum, A.W.D, Orth. R. J. and Duarte, C.M. eds. Springer, 1-23.

Hemminga, M.A. and C.M. Duarte. 2000. Seagrass Ecology. University of Cambridge Press, 1-231.

Huh, S.H., S.N. Kwak and H.W. Kim. 2008. Feeding habits of *Pseudoblennius percoides* (Pisces; Cottidae) in an eelgrass (*Zostera marina*) bed of Dongdae Bay. Kor. J. Ichthy., 20, 45-53.

Huh, S.H., S.N. Kwak and K.W. Nam. 1998. Seasonal variations of eelgrass (*Zostera marina*) and epiphytic algae in eelgrass beds in Kwangyang Bay. J. Korean Fish. Soc., 31, 56-62.

Huh, S.H. and S.N. Kwak. 1997. Species composition and seasonal variations of fishes in eelgrass (*Zostera marina*) bed in Kwangyang Bay. Kor. J. Ichthyol., 9, 202-220.

Hwang, W.J. 2007. Species composition and seasonal variation in fishes in the eelgrass (*Zostera marina*) bed in Aenggang Bay, Korea. M.S.Thesis, Pukyong National University, Busan, 1-63.

Kaldy, J.E. and K.S. Lee. 2007. Factors controlling *Zostera marina* L. growth in the eastern and western Pacific Ocean: comparisons between Korea and Oregon, USA. Aquat. Bot., 87, 116-126.

Kang, J.W. 1968. Illustrated Encyclopedia of Fauna & Flora of Korea. Vol. 8, Marine Algae. Samhwa Press, Seoul, Korea.

Kim, K.Y. and T.S. Choi. 2004. Variability in abundance and morphological attributes of *Zostera marina* L. from the southern coast of Korea. Bot. Mar., 47, 287-

294.
Klumpp, D.W., R.K. Howard and D.A. Pollard. 1989. Trophodynamics and nutritional ecology of seagrass communities. In: Biology of seagrasses: A treatise on the biology of seagrasses with special reference to the Australian region. Larkum, A.W.D. McComb, A.J. and Shepherd, S.A. eds. Elsevier Science Publishers B. V., New York/Amsterdam, 394-437.
Kwak, S.N. and S.H. Huh. 2003a. Feeding habits of juvenile *Liparis tanakai* in eelgrass (*Zostera marina*) beds in Kwangyang Bay. J. Kor. Fish. Soc., 36, 372-377.
Kwak, S.N. and S.H. Huh. 2003b. Feeding habits of *Limanda yokohamae* in the eelgrass (*Zostera marina*) bed in Kwangyang Bay. J. Kor. Fish. Soc., 36, 522-527.
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. Environ. Biol. Fish., 74,129-140
Kwak, S.N., S.H. Huh and B.J. Seung. 2008. Feeding habits of *Hippocampus mohnikei* in an eelgrass (*Zostera marina*) bed. Kor. J. Ichthy., 20, 112-116.
Kwak, S.N., S.H. Huh and C.G. Choi. 2006. Comparisons of fish assemblages associated with eelgrass beds and adjacent unvegetated habitat in Jindong Bay. Kor. J. Ichthyol., 18, 119-128.
Lee, I.K. and J.W. Kang. 1986. A check list of marine algae in Korea. Kor. J. Phycol., 1, 311-325.
Lee, Y.P. and S.Y. Kang. 2001. A Catalogue of the Seaweeds in Korea. Cheju National University Press, Cheju, Korea.
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. J. Kor. Fish. Soc., 33, 439-447.
Lee, K.S. and S.Y. Lee. 2003. The seagrasses of the Republic of Korea, In: World Atlas of seagrasses: present status and future conservation. Green, E.P., F.T. Short, and M.D. Spalding. eds. University of California Press, Berkerly, 193-198.
May, V. 1982. The use of epiphytic algae to indicate environmental changes, Aust. J. Ecol., 7, 101-102.
Morgan, M.D. and C.L. Kitting. 1984. Production of the utilization of the seagrass *Halodule wrightii* and its attached epiphytes. Limnol. Oceanogr., 29, 1066-1076.
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. Mar. Ecol. Prog. Ser., 244, 299-305.
Park, S.R. 2008. Production dynamics of three *Zostera* species on the southern coast of the Korean peninsula. Ph.D. Thesis, Pusan National University, Pusan, 1-235.
Song, C.B. 1986. An ecological study of the intertidal macroalgae in Kwangyang Bay, Southern Coast of Korea. Kor. J. Phycol., 1, 203-223.
Yoon, S.P. 2006. The eelgrass, *Zostera marina* and its associated macroinvertebrate communities in Gwangyang Bay, Korea. Ph.D. Thesis, Inha University, 1-237.

(Received 30 April 2009; Revised 1 June 2009; Accepted 3 September 2009)