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Seagrass (*Zostera marina* L., Zosteraceae) Bed in the Brackish Lake Hwajinpo, Korea

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화진포 기수호의 해산식물 거머리말 (*Zostera marina* L., Zosteraceae). 이상용 · 권천중 · 허 승[1] · 최청일* (한양대학교 이과대학 지구해양과학과, 안산 425-791, [1]국립수산진흥원 해양연구과, 부산 619-902)

자연 기수호인 화진포호에서 자생하는 거머리말(*Zostera marina*)의 분포와 생육환경을 파악하기 위하여 1998년 6월과 2000년 7월에 식물체와 퇴적물을 채집하여 수질과 함께 분석하였다.
거머리말 초지의 분포는 해수와 담수의 수체의 소통이 원활한 지역으로 수심 0.8~1.5 m에 서식하였으며, 초지의 면적은 약 3,200 m^2로 해안과 연결되는 호수 입구 쪽을 따라 길게 분포하였다. 서식지의 염분은 8.0~23.0‰, 수온은 22.0~23.7°C, pH는 8.34~8.62으로 나타났으며, 영양염의 농도는 인접한 해양의 거머리말 생육지 보다 낮았다(TN: 24.34 μM, NH_4-N: 2.57 μM, NO_3-N: 0.56 μM, NO_2-N: 0.27 μM, TP: 2.08 μM, PO_4-P : 0.34 μM). 조사지역의 부유형물질(Suspended particulate matter, SPM)의 농도는 62.8 mg/l이였으며, 입자성유기물질(particulate organic matter, POM)은 평균 21.3 mg/l로서 평균 33.9%의 부유 유기물 함량을 나타내었다. 서식지의 퇴적환경은 4 cm까지는 호기성이었으며, 3.13Φ의 세립한 사질로 구성되었다. 식물체의 외부 형태는 협엽성 거머리말의 형태적 특징을 나타내었으며, 식물체의 길이는 70.0~126.5 cm, 잎 너비는 5~7 mm의 범위로 나타났다. 단위 면적당 서식밀도는 264~296 개체이었으며, 개체당 건중량은 1.26±0.75 g로 나타났다. 화진포호의 거머리말 초지의 생물량은 332.6~373.0 g/m^2의 범위이었다. 한반도에서 거머리말의 생육환경은 기수호인 화진포호까지 분포되었으며, 형태학적인 특징이 다양하게 출현하였다.

Key words : Hwajinpo Lake, Seagrass, *Zostera marina*, Brackish lake, Biomass

INTRODUCTION

On the eastern coast of Korean Peninsula there are only 9 naturally formed brackish lakes, among these Hwajinpo and Chungcho Lake are being flushed regularly with seawater and able to provide habitats for marine biota (Kim *et al*., 1981). Recent land development around Chungcho Lake made the lake heavily polluted and biodiversity has been reduced so much that the lake is no longer a naturally formed brackish lake (Jun, 1996; Jun *et al*., 1996).

The biota of Hwajinpo, supported by diverse habitat characteristics, is euryhaline with a particular tolerance for high salinity (Choi *et al*., 1975). The lake also is provided with high nutrients from inflowing freshwater from tributaries, although the numbers of stenohaline as well as euryhaline species are limited due to the existing low diversity with a dense population in the simplified food web (Kim, 1996b).

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Zostera (seagrass) beds occur in most shallow, sheltered soft-bottomed marine coastline and estuaries of Korea (Lee, 1998). *Zostera* is an aquatic flowering plant, and is capable of reproducing entirely underwater (Kirkman, 1985). The genus *Zostera*, consisting of 11 species, is primarily distributed in temperate regions, and five (5) species were found on the Korean Peninsula (Miki, 1932; Kuo and McComb, 1989; Shin and Choi, 1998). *Z. marina* is characterized by a complicated pattern of morphological variations and biomass change, which are largely affected by the variation of environmental parameters, such as temperature, water turbidity, sediment stability and nutrient levels (Sfriso and Ghetti, 1998).

The importance of *Zostera* ecosystems is to provide a sheltered and nutrient-rich habitat for diverse flora and fauna. *Zostera* beds mechanically facilitate the reduction of wave and current energy, to filter suspended sediments from the water, and to stabilize bottom sediments (Fonseca and Cahalan, 1992). The *Zostera* beds on near estuaries are also nutrient sinks, a buffer for filtering nutrient and chemical sources from the marine environment (Short and Short, 1984). *Zostera* beds support numerous herbivore-and detritivore-based food chains, so that they are considered to be very productive pastures of the sea or estuaries (McRoy and Helfferich, 1980).

Despite the importance of its preciousness and diverse ecological characteristics, studies on these brackish lakes have been neglected. Only a very few studies on water quality, distribution of plankton (Hong *et al*., 1969; Cho *et al*., 1975; Chun *et al*., 1996; Kim, 1996a), eutrophication (Huh *et al*., 1999), fauna (Kim, 1996b) and sediment pollution (Chun, 1996) were reported.

The aim of this study was to integrate the knowledge acquired about *Zostera marina* distribution in the truly brackish lake, Hwajinpo, in Korea by studying the environmental factors (nutrients, salinity, temperature, sediment type), and morphometric parameters (shoot density, shoot height, leaves per shoot, *etc*) of *Z. marina* that populate the lagoon. Additionally we describe changes in the morphological variations and biomass of *Zostera marina* at the Hwajinpo Lake and Duksan Port.

MATERIALS AND METHODS

Experimental plants, seawater and sediments were collected from meadows of *Z. marina* in Hwajinpo Lake (128° 26′E, 38° 28′N) and Duksan Port (129° 15′E, 37° 23′N). These study sites, about 140 km apart, are located in the middle of the east coast of the Korean Peninsula and have been the focus of different habitat environments on Korean seagrass. Hwajinpo Lake is composed of both an outer (Yeoho) and inner (Laeho) lake, which are separated by a submerged sand bar. The water surface area is 2.31 km^2 and the maximum depth is 4.6 m. Seawater surges to the outer lake, particularly during typhoon seasons and enables some marine fauna to move into the lake while several small tributaries are replenishing the inner lake. A *Zostera marina* bed is lo-

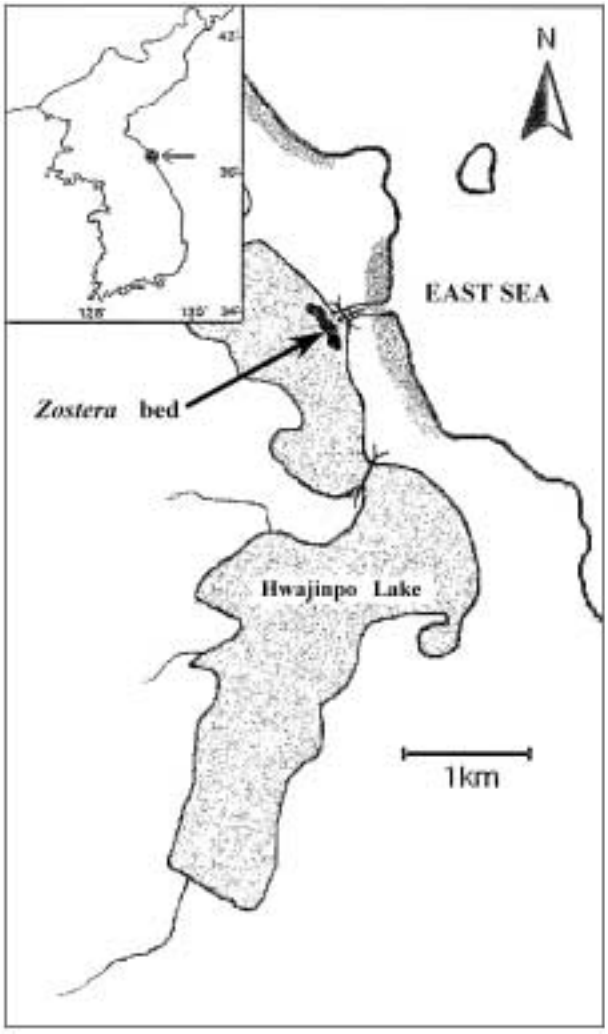

Fig. 1. Map of Hwajinpo Lake in the eastern coast of Korea. Zostera marina beds were distributed around the river-mouth of Hwajipo Lake.

cated in the outer lake, parallel to the seacoast, with an area of 3,200 m^2 (Fig. 1). Vegetation at Duksan Port was a mixed assemblage of *Z. marina* and *Z. caespitosa*. The depth of water was approximately 3.4 to 5.2 m at mean low water. This vegetation shows marked seasonal variation in biomass and life cycle and is characterized by typically oceanic environments (Lee, 1998).

Samples were collected in June 1998 and July in 2000. Water samples for temperature, salinity, pH and dissolved nutrients analyses were taken in the vegetated water, at 1 m depth. Water temperature and salinity were measured with a salinometer (YSI-100), and pH was assessed using a pH meter (Horiba U-10 model). Total nitrogen (TN), ammonia, nitrate, nitrite, phosphorus and total phosphorus (TP) were measured following Strickland and Parsons (1972).

Sediment samples were collected with a core sampler with 10 cm diameter to a depth of about 20 cm at the selected station. Sediment samples were dried at 60°C for 24 hrs to a constant weight and used to determine grain size distribution and organic content.

Z. marina plants were sampled in monospecific stands, and about 20 shoots were randomly collected from a quadrant (0.25 m^2) within the meadow. Plants were gently cleaned of sediment using tap water and epiphytes were removed by gently scraping. The plants were separated into individual shoot units that included healthy leaves, roots and rhizome. Measurements of leaf length (LL), width (LW), and shoot density (SD) of the vegetation shoots, and flowering shoots were routinely made when sampling *Z. marina* standing stock. The values for LL and LW were obtained by averaging the maximum leaf size of 10 vegetative shoots. SD value was obtained from the estimates of biomass in which all shoots in four random 0.5 m × 0.5 m quadrants were counted *in situ*. Shoot samples were counted for each quadrant and individual spathes on the floral shoots were counted separately. Rhizome length measurements were made by determining the total length of horizontal rhizome in each sample. Biomass was measures using the standard drying method and was expressed in grams dry weight per square meter (Ott, 1990).

RESULTS

Z. marina was found to be distributed along the eastern coast of Korea (Fig. 2). The first time (1998), the *Z. marina* beds in the brackish lake, Hwajinpo, were found for about 3,200 m^2 and distributed around the lake-mouth parallel to the seacoast.

The depth of *Z. marina* beds ranged from 0.8 to 1.5 m. The water temperature, pH and salinity in

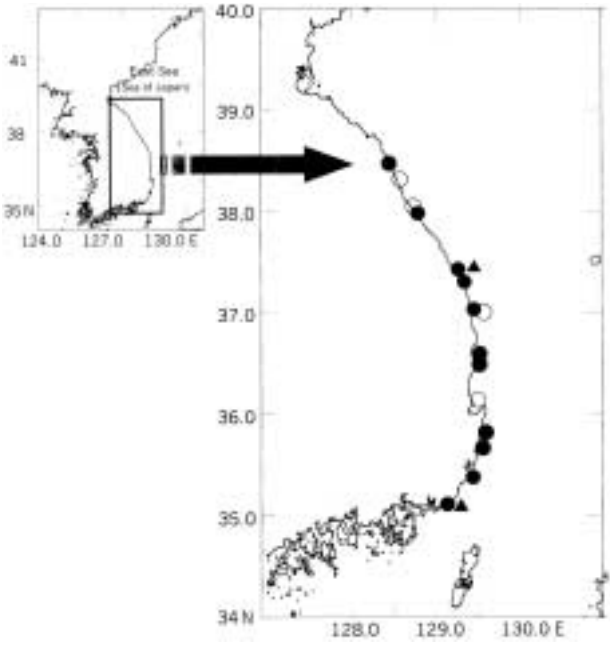

Fig. 2. Distribution of Zostera species in the eastern coast of Korea. (*Z. marina* L. (●), *Z. asiatica* Miki (○), *Z. caespitosa* Miki (▲).

Table 1. Comparison of habitat characteristics of *Zostera marina* beds in the Hwajinpo Lake and Duksan Port, Korea. Data values show ranges and mean ±standard deviation.

Sites	Hwajinpo Lake	Duksan Port (East Sea)
Habitat depth (m)	0.8~1.5	3.5~5.0
Salinity (‰)	8.0~23.0	28.4~34.3
pH	8.34~8.62	8.09~8.47
SPM (mg/L)	62.8	54.5
POM (mg/L)	21.3	36.6
TN (μM)	24.34±0.076	34.51±0.081
Ammonia-N (μM)	2.57±0.17	1.24±0.05
Nitrate-N (μM)	0.56±0.008	1.10±0.019
Nitrite-N (μM)	0.27±0.004	0.12±0.011
TP (μM)	2.08±0.071	1.37±0.014
Phosphorus-P (μM)	0.34±0.004	0.93±0.006
Sediment grain size (Φ)	3.1	2.3
Sediment type	sand	sand

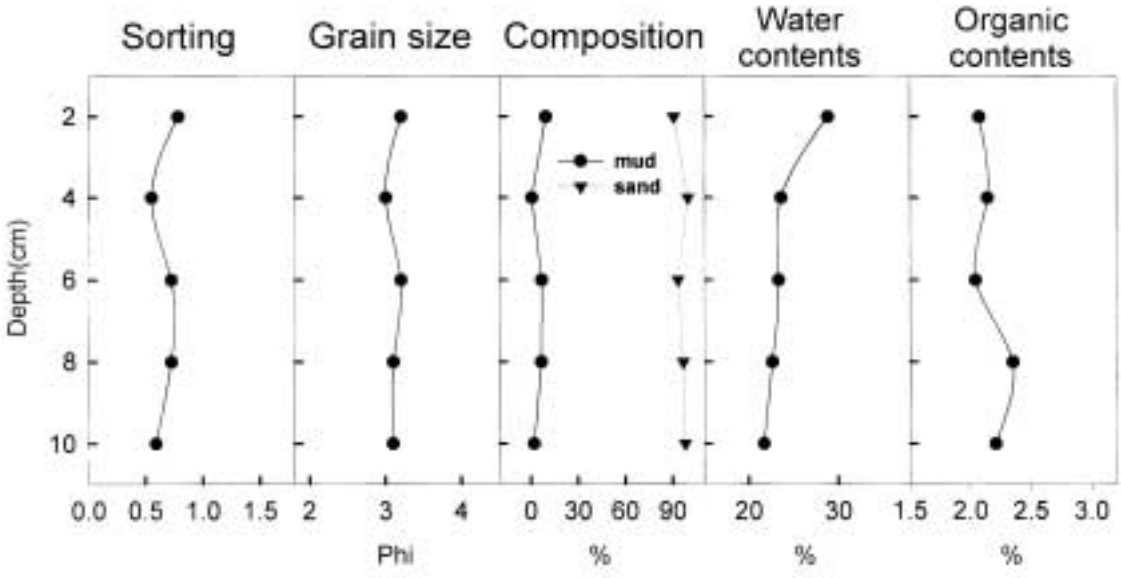

Fig. 3. Vertical profiles of Zostera marina bed sediment from Hwajipo Lake.

Z. marina beds ranged from 8.0～23.0%, 8.34～8.62 and 22.0～23.7°C, respectively. The range of salinity in *Z. marina* beds was higher than in the other areas of the lake and is considered to be brackish.

Mean concentration of measured nutrients was generally low. Ammonium, nitrite and TP concentration in water was generally higher for Hwajinpo Lake when compared with Duksan Port (Table 1). The suspended particulate matter (SPM) concentration averaged 62.8 mg/l and the amount of particulate organic matter (POM) averaged 21.3 mg/l, which is 33.9% of the SPM.

Sediments at these sampling sites were predominated by sand. The Hwajinpo Lake area had a smaller median grain size (3.1Φ) than the Duksan Port site (2.3Φ) as well as a greater percentage of fine material. Vertical sediment grain size distribution of the Hwajinpo Lake vegetation was homogeneously sand up to at least 10 cm depth. Organic content (% dry weight) homogeneously was distributed, while water contents (% dry weight) varied between 21.7 and 28.8% (Fig. 3).

Z. marina vegetation at Hwajinpo Lake was generally submerged, and the morphological characteristics can be classified as a steno-leaf type in view of the shoot length, leaf width, and number of leaf veins (Table 2). The shoots size of *Z. marina* beds in Hwajinpo varied between vegetation and flowering shoots, and the leaf size, width and vein number were smaller than those in Duksan Port. Shoot densities ranged from 264 to 296/m^2 and plants biomass was estimated from 332.6 to 373.0 g dw/m^2. The morphological difference of *Zostera* between the two regions seemed to be complicated by varied salinity and a difference in water depth.

Table 2. Comparison of morphological characteristics, shoot density and biomass of *Zostera marina* beds in the Hwajinpo Lake and Duksan Port, Korea. Data values show ranges and mean± standard deviation (n = 10).

Characters \ Sites		Hwajinpo Lake	Duksan Port (East Sea)
Vegetation shoot height (cm)		70.0～126.5	87.2～111.4
Flowering shoot height (cm)		80.1～142.6	138～195
Leaf	length (cm)	55.5～101.0	70.4～88.7
	width (mm)	5～7	7～11.5
	apex shape	retuse, emarginate	round
	number of vein	5	7
	No.	5～6	3～7
Rhizome	length (mm)	9～22	17～36
Fruits	shape	ellipsoid, striated	ellipsoid, striated
Shoot density (ea/m^2)		264～296	396～440
Biomass of individual (dry wt.)		1.26±0.75	1.58±0.83
Biomass (dry wt/m^2)		332.0～373.0	625.7～695.2

DISCUSSION

The bed of *Zostera marina* was first been reported in the brackish Hwajinpo Lake (Lee *et al*., 2000), which is separated by a sand bar into an inner lake with nearly freshwater (5.1～18.4‰) and an outer lake with mostly salt-water (10.1～25.1‰). The species of *Z. marina* that extend to brackish lake is exposed to low salinity.

Huh *et al*. (1999) reported that the lake readily provided a habitat for brackish biota. Kim *et al*. (1981) and Kim (1996b) reported that the lake, particularly the outer lake, provided a good habitat for breeding both fresh and sea water fish. The current find of a *Zostera* bed in the outer lake mouth confirms its important role for distribution in the brackish lake, but these beds were not known to have the energy flow and material cycling.

The biomass of the *Z. marina* bed in Hwajinpo Lake, ranged from 332.6～373.0 g dry wt/m^2, and the total biomass of the area was 1064.3～1193.6 kg. This biomass is a primary producer and later, by detritus drive, this lake ecosystem was found to be rich in organic matter. It is thought that these beds further provide a higher level of dissolved oxygen and have a role in filtrating and buffering the in and out flow of the waters through the channel opening (Ricklefs, 1990; Short and Short, 1984).

This study provides some environmental factors related with biomass only for *Z. marina* beds, yet biota studies in the bed and life cycle study of the beds has not been pursued. Only one sampling in the summers of 1999 and 2000 also prevented a conclusion on the temporal variation of the bed. However, considering the importance of the seagrass in the brackish lake ecosystem, further studies on these aspects should be pursued and necessary one. Evolutionary studies on Zosteraceae habitats will be particularly important since these plants propagated from fresh water to seawater (den Hartog, 1970)

Although the bed occupies only a small fraction of its potential habitat in Hwajinpo Lake, we predict significant changes in the ecology of this brackish water with the introduction and spread of *Z. marina* forming beds in the brackish water in Korea. Since our knowledge of *Z. marina* production is still underrepresented in Hwajinpo Lake, the high biomass and production of *Z. marina* beds are suggested to be directly linked to the important ecological roles as they play in the brackish ecosystem. Brackish water fish species are limited in diversity, although easy breeding with few predators makes for rapid population growth (Kim, 1996b). Brackish species are well adapted to breed in large numbers, both in primary and secondary production. Primary production reported was to be equal to that of coral reefs and terrestrial rainforests (McRoy and McMillan, 1977).

The morphological characteristics of *Z. marina* in Hwajinpo Lake appeared to be largely affected by the substrate and sediment environment. The correlation between vegetative activity and environmental variables in *Z. marina* is not easy to determine from only one sampling in each summer. However, this study confirms that vegetative growth in terms of the density of shoots within *Z. marina* beds was related to water depth and light intensity. Detrital *Z. marina* after good vegetative growth may provide mineral and organic sediment (Harrison and Mann, 1975), and this also may meditate nutrient availability to other biota in the Hwajinpo Lake.

ABSTRACT

This study was conducted to clarify the habitat characteristics and distribution of seagrass, *Zostera marina* L. (Zosteraceae) in the brackish Hwajinpo Lake, Korea in June 1998 and July 2000. *Z. marina* beds were distributed along the sea-side cost of the lower lake mouth at 0.8 to 1.5m in depth, and the seagrass bed area was about 3,200 m^2. Salinity, water temperature and pH were in the range of 8.0～23.0‰, 22.0～23.7 °C and 8.34～8.62, respectively. Nutrient concentrations were generally low (TN: 24.34 μM, NH_4-N: 2.57 μM, NO_3-N: 0.56 μM, NO_2-N: 0.27 μM, TP: 2.08 μM, PO_4-P: 0.34 μM). Suspended particulate matters (SPM) concentration averaged 62.8 mg/l and particulate organic matter (POM) averaged 21.3 mg/l. Organic content of SPM averaged 33.9%. The beds substratum was composed of well-sorted, fine sand and its mean grain size was 3.13Φ. The *Z. marina* vegetation was almost submerged, and the morphological characteristics can be classified as steno-leaf phenotype by the shoot length, leaf width, and number of leaf vein. Shoot length and leaf width were 70.0～126.5 cm and 5～7 mm, respectively. Shoot den-

sities ranged from 264 to 296/m^2, and the plants biomass was estimated at 332.6 to 373.0 g dw/m^2. Therefore, the habitats of *Z. marina* in Korea were recognized in a brackish lake, and morphological characteristics appeared to be variable.

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