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Distribution of Aquatic Macrophytes in the Littoral Zone of Lake Paltangho, Korea

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팔당호 연안대에서 대형수생식물의 분포

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ABSTRACT

In the littoral zone of Lake Paltangho, a vegetation map of aquatic macrophytes was constructed to estimate their occupied area, and the change of abundance of submersed macrophytes was examined along water depth to elucidate niche preferences on the depth gradient. Total area of the littoral zone was 267 ha, of which submersed, emergent and floating-leaved macrophytes covered 155 ha, 103 ha and 10 ha, respectively. Submersed macrophytes were distributed within a water-depth of 2.5 m, with an apparent pattern of zonation: *Vallisnaria gigantea* was exclusively found at the shallowest water, *Hydrilla verticillata* at the intermediate depth and *Ceratophyllum demersum* at the deeper water depth of 1.5~2.5 m.

Key words: Aquatic macrophyte, Lake Paltangho, Vegetation map, Water depth, Zonation

INTRODUCTION

A central issue in ecology is what environmental factors determine the distribution and abundance of species (Krebs 1985). In the littoral zone of lakes, the ecological steepness of vertical (depth) gradient is widely recognized (Sculthorpe 1967, Hutchinson 1975). Aquatic macrophytes are distributed on this gradient according to their niche preferences (Rorslett and Agami 1987). Among many factors that determine their distribution and abundance are water depth, sediment type, water turbidity, water chemistry, shoreline disturbance, herbivore grazing, and human activities (Spence 1982). As a result of niche segregation, zonation in the littoral zone of lakes and slow-moving streams is common. In general, emergent macrophytes are found in the most shallow portion of the littoral zone. Floating-leaved plants are commonly found in the lower littoral area at depths between 1

and 3 m. Submersed plants may occur from edge of shore to the interface of littoral and profundal zones (APHA 1989).

Lake Paltangho functions as a reservoir for drinking water for the people of Metropolitan Area of Seoul, and the management of water quality, therefore, is very important in this lake. However, rapid eutrophication of the lake has taken place during the last 20 years (Han *et al.* 1993). In the littoral zone of Lake Paltangho, aquatic macrophytes are widely distributed. They respond to the quality of water in which they grow; thus a better understanding of their ecological aspects is important for water quality evaluation.

The objectives of this study were to construct a vegetation map of the littoral zone of Lake Paltangho for the estimation of area occupied by aquatic macrophytes, and to elucidate the change in abundance along water-depth, particularly for submersed macrophytes.

STUDY AREA

Lake Paltangho is located in the middle of the Peninsula Korea, about 30 km east of Seoul (Fig. 1). This lake is an artificial reservoir, which was constructed in 1973. It can be considered as a lake or a river due to its long length and narrow width as well as the hydrology of very short retention time, about 5 days. Because the lake has a wide drainage area of 23,608 km^2 in comparison with its total water surface of 36.5 km^2, it is susceptible to eutrophication from great pollution source in its basin (NIER 1988). There is a wide area of littoral zone, which was mainly agricultural land before the construction of the dam. For this study, the survey area was restricted to 19.4 km^2 within 37° 34′30″ N to north, 37° 27′00″ N to south and 127° 22′30″ E to east.

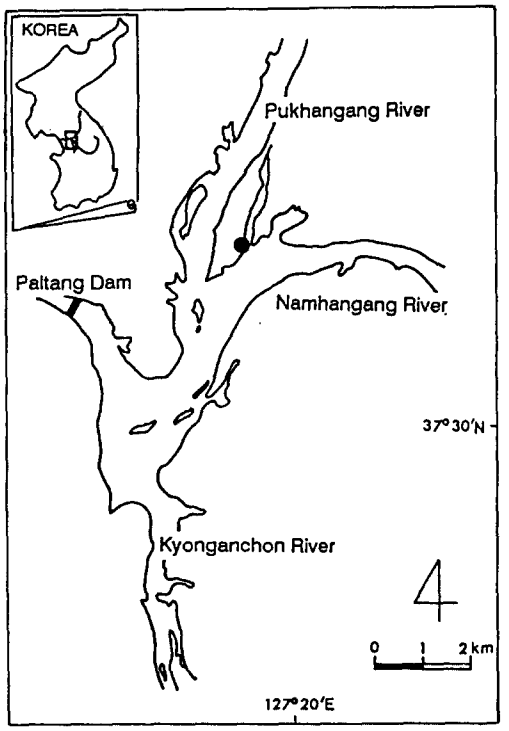

Fig. 1. A map showing the study area of Lake Paltangho. Closed circle indicates the sampling site of submersed macrophytes.

METHODS

Actual vegetation map of aquatic macrophytes in Lake Paltangho was constructed using field reconnaissance in July and August 1988. At lush growth stage, the outline of pure stands of floating-leaved or emergent littoral macrophytes and

mixed stands of submersed vegetation could be determined by visual observation from land and ship. The area occupied by aquatic macrophytes was drawn on a 1:5,000 scale map. The area enclosed by each species or growth-form on the map was determined by a planimeter.

To investigate changes in biomass of submersed macrophytes along water depth, sampling was conducted at an embayment of Yangsuri, Yangsumyon, Yangpyonggun, Kyonggido in July 1988 (Fig. 1). Samples were taken along transect lines by using home-made sampler. This sampler had an hexahedral frame of a steel having outside dimensions of 0.5 m × 0.5 m × 0.4 m. A 0.5 m blade at the bottom edge of a front face of the sampler was used to cut vegetation during the drag. Five faces except a front face were covered with a net screen. The sampler was pulled to a 2 m distance from shore. The area sampled by each drag was 1 m^2. The collected macrophytes were sorted by species, the sediment and periphyton were removed by washing, and total dry weight at 80℃ was determined.

RESULTS

Area Occupied by Macrophytes

Thirty-eight taxa of aquatic macrophytes were found in the littoral zone of Lake Paltangho (Cho 1992). As a result of classification by the growth-form, number of species in each growth-form was 20 (52.6%) emergent, 12 (31.6%) submersed, 3 (7.9%) floating-leaved and 3 (7.9%) free floating macrophytes. The upper littoral zone of shallower water-depth was dominated by emergent macrophytes such as *Phragmites australis* (Cavanilles) Trinius ex Steudel, *Zizania latifolia* Turczaninov and *Typha angustifolia* L. The lower littoral zone of deeper water-depth was dominated by floating-leaved macrophytes such as *Nelumbo nucifera* Gaertner and *Trapa japonica* Flerov, free floating macrophytes such as *Salvinia nataus* (L.) Allioni, and submersed macrophytes such as *Hydrilla verticillata* Caspary, *Potamogeton maackianus* A. Bennett and *Ceratophyllum demersum* L. Other macrophytes occurred in small patches rather than in extensive beds. Frequently patches consisted of pure stands of single species.

In Lake Paltangho, the littoral zone of macrophyte stands was distributed almost in form of belts along the shore. The distribution maps of aquatic macrophytes in three main areas of the lake, where the littoral zone was widely distributed, are presented at Figs. 2, 3 and 4. In the flux of River Kyongancheon in Kwangdong-ri, *Z. latifolia* was dominantly distributed along the eastern shore, and other emergent macrophytes such as *T. angustifolia, Scirpus triqueter, S. tabernaemontani* and *P. australis* formed the small patches (Fig. 2). At the deeper littoral zone, submersed macrophytes were widely distributed. In the eastern central region of the lake in Kuiyo-ri, *T. angustifolia* was distributed in the most upper littoral zone around islands, and other emergent macrophytes such as *Z. latifolia* and *P. australis*, and *N. nucifera* and floating-leaved macrophytes appeared at small

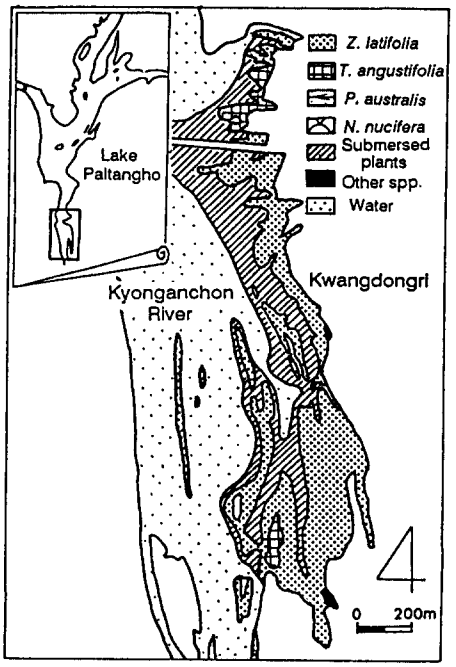

Fig. 2. A vegetation map in the littoral zone at Kwangdongri.

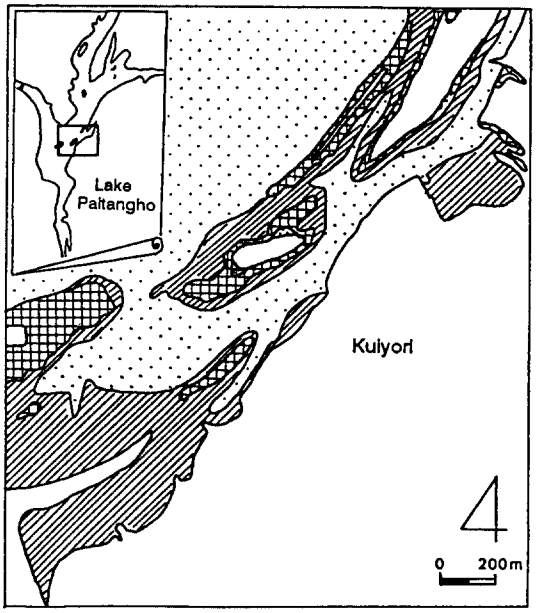

Fig. 3. A vegetation map in the littoral zone at Kuiyori.

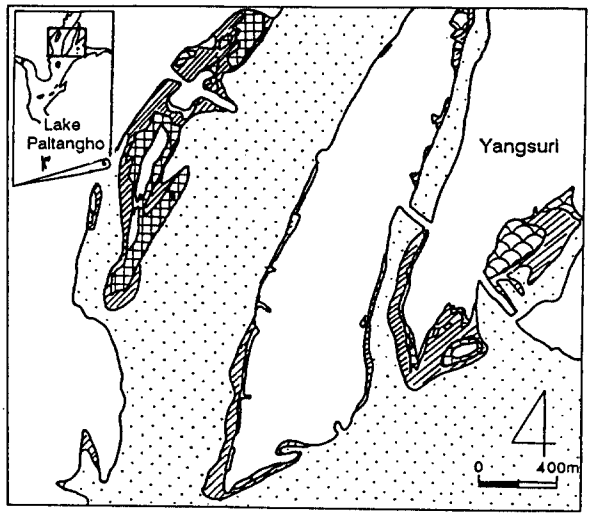

Fig. 4. A vegetation map in the littoral zone at Yangsuri.

areas (Fig. 3). In bays between island and shore submersed macrophytes covered the extensive area. In the junction of River Pukhangang and River Namhangang in Yangsu-ri, *T. angustifolia* had a predominant distribution area along shore and around islands, and other many emergent macrophytes could be found, and *N. nucifera* as a floating-leaved macrophyte occupied the large area in the Yongdam-ho (Fig. 4).

Total littoral zone in the study area of the lake occupied 267.1 ha, of which submersed, emergent and floating-leaved macrophytes covered 154.6 ha(58%), 102.9 ha(38%) and 9.6 ha(4%), respectively (Table 1). Out of the area occupied by emergent macrophytes, *T. angustifolia*, *Z. latifolia* and *P. australis* accounted for 60.0 ha, 39.8 ha and 2.3 ha, respecti-

Table 1. Area covered by macrophytes in Lake Paltangho

Plants	Occupied area (ha)		
Emergent plants		102.9	(38%)
Typha angustifolia	60.0		
Zizania latifolia	39.8		
Phragmites australis	2.3		
Others	0.8		
Floating-leaved plants		9.6	(4%)
Nelumbo nucifera	9.4		
Nymphoides indica	0.2		
Submersed plants		154.6	(58%)
Total		267.1	(100%)

vely. *N. nucifera* occupied the most of the area distributed by floating-leaved macrophytes.

Distribution of Submersed Macrophytes along Water-depth

At the sampling site of submersed macrophytes including *T. japonica*, they grew down to a depth of 2.5 m, and reached the maximum biomass, 322 g DM /m^2, at depth of 1.5 m ~ 2.0 m in July (Table 2). *C. demersum* and *H. verticillata* dominated out of the 8 collected species. Particularly, *C. demersum* reached its greatest biomass of 287 g DM /m^2 at depths of 1.5 ~ 2.0 m, and this amount corresponded to 89% of total biomass at these depths. On the other hand, *H. verticillata* dominated more vigorously at the shallower depths than 1.5 m. Its maximum biomass, 105 g DM /m^2, was observed at depths of 0.5 ~ 1.0 m, and this amount corresponded to 94% of total biomass at these depths. It is noteworthy that *Vallisnaria gigantea* occurred only to a depth of 1.0 m, and reached the greatest biomass at depths of 0 ~ 0.5 m. Other species such as *Potamogeton maackianus, P. perfoliatus, Myriophyllum spicarum* and *Najas marina* achieved little growth at the sampling site, and were observed in small patches.

Table 2. Standing biomass(g DM /m^2) of submersed plants and *Trapa japonica* along water depth in Lake Paltangho on July 18, 1988 (Mean ± SD)

	Water depth (m)				
	0~0.5	0.5~1.0	1.0~1.5	1.5~2.0	2.0~2.5
Ceratophyllum demersum	1 ± 1	3 ± 1	73 ± 109	287 ± 145	175
Hydrilla verticillata	64 ± 32	105 ± 31	87 ± 44	13 ± 16	9
Potamogeton maackianus	1 ± 2	1 ± 1	1 ± 2	5 ± 2	0
Vallisnaria gigantea	3 ± 3	1 ± 1	0	0	0
Other submersed plants*	1 ± 1	1 ± 2	0	1 ± 1	0
Trapa japonica	0	0	0	16 ± 29	0
Total	70 ± 30	111 ± 31	161 ± 94	322 ± 164	184

* *Myriophyllum spicarum, Potamogeton perfoliatus, Najas marina*

DISCUSSION

In Lake Paltangho, the area occupied by aquatic macrophytes was 267 ha, which was equivalent to 14% of total water surface area, 1940 ha. Out of emergent macrophytes, *T. angustifolia* and *Z. latifolia* were widely distributed in the upper littoral zone. It is supposed that their distribution area will decrease by disturbance of human activity and by eutrophication of water. For example, wave from the wakes of ships damages and uproots emergent macrophytes. The increase of nutrients in the lake also leads to mechanical damage of stems by thick layers of algal bloom such as *Cladophora* (Sukopp and Markstein 1989).

Although submersed macrophytes can extend to a depth of 10 m in oligotrophic lakes (Spence 1982), they were distributed only within a depth of 2.5 m in Lake Paltangho, which was undertaken by rapid eutrophication (Han *et al.* 1993). The factors which were associated with eutrophication and probably caused changes in the distribution of submersed macrophytes are changes in water turbidity and chemistry. Decreases in water transparency are ascribed as the main reason for the deep water extension of macrophytes. In Lake Paltangho the Secchi depth decreased by about 2 m over 1988-1989 (NIER 1988, 1989). Nutrient enrichment may be the primary cause of the ecological imbalance that has led to massive algal blooms and the decline of submersed macrophytes. The response of freshwater systems to nutrient enrichment and the competitive relationship, primarily for light, between phytoplankton and macrophytes has been well documented (Wetzel 1983). On the other hand, restriction of submersed macrophytes beyond the shallower depth of water in Lake Paltangho can be attributed to its fast-moving currents at the central part of the lake (Haslam 1978).

In Lake Paltangho, occurrence of *V. gigantea* was restricted to the shallow water (0 ~ 5 m), *H. verticillata* occurred at some intermediate depth (0 ~ 1.5 m), and *C. demersum* occurred predominantly in the littoral zone of the deeper water (1.5 ~ 2.5 m). Generally submersed macrophytes can be classified according to growth-from: canopy-producing, erect, rosette and bottom-dwelling (Chamber 1987). *V. gigantea* is a ruderal rosette, which can survive disturbance of ice and wave erosion in the shallowest part of the littoral zone (Keddy 1983, Kautsky 1988). However, *C. demersum* and *H. verticillata* are competitive canopy-producing species because of their capability to elongate and concentrate their photoreceptive biomass at the water surface (Barko and Smart 1981, Kautsky 1988). Because *C. demersum* is especially non-rooted macrophytes, it can easily occupy canopy even at the deep water-depth (Hough *et al.* 1989). *C. demersum* is, however, sensitive to emergence, desiccation and being frozen in the ice, and these factors may also cause its absence in the shallower parts of the littoral zone (Ozimek and Kowalczewski 1984).

In Lake Paltangho, biomass of *C. demersum*, a canopy-producing and non-rooted macrophyte, was 60% of all macrophytes and mass occurrences of filamentous algae could

easily be found both on large area of the substrate surfaces in the littoral zone and among the macrophytes specially at the embayment. At the most polluted site, the community primarily consisted of canopy-producing and erect forms particularly non-rooted macrophytes (Chambers 1987, Hough *et al.* 1989). As lakes become progressively enriched, filamentous algae generally grow more and more rapidly (Hough *et al.* 1989). From this observation, severe eutrophication might have already taken place in Lake Paltangho, at least at several embayments.

A more complete understanding of the factors controlling the distribution and abundance of submersed macrophytes in the littoral zone of Lake Paltangho remains a subject for further research.

적 요

팔당호 연안대에서 종 혹은 생육형에 따라 대형수생식물의 점유면적을 추정하였고, 특히 침수식물에 대하여 수심에 따른 각 종별 생물량의 변화를 조사하였다. 팔당호에서 대형수생식물의 점유면적은 267 ha이었으며, 정수식물 중 애기부들(*Typha angustifolia*)과 줄(*Zizania latifolia*)이, 부엽식물 중 연꽃(*Nelumbo nucifera*)이, 침수식물 중 붕어마름(*Ceratophyllum demersum*), 검정말(*Hydrilla verticillata*), 새우가래(*Potamogeton maackianus*)가 우점하였다. 특히 침수식물은 수심에 따라 뚜렷한 대상분포를 하였는데, 나사말(*Vallisnaria gigantea*)은 수심 0.5 m 이내에서, 검정말은 1.5 m 이내에서, 붕어마름은 1.5~2.5 m에서 우점하였다.

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