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Characteristics of Vascular Plants in Yongyangbo Wetlands

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ABSTRACT

The objective of this study was to provide basic data for the conservation of wetland ecosystems in the Civilian Control Zone and the management of Yongyangbo wetlands in South Korea. Yongyangbo wetlands have been designated as protected areas. A field survey was conducted across five sessions between April 2019 and August of 2019. A total of 248 taxa were identified during the survey, including 72 families, 163 genera, 230 species, 4 subspecies, and 14 varieties. Their life-forms were Th (therophytes) - R_5 (non-clonal form) - D_4 (clitochores) - e (erect form), with a disturbance index of 33.8%. Three taxa of rare plants were detected: *Silene capitata* Kom. and *Polygonatum stenophyllum* Maxim. known to be endangered species, and *Aristolochia contorta* Bunge, a least-concern species. *S. capitata* is a legally protected species designated as a Class II endangered species in South Korea. A total of 26 taxa of naturalized plants were observed, with a naturalization index of 10.5%. There was one endemic plant taxon (*Salix koriyanagi* Kimura ex Goerz). In terms of floristic target species, there was one taxon in class V, one taxon in Class IV, three taxa in Class III, five taxa in Class II, and seven taxa in Class I. Three invasive alien species (*Ambrosia trifida* L., *Ambrosia artemisiifolia* L., and *Humulus japonicus* Siebold & Zucc) were observed. For continuous conservation of Yongyangbo Wetlands, it is necessary to remove invasive alien plants and block the inflow of non-point pollutants.

Keywords: Civilian control zone, Endangered species, Life form, Naturalization index, Vascular plants, Wetlands

Introduction

Wetlands are transitional zones between terrestrial and aquatic ecosystems (Yi & Nam, 2008) that are permanently or seasonally humid (Park *et al*., 2000). They are characterized by high productivity and rich biodiversity. Wetlands provide humans with various ecological services by offering an abundance of natural resources and creating unique natural landscapes (Ahn *et al*., 2016; Kim, 2003). Depending on where they are formed, wetlands can be categorized as coastal wetlands, inland wetlands (riverine, lacustrine, and mountainous palustrine), or constructed wetlands, each of which has its value as a unique ecological habitat (Ministry of Environment (ME), 2010).

The Civilian Control Zone (CCZ) in South Korea is located 5–20 km south of the demilitarized zone (DMZ), consisting of 15 cities or counties (*si/gun*) and 98 *eup/myeon* (Lee, 2004). Civilian access to this region has been restricted for approximately 60 years, leading to the formation of a unique natural ecosystem that cannot be found in other regions (Cha *et al*., 2000). There is a broad distribution of wetlands and paddy fields that display high biodiversity and ecosystem connectivity (Park & Nam, 2013). The entire region outside the DMZ, including the CCZ, consists of 3.3% of wetlands (Lim, 2006). Yongyangbo Wetlands, located close to the southern border of the DMZ, consist of lacustrine wetlands formed owing to the influence of Yongyang Weir and the riverine wetlands between Yongyang Weir and Sinamjeongyo Bridge. The Hwagang River, which is a branch of the Hantangang River, originates from Suribong Peak, Geumseong-myeon,

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Kimhwa-gun, entering South Korea after it crosses the Military Demarcation Line. Sediment carried by the river accumulates upstream of Yongyang Weir, which is believed to have led to the formation of lacustrine wetlands (National Institute of Ecology (NIE), 2019).

Several survey studies on forests have focused on the distribution of plants throughout the DMZ, starting with a study on the distribution of *Pinus densiflora* Siebold & Zucc. (Lee, 1968; Moon, 2019). Recent studies have been conducted in Gwangchiryeong, Yang-gu (Heo *et al*., 2017) and Daedeukbong Peak, Cheolwon-gun (An *et al*., 2018). In terms of wetland studies, some studies have been conducted on the flora in the Hak Reservoir, which is connected to the Hantangang River water system in the region bordering the DMZ (Shin *et al*., 2015).

In this study, we performed a floristic survey of Yongyangbo Wetlands in the CCZ under circumstances that ecological surveys, including floristic surveys, were limited by restricted access to the region. This is necessary for military reasons. It is also necessary due to local characteristics such as the presence of mines scattered around the area (Oh *et al*., 2009). Through this survey, we ascertained the distribution of endangered wild plant habitats and the distribution of naturalized plants that might threaten the ecosystem. Results of our survey can be used as basic data to support the conservation of wetland ecosystems in the CCZ and for the management of Yongyangbo Wetlands, which have been designated as wetland protected areas.

Materials and Methods

Survey area

In terms of administrative districts, Yongyangbo Wetlands bridge Yongyang-ri and Amjeong-ri in Kimhwa-eup, Cheolwon-gun, Gangwon-do, and South Korea. Specifically, it is a region between 37°12′08″N and 37°14′00″N, 127°42′48″E, and 127°44′22″E (Fig. 1). The survey area was about 0.77 km^2 with an average altitude of 227.7m and an average slope of 2.8°. According to data from the Cheolwon Weather Station, over the last 30 years (1989–2018), the mean annual air temperature was 10.25°C and the mean annual precipitation was 1,381.14 mm in the Yongyangbo Wetlands as a whole, which was similar to the mean annual precipitation across South Korea. Approximately 72.5% of the total annual precipitation occurs in summer (June to September), showing typical rainfall characteristics of a temperate monsoon region, with large differences in precipitation between seasons (NIE, 2019).

Survey method

A field survey of five sessions was conducted between April and August 2019 in accordance with the National Wetland Survey Protocol (ME, 2011). The survey was conducted on foot, covering the entire Yongyangbo Wetlands. Identification and classification were performed as described by Lee (1996a), Lee (1999), and Park (2009). Scientific and Korean names were assigned in accordance with the National List of Species of Korea (National Institute of Biological Resources (NIBR), 2020). Plant lists

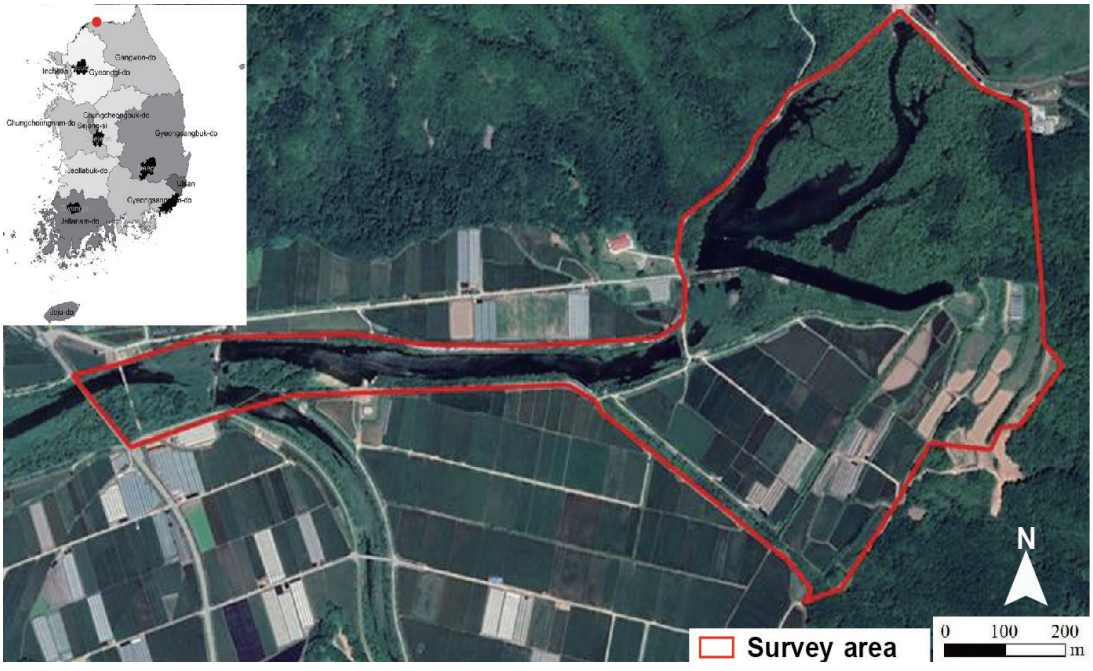

Fig. 1. Map of the survey area in Yongyangbo Wetlands.

were grouped by taxonomic ranks of family and below and arranged in alphabetical order. Based on plants identified in the survey, life-forms (Lee, 1996b), endemic plants (Chung *et al*., 2017), floristic target species (NIE, 2018), and rare plants (Korea National Arboretum (KNA), 2008) were summarized. Naturalized plants were investigated as described by Lee *et al*. (2011) and Ryu et al. (2017). Floristic richness (Kim & Lee, 2006) was analyzed to investigate the biodiversity of plants in the survey. To ascertain the degree of wetland disturbance, disturbance index (Benabdelmoumene *et al*., 2014) and naturalization index (Numata, 1975) were calculated.

Results and Discussion

Flora of vascular plants

The flora observed at Yongyangbo Wetlands consisted of a total of 248 taxa, 72 families, 163 genera, 230 species, 4 subspecies, and 14 varieties. There were 4 taxa of Pteridophyta (4 families, 4 genera, 4 species), 1 taxon of Pinophyta (1 family, 1 genus, 1 species), and 243 taxa of Magnoliophyta (67 families, 158 genera, 164 species, 4 subspecies, 14 varieties; Table 1, Supplementary Table 1), corresponding to approximately 5.4% of 4,596 vascular plant taxa found in the Korean Peninsula (NIBR, 2020). The most commonly observed families in order of descending richness were Poaceae (26 taxa, 10.5%), Asteraceae (25 taxa, 10.1%), Cyperaceae (17 taxa, 6.9%), and Fabaceae (17 taxa, 6.9%; Table 2). The floristic diversity of Yongyangbo Wetlands was 1.52, higher than that of Hak Reservoir near the DMZ in Cheolwon (1.38, Shin *et al*., 2015) but lower than that of Daedeukbong Peak (1.59, An *et al*., 2018). Floristic diversity was calculated as the species-to-genera ratio, with a larger value indicating more diverse genera containing a broader spectrum of species (Kim & Lee, 2006).

Table 1. Number of vascular plants in Yongyangbo Wetlands

Taxa	Fam.	Gen.	Sp.	Subsp.	Var.	For.	Total
Pteridophyta	4	4	4	-	-	_	4
(Polypodiopsida)	(3)	(3)	(3)	-	-	_	(3)
(Equisetopsida)	(1)	(1)	(1)	-	-	_	(1)
Pinophyta	1	1	1	-	-	_	1
(Pinopsida)	(1)	(1)	(1)	-	-	_	(1)
Magnoliophyta	67	158	225	4	14	_	243
(Magnoliopsida)	(55)	(124)	(164)	(4)	(13)	_	(181)
(Liliopsida)	(12)	(34)	(61)	-	(1)	_	(62)
Total	72	163	230	4	14	_	248

Table 2. Family compositions of vascular plants in Yongyangbo Wetlands

Family	No. of taxa	Ratio (%)
Poaceae	26	10.5
Asteraceae	25	10.1
Cyperaceae	17	6.9
Fabaceae	17	6.9
Polygonaceae	12	4.9
Brassicaceae	12	4.9
Rosaceae	11	4.5
Apiaceae	10	4.1
Caryophyllaceae	7	2.8
Lamiaceae	6	2.4
Liliaceae	6	2.4
Salicaceae	6	2.4
Others (60 families)	93	37.2
Total	248	100.0

Life-forms

Raunkiaer dormancy forms of the 248 taxa in the survey area were analyzed. The dormancy form with the highest richness was therophytes (Th) in 73 taxa (29.4%), followed by hemicryptophytes (H) in 64 taxa (25.8%), geophytes (G) in 35 taxa (14.1%), and helophytes (HH) and nanophanerophytes (N) in 17 taxa (6.9%; Table 3). Montane wetlands tend to show a high abundance of hemicryptophytes (Kim *et al*., 2011; Ko *et al*., 2014), while riverine wetlands such as Yongyangbo Wetlands are at low altitudes and surrounded by farmland, roads, and other facilities, resulting in the appearance of a large number of therophytes, including naturalized plants. The disturbance index at Yongyangbo Wetlands was 33.8%, indicating a more stable habitat than orchards (47.0%, Kim *et al*., 2019) or fields (55.0%, Kim *et al*., 2015) known to undergo continual human management. It is also a more stable habitat than Hak Reservoir, which is a lacustrine wetland in the DMZ (38.2%, Shin *et al*., 2015).

The most commonly observed radicoid form was R_5 (147 taxa, 59.3%) (a non-clonal form, such as *Erigeron annuus* (L.) Pers., *Setaria pumila* (Poir.) Roem. & Schult., or *Inula britannica* var. *japonica* (Thunb.) Franch. & Sav), followed by R_3 (49 taxa, 19.7%) that showed short-branching rhizomes and clonal growth over a narrow range, such as *Eragrostis ferruginea* (Thunb.) P. Beauv. or *Aster incises* Fisch. (Table 4). Among disseminule forms, clitochores (D_4, 129 taxa, 52.0%) was the most common, followed by anemochore or hydrochore (D_1, 44 taxa, 17.8%) (for which seeds

are carried on wind or water) and zoochore (D_3, 24 taxa, 9.7%) (for which seeds are carried by sticking to animals or humans) (Table 5). Among growth forms as a way to categorize the state of growth and morphology of aerial parts, the erect form (73 taxa, 29.4%) was the most common, followed by the tussock form (t, 40 taxa, 16.1%) and the pseudo-rosette form (ps, 27 taxa, 10.9%; Table 6). Thus, life forms of plants in Yongyangbo Wetlands could be Th-R_5-D_4-e. This is a life-form composition similar to that of plants in orchards and fields, but different from the life-form composition of H-R_5-D_4-e generally observed for forest plants (Kang *et al*., 2006).

Table 3. Dormancy form of vascular plants in Yongyangbo Wetlands

Dormancy form*	Perennial								Annual		
Dormancy form*	Ch	E	G	H	HH	M	MM	N	$HH_{(Th, Thw)}$	Th	$Th_{(w)}$
No. of taxa	11	1	35	64	17	16	14	17	6	32	35
Ratio (%)	4.4	0.4	14.1	25.8	6.9	6.5	5.6	6.9	2.4	12.9	14.1

*Ch, chamaephyte; G, geophyte; H, hemicryptophyte; HH, hydatophyte; M, microphanerophyte; MM, megaphanerophyte; N, nanophanerophyte; Th, therophyte (summer annual); Th(w): therophyte (winter annual).

Table 4. Radicoid form of vascular plants in Yongyangbo Wetlands

Radicoid form*	R_{1-2}	R_{2-3}	$R_{2-3(b)}$	R_3	$R_{3(b)}$	$R_{3(O)}$	$R_{3(s)}$	$R_{3(v)}$	R_4	R_5	$R_{5(b)}$	$R_{5(O)}$	$R_{5(s)}$	$R_{(s)}$	$R_{(v)}$
No. of taxa	1	29	1	38	2	1	2	6	18	141	1	1	4	2	1
Ratio (%)	0.4	11.7	0.4	15.3	0.8	0.4	0.8	2.4	7.3	56.9	0.4	0.4	1.6	0.8	0.4

*R_1 : widest extent of rhizomatous growth; R_2 : moderate extent of rhizomatous growth; R_3 : narrowest extent of rhizomatous growth; R_4 : clonal growth by stolons and struck roots; R_5 : non-clonal growth; R_{1-2} : plants with rhizomatous mutation of R_1 and R_2 ; R_{2-3} : plants with rhizomatous mutation of R_2 and R_3 , $R_{(b)}$: Bulb, $R_{(c)}$: Corm, $R_{(o)}$, oblique type, $R_{(s)}$: succulent type, $R_{(v)}$: vertical type.

Table 5. Disseminule form of vascular plants in Yongyangbo Wetlands

Disseminule form*	D_1	$D_{1,4}$	D_2	$D_{2,4}$	D_3	$D_{3,2}$	D_4	$D_{4,1}$	$D_{4,2}$	$D_{5,4}$
No. of taxa	44	9	24	10	24	1	129	4	1	2
Ratio (%)	17.8	3.6	9.7	4.0	9.7	0.4	52.0	1.6	0.4	0.8

*D_1: widely disseminated by wind or water; D_2: disseminated attachment with or eaten by animals and humans; D_3: disseminated by mechanical propulsion of dehiscence of fruits; D_4: no special modification for dissemination; D_5: not producing seeds; $D_{1,4}$: plants with D_1 and D_4 , $D_{2,4}$: plants with D_2 and D_4 , $D_{3,2}$: plants with D_3 and D_2 , $D_{4,1}$: plants with D_4 and D_1 , $D_{4,2}$: plants with D_4 and D_2 , $D_{5,4}$: plants with D_5 and D_4.

Table 6. Growth form of vascular plants in Yongyangbo Wetlands

Growth form*	b	b,e	b-l	b-p	b-ps	e	e,b	l	l-b	p	p-b	p-e	p-l	p-ps	pr	ps	ps-b	r	t	t-p
No. of taxa	16	1	6	4	3	73	12	21	3	2	1	1	1	4	15	27	2	13	40	3
Ratio (%)	6.5	0.4	2.4	1.6	1.2	29.4	4.8	8.5	1.2	0.8	0.4	0.4	0.4	1.6	6.1	10.9	0.8	5.3	16.1	1.2

*b: branched form; e: erect form; l: liana form; p: procumbent form; pr: partial-rosette form; ps: pseudo-rosette form; r: rosette form; t: tussock form, b,e: b form and/or e form, b-l: b form with liana stem, b-p: b form with procumbent stem, b-ps: b form with pseudo-rosette, e,b: e form and/or b form, l-b: l form with branched form, p-b: p form with branched form, p-e: p form with e form, p-l: p form with liana form, p-ps: p form with pseudo-rosette, ps-b: ps form with branched form, t-p: t form with procumbent stem.

Fig. 2. Rare plants in Yongyangbo Wetlands. A. *Silene capitata* Kom., endangered species Class II; B. *Polygonatum stenophyllum* Maxim., endangered species; C. *Aristolochia contorta* Bunge, least concern.

Rare and endemic plants

Rare plants are native plants that require special protection because of their decreasing population sizes or habitats. Three taxa of rare plants were observed in Yongyangbo Wetlands: *Silene capitata* Kom., *Polygonatum stenophyllum* Maxim. (both of which are classified as endangered species), and *Aristolochia contorta* Bunge (Classified as a species of least concern) (Fig. 2). Of these, *S. capitata* has been designated by the Ministry of Environment as a Class II endangered wildlife. Forty individuals were observed on roadside cliffs at three points. A relatively large distribution of *A. contorta* was observed near the farmland and edges of the wetlands.

Because Yongyangbo Wetlands are located in the CCZ, it is not a region that can be freely accessed by civilians. However, it can be accessed by tourists who submit an application. The endangered plant *S. capitata* is located on rocks behind an exploration zone made of wooden decking. Therefore, there is a risk of destruction due to the approach of tourists. To protect *S. capitata*, it is necessary to take active measures to prevent its destruction, such as installing signposts or a fence to restrict access.

Endemic plants are native plants that are only found in South Korea. *Salix koriyanagi* Kimura ex Goerz was the only endemic plant taxon observed in the survey area. This species was observed on flat sands of the river terrace where waterways meet upstream of Yongyangbo Wetlands. *Salix purpurea* var. *smithiana* Trautv. and *S. koriyanagi* were co-dominant. They formed a unique vegetative landscape that characterized Yongyangbo Wetlands.

Floristic target species and naturalized plants

A total of 17 taxa of floristic target species were identified in Yongyangbo Wetlands. There was one Class V taxon (*S. capitata)*, one Class IV taxon (*P. stenophyllum*), three Class III taxa (*Sinomenium acutum* (Thunb.) Rehder & E. H. Wilson, *Thalictrum rochebrunianum* Franch. & Sav., *S. purpurea* var. *smit hiana*), five Class II taxa (*Alisma orientale* (Sam.) Juz., *Alisma canaliculatum* A. Braun & C. D. Bouché, *Carex planiculmis* Kom., *Weigela florida* (Bunge) A. DC., *Mukdenia rossii* (Oliv.) Koidz.), and seven Class I taxa (*Adoxa moschatellina* L., *A. contorta, Impatiens nolitangere* L., *Deutzia uniflora* Shirai, *Salix chaenomeloides* Kimura, *Hemiptelea davidii*(Hance) Planch., *Ulmus davidiana* var. *japonica* (Rehder) Nakai; Table 7).

There were 26 taxa of naturalized plants observed in the survey area, including *Fallopia dumetorum* (L.) Holub, *Rumex crispus* L., *Chenopodium album* var. *spicatum* W. D. J. Koch, *Lepidium virginicum* L., *Thlaspi arvense* L., and *Potentilla supina* L. The naturalization index was 10.5%. Annual herbaceous plants (16 taxa) constituted the largest proportion of these, followed by perennial herbaceous plants (eight taxa) and woody plants (two taxa; Table 8). Most naturalized plants were observed near roads, where there were frequent human interferences. Three invasive alien species were observed: *Ambrosia trifida* L., *Ambrosia artemisiifolia* L., and *Humulus japonicus* Siebold & Zucc. Although only a small number of scattered individuals were observed owing to regular weeding, given that they must have entered from adjacent areas, changes in population sizes for these species need to be monitored continuously.

Conclusion and Suggestions

According to results of this study, a total of 248 taxa were identified in the Yongyangbo Wetlands during the survey, including 72 families and 163 genera. The most commonly observed families, in order of descending richness, were Poaceae, Asteraceae, Cyperaceae, and Fabaceae. Their life-forms were characterized by Th-R_5-D_4-e, a life-form composition similar to that of plants in orchards and fields. Three taxa of rare plants were observed, including *S. capitata* (a Class II endangered wildlife), 26 taxa of naturalized plants, and 3 taxa of invasive alien species. The disturbance index was 33.8%, indicating that the habitat

Table 7. Growth form of vascular plants in Yongyangbo Wetlands

Grade	Family	Scientific name
V	Caryophyllaceae	*Silene capitata* Kom.
IV	Liliaceae	*Polygonatum stenophyllum* Maxim.
III	Menispermaceae	*Sinomenium acutum* (Thunb.) Rehder & E. H. Wilson
	Ranunculaceae	*Thalictrum rochebrunianum* Franch. & Sav.
	Salicaceae	*Salix purpurea* var. *smithiana* Trautv.
II	Alismataceae	*Alisma orientale* (Sam.) Juz.
		Alisma canaliculatum A. Braun & C. D. Bouché
	Cyperaceae	*Carex planiculmis* Kom.
	Diervillaceae	*Weigela florida* (Bunge) A. DC.
	Saxifragaceae	*Mukdenia rossii* (Oliv.) Koidz.
I	Adoxaceae	*Adoxa moschatellina* L.
	Aristolochiaceae	*Aristolochia contorta* Bunge
	Balsaminaceae	*Impatiens nolitangere* L.
	Hydrangeaceae	*Deutzia uniflora* Shirai
	Salicaceae	*Salix chaenomeloides* Kimura
	Ulmaceae	*Hemiptelea davidii* (Hance) Planch.
		Ulmus davidiana var. *japonica* (Rehder) Nakai

Table 8. Naturalized plants in Yongyangbo Wetlands

Family	Scientific name	Dormancy form
Asteraceae	*Ambrosia trifida* L.*	Th
	Ambrosia artemisiifolia L.*	Th
	Carduus crispus L.	$Th_{(w)}$
	Conyza canadensis (L.) Cronquist	$Th_{(w)}$
	Erigeron annuus (L.) Pers.	$Th_{(w)}$
	Galinsoga quadriradiata Ruiz & Pav.	Th
	Taraxacum officinale F. H. Wigg.	H
Brassicaceae	*Lepidium virginicum* L.	$Th_{(w)}$
	Thlaspi arvense L.	$Th_{(w)}$
Chenopodiaceae	*Chenopodium album* var. *spicatum* W. D. J. Koch	Th
Convolvulaceae	*Ipomoea purpurea* (L.) Roth	Th
Euphorbiaceae	*Euphorbia maculata* L.	Th
Fabaceae	*Amorpha fruticosa* L.	N
	Melilotus suaveolens Ledeb.	$Th_{(w)}$
	Robinia pseudoacacia L.	MM
	Trifolium pratense L	H
	Trifolium repens L.	Ch
Iridaceae	*Iris pseudacorus* L.	G
Onagraceae	*Oenothera biennis* L.	$Th_{(w)}$
Poaceae	*Bromus tectorum* L.	Th
	Festuca arundinacea Schreb.	H
	Poa pratensis L.	H
Polygonaceae	*Fallopia dumetorum* (L.) Holub	Th
	Rumex crispus L.	H
Rosaceae	*Potentilla supina* L.	CH
Scrophulariaceae	*Veronica americana* Schwein. ex Benth.	$Th_{(w)}$

* Invasive alien species. Abbreviations for dormancy forms are shown in Table 3.

was more stable than that of orchards or fields.

The Yongyangbo Wetlands have been designated as a protected wetland area because of their excellent naturality and integrity obtained through long-time preservation with high biodiversity based on various habitat environments. In particular, it is an area where genetic exchange with wildlife populations is possible as it is an ecological linkage channel with the northern area. The activation of eco-tourism will introduce economic vitality to the depressed local economy in the DMZ area. In order to maintain its functions and roles, systematic management of these wetlands is necessary because there is concern of threats to habitats of indigenous species and the distribution of alien species caused by disturbances to the environment from military units, farmers, visitors, and river facility management, *inter alia.*

Conflict of Interest

The authors declare that they have no competing interests.

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Supplementary Table 1. Vascular plants in Yongyangbo Wetlands

Family	Scientific name	A	B	C	D	E	F
Equisetaceae	*Equisetum arvense* L.	G	R_{2-3}	D_1	e		
Athyriaceae	*Athyrium niponicum* (Mett.) Hance	G	R_{2-3}	D_1	t		
Dryopteridaceae	*Polystichum tripteron* (Kunze) C. Presl	H	$R_{(v)}$	D_1	t		
Thelypteridaceae	*Thelypteris palustris* (A. Gray) Schott	G	R_{2-3}	D_1	e		
Cupressaceae	*Metasequoia glyptostroboides* Hu & W. C. Cheng	MM	R_5	D_1	e		
Salicaceae	*Salix chaenomeloides* Kimura	MM	R_5	D_1	e		I
	Salix gracilistyla Miq.	N	R_5	D_1	b		
	Salix pierotii Miq.	MM	R_5	D_1	e		
	Salix koriyanagi Kimura ex Goerz***	N	R_4	D_1	b		
	Salix purpurea var. *smithiana* Trautv.	N	R_5	D_1	b		III
	Salix triandra subsp. nipponica (Franch. & Sav.) A.K. Skvortsov	M	R_5	D_1	e		
Fagaceae	*Castanea crenata* Siebold & Zucc.	MM	R_5	D_4	e		
	Quercus mongolica Fisch. ex Ledeb.	MM	R_5	D_4	e		
	Quercus variabilis Blume	MM	R_5	D_4	e		
Ulmaceae	*Hemiptelea davidii* (Hance) Planch.	MM	R_5	D_1	e		I
	Ulmus davidiana var. *japonica* (Rehder) Nakai	MM	R_5	D_1	e		I
	Zelkova serrata (Thunb.) Makino	MM	R_5	D 1	e		
Cannabaceae	*Humulus japonicus* Siebold & Zucc.	Th	R_5	D_4	l		
Moraceae	*Morus alba* L.	MM	R_5	D_2	e		
	Morus bombycis Koidz.	MM	R_5	D_2	e		
Urticaceae	*Pilea mongolica* Wedd.	Th	R_5	D_4	e		
Polygonaceae	*Aconogonon alpinum* (All.) Schkuhr	H	R_{2-3}	D_4	e		
Polygonaceae	*Fallopia dumetorum* (L.) Holub	TH	R_5	D_4	l	○	
	Persicaria hastatosagittata (Makino) Nakai ex T. Mori	$HH_{(Th)}$	R_4	$D_{4,1}$	b-l		
	Persicaria hydropiper (L.) Delarbre	$HH_{(Th)}$	R_4	$D_{4,1}$	e,b		
	Persicaria lapathifolia (L.) Delarbre	Th	R_5	D_4	e,b		
	Persicaria perfoliata (L.) H. Gross	Th	R_5	D_4	b-l		
	Persicaria senticosa (Meisn.) H. Gross ex Nakai	Th	R_5	D_4	b-l		
	Persicaria thunbergii (Siebold & Zucc.) H. Gross	$HH_{(Th)}$	R_4	$D_{4,1}$	b-p		
	Polygonum aviculare L.	Th	R_5	D_4	b,e		
	Rumex acetosa L.	H	R_5	D_4	ps		
	Rumex conglomeratus Murray	H	R_5	D_4	ps		
	Rumex crispus L.	H	R_5	D_4	ps	○	
Caryophyllaceae	*Arenaria serpyllifolia* L.	$Th_{(w)}$	R_5	D_4	b		
	Cerastium fontanum subsp. *vulgare* (Hartm.) Greuter & Burdet	H	R_5	D_4	b		
	Pseudostellaria heterophylla (Miq.) Pax	H	$R_{(s)}$	D_4	b		
	Sagina japonica (Sw.) Ohwi EN	$Th_{(w)}$	R_5	D_4	b		
	Silene capitata Kom.** EN	H	R_5	D_4	b		V
	Stellaria alsine var. *undulata* (Thunb.) Ohwi	$Th_{(w)}$	R_5	D_4	b		
	Stellaria aquatica (L.) Scop.	$Th_{(w)}$	R_5	D_4	b		
Chenopodiaceae	*Chenopodium album* var. *spicatum* W. D. J. Koch	Th	R_5	D_4	e,b	○	
	Chenopodium album L.	Th	R_5	D_4	e		
Amaranthaceae	*Achyranthes bidentata* var. japonica Miq.	H	R_5	D_2	e		
Lauraceae	*Lindera obtusiloba* Blume	N	R_5	D_2	e		
Ranunculaceae	*Clematis apiifolia* DC.	N	R_4	D_1	l		
	Ranunculus japonicus Thunb.	H	R_5	D_4	ps		
	Thalictrum aquilegifolium var. *sibiricum* Regel & Tiling	G	R_5	D_4	ps		
	Thalictrum minus var. *hypoleucum* (Siebold & Zucc.) Miq.	G	R_5	D_4	e		
	Thalictrum rochebrunianum Franch. & Sav.	G	R_5	D_4	e		III
Menispermaceae	*Menispermum dauricum* DC.	N	R_{2-3}	D_1	l		
	Sinomenium acutum (Thunb.) Rehder & E. H. WilsonLC	N	R_{2-3}	D_1	l		III
Aristolochiaceae	*Aristolochia contorta* Bunge	H	R_5	D_1	l		I
Actinidiaceae	*Actinidia arguta* (Siebold & Zucc.) Planch. ex Miq.	M	R_5	D_1	l		
Clusiaceae	*Hypericum ascyron* L.	H	R_5	D_3	e		
	Hypericum erectum Thunb.	H	R_3	D_4	e		

Family	Scientific name	A	B	C	D	E	F
Papaveraceae	*Chelidonium majus* var. *asiaticum* (H. Hara) Ohwi	$Th_{(w)}$	R_5	$D_{4,2}$	e		
Fumariaceae	*Corydalis speciosa* Maxim.	$Th_{(w)}$	R_5	D_3	b		
	Corydalis remota Fisch. ex Maxim.	G	$R_{(s)}$	D_3	ps		
Brassicaceae	*Arabis glabra* (L.) Bernh.	$Th_{(w)}$	R_5	D_4	pr		
	Barbarea orthoceras Ledeb.	$HH_{(Thw)}$	R_5	D_4	pr		
	Capsella bursa-pastoris (L.) Medik.	$TH_{(w)}$	R_5	D_4	ps		
	Cardamine flexuosa With.	$TH_{(w)}$	R_5	D_3	ps		
	Cardamine fallax (O. E. Schulz) Nakai	$TH_{(w)}$	R_5	D_3	ps		
	Cardamine impatiens L.	$HH_{(Thw)}$	R_6	D_4	ps		
	Cardamine leucantha (Tausch) O. E. Schulz	H	R_3	D_4	e		
	Draba nemorosa L.	$Th_{(w)}$	R_5	D_4	ps		
	Lepidium virginicum L.	$Th_{(w)}$	R_5	D_4	ps	○	
	Rorippa indica (L.) Hiern	$Th_{(w)}$	R_5	D_4	pr		
	Rorippa palustris (L.) Besser	$Th_{(w)}$	R_5	D_4	ps		
	Thlaspi arvense L.	$Th_{(w)}$	R_5	D_4	pr	○	
Crassulaceae	*Sedum kamtschaticum* Fisch. & C. A. Mey.	H	R_3	D_4	b		
	Sedum sarmentosum Bunge	H	R_4	D_4	b-p		
Hydrangeaceae	*Deutzia uniflora* Shirai	N	R_3	D_4	e,b		I
Saxifragaceae	*Mukdenia rossii* (Oliv.) Koidz.	E	R_4	D_4	r		II
Rosaceae	*Crataegus pinnatifida* Bunge	M	R_5	D_2	e		
	Duchesnea indica (Andr.) Focke	Ch	R_4	D_2	p-ps		
	Potentilla kleiniana Wight & Arn.	Ch	R_5	D_4	p-ps		
	Potentilla supina L.	Ch	R_5	D_4	b-ps	○	
	Prunus japonica var. *nakaii* (H. Lev.) Rehder	N	R_5	D_2	e,b		
	Prunus padus L.	MM	R_5	D_2	e		
	Prunus persica (L.) Batsch	M	R_5	D_2	e		
	Rosa multiflora Thunb.	N	R_3	D_2	e		
	Rubus crataegifolius Bunge	N	R_5	D_2	e		
	Rubus parvifolius L.	N	R_5	D_2	p-l		
	Spiraea prunifolia var. *simpliciflora* (Nakai) Nakai	N	R_5	D_4	e,b		
Fabaceae	*Amorpha fruticosa* L.	N	R_5	D_4	e	○	
	Amphicarpaea bracteata subsp. *edgeworthii* (Benth.) H. Ohashi	Th	R_5	D_3	l-b		
	Kummerowia stipulacea (Maxim.) Makino	Th	R_5	D_3	e,b		
	Kummerowia striata (Thunb.) Schindl.	Th	R_5	D_4	e,b		
	Lathyrus davidii Hance	G	R_5	D_3	e,b		
	Lespedeza bicolor Turcz.	N	R_5	D_4	e		
	Lespedeza cuneata (Dum. Cours.) G. Don.	H	R_5	D_4	b		
	Melilotus suaveolens Ledeb.	$Th_{(w)}$	R_5	D_4	b	○	
	Pueraria lobata (Willd.) Ohwi	Ch	R_5	D_4	l-b		
	Robinia pseudoacacia L.	MM	R_5	D_3	e	○	
	Sophora flavescens Aiton	G	R_3	D_4	e,b		
	Trifolium pratense L.	H	R_3	D_4	e,b	○	
	Trifolium repens L.	Ch	R_4	D_4	p	○	
	Vicia amoena Fisch. ex Ser.	G	R_{2-3}	D_3	l		
	Vicia amurensis Oett.	G	R_5	D_3	l		
	Vicia unijuga A. Braun	G	R_3	D_3	e		
	Vigna angularis var. *nipponensis* (Ohwi) Ohwi & H. Ohashi	Th	R_5	D_3	l		
Oxalidaceae	*Oxalis corniculata* L.	Ch	R_4	$D_{3,2}$	p-b		
Geraniaceae	*Geranium sibiricum* L.	H	R_5	D_3	psb		
	Geranium thunbergii Siebold ex Lindl. & Paxton	H	R_5	D_3	psb		
Euphorbiaceae	*Acalypha australis* L.	Th	R_5	D_3	e		
	Euphorbia maculata L.	Th	R_5	D_3	b-p	○	
	Flueggea suffruticosa (Pall.) Baill.	M	R_5	D_4	e		
Anacardiaceae	*Rhus javanica* L.	M	R_5	D_4	e		

Family	Scientific name	A	B	C	D	E	F
Aceraceae	*Acer tataricum* subsp. *ginnala* (Maxim.) Wesm.	M	R_5	D_1	e		
Balsaminaceae	*Impatiens nolitangere* L.	Th	R_4	D_3	e		I
	Impatiens textori Miq.	Th	R_4	D_3	e		
Celastraceae	*Celastrus flagellaris* Rupr.	M	R_5	$D_{2,4}$	l		
	Celastrus orbiculatus Thunb.	M	R_5	$D_{2,4}$	l		
Staphyleaceae	*Staphylea bumalda* DC.	M	R_5	D_4	e		
Vitaceae	*Parthenocissus tricuspidata* (Siebold & Zucc.) Planch.	M	R_5	$D_{2,4}$	l		
Onagraceae	*Oenothera biennis* L.	$Th_{(w)}$	R_5	$D_{4,1}$	pr	○	
Haloragaceae	*Myriophyllum spicatum* L.	HH	R_{2-3}	D_1	e		
Violaceae	*Viola lactiflora* Nakai	H	$R_{3(v)}$	D_3	r		
	Viola mandshurica W. Becker	H	$R_{3(v)}$	D_3	r		
	Viola verecunda A. Gray	H	$R_{3(v)}$	D_3	b-ps		
Cucurbitaceae	*Trichosanthes kirilowii* Maxim.	G	$R_{5(o)}$	$D_{2,4}$	l		
Cornaceae	*Cornus controversa* Hemsl.	MM	R_5	$D_{2,4}$	e		
	Cornus kousa F. Buerger ex Miq.	M	R_5	$D_{2,4}$	e		
Araliaceae	*Aralia elata* (Miq.) Seem.	M	R_5	$D_{2,4}$	e		
Apiaceae	*Angelica cartilaginomarginata* (Makino ex Y. Yabe) Nakai	G	$R_{3(s)}$	D_4	ps		
	Angelica dahurica (Fisch. ex Hoffm.) Benth. & Hook. f. ex Franch. & Sav.	G	$R_{5(s)}$	D_4	ps		
	Angelica amurensis Schischk.	G	R_3	D_4	ps		
	Anthriscus sylvestris (L.) Hoffm.	H	$R_{5(s)}$	D_4	ps		
	Oenanthe javanica (Blume) DC.	HH	R_4	$D_{1,4}$	p-ps		
	Ostericum grosseserratum (Maxim.) Kitag.	H	R_3	D_4	ps		
	Peucedanum terebinthaceum (Fisch. ex Trevir.) Ledeb.	H	R_5	D_4	ps		
	Pimpinella brachycarpa (Kom.) Nakai	G	R_3	D_4	ps		
	Sium suave Walter	HH	R_5	D_4	ps		
	Torilis japonica (Houtt.) DC.	$Th_{(w)}$	R_5	D_2	ps		
Oleaceae	*Ligustrum obtusifolium* Siebold & Zucc.	M	R_5	D_2	e		
Asclepiadaceae	*Metaplexis japonica* (Thunb.) Makino	G	R_{2-3}	D_1	l		
Rubiaceae	*Galium maximowiczii* (Kom.) Pobed.	H	R_5	D_2	e		
	Galium spurium L.	$Th_{(w)}$	R_5	D_2	b-l		
	Rubia argyi (H. Lev. & Vaniot) H. Hara ex Lauener & D.K. Ferguson	G	R_3	D_2	b-l		
	Rubia cordifolia L.	G	R_3	D_2	b-l		
Polemoniaceae	*Phlox subulata* L.	H	R_{2-3}	D_4	e,b		
Convolvulaceae	*Calystegia hederacea* Wall.	G	R_{2-3}	$D_{5,4}$	l		
	Calystegia pubescens Lindl.	G	R_{2-3}	$D_{5,4}$	l		
	Ipomoea purpurea (L.) Roth	Th	R_5	D_4	l	○	
Boraginaceae	*Trigonotis peduncularis* (Trevir.) Steven ex Palib.	$Th_{(w)}$	R_5	D_4	b		
Lamiaceae	*Clinopodium micranthum* (Regel) H. Hara	H	R_5	D_4	b		
	Isodon inflexus (Thunb.) Kud	G	R3	D_4	e		
	Leonurus japonicus Houtt.	$Th_{(w)}$	R_5	D_4	pr		
	Lycopus lucidus Turcz. ex Benth.	HH	R_{2-3}	D_4	e		
	Salvia plebeia R. Br.	$Th_{(w)}$	R_5	D_4	ps		
	Teucrium japonicum Houtt.	H	R_{2-3}	D_4	e		
Scrophulariaceae	*Mazus pumilus* (Burm. f.) Steenis	$Th_{(w)}$	R_5	D_4	b-ps		
	Veronica americana Schwein. ex Benth.	$Th_{(w)}$	R_5	D_4	e	○	
Phrymaceae	*Phryma leptostachya* var. *oblongifolia* (Koidz.) Honda	G	R3	D_2	e		
Plantaginaceae	*Plantago asiatica* L.	H	$R_{3(o)}$	$D_{2,4}$	r		
Caprifoliaceae	*Lonicera japonica* Thunb.	M	R3	$D_{2,4}$	l-b		
Adoxaceae	*Adoxa moschatellina* L.	H	R3	D_4	ps		I
	Sambucus williamsii Hance	M	R_5	D_2	e		
Diervillaceae	*Weigela florida* (Bunge) A. DC.	N	R_5	D_4	e		II
Campanulaceae	*Lobelia chinensis* Lour.	H	R4	D_4	p-e		
Asteraceae	*Ambrosia artemisiifolia* L.*	Th	R_5	D_4	e	○	

Family	Scientific name	A	B	C	D	E	F
	Ambrosia trifida L.*	Th	R_5	D_4	e	○	
	Artemisia annua L.	Th	R_5	D_4	e		
	Artemisia capillaris Thunb.	H	R_3	D_4	e		
	Artemisia codonocephala Diels	H	R_{2-3}	D_4	e		
	Artemisia lancea Vaniot	H	R_{2-3}	D_4	e		
	Artemisia montana (Nakai) Pamp.	Ch	R_{2-3}	D_4	pr		
	Artemisia indica Willd.	Ch	R_{2-3}	D_4	pr		
	Artemisia selengensis Turcz. ex Besser	H	R_{2-3}	D_4	e		
	Aster tataricus L. f.	H	R_3	D_1	e		
	Aster incisus Fisch.	Ch	R_3	D_4	pr		
	Aster yomena (Kitam.) Honda	Ch	R_3	D_4	pr		
	Carduus crispus L.	$Th_{(w)}$	R_5	D_1	pr	○	
	Conyza canadensis (L.) Cronquist	$Th_{(w)}$	R_5	D_1	pr	○	
	Crepidiastrum sonchifolium (Bunge) Pak & Kawano	$Th_{(w)}$	R_5	D_1	ps		
	Erigeron annuus (L.) Pers.	$Th_{(w)}$	R_5	D_1	pr	○	
	Galinsoga quadriradiata Ruiz & Pav.	Th	R_5	D_4	e	○	
	Hemistepta lyrata Bunge	$Th_{(w)}$	R_5	D_1	pr		
	Inula britannica var. *japonica* (Thunb.) Franch. & Sav.	G	R_5	D_1	e		
	Ixeris polycephala Cass.	H	R_5	D_1	e		
	Ixeris stolonifera A. Gray	CH	R_4	D_1	p-ps		
	Lactuca indica L.	$Th,Th_{(w)}$	R_5	D_1	pr		
	Taraxacum coreanum Nakai	H	$R_{3(v)}$	D_1	r		
	Taraxacum officinale F. H. Wigg.	H	$R_{3(v)}$	D_1	r	○	
	Taraxacum platycarpum Dahlst.	H	$R_{3(v)}$	D_1	r		
Alismataceae	*Alisma canaliculatum* A. Braun & C. D. Bouché	HH	R_5	D_1	r		II
	Alisma orientale (Sam.) Juz.	HH	R_5	D_1	r		II
Hydrocharitaceae	*Hydrilla verticillata* (L. f.) Royle	HH	R_5	D_1	e		
Potamogetonaceae	*Potamogeton pusillus* L.	HH	R_5	D_1	e		
Liliaceae	*Allium macrostemon* Bunge	G	$R_{3(b)}$	D_4	r		
	Allium monanthum Maxim.	G	$R_{2-3(b)}$	D_4	r		
	Allium sacculiferum Maxim.	G	$R_{3(b)}$	D_4	r		
	Hosta longipes (Franch. & Sav.) Matsum.	H	R_5	D_4	r		
	Polygonatum stenophyllum Maxim.	G	R_3	$D_{2,4}$	e		IV
	Barnardia japonica (Thunb.) Schult. & Schult. f.	G	$R_{5(b)}$	D_4	t		
Smilacaceae	*Smilax nipponica* Miq.	G	R_5	D_2	e		
	Smilax sieboldii Miq.	N	R_5	D_2	l		
Dioscoreaceae	*Dioscorea polystachya* Turcz.	G	$R_{5(s)}$	D_1	l		
	Dioscorea nipponica Makino	G	$R_{3(s)}$	D_1	l		
Iridaceae	*Iris pseudacorus* L.	G	R_3	D_3	ps	○	
	Iris sanguinea Donn ex Hornem.	G	R_3	D_3	ps		
Juncaceae	*Juncus decipiens* (Buchenau) Nakai	HH	R_3	$D_{1,4}$	t		
Commelinaceae	*Commelina communis* L.	Th	R_5	D_4	b-p		
Poaceae	*Elymus ciliaris* (Trin.) Tzvelev	$Th_{(w)}$	R_5	D_4	t		
	Elymus tsukushiensis Honda	$Th_{(w)}$	R_5	D_4	t		
	Alopecurus aequalis Sobol.	$Th_{(w)}$	R_5	$D_{1,4}$	t		
	Bromus japonicus Thunb.	Th	R_5	D_4	t		
	Bromus tectorum L.	Th	R_5	D_4	t	○	
	Digitaria ciliaris (Retz.) Koeler	Th	R_4	D_4	t-p		
	Spodipogon cotulifer (Thunb.) Hack.	H	R_3	$D_{1.4}$	t		
	Echinochloa crus-galli (L.) P. Beauv.	$HH_{(Th)}$	R_5	D_4	t-p		
	Eleusine indica (L.) Gaertn.	Th	R_5	D_4	t		
	Eragrostis ferruginea (Thunb.) P. Beauv.	H	R_3	D_4	t		
	Festuca arundinacea Schreb.	H	R_5	D_1	t	○	
	Miscanthus sacchariflorus (Maxim.) Hack.	H	R_{2-3}	D_4	t		
	Muhlenbergia huegelii Trin.	H	R_3	D_1	t-p		
	Oplismenus undulatifolius (Ard.) Roem. & Schult.	H	R_4	D_4	p		
	Phalaris arundinacea L.	HH	R_{2-3}	D_2	e		

Family	Scientific name	A	B	C	D	E	F
	Phragmites australis (Cav.) Trin. ex Steud.	HH	R_{1-2}	D_1	e		
	Phragmites japonica Steud.	HH	R_4	D_1	e		
	Poa annua L.	$Th_{(w)}$	R_5	D_4	t		
	Poa hisauchii Honda	$Th_{(w)}$	R_5	D_4	t		
	Poa pratensis L.	H	R_{2-3}	D_4	t	○	
	Poa sphondylodes Trin.	H	R_5	D_4	t		
	Setaria faberi R. A. W. Herrm.	Th	R_5	D_4	t		
	Setaria pumila (Poir.) Roem. & Schult.	Th	R_5	D_4	t		
	Setaria viridis (L.) P. Beauv.	Th	R_5	D_4	t		
	Spodipogon sibiricus Trin.	H	R_3	D_4	e		
	Trisetum bifidum (Thunb.) Ohwi	H	R_3	D_4	t		
Typhaceae	*Typha orientalis* C. Presl.	HH	R_{2-3}	D_{1-4}	t		
Cyperaceae	*Carex breviculmis* R. Br.	H	R_3	D_4	t		
	Carex dimorpholepis Steud.	H	R_3	D_4	t		
	Carex forficula Franch. & Sav.	H	R_3	D_4	t		
	Carex heterolepis Bunge	H	R_{2-3}	D_4	t		
	Carex japonica Thunb.	H	R_{2-3}	D_4	t		
	Carex laevissima Nakai	H	R_3	D_4	t		
	Carex lanceolata Boott	H	R_3	D_4	t		
	Carex leiorhyncha C. A. Mey.	H	R_3	D_4	t		
	Carex maackii Maxim.	H	R_3	D_4	t		
	Carex miyabei Franch.	HH	R_{2-3}	D_4	t		
	Carex neurocarpa Maxim.	H	R_3	D_4	t		
	Carex planiculmis Kom.	H	R_{2-3}	D_4	t		II
	Cyperus amuricus Maxim.	Th	R_5	D_4	t		
	Cyperus iria L.	Th	R_5	D_4	t		
	Eleocharis valleculosa var. *setosa* Ohwi	HH	R_5	$D_{1,4}$	t		
	Eleocharis ussuriensis G. Zinserl.	HH	R_{2-3}	$D_{1,4}$	t		
	Scirpus radicans Schkuhr	HH	R_{2-3}	$D_{1,4}$	t		

* Invasive alien species, ** endangered species Class ll, ***endemic plant, EN: rare plants classified as endangered species, LC: rare plants classified as least concern, A: dormancy form, B: radicoid form, C: disseminule form, D: growth form, E: naturalized plant, F: grade of floristic target species. Abbreviations for life forms (A~D) are shown in Tables 3~6.