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The Optimal Environmental Ranges for Wetland Plants: Ⅱ. *Scirpus tabernaemontani* and *Typha latifolia*

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ABSTRACT: We studied the optimal ranges of water and soil characteristics for wetland plants, particularly *Scirpus tabernaemontani* (softstem bulrush) and *Typha latifolia* (broadleaf cattail), which are dominant species with potential for restoration of Korean wetlands. We observed vegetation in *S. tabernaemontani* and *T. latifolia* communities from the mid to late June, 2005, and measured characteristics of water environments such as water depth (WD), temperature (WT), conductivity (WC), and concentration of several ions (NO_3^--N, Ca^{2+}, Na^+, Mg^{2+}, and K^+), and characteristics of soil environments such as soil texture, organic matter (loss on ignition, LOI), conductivity, and pH. The *S. tabernaemontani* community was accompanied by *Zizania latifolia* (Manchurian wildrice), *Persicaria thunbergii* (Korean persicary), *Actinostemma lobatum* (lobed actinostemma), and *Beckmannia syzigachne* (American slough grass), while the *T. latifolia* community was accompanied by *P. thunbergii, T. angustifolia* (narrowleaf cattail), and *Glycine soja* (wild soybean). We defined the optimal range for distribution (ORD) as the range that each plant was crowded. The optimal range of water characteristics for the *S. tabernaemontani* community was a WD 10～50 cm, WT 24.0～32.0℃, WC 100～500 μS/cm, NO_3^--N 0～60 ppb, K^+ 0.00～1.50 ppm, Ca^{2+} 7.50～17.50 ppm, Na^+ 2.50～12.50 ppm, and Mg^{2+} 3.00～7.00 ppm. In addition, the optimal range of soil characteristics for the *S. tabernaemontani* community was a soil texture of loam, silty loam, and loamy sand, LOI 8.0～16.0%, pH 5.25～6.25, and conductivity 10～70 μS/cm. The optimal range of water characteristics for the *T. latifolia* community was a WD 10～30 cm, WT 22.5～27.5℃, WC 100～400 μS/cm, NO_3^--N 0～60 ppb, K^+ 0.00～1.50 ppm, Ca^{2+} 0.00～17.50 ppm, Na^+ 0.00～12.50 ppm, and Mg^{2+} 0.00～5.00 ppm, and the optimal range of soil characteristics for the *T. latifolia* community was a soil texture of loam, sandy loam, and silty loam, LOI 3.0～9.0%, pH 5.25～7.25, and conductivity 0～70 μS/cm.

Key words: Soil texture, Water depth, Wetland creation, Wetland plants, Wetland restoration

INTRODUCTION

Wetlands, which are the ecotones between terrestrial and aquatic ecosystems, play many roles such as increasing biodiversity, offering habitats for rare species, increasing productivity, and controlling flood (Mitsch and Gosselink 2000). Recently, as recognition of the importance of wetlands has grown, conservation managers are actively creating and restoring wetlands. However, wetland restoration has not always been successful due to the lack of important information about the optimal habitat characteristics for wetland plants (Kim and Cho 1999). Therefore, a better understanding of wetland environments and the ecological characteristics of habitats for wetland plants is important for conservation planning and management.

Although much research has been conducted on the habitat characteristics of wetland plants in Korea (Cho 1995, Yoon et al. 2002, Lee et al. 2005), only specific sites have been investigated, and the full characteristics of the plant communities in these habitats have not been addressed. As each species is distributed in different microhabitats, it is important to plant each species in accordance with its preferred habitat characteristics. Previous studies of habitat characteristics of wetland plant species (Cho and Kim 1994, Shin et al. 1997, Lee et al. 2001) have not examined the growing states of plants along environmental gradients. Moreover, it is difficult to generalize from the results of these studies because they were constrained to specific sites. We investigated the distribution of the dominant plant species in wetlands, determined the characteristics of their habitats, and derived fundamental information necessary for the restoration of wetlands. We studied the environments of *Scirpus tabernaemontani* Gmelin (softstem bulrush) and *Typha latifolia* L. (broadleaf cattail), which are perennial emergent plants found in wetlands.

Scirpus tabernaemontani and *T. latifolia* are good candidates for

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wetland restoration because they promote vegetation establishment on lakeshores, provide nesting and refuge sites for birds, and function to purify water (Ministry of Environment 2002a). However, previous studies of *S. tabernaemontani* and *T. latifolia* in Korea (Choi 2000, Oh 2000) focused only on their taxonomy. Therefore insufficient information is available about their environmental requirements. It is the objective of our study to determine the structure of *S. tabernaemontani* and *T. latifolia* communities (including biotic and abiotic factors), and the environmental requirements of *S. tabernaemontani* and *T. latifolia*. This study will supply basic data for the restoration of habitats of these two species.

METHODS

Study Areas

We studied seventeen wetlands, including static and flowing wetlands, in different regions of the country (Fig. 1). Most wetlands studied were located in metropolitan areas (e.g. the Namhan-river in Gwangju city, Wangsuk stream in Guri city, and reservoirs in Siheung city) and in the Gyeongsangnam-do area. The metropolitan study areas were adjacent to agricultural lands and the sources of water supplying the lands, and play important roles in the control of flooding (Gyeonggi Research Institute 1997). These areas consisted of flat areas of land with an elevation of approximately 0～50 m asl. The study areas in Gyeongsangnam-do were back marshes located on the Hwang-river and the Nakdong-river in Hapchon-gun, Changnyeung-gun, and Uiryeong-gun (Ministry of Environment 2002b).

Vegetation Survey

We conducted our study from 14 to 28 June, 2005, before water levels rose with the approaching monsoon season. Most wetland plants had become established before this period. We randomly placed 1 m × 1 m study quadrats throughout the study areas, including a total of 43 quadrats of *S. tabernaemontani* and 47 of *T. latifolia*. The quadrats varied in the extent of cover and the growth conditions of *S. tabernaemontani* or *T. latifolia*. In each quadrat, we measured the cover, density, and height of the target species according to a modified version of the plant sociological method of Braun-Blanquet (Mueller-Dombois and Ellenberg 1974, Kim et al. 2004). Identification of plants followed Lee (2002) and Lee (2003).

Environment Survey and Analyses

Water depth (WD), temperature (WT, measured with a Testo 110), and conductivity (WC, measured with a Corning Checkmate Ⅱ) were measured in each quadrat in which vegetation was surveyed. We defined WD as the distance from the water table to soil surface; it was positive when the soil surface was below the water table and negative when the soil surface was above the water table. Every variable was measured in the center of the vegetation. Water samples were collected in each quadrat and filtered using a membrane filter (pore size 0.45 μm). We then analyzed the nutrients in the water. The content of NO_3^--N in each water sample was analyzed using the Hydrazine method (Kamphake et al. 1967), and the content of cations such as K^+, Ca^{2+}, Na^+, and Mg^{2+} in each water sample was measured using an Atomic Absorption Spectrometer (VARIAN, Model AA240FS). We collected five 5～10 cm soil cores with a 5.5 cm-diameter PVC tube in each quadrat. The core samples were then sealed and transported to the laboratory. Wet soil and distilled water were mixed at a ratio of 1:5 (W/W), and the mixture was shaken for thirty minutes, then allowed to rest for two hours for stabilization. We then measured the conductivity (Corning, Model 311) and pH (Fisher, Model AP63) of the soil. The organic content was analyzed by loss on ignition (LOI; Boyle

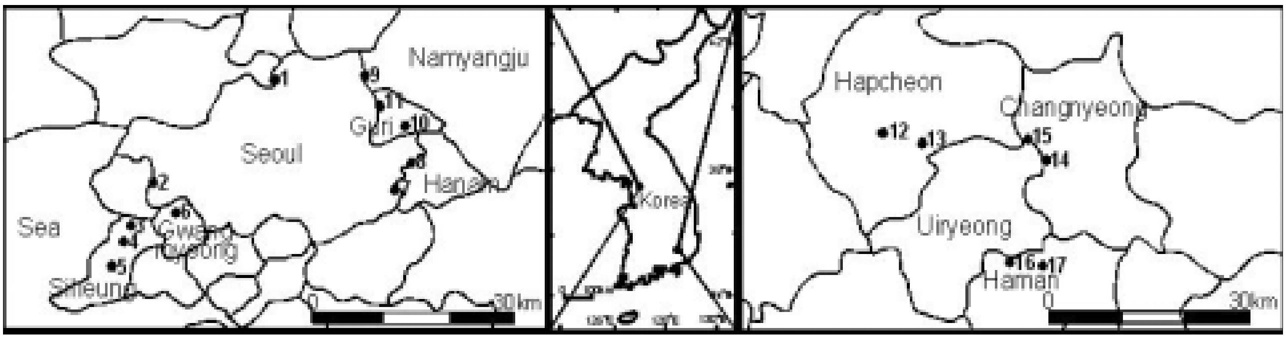

Fig. 1. Study areas. Left: areas in Seoul and Gyeonggi-Do, Right: areas in Gyeongsangnam-Do. 1: Jinkwannae dong ecological preservation area, 2: Gung dong reservoir, 3: Gwarim reservoir, 4: Dochang reservoir, 5: Majeon reservoir, 6: Anteo reservoir, 7: Gyeongan stream 8: Namhan river (Namjongmyeon) 9: Wangsuk stream 10: Jangja pond, 11: Emunan reservoir, 12: Paksilji, 13: Chungyangji, 14: Taehakji, 15: Mokpo, 16: Taepyeongnup, 17: Chinnalnup.

2004). After being sieved by 2 mm sieve, the soil texture was determined using the Hydrometer Method and the texture triangle (USDA; Carter 1993).

Data Analyses

We calculated importance value (IV), occurrence frequency (Occc), and diversity index (H') for the vegetation data in each quadrat (Shannon and Weaver 1949, Kim et al. 2004):

IV (%) = relative cover + relative density,

H' = $-\sum P_i \log P_i$ (P_i= cover of specific species i/total cover),

Occ (%) = (number of quadrats in specific range/ total number of quadrat) × 100.

To determine the optimal environments for the growth and distribution of *S. tabernaemontani* and *T. latifolia*, we divided each environmental variable into several classes using Sturges' rule (Sturges 1926). We then categorized their distribution patterns into several classes according to the environmental variables shown in Figs. 2~5, and calculated the median, maximum, and minimum values for the Ⅳ, density, cover, height, and species diversity index for each range.

In previous studies, average values and standard deviations have been used as measures of optimal environmental characteristics for plant growth. In this study, however, we considered the full range for environment variables, as plants are tolerant of some variation in environmental conditions. We defined the optimal range for distribution (ORD) for a plant as the range in which each plant was found to be crowded. The total occurrence of each plant within its ORD was ~50~90%. The ORD for each plant included a range narrower than half of the full range of incidence for each environmental variable.

RESULTS

Structure of Plant Communities

Twenty-six plant species from 17 families and 23 genera were found in the *S. tabernaemontani* community. *Zizania latifolia* (Griseb.) Turcz. ex Stapf (Manchurian wildrice) was the species co-occurring with *S. tabernaemontani* most frequently, being found in 58% of quadrats containing *S. tabernaemontani*. Other species frequently found in this community included *Persicaria thunbergii* H. Gross (Korean persicary), *Actinostemma lobatum* Maxim (lobed actinostemma), and *Beckmannia syzigachne* (Steud) Fernald (American slough grass), with frequencies of occurrence of 35%, 33%, and 26%, respectively.

Twenty-three plant species from 15 families and 21 genera were found in the *T. latifolia* community. *Persicaria thunbergii* was the plant most frequently found with *T. latifolia*, with a frequency of occurrence of 51% in *T. latifolia* quadrats, followed by *T. angustifolia* and *Glycine soja* Siebold & Zucc. (wild soybean) with frequencies of occurrence of 28% and 21%, respectively.

Optimal Environmental Ranges for *S. tabernaemontani* Communities

Water Characteristics

Scirpus tabernaemontani communities were distributed from WD ~45~85 cm. The ORD of WD was 10~50 cm, with an *S. tabernaemontani* occurrence of 78% (Fig. 2a). In the ORD of WD, the median density of *S. tabernaemontani* was 44 individuals/m^2, the median cover was 45%, the median Ⅳ was 91%, the median height was 160 cm, and the species diversity of was 1.2. The frequency of co-occurrence of *Z. latifolia* was 20%, and the frequency of co-occurrence of *P. thunbergii, A. lobatum,* and *B. syzigachne* were all 8~11% in the ORD of WD for *S. tabernaemontani*.

Scirpus tabernaemontani communities were found in WC from 19~727 μS/cm, WT from 12.7~32.4℃, and NO_3^--N content from 2~300 ppb in the water. The ORD for WT was 24.0~32.0℃ with *S. tabernaemontani* occurrence of 76% (Fig. 2b), the ORD for WC was 100~500 μS/cm with *S. tabernaemontani* occurrence of 88% (Fig. 2c), and the ORD for NO_3^--N content was 0~60 ppb with *S. tabernaemontani* occurrence of 64% (Fig. 2d).

Scirpus tabernaemontani communities were distributed in waters with K^+ concentrations from 0.32~12.62 ppm, Ca^{2+} concentrations ranging from 2.30~73.75 ppm, Na^+ concentrations from 3.81~39.70 ppm, and Mg^{2+} concentrations from 1.19~18.39 ppm. The ORD for K^+ was 0.00~1.50 ppm with *S. tabernaemontani* occurrence of 63% in (Fig. 2e). For Ca^{2+}, the ORD was 7.50~17.50 ppm with *S. tabernaemontani* occurrence of 70% (Fig. 2f). For Na^+, the ORD was 2.50~12.50 ppm, with *S. tabernaemontani* occurrence of 68% (Fig. 2g). For Mg^{2+}, the ORD was 3.00~7.00 ppm with *S. tabernaemontani* occurrence of 78% (Fig. 2h).

Soil Characteristics

Scirpus tabernaemontani communities were found in soils with LOI of 1.5~27.5% and soil conductivity of 19 ~152 μS/cm. The ORD for LOI was 8.0~16.0% (50% of *S. tabernaemontani* communities; Fig. 3a). *S. tabernaemontani* communities were found in soils of pH 4.95~7.38. However, 93% of *S. tabernaemontani* lived in soil with pH 5.25~7.25. The ORD for soil pH, 5.25~6.25, was weakly acidic, and the *S. tabernaemontani* occurrence in soils in this range was 57% (Fig. 3b). The ORD for soil conductivity was 10~70 μS/cm (74% pf *S. tabernaemontani* communities; Fig. 3c). Most

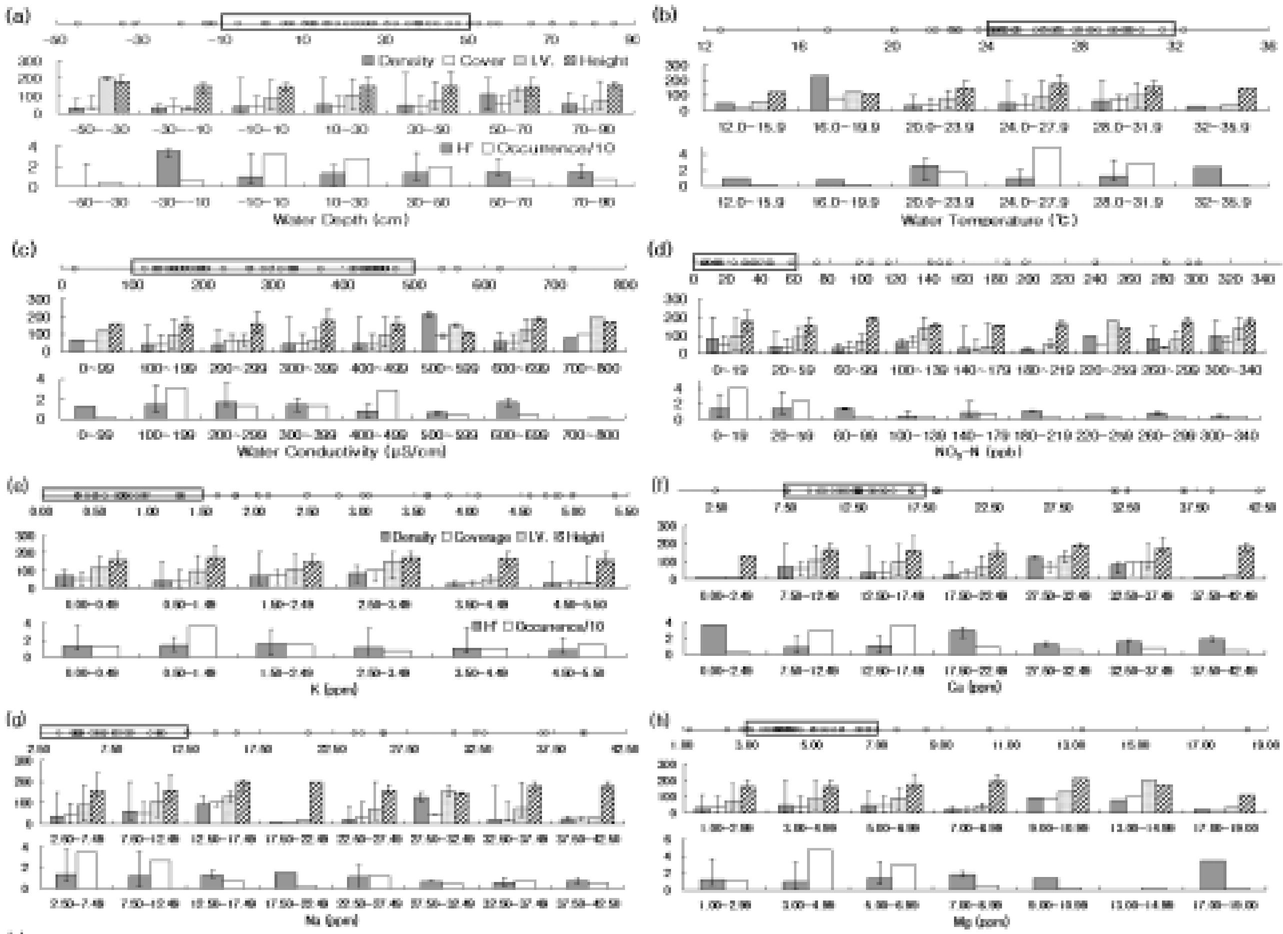

Fig. 2. Distribution patterns of *Scirpus tabernaemontani* according to water characteristics: (a) water depth, (b) water temperature, (c) water conductivity, (d) nitrate (NO_3^--N), (e) K^+, (f) Ca^{2+}, (g) Na^+, and (h) Mg^{2+}. The circles on the line represent the distribution of samples (quadrat locations) on the gradient of the corresponding environmental factors. The box on the line shows the optimal range for distribution (ORD) of each corresponding environmental variable. Density (individuals/m^2), Cover(%), Ⅳ=importance value (%), and Height (cm) =the average height of *Scirpus tabernaemontani*.

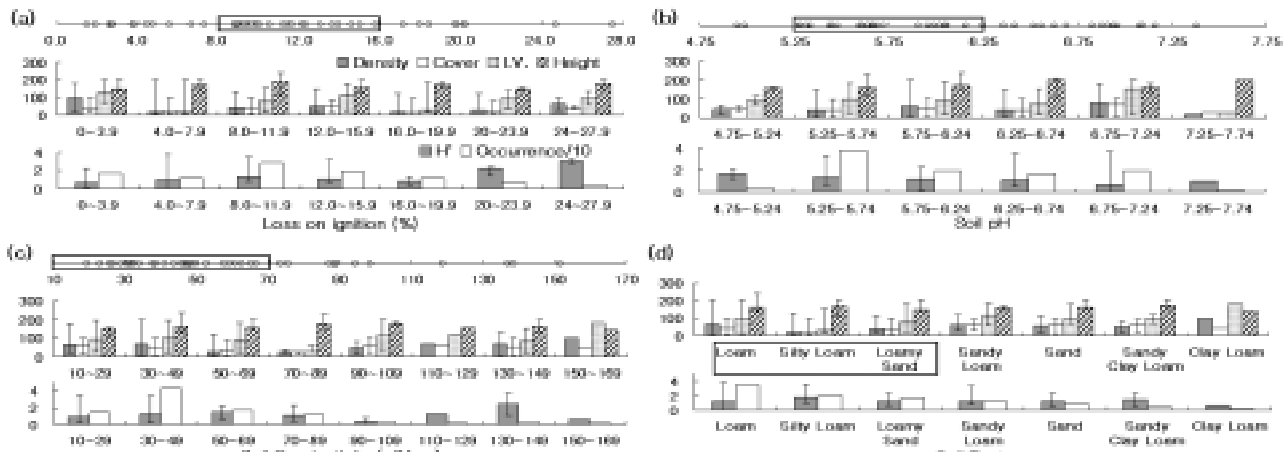

Fig. 3. Distribution patterns of *Scirpus tabernaemontani* according to soil characteristics: (a) loss on ignition, (b) soil pH, (c) soil conductivity, and (d) soil texture. The explanation for this figure is the same as that for Fig. 2.

S. tabernaemontani communities (34%) were found in loam, followed by silty loam (20%), and loamy sand (17%). These soil types were the ORD for soil textures, and the total occurrence of *S. tabernaemontani* communities in these soil textures was about 70% (Fig. 3d). The median density of *S. tabernaemontani* communities in the ORD of soil textures was 40 individuals/m^2, while the median cover was 40%, the median Ⅳ was 76%, the median height was 160 cm, and the median species diversity was 1.3. In this optimal range, *Z. latifolia* and *P. thunbergii* had the highest rate of co-occurrence, occurring in 47% and 60% of quadrats, respectively, followed by *A. lobatum* (33% of quadrats) and *B. syzigachne* (33% of quadrats).

Optimal Environmental Ranges for the *T. latifolia* Community

Water Characteristics

Typha latifolia communities was found in WD ～40～60 cm, and their ORD for WD was ～10～30 cm (73% of *T. latifolia* communities; Fig. 4a). The median density of *T. latifolia* in the ORD for WD was 7 individuals/m^2, while the median cover was 32%, the median Ⅳ was 65%, the median height was 178 cm, and the species diversity was 1.8. *P. thunbergii* was found in 50% of *T. latifolia* communities in the ORD for WD, while *T. angustifolia, G. soja*, and *J. effusus* var. *decipiens* were also found in 20～25% of *T. latifolia* communities. *Typha latifolia* community was distributed in the WC 103～883 μS/cm. *Typha latifolia* communities were found in WT of 18.1～30.7℃. The ORD for WT was 22.5～−7.5 ℃ (53% of *T. latifolia* communities; Fig. 4b). The ORD of WC was 100～400 μS/cm, and the occurrence of *T. latifolia* communities in the ORD of WC was 60% (Fig. 4c).

Typha latifolia communities were found in waters with NO_3^--N

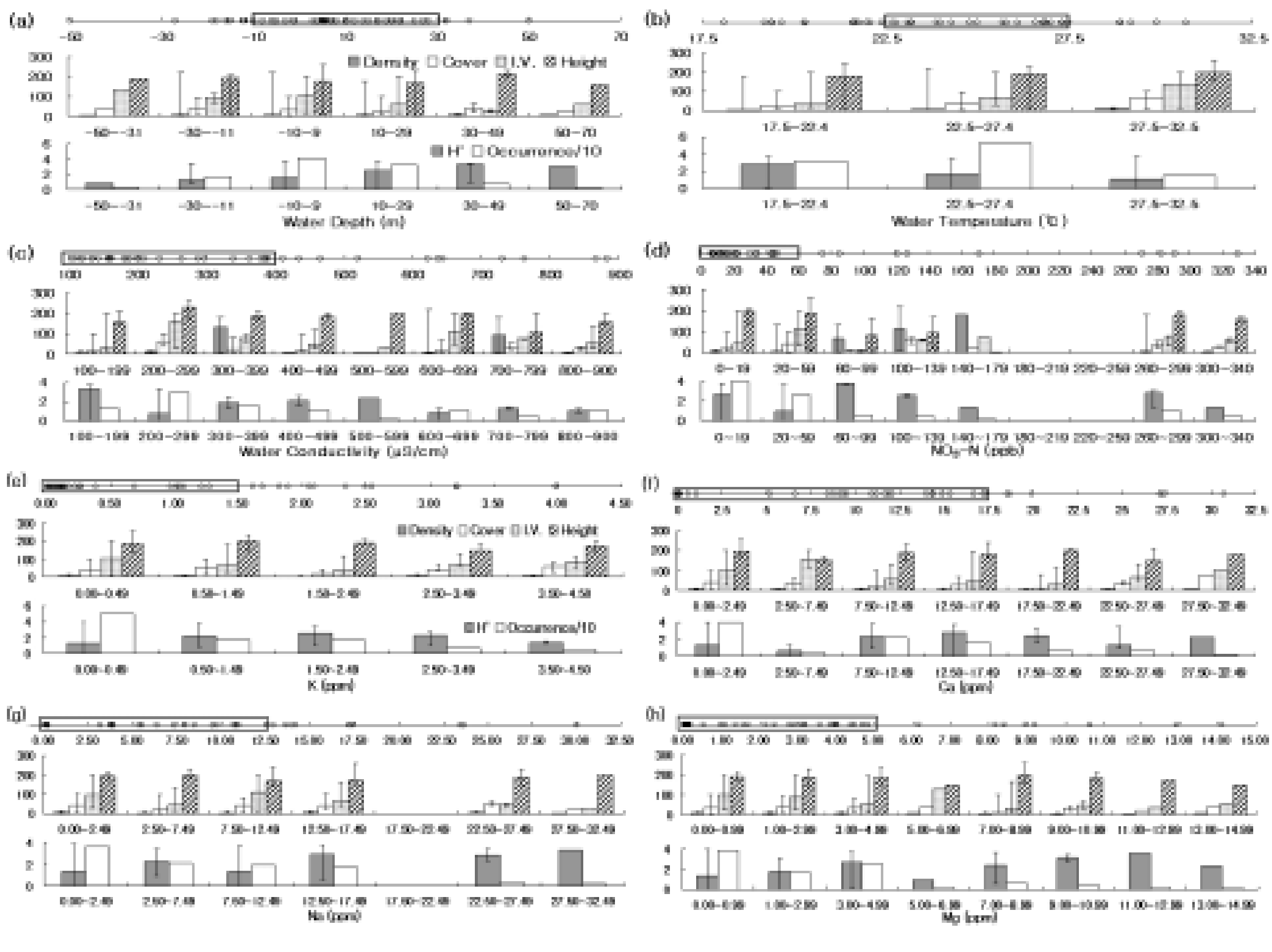

Fig. 4. Distribution patterns of *Typha latifolia* according to water characteristics: (a) water depth, (b) water temperature, (c) water conductivity, (d) nitrate(NO_3^--N), (e) K, (f) Ca, (g) Na, and (h) Mg. The circles on the line represent the distribution of samples (quadrat locations) on the gradient of corresponding environmental factors. The box on the line shows the optimal range for distribution (ORD) of each corresponding environmental variable. Density (No./m^2), Cover (%), I.V.=importance value (%), and Height (cm)=the average height of *Typha latifolia*.

content of 7~330 ppb The ORD for NO_3^--N content was 0~60 ppb (66% of *T. latifolia* communities; Fig. 4d). *Typha latifolia* communities were distributed in water with K^+ content from 0.00~8.08 ppm, Ca^{2+} content from 1.06 ~30.72 ppm, Na^+ content from 0.00~30.00 ppm, and Mg^{2+} content from 0.00~14.10 ppm, respectively. While the ORD of K^+ content was 0.00~1.50 ppm (68% of *T. latifolia* communities; Fig. 4e), the ORD of Ca^{2+} content was 0.00~17.50 ppm (78% of *T. latifolia* communities; Fig. 4f), the ORD of Na^+ content was 0.00~12.50 ppm (77% of *T. latifolia* communities; Fig. 4g), and the ORD of Mg^{2+} content was 0.00~5.00 ppm (80% of *T. latifolia* communities; Fig. 4h).

Soil Environment

Typha latifolia communities were found in soils with LOI of 2.2~14.5% and pH 4.48~7.65, the ORD for LOI was 3.0~9.0% (70% of *T. latifolia* communities; Fig. 5a), and the ORD for pH was 5.25 ~7.25 (77% of *T. latifolia* communities; Fig. 5b). *Typha latifolia* communities were found in soils with conductivity of 16~190 μS/cm, and the ORD for soil conductivity was 0~70 μS/cm (62% of *T. latifolia* communities; Fig. 5c). 35% of *T. latifolia* communities were found in loam, 23% were found in sandy loam, and 15% were found in silty loam. Therefore, the ORD of soil textures included loam, sandy loam, and silty loam, and 73% of *T. latifolia* communities were found in the ORD of soil textures (Fig. 5d). *Typha latifolia* communities were rarely found in sandy clay loam. The median density of *T. latifolia* communities in the ORD for soil textures was 5 individuals/m^2, while the median cover was 30%, the median Ⅳ was 65%, the median height was 190 cm, and the median species diversity was 2.1. In the optimal range of soil textures, *P. thunbergii* co-occurred with *T. latifolia* in 50% of quadrats, while *Typha angustifolia* and *E. arvense* each co-occurred with *T. latifolia* in 30% of quadrats.

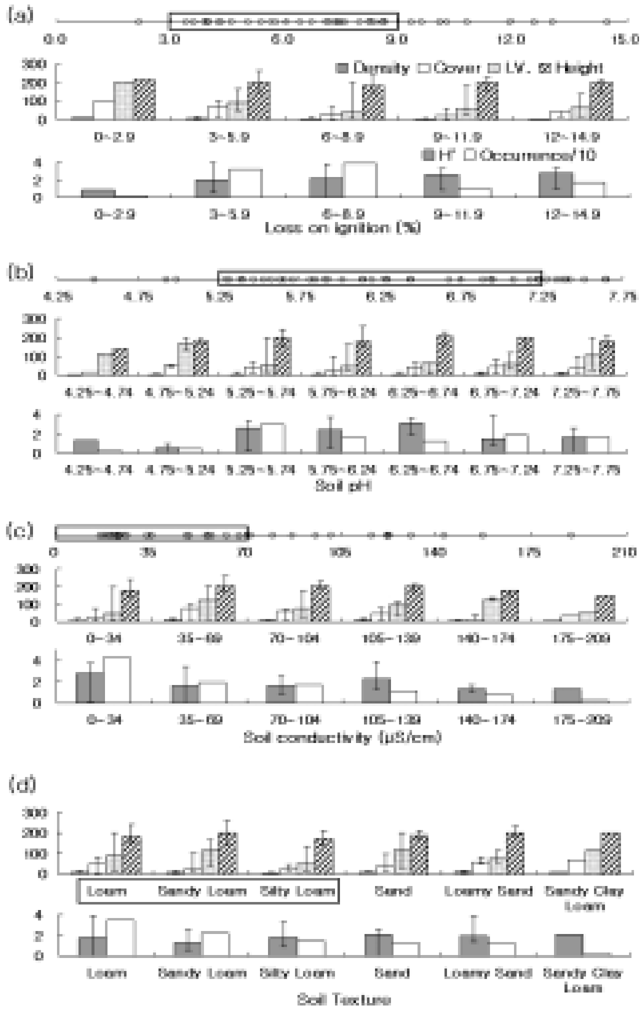

Fig. 5. Distribution patterns of *Typha latifolia* according to soil characteristics: (a) loss on ignition, (b) soil pH, (c) soil conductivity, and (d) soil texture. The explanation for this figure is the same as that for Fig. 4.

DISCUSSION

Water Characteristics and the Distribution of *S. tabernaemontani* and *T. latifolia*

The distribution of wetland plants depends on WD and fluctuations in the water level (Hutchinson 1975, Spence 1982, Van der Valk et al. 1994, Coops and van der Velde 1996), because the chemical characteristics of water and sediments are affected by WD (Spence 1982, Grace 1988), and water level fluctuations affect competition between species over the long term (Grace and Wetzel 1981).

Scirpus tabernaemontani

The maximum limit of WD in *S. tabernaemontani* habitats was reported to be 0 cm in Paldang-lake, Korea (Lee et al. 2002), whereas the maximum limit was 85 cm in our study (Table 1). *Scirpus tabernaemontani* grows well even in deep water because it has an elastic stem without leaves, and tolerates anaerobic soils (Hutchinson 1975). Generally, *S. tabernaemontani* is distributed in deeper water than the exotic *S. maritimus* L. (cosmopolitan bulrush) and *S. ancistrochaetus* Schuyler (barbedbristle bulrush) (Clevering and van Gulik 1997, Lentz and Dunson 1998) because it is more sensitive to frost and drought (Hutchinson 1975). After the rainy season, *S. tabernaemontani* density begins to decline (Han et al. 2002). Rising water levels increase the release of ethylene gas, which causes *Scirpus* spp. to rapidly age (Lentz and Dunson 1998). Therefore, *S. tabernaemontani* should be planted in an appropriate WD to avoid early senescence of individual *S. tabernaemontani* plants. A previous study reported that both the density and species

Table 1. Minimum, maximum, and ORD of physico-chemical characteristics of the environment in which *Scirpus tabernaemontani* Gmelin (softstem bulrush) and *Typha latifolia* L. (broadleaf cattail) were distributed. Occ.(%)=Occurrence frequency

		Scirpus tabernaemontani Gmelin (softstem bulrush) (*n*=43)			*Typha latifolia* L. (broadleaf cattail) (*n*=47)		
		Minimum～Maximum	ORD		Minimum～Maximum	ORD	
			Range	Occ. (%)		Range	Occ. (%)
Water	Depth(cm)	−45～85	−10～50	78	−40～60	−10～30	73
	Temperature (℃)	12.7～32.4	24.0～32.0	76	18.1～30.7	22.5～27.5	53
	Conductivity (μS/cm)	19～727	100～500	88	103～883	100～400	60
	NO_3^--N (ppb)	2～300	0～60	64	7～330	0～60	66
Ion in water	K^+ (ppm)	0.32～12.62	0.00～1.50	63	0.00～8.08	0.00～1.50	68
	Ca^{2+} (ppm)	2.30～73.75	7.50～17.50	70	1.06～30.72	0.00～17.50	78
	Na^+ (ppm)	3.81～39.70	2.50～12.50	68	0.00～30.00	0.00～12.50	77
	Mg^{2+} (ppm)	1.19～18.39	3.00～7.00	78	0.00～14.10	0.00～5.00	80
Soil	LOI (%)	1.5 ～27.5	8.0～16.0	50	2.2～14.5	3.0～9.0	70
	Sand (%)	20.1～100.0			10.0～95.9		
	Clay (%)	0.0～30.0			2.0～17.8		
	Silt (%)	0.0～70.2			1.4～79.2		
	Soil Texture	Loam Silty loam Loamy sand Sandy loam Sand Sandy clay loam Clay loam	Loam	34	Loam Sandy loam Silty loam Sand Loamy sand Sandy clay loam	Loam	35
			Silty loam	20		Sandy loam	23
			Loamy sand	17		Silty loam	15
	pH	4.95～7.38	5.25～6.25	57	4.48～7.65	5.25～7.25	77
	Conductivity (μS/cm)	19～152	10～70	74	16～190	0～70	62

diversity of wetland plants decreases with increasing water levels (Van der Valk et al. 1994). In this study, we also found that the species diversity decreased with increasing WD. However, the density did not decrease with increasing WD because *S. tabernaemontani* could grow in deep water, which allowed it to avoid competition with other species (Coops et al. 1996). The Ⅳ of *S. tabernaemontani* in our study was high, at about 134% in water of 50～70 cm depth, and the species diversity was low at about 1.4 in this WD, indicating a pure *S. tabernaemontani* community. Previous studies have reported that *Z. latifolia* is generally found in deeper water than *S. tabernaemontani* (Kwon et al. 2006, Lee et al. 2005). *Zizania latifolia* was found in depths between 15～95 cm, with a mean WD of 0.5 m (Lee et al. 2005), and an ORD of WD of 5～40 cm (Kwon et al. 2006). In this study, both *Z. latifolia* and *S. tabernaemontani* were found frequently, but the frequency of *Z. latifolia* in deeper water was higher than that of *S. tabernaemontani*.

Typha latifolia

Typha latifolia is found in shallow water with small water level fluctuations (Han et al. 2002), whereas its congener *T. angustifolia* is found in WD from 20～82 cm, with an ORD of 20～24 cm (Kwon et al. 2006). In our study, *T. angustifolia* was found in deeper waters than *T. latifolia*, which is in accordance with the results of the previous study. The short and broad leaves of *T. latifolia* provide a large surface area for photosynthesis, enabling its shoots to appear earlier than those of *T. angustifolia*, and permitting it to endure shadier habitats than *T. angustifolia*. These advantages allow *T. latifolia* to outcompete *T. angustifolia* in shallow areas, restricting *T. angustifolia* to deeper waters (Grace and Wetzel 1981).

Soil Characteristics and the Distribution of *S. tabernaemontani* and *T. latifolia*

Scirpus tabernaemontani

Scirpus tabernaemontani was found in loam and silty loam soils in this study. This species also rarely occurs in sandy clay loam and clay loam soils. The absorption of water and nutrients in clay soils is difficult for plants due to the strong adherence of water to clay particles (Robinson 1951). *Zizania latifolia*, which frequently appeared together with *S. tabernaemontani*, had an ORD for soil textures similar to that of *S. tabernaemontani*, although *S. tabernaemontani* was generally found in soils containing more sand with particle diameters <0.02～2 mm, which suggests that sand content may more important for *S. tabernaemontani* than for *Z. latifolia*.

Typha latifolia

Generally, suitable soils for the growth of *Typha* spp. contain 25.0～37.5% clay-like loam with fine particles. *Typha latifolia* was distributed in silty and sandy loam in Paldang-lake. In this study, *T. latifolia* community was also distributed in loam, sandy loam, and silty loam(Fig. 5d). *Typha latifolia* also rarely occurred in the sandy clay loam like *S. tabernaemontani*.

Soil pH can also affect plant growth. The acidification of wetland soil can cause the eluviation of basic ions, and inactivity of nitrification, which can restrict plant growth (Marschner 1995). The ORD of soil pH for *S. tabernaemontani* was weakly acidic at 5.25～6.25 (Fig. 3b). *Typha latifolia* was distributed in a broader range of soil pH, from weakly acidic to neutral soil (Fig. 5b).

Scirpus tabernaemontani was distributed in reservoirs and waters with low current velocity. The range of distribution of *T. latifolia* was ecologically and geographically narrower than that of its congener *T. angustifolia*, while water depth and soil texture were important for the distribution of both species. Our results provide information that may be useful in wetland restoration efforts (Table 1).

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