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Flora and Vegetation Characteristics of the Natural Habitat of the Endangered Plant *Pterygopleurum neurophyllum*

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Abstract: This study analyzed the flora, life form, and vegetation of the Nakdong River wetland. Vegetation analysis was performed on 37 plots using the phytosociological method of the Zürich-Montpellier School. PCA analysis was conducted by using the vegetation data (ground cover of class; 1~9) of 37 plots surveyed by phytosociological method. PCA (Principal Component Analysis) was used to statistically analyze the objectivity of the community classification and the character species. The traditional classification and mathematical statistic methods were used. A total of 82 taxa belonging to 28 families, 65 genera, 72 species, 2 subspecies, and 8 varieties were present in the vegetation of the survey area. The life form was analyzed to be the Th-R_5-D_4-e type. The communities were classified into seven communities: *Miscanthus sacchariflorus* community, *Phragmites communis* community, *Phragmites communis*–*Carex dispalata* community, *Ulmus parvifolia* community, *Zizania latifolia* community, *Setaria viridis* community, and *Salix koriyanagi*–*Salix chaenomeloides* community. As a result of PCA analysis, it was classified into seven communities. Seven communities were analyzed, where the most dominant species (*M. sacchariflorus*, *P. communis*, *C. dispalata*, *U. parvifolia*, *Z. latifolia*, *S. viridis*, *S. koriyanagi*, *S. chaenomeloides*) of each community were examined as character species. Another species is analyzed as *Salix koreensis*. Of the sixteen *M. sacchariflorus* communities, *Pterygopleurum neurophyllum* was present in six plots (A-2 group) but not in ten plots (A-1 group). These two groups showed differences in coverage and the number of occurring species. As for the relative net contribution degree (r-NCD) in the A-2 group, most species showed low r-NCD except for *M. sacchariflorus*, which showed an r-NCD of 100. The r-NCDs in the A-1 group were as follows: *Miscanthus sacchariflorus* (100), *P. neurophyllum* (21.74), and *Persicaria perfoliata* (10.14). Therefore, *P. neurophyllum* is difficult to grow in the A-1 group. As a result, it is thought that the high density of *M. sacchariflorus* affects the growth and distribution of *P. neurophyllum.* In order to expand and maintain *P. neurophyllum*, the habitat environment needs to be altered by adjusting the density of *M. sacchariflorus.*

Keywords: auto ecology; phytosociological method; lifeform; ecological traits; endangered species

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Citation: Park, H.J.; Kim, S.; Lee, C.W.; Kim, N.Y.; Hwang, J.E.; An, J.; Park, H.B.; Kim, P.B.; Lee, B.-D. Flora and Vegetation Characteristics of the Natural Habitat of the Endangered Plant *Pterygopleurum neurophyllum*. *Diversity* **2021**, *13*, 401. https://doi.org/10.3390/d13090401

Academic Editors: Mario A. Pagnotta and Jorge Capelo

Received: 22 July 2021
Accepted: 23 August 2021
Published: 25 August 2021

1. Introduction

The importance of the ecological and economic value of a country's biological resources has been increasing since the Convention on Biological Diversity concluded in 1992, and sovereignty over biological resources began to be systematized [1]. However, species extinction continues to increase on Earth as the number of direct and indirect threats to species has increased [2,3]. It has been suggested that various factors such as habitat destruction, environmental pollution, and climate change have endangered plant species [4–8]. Ultimately, changes in the physical environment and climate owing to increased anthropogenic activities place plants at the risk of extinction [9]. These changes can be fatal for plant species with narrow distribution and low adaptability [1,10]. The International Union for Conservation of Nature (IUCN) reported that the number of endangered plants worldwide increased from 16,000 in 2019 to 20,000 in 2020, which is 4000 more species per year [11]. Moreover, the IUCN forecasted that approximately 20% of 250,000 vascular plants growing on the Earth will become extinct within the next 50 years [12–14]. Under these circumstances, each country designates, protects, and manages endangered species separate from the Red List [15]. South Korea also legally designates and manages 267 endangered species according to the "Wildlife Protection and Management Act". Therefore, efforts to prevent this global trend, habitat loss of plant species, and ecological imbalance are necessary.

Pterygopleurum neurophyllum (Maxim.) Kitag (Figure 1) is a perennial plant belonging to the Apiaceae family and is limitedly distributed in the temperate climate regions of Korea, Japan, and China, particularly as one species in one genus in the Korean Peninsula [16]. This species is designated and managed as a Class II Endangered Species and Critically Endangered (CR) Class by the Ministry of Environment in South Korea and as an Endangered (EN) Class in Japan [16]. A few individuals of this species are naturally grown in the Nakdong River backswamp in Yangsan-si, South Gyeongsang-do. It has been reported in Dongjak-dong wetland in Seoul [17], and the specimens have been collected and recorded from wetlands and grasslands in Oryu-dong, Seoul, in 1967; Taereung, Seoul, in 1940; and Cheongnyangni, Seoul, in 1902. It has also been reported to grow naturally in Jeonju in Jeollabuk-do, Jeollanam-do, and Gyeongsangnam-do [16,18,19], but currently it has not been confirmed anywhere else, except in Yangsan, Gyeongsangnam-do.

Figure 1. Photos of *Pterygopleurum neurophyllum* and wild habitat in research site.

Very little is known about the ecology of *P. neurophyllum*. Kwon et al. [20] recently evaluated the germination characteristics of *P. neurophyllum* seeds [20]. They showed that the seed embryos of *P. neurophyllum* began to develop after 4 weeks of low-temperature treatment (4 °C) and developed rapidly after 8 weeks. The seeds were germinated after 12 weeks, and the germination rate was 23.1%. When the seeds were treated for 12 weeks with low-temperature treatment and were submerged in 50% sulfuric acid (H_2SO_4) for 30 min, the germination rate was 29.4%. When the seeds were treated for 12 weeks with low-temperature treatment and GA_3 (0.5 g L^{-1}), the germination rate was 37.2%, which was the highest. The germination rate was the highest (79.8%) when both methods were applied. Low-temperature treatment and GA_3 treatment after sulfuric acid pre-treatment broke dormancy and improved the germination rate of seeds. Although Son et al. [21] examined the vegetation and soil characteristics of *P. neurophyllum* in the remaining natural habitat in Yangsan-si, Gyeongsangnam-do, they did not record the distribution of *P. neurophyllum* [21]. As a result, the detailed characteristics of the native habitats of *P. neurophyllum*, including the vegetation of the native habitats, cannot be deduced. However, the results of this study showed that willows, common ditch reeds, reeds, and *Zizania latifolia* were growing in the Wondong marsh where *P. neurophyllum* was growing naturally. The soil analysis revealed no special findings, except that the sand content was high. It is assumed that, unlike general wetlands, this wetland has high sand content because it is behind the river; hence, the sand is transported to the marsh owing to flooding during the rainy season from the mainstream of the Nakdong River. Meanwhile, some studies have been conducted in Japan as well. Suzuki and Kokufuta examined the endangered plant in Japan and also recorded the habitat status of *P. neurophyllum* [22]. It was reported that the overall *P. neurophyllum* population has declined and is on the path of extinction owing to river development in its habitats (Ibaraki, Chiba, Tochigi, Gunma, Saitama, Oita, Kumamoto, and Kagoshima Prefectures). Moreover, Obata et al. and Sato et al. [23,24] included the emergence frequency of endangered species *P. neurophyllum* as a part of the Watarase Reservoir Restoration Project, which is distributed across Tochigi, Gunma, Saitama, and Ibaraki prefectures in Japan [23,24]. However, only a few studies have reported the vegetation and companion species of *P. neurophyllum* by investigating its actual natural habitat from plant and ecological perspectives. No study has analyzed the habitat characteristics of native *P. neurophyllum* in Japan as well as in South Korea.

This study analyzed and evaluated the habitat environment characteristics of *P. neurophyllum* by focusing on the vegetation for the first time. This study aimed to analyze the flora and vegetation characteristics of the Nakdong River backswamp in Gyeongsangnam-do, the only native habitat of *P. neurophyllum*, and the distribution and vegetation structure characteristics of natural habitats. The elucidation of vegetation structure characteristics of *P. neurophyllum*, an endangered species, carries great academic importance, and it is expected that the analysis results can be used as baseline data for establishing restoration and conservation strategies for *P. neurophyllum*.

2. Materials and Methods

2.1. Study Site Overview

In this study, a flora and vegetation survey was conducted from July to September 2020 in the Wondong wetland in Yangsan-si, Gyeongsangnam-do, known as the native habitat of *Pterygopleurum neurophyllum* (Figure 2). This wetland was formed by the interactions between natural factors (e.g., the overflow of Nakdong River) and anthropogenic factors (e.g., agriculture). Roads and trails are built north of the study site, and it was affected by artificial disturbance because some areas were being covered by soil. The stream passing through the study site is the Singok-cheon Stream, which originates from Mt. Cheontae-san (Samrangjin-eup, Miryang-si). The Nakdong River flows at the south, and Wondong-cheon Stream, which originates from the valleys of Mt. Gaji-San at Milyang and Unyang, flows at the east. The water system affecting the study site is the Nakdong River on a large scale and Singok-cheon Stream and Wondong-cheon Stream on a small scale. During the rainy season in summer, the river overflowed and the entire study site was flooded. As it is a wetland located downstream of the river, the altitude of the study site is at the sea level, and it had almost no slope. At the study site, the mean annual temperature over the past 10 years was 14.9 °C, and the mean annual precipitation over the past 10 years was 1473 mm (Yangsan-si Meteorological Observatory). These values were approximately 1 °C higher than the mean temperature (13.8 °C) and 75 mm higher than the mean annual precipitation (1398 mm) of South Korea, respectively [25].

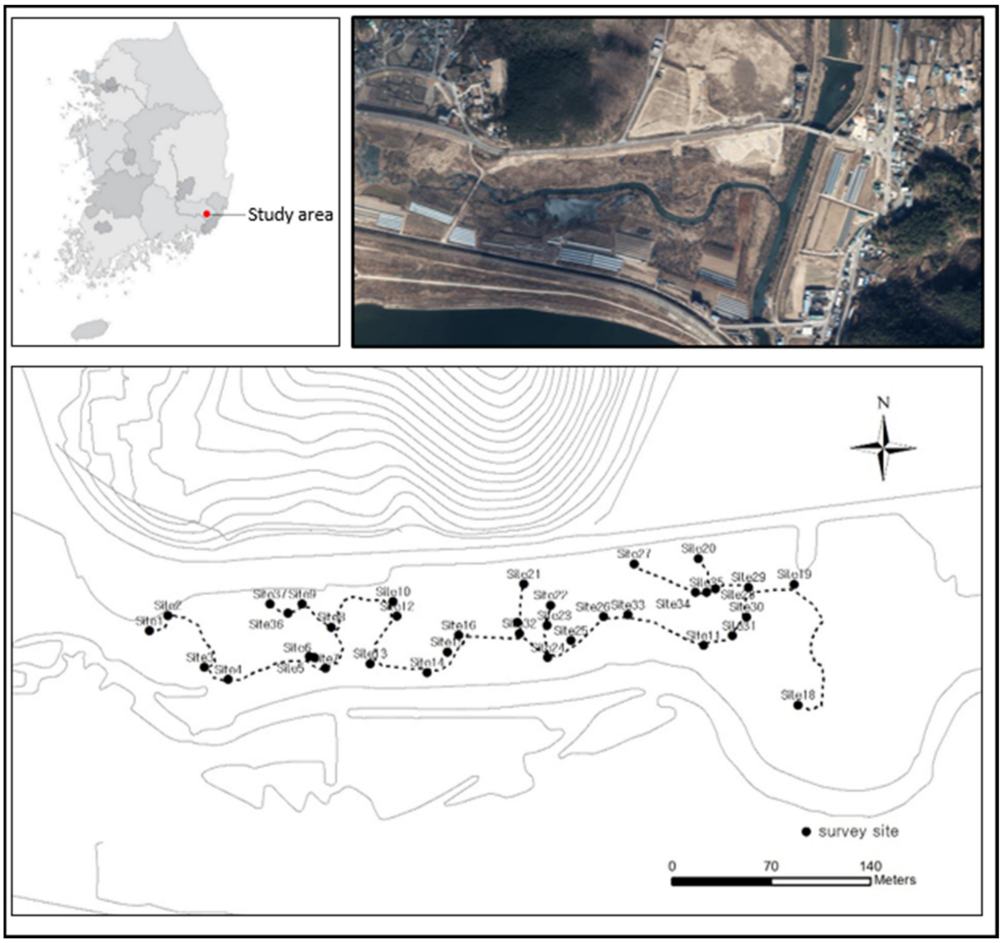

Figure 2. Survey site of study area.

2.2. Survey and Analysis

For the flora survey, based on the route (Figure 2) traveled during the vegetation survey, plants that appeared and were observed during the survey were recorded. The observed plants were identified and classified according to illustrated books of the flora [18,19,26–28]. The arrangement of the botanical list followed the classification system of Cronquist [29], and the scientific and Korean names in this study followed Kim et al.'s study [30]. The endemic species of the Korean Peninsula [31], Floristic Regional Indicator Species [32], the Red List [16], and Ecosystem Disturbance and Exotic Plants [33] were analyzed based on the list of the vascular plants. The life form of the observed plant species was classified (i.e., dormancy, radicoid, disseminule, and growth) and presented by using the method of Raunkiaer and Numata after the modification of Lee's method for adaptation to plant species in South Korea [19,34,35].

The vegetation survey was conducted at 37 plots in the study site including the area where *Pterygopleurum neurophyllum* was growing (Figure 2). Vegetation survey was conducted on 6 plots where *P. neurophyllum* was distributed, and the rest 31 plots were randomly selected. It was conducted according to the phytosociological method of the Zürich-Montpellier School [36]. The size of the quadrat was 4 m^2 (2 m × 2 m) for herbaceous communities and 25 m^2 (5 m × 5 m) for arborescent communities considering the characteristics of the communities including topography, upper canopy, and height of the plant species. The ground cover class of the observed plant species was measured by using the combined cover degree (9 degrees) (Figure 3) [37].

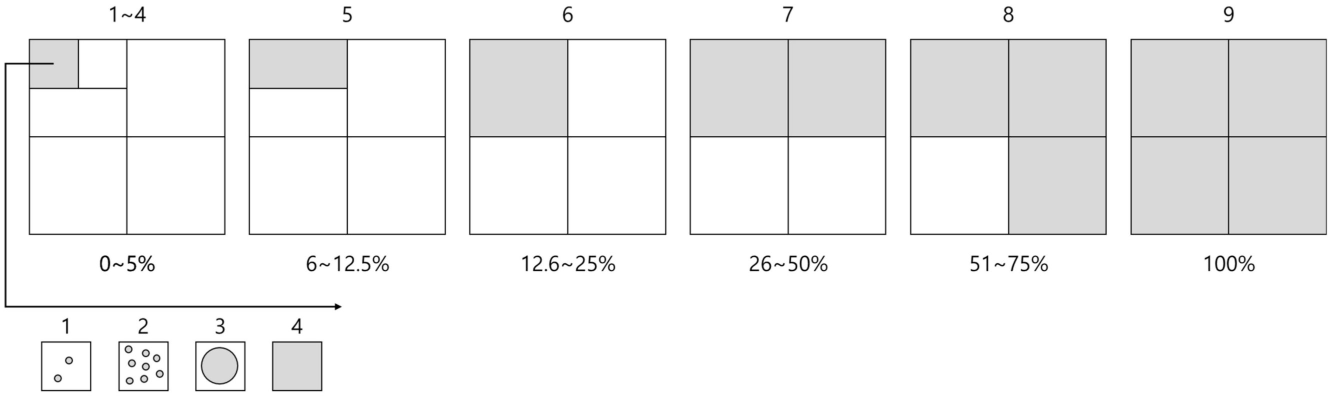

Figure 3. Criteria for determining the cover degree of plant species [37]. White and gray areas indicate the quadrat areas without and with vegetation cover, while values above and below the squares represent scores (9 degrees) and proportions of the vegetated areas (up to 100%) for each ground cover class, respectively.

Moreover, this study applied the traditional classification method and a classification method transformed by natural logarithm, which is advantageous for mathematical analysis, for the extraction of vegetation units [38]. The relative net contribution degree (*r-NCD*), a quantitative relative value, was also calculated, which converted the contribution of each observed plant species to the plant community into a percentage for easy comparative analysis [39]. The absolute contribution (*NCD*) value and the relative contribution value were derived using the following formula:

$$NCDi = \sum Ci/N \times ni/N\ (Cmin \leq NCD \leq \mathrm{Cmax}) \quad (1)$$

$$r\text{-}NCDi = \sum Ci/NCDmax \times 100 \quad (2)$$

where $\sum Ci$, N, ni, and $NCDmax$ indicate the accumulated ground cover of species i in a community, the number of sampling plots for a target plant community, the number of sampling plots in which species i appeared, and the maximum contribution value within a target plant community, respectively. PCA analysis was used to analyze the statistical classification of community and indicator species of the community. For PCA analysis, the PC-ORD (Ver. 5.17) program was used, and vegetation survey data of 37 plots (ground cover of class; 1~9) (Appendix A Table A1) were used.

3. Results and Discussion

3.1. Flora

The flora survey in the natural habitat of *Pterygopleurum neurophyllum* confirmed 82 taxa: 28 families, 65 genera, 72 species, 2 subspecies, and 8 varieties. Among them, Asteraceae plants appeared the most (11 taxa), followed by Polygonaceae (10 taxa), Cyperaceae (9 taxa), and Poaceae (9 taxa) plants. Pteridophytes and gymnosperms were not found, but 22 taxa of monocotyledons and 60 taxa of dicotyledons were observed (Table 1).

Table 1. The number of vascular plants in study area.

Taxa	Family	Genus	Species	Subspcies	Variety	Form	Total
Pteridophyta	0	0	0	0	0	0	0
Gymnospermae	0	0	0	0	0	0	0
Angiospermae	28	65	72	2	8	0	82
Monocotyledoneae	5	18	18	0	4	0	22
Dicotyledoneae	23	47	54	2	4	0	60
Total	28	65	53	2	8	0	82

Two taxa of endangered species were found in the study site (*Pterygopleurum neurophyllum* and *Viola raddeana*). One taxon of endemic species in the Korean Peninsula was observed (*Salix koriyanagi*). *P. neurophyllum* and *V. raddeana* are endangered (CR) species listed in the Korean Red List, designated by the Ministry of Environment. The analysis results of floristic regional indicator plants (classifying floras into phytogeographic categories according to the degree of uniqueness in each region) revealed six taxa. One taxon (*P. neurophyllum*) was observed in Class V and is considered to have high phytogeographical value owing to its limited spatial distribution in South Korea. In addition, one taxon (*Veronica peregrina*) was observed in Class III, one taxon (*V. raddeana*) was observed in Class II, and three taxa (*Actinostemma lobatum*, *Salix chaenomeloides*, and *Ulmus parvifolia*.) were observed in Class I. Furthermore, 13 taxa (5 families) of alien plants, including *Rumex nipponicus*, *Amaranthus patulus*, *Bidens frondosa*, and *Sonchus oleraceus*, were confirmed (Table 2). Two taxa (one family) of invasive alien plants, *Ambrosia artemisiifolia* and *A. trifida*, were also identified (Table 2).

The flora results of the native habitat of *Pterygopleurum neurophyllum* revealed that the overall rarity or specificity of the ecosystem was not high, as there were no species with a high floristic regional class or there were not a lot of endemic species in the Korean Peninsula. However, the study area was considered to be very important and to have very high protection value because *P. neurophyllum* and *Viola raddeana*, which are Class II endangered species that are distributed in a very limited area in South Korea, were found at the study site. In terms of invasive alien plants, species such as *Ambrosia artemisiifolia* and *A. trifida*, which have excellent environmental adaptability, can reproduce anywhere, and can form a large community, were observed. Due to the fact that these species can suppress existing ecosystem constituents or alter the ecosystem structure, active measures such as the physical removal of *A. artemisiifolia* and *A. trifida.* must be implemented to maintain the existing ecosystem [40].

Table 2. The list of vascular plants in study area.

Family Name	Scientific Name	Note
Salicaceae	*Salix chaenomeloides* Kimura	I
	Salix koreensis Andersson	
	Salix koriyanagi Kimura	En
Ulmaceae	*Ulmus parvifolia* Jacq.	I
Cannabaceae	*Humulus japonicus* Siebold and Zucc	Ip
Polygonaceae	*Persicaria hydropiper* (L.) Spach	
	Persicaria lapathifolia (L.) Gray	
	Persicaria maackiana (Regel) Nakai ex Mori	
	Persicaria nodosa Opiz	
	Persicaria perfoliata (L.) H.Gross	
	Persicaria sagittata (L.) H.Gross ex Nakai	
	Persicaria thunbergii (Siebold and Zucc.) H. Gross	
	Polygonum aviculare L.	
	Rumex nipponicus Franch. and Sav.	Ap
	Rumex coreanus Nakai	Ap
Chenopodiaceae	*Chenopodium album* L.	Ap
Amaranthaceae	*Achyranthes japonica* (Miq.) Nakai	
	Amaranthus patulus Bertol.	Ap
Potulacaceae	*Portulaca oleracea* L.	
Caryophyllaceae	*Stellaria alsine* var. *undulata* (Thunb.) Ohwi	
Rannunculaceae	*Ranunculus chinensis* Bunge	
Cruciferae	*Capsella bursa-pastoris* (L.) Medik.	
	Lepidium apetalum Willd.	Ap
	Rorippa palustris (Leyss.) Besser	

Table 2. *Cont.*

Family Name	Scientific Name	Note
Rosaceae	*Potentilla anemonefolia* Lehm.	
	Rosa multiflora Thunb.	
	Rubus parvifolius L.	
Leguminosae	*Aeschynomene indica* L.	
	Amorpha fruticosa L.	Ap
	Amphicarpaea bracteata subsp. *edgeworthii* (Benth.) H. *Ohashi*	
	Glycine soja Siebold and Zucc.	
	Kummerowia striata (Thunb.) Schindl.	
	Lespedeza cuneata G.Don	
Euphorbiaceae	*Acalypha australis* L.	
	Phyllanthus ussuriensis Rupr. and Maxim.	
Aceraceae	*Acer tataricum* subsp. *ginnala* (Maxim.) Wesm.	
Violaceae	*Viola lactiflora* Nakai	
	Viola raddeana Regel	II, CR
	Viola mandshurica W. Becker	
Cucurbitaceae	*Actinostemma lobatum* Maxim.	I
Onagraceae	*Polygonum aviculare* L.	
Apiaceae	*Pterygopleurum neurophyllum* (Maxim.) Kitag.	V, CR
Primulaceae	*Lysimachia vulgaris* var. *davurica* (Ledeb.) R.Kunth	
Rubiaceae	*Galium dahuricum* var. *tokyoense* (Makino) Cufodontis	
	Galium spurium var. *echinospermum* (Wallr.) Hayek	
	Paederia scandens (Lour.) Merr.	
Labiatae	*Mosla dianthera* (Buch.-Ham. ex Roxb.) Maxim.	
Scrophulariaceae	*Mazus pumilus (Burm. f.) Steenis*	
	Veronica peregrina L.	III
Compositae	*Ambrosia artemisiifolia* L.	Ap, Iap
	Ambrosia trifida.L.	Ap, Iap
	Artemisia princeps Pamp.	
	Bidens bipinnata L.	
	Bidens frondosa L.	Ap
	Conyza canadensis (L.) Cronquist	Ap
	Conyza sumatrensis E.Walker	Ap
	Cosmos bipinnatus Cav.	Ap
	Eclipta prostrata (L.) L.	
	Sonchus oleraceus L.	Ap
	Xanthium canadense Mill	Ap
Dioscoreaceae	*Dioscorea batatas* Decne.	
Juncaceae	*Juncus effusus* var. *decipiens* Buchenau	
Commelinaceae	*Commelina communis* L.	
	Murdannia keisak (Hassk.) Hand.-Mazz.	

Table 2. *Cont.*

Family Name	Scientific Name	Note
Gramineae	*Agropyron tsukushiense* var. *transiens* (Hack.) Ohwi *Bromus japonicus* Thunb. *Echinochloa crusgalli* (L.) P.Beauv. *Hemarthria sibirica* (Gand.) Ohwi *Leersia japonica* (Honda) Honda *Miscanthus sacchariflorus* (Maxim.) Benth. *Phragmites communis* Trin. *Setaria viridis* (L.) P.Beauv. *Zizania latifolia* (Griseb.) Turcz. ex Stapf	
Cyperaceae	*Scirpus radicans* Schkuhr *Cyperus microiria* Steud. *Cyperus orthostachyus* Franch. and Sav. *Carex dimorpholepis* Steud *Carex dispalata* Boott *Carex neurocarpa* Maxim. *Carex thunbergii* var. *appendiculata* Trautv. *Eleocharis acicularis* (L.) Roem. and Schult. *Kyllinga brevifolia* var. *leiolepis* (Franch. and Sav.) H. Hara	

I, II, III, and V: floristic regional indicator plants in Korea; Ap: alien plants in Korea; Iap: Invasive alien plants in Korea; CR: Critically Endangered (red list plants); En: Endemic plants in Korea.

3.2. Life Form of Observed Plants

The life form of an observed plant is determined to some extent by the climatic, geographical, and ecological factors of the site and the degree of disturbance. Hence, analyzing the growing environment by investigating the life form of the observed plant is an important analysis method for evaluating the environmental and ecological characteristics of study sites [41]. This study analyzed the dormancy form of the 82 taxa that appeared in the study site according to the method of Raunkiaer (Table 3). It was found that most taxa (29 taxa; 35.37%) were annual plants (Th), 12 taxa (14.63%) were hemicryptophytes (H), 10 taxa (12.20%) were Helophytes (HH), and 9 taxa (10.98%) were annual Helophytes (10.98%). It seems that because the study site was a backswamp of a river, which has frequent changes in the growing environment such as soil moisture, soil characteristics (nitrogen and phosphoric acid), and flooding, various annual plants, pioneer species which are advantageous in invasion and settlement [41], hemicryptophytes, and aquatic plants were present during the rainy season. It also seems that a few aquatic plants appeared despite the study site being a wetland because emerged plants such as *Miscanthus sacchariflorus* and *Phragmites communis* showed extensive ground cover, and the water quantity was not properly maintained.

Among propagation forms, the most common radicoid form of the plants was R_5 (55 taxa: 67.07%), which did not make any underground or ground connections. Ten taxa (12.20%) were R_3, which had short-branched rhizomes and narrow-range connections. Seven taxa (8.54%) were classified as $R_{2,3}$, which had both R_2, which made lateral rhizome branches and connections in a slightly wider area, and R_3, which formed short-branched rhizomes and the narrowest range of connections. Most species observed in the study site did not develop rhizomes, and they were short-branched and formed narrow-range connections even if rhizomes were developed. In terms of disseminule forms, the gravity dispersion form (D_4) appeared most frequently (40 taxa: 48.78%), followed by the wind and water dispersion form (D_1; 14 taxa: 15.85%), and $D_{1,4}$ showed the characteristics of D_1 and D_4 (10 taxa: 12.20%). In terms of growth forms, the erect (e) form was observed most frequently (25 taxa: 30.49%), followed by the thick (t) form (15 taxa: 18.29%), and the pseudorosette (ps) form (7 taxa: 8.54%). The reproduction and growth of plants are closely related to adaptation to the environment. The fact that R_5 and R_3 were more common than other underground organ types and that gravity dispersion and wind and water dispersion forms appeared at a higher rate may be a result of the fast life cycle providing a competitive advantage in an environment where reproduction and adaptation were difficult [42]. In other words, the dormant form of the study site had a high percentage of annuals and a low percentage of perennials. Among propagation forms, R_5 plants without connections were dominant, and the ratio of wind and water dispersion and gravity dispersion forms was high, indicating that there was continuous invasion and disturbance of pioneer species. However, as the perennial hemicryptophytes *Miscanthus sacchariflorus* and *Phragmites communis* dominated at a high rate, it is expected that pioneers species cannot easily enter the site as they are outcompeted. Even if pioneer species invade, it is assumed that their stable status would be maintained after being pushed behind in the competition.

Table 3. Life form spectra of study area.

	Dormancy Form							
	Ch	H	HH	HH(Th)	MM	N	Th	Th(w)
species	4	12	10	9	4	4	29	10
%	4.88	14.63	12.20	10.98	4.88	4.88	35.37	12.20

	Propagation Form														
	Radicoid form								Disseminule form						
	R_5	$R_{2,3}$	$R_{1,2}$	R_3	$R_{3(s)}$	$R_{3(v)}$	R_4	$R_{5(s)}$	D_1	$D_{1,2}$	$D_{1,4}$	D_2	D_3	D_4	$D_{4,1}$
species	55	7	1	10	1	3	4	1	13	1	10	8	7	40	3
%	67.07	8.54	1.22	12.20	1.22	3.66	4.88	1.22	15.85	1.22	12.20	9.76	8.54	48.78	3.66

	Growth Form																
	b	b,e	b-l	b-p	e	e,b	e,p	l-b	l	b-ps	p-l	p-ps	pr	ps	r	t	t-p
species	5	1	3	3	25	4	1	3	3	1	1	1	4	7	2	15	3
%	6.10	1.22	3.66	3.66	30.49	4.88	1.22	3.66	3.66	1.22	1.22	1.22	4.88	8.54	2.44	18.29	3.66

Th: Therophytes; Th(w): Therophyte(Winter annual); H: Hemicryptophytes; Ch: Chamaiphytes; N: Nanophanerophytes, MM: Mesophanerophytes; HH: Helophytes; HH(Th): Helophytes(Therophytes); R_1: Widest extent of rhizomatous growth; R_2: Moderate extent of rhizomatous growth; R_3: narrowest extent of rhizomatous growth; R_5: Non-clonal growth monophyte; $R_{2,3}$ or $R_{1,2}$: plant with rhizomatous mutation of R_2 and R_3 or R_1 and R_2; $R_{(s)}$: Succulent type; $R_{(v)}$: Vertical type; D_1: disseminated widely by wind or water; D_2: disseminated attaching with or eaten by animals and man; D_3: disseminated by mechanical propulsion of dehiscence of fruits; D_4: having no special modification for dissemination; D_5: not producing seeds); $D_{1,4}$: plant with D_1 and D_4; b: branched form; e: erect form; p: procumbent form; pr: partial-rosette form; ps: pseudo-rosette form; r: rosette form; t: tussock form; l: liane form; e,b: erect or branched form; b-l: b form with liane form; b-p: b form with procumbent stem; b-ps: b form with pseudo-rosette; p-ps: p form with pseudo-rosette; t-p: t form with procumbent stem.

The life form of the species found in the study site was Th-R_5-D_4-e type, which was a different dormancy form from H-R_5-D_4-e type, a typical type in the estuary of the central region of South Korea [43]. It seems that Th, more favorable to settlement than Hemicryptophyytes (H), appears more than H because the study site is adjacent to the surrounding road; is exposed to an environment that can be easily invaded owing to human access by road and building construction throughout the year; and undergoes alterations and disturbances in the existing growing environment owing to heavy precipitation in the rainy season. The life form of *Pterygopleurum neurophyllum* is HH-$R_{3(s)}$-D_4-ps. As an aquatic plant with advantages for growing in the wetlands, its rhizome develops in a narrow range, has a succulent type that stores water in the plant body, and has the property of $R_{3(s)}$, which was the only species in the study site possessed that property. It seems that although *P. neurophyllum* is a wetland plant that grows in humid environments, it can withstand water shortage or an arid environment for a certain period of time. For propagation, a gravity dispersion type refers to the dispersion in which the seeds are dropped by gravity and dispersed by the flow of the surrounding water, followed by reproduction when the water quantity is high. Although it is necessary to conduct studies on *P. neurophyllum* in various fields, considering the life form characteristics of this study including those of another existing seed study [20], it does not seem that *P. neurophyllum* is a species that has difficult seed germination conditions or is difficult to grow or propagate. Instead, it is expected that site characteristics such as the disturbance, vegetation, and surrounding environment of the location affect the growth and adaptation of *P. neurophyllum*.

3.3. Classification of Plant Communities

Vegetation of 37 plots within the study site was classified into seven communities: *Miscanthus sacchariflorus* community, *Phragmites communis* community, *Phragmites communis–Carex dispalata* community, *Ulmus parvifolia* community, *Zizania latifolia* community, *Setaria viridis* community, and *Salix koriyanagi–Salix chaenomeloides* community. Plant species constituting the classified plant communities were of 58 taxa (Table 4) (Appendix A Table A1).

Table 4. Synopsis of plant communities in study area by r-NCD value.

Community Type		A	B	C	D	E	F	G
Number of plots		16	5	3	3	3	3	4
Mean of Coverage (%)		90 (±11.6)	96 (±2.2)	93.4 (±2.9)	73.4 (±2.9)	91.7 (±2.9)	78.4 (±12.6)	73.8 (±14.4)
Mean of Height (m)		1.95 (±0.3)	2.08 (±0.4)	1.93 (±0.1)	5.5 (±0.5)	1.7 (±0.15)	0.94 (±0.1)	4 (±0.6)
Total number of occurring species		34	18	15	15	8	30	19
Mean number of occurring species		7 (±3)	6 (±2.3)	9.4 (±3.1)	9 (±2)	4.7 (±0.6)	17.4 (±2.5)	10.5 (±2.6)
Character species of community					r-NCD(%)			
Miscanthus sacchariflorus	H	100	-	6.06	25.00	1.33	-	10.34
Phragmites communis	H	6.25	100	100	16.67	16.00	-	6.90
Carex dispalata		0.05	0.47	95.45	-	-	-	-
Ulmus parvifolia	T2	-	-	-	100	-	-	-
Zizania latifolia	H	0.14	0.93	-	-	100	-	-
Setaria viridis	H	-	-	-	-	-	100	-
Salix koriyanagi	T2	-	-	-	1.39	-	-	100
Salix chaenomeloides	T2	-	-	-	-	-	-	96.55
Companions								
Persicaria perfoliata	H	7.64	9.77	18.18	12.50	5.33	17.39	7.76
Pterygopleurum neurophyllum	H	2.78	-	-	-	-	-	-
Lespedeza cuneata	H	2.96	0.47	-	-	1.33	1.45	3.45
Humulus japonicus	H	0.42	0.47	-	8.33	-	13.04	3.45
Rosa multiflora	H	1.16	0.47	-	16.67	-	8.70	5.17
Paederia scandens	H	2.27	0.47	1.52	1.39	-	-	3.45
Persicaria lapathifolia	H	1.16	2.79	-	1.39	-	-	10.34
Salix koreensis	T2	0.05	-	-	-	-	-	31.03
Carex thunbergii var. *appendiculata*	H	0.28	-	-	1.39	-	-	7.76
Actinostemma lobatum	H	0.42	7.44	1.52	-	5.33	-	-
Persicaria nodosa	H	0.05	-	-	-	-	14.49	-
Persicaria sagittata	H	0.05	-	1.52	1.39	1.33	-	-
Commelina communis	H	-	-	-	-	-	17.39	-
Rumex nipponicus	H	-	1.86	-	-	-	13.04	-
Kummerowia striata	H	-	-	-	-	-	17.39	-
Ambrosia artemisiifolia	H	-	1.86	-	-	-	13.04	-
Ambrosia trifida	H	0.05	-	-	5.56	-	1.45	-
Galium dahuricum var. *tokyoense*	H	0.74	0.47	1.52	1.39	-	1.45	-
Carex dimorpholepis	H	0.19	0.47	6.06	1.39	-	-	5.17
Hemarthria sibirica	H	0.93	-	6.06	-	-	1.45	-
Persicaria maackiana	H	-	0.93	6.06	-	1.33	1.45	-

Table 4. *Cont.*

Community Type		A	B	C	D	E	F	G
Persicaria hydropiper	H	-	0.47	6.06	1.39	-	-	-
Echinochloa crusgalli	H	-	-	-	-	-	5.80	-
Achyranthes japonica	H	0.42	0.47	-	-	-	-	0.86
Mosla dianthera	H	0.05	-	-	-	-	5.80	0.86
Conyza canadensis	H	0.05	-	-	-	-	5.80	0.86
Artemisia princeps	H	2.22	-	-	-	-	-	-
Phyllanthus ussuriensis	H	-	-	-	-	-	1.45	-
Potentilla anemonefolia	H	0.74	-	-	-	-	1.45	-
Acalypha australis	H	0.05	-	-	-	-	1.45	-
Galium spurium var. *echinospermum*	H	-	0.47	-	-	-	-	-
Scirpus radicans	H	-	-	18.18	-	-	-	-
Bidens bipinnata	H	-	-	-	-	-	5.80	-
Chenopodium album	H	-	-	1.52	-	-	1.45	-
Carex neurocarpa	H	0.05	-	-	-	-	-	-
Bromus japonicus	H	0.05	-	-	-	-	-	-
Agropyron tsukushiense var. *transiens*	H	0.05	-	-	-	-	-	0.86
Conyza sumatrensis	H	0.05	-	-	-	-	-	-
Lysimachia vulgaris var. *davurica*	H	0.05	-	-	-	-	-	-
Acer tataricum subsp. *ginnala*	H	0.05	-	-	-	-	1.45	-
Glycine soja	H	0.05	-	-	-	-	-	-
Eclipta prostrata	H	-	-	-	-	-	1.45	-
Juncus effusus var. *decipiens*	H	-	-	-	-	-	1.45	-
Rorippa palustris	H	-	-	-	-	-	1.45	-
Xanthium canadense	H	-	-	-	-	-	1.45	-
Dioscorea batatas	H	-	-	-	-	-	1.45	-
Cyperus amuricus	H	-	-	1.52	-	-	-	-
Cosmos bipinnatus	H	-	-	-	-	-	1.45	-
Rubus parvifolius	H	0.05	-	-	-	-	-	-
Amaranthus patulus	H	-	-	-	-	-	1.45	-
Amorpha fruticosa	S	-	-	-	-	-	-	0.86
Viola lactiflora	H	-	-	-	-	-	-	0.86

A: Miscanthus sacchariflorus community; B: Phragmites communis community; C: Phragmites communis-Carex dispalata community; D: Ulmus parvifolia community; E: Zizania latifolia community; F: Setaria viridis community; G: Salix koriyanagi-Salix chaenomeloides community. T2: subtree; S: shrub; H: herb. r-NCDi: ∑Ci/NCDmax × 100. ∑Ci: the accumulated ground cover of species i in a community; NCDmax: the maximum contribution value within a target plant community {NCDi = ∑Ci/N × ni/N (Cmin ≤ NCD ≤ Cmax)}; N: the number of sampling plots for a target plant community; ni: the number of sampling plots in which species i appeared.

The relative contributions of each community, mean ground cover, mean number of observed species, and mean height are presented in Table 4. Plant species of 34 taxa appeared in 16 plots of the *Miscanthus sacchariflorus* community. *M. sacchariflorus* appeared with the highest relative contribution (100), followed by *Persicaria perfoliata* (7.64) and *Phragmites communis* (6.25) (Table 4). In the *P. communis* community, eighteen taxa appeared in five plots, and *P. communis* appeared with the highest relative contribution (100), followed by *P. perfoliata* (9.77), and *Actinostemma lobatum* (7.44). In the *P. communis–Carex dispalata* community, fifteen taxa appeared in three plots, and *P. communis* showed the highest relative contribution (100), followed by *C. dispalata* (95.45) and *P. perfoliata* (18.18). In the *Ulmus parvifolia* community, fifteen taxa appeared in three plots. There were three layers in the canopy: an arborescent layer, a shrub layer, and an herbaceous layer. *U. parvifolia* appeared with the highest relative contribution (100), followed by *M. sacchariflorus* (25) and *P. communis* (16.67) in the herbaceous layer. *Rosa multiflora* (16.67) had the highest relative contribution in the shrub layer. In the *Zizania latifolia* community, eight taxa appeared in three plots, and the number of observed species was the lowest among the examined communities. *Z. latifolia* showed the highest relative contribution (100), followed by *P. communis* (16), *P. perfoliata* (5.33), and *Actinostemma lobatum* (5.33). In the *Setaria viridis* community, thirty taxa appeared in three plots. *S. viridis* appeared with the highest relative contribution (100), followed by *Commelina communis*, *Kummerowia striata*, and *P. perfoliata* (17.39). In the *Salix koriyanagi–Salix chaenomeloides* community, nineteen taxa appeared in four plots. The vertical structure comprised an arborescent layer, a shrub layer, and an herbaceous layer. *S. koriyanagi* appeared with the highest relative contribution (100) in the arborescent layer, followed by *S. chaenomeloides* (96.55) and *S. koreensis* (31.03) (Table 4).

The PCA analysis results are presented in Figure 4. PCA analysis was performed in order to secure the objectivity of community classification. The PCA analysis results are presented in Figure 4. The results were analyzed by one axis and two axis. Similarly to the community classification analyzed using the traditional classification method, the statistical classification using the PCA analysis was also classified into seven communities (Figure 4). In addition, the character species (*M. sacchariflorus, P. communis, C. dispalata, U. parvifolia, Z. latifolia, S. viridis, S. koriyanagi,* and *S. chaenomeloides*) of each seven communities analyzed in the traditional classification method were analyzed as character species contributing to the classification of each community in PCA analysis. Another species is the *Salix koreensis*, which showed rather high contributions as a result of the PCA analysis. The reason for this is that the *Salix koreensis* was not distributed in other communities other than the *S. koriyanagi–S. chaenomeloides* community or showed a very low degree of dominance. Through these results, the significance of a plant phytosociological community classification was secured. It is judged that the physiognomy, which is an important factor in the field survey, has properly selected a survey plot.

The *Phragmites communis* and communities accounted for the majority of the vegetation in the study site. The *Zizania latifolia*, *Setaria viridis*, and *Ulmus parvifolia* communities dominated at the boundary of the plots. The *Salix koriyanagi–Salix chaenomeloides* community was distributed partially on a small scale. The *Miscanthus sacchariflorus* community, which distributed over the widest area, was observed on mounds that were relatively high owing to the sedimentation of sand and debris of *M. sacchariflorus* in the wetland. The *P. communis* community was not observed on mounds. It was different from the distribution of the *P. communis* community and *M. sacchariflorus*. Moreover, accompanying species hardly appeared in the *P. communis* and *M. sacchariflorus* communities due to high dominance. In addition, these two communities are emerged plant communities in the riverside wetland and grow in emerged areas where the water barely flows or is stagnant [44]. It seems that they can create a community easily by forming rhizomes, and they are very advantageous for maintaining the community owing to its strong vitality [44]. The *U. parvifolia* community showed the characteristic of being distributed at the edge of the wetland without stagnant water but with a humid environment. Although it is a wetland plant, it can grow in a rather humid environment and has strong resistance to wet environments. It is believed that the *U. parvifolia* community will be maintained continuously unless rapid environmental changes and disturbances such as urban development occur. The *Z. latifolia* community grows in an environment with shallow water depth throughout the year and forms a colony at the boundary between water and land. Floating leaved plants and emerged plants should be concurrently present with it owing to the site characteristics of the *Z. latifolia* community, but these species were not observed in this study. The *Setaria viridis* community can be commonly found in fields and riversides across South Korea. The *S. viridis* community in the study site was present in a rather arid area away from the wetland, which had the characteristic of temporarily supplying soil moisture during the period of intermittent increased precipitation. Moreover, due to the site of the community, tall plant species were not found and the cover of the community was low. This community had higher biodiversity than other communities because it was easy for annual plants such as *Kummerowia striata*, *Acalypha australis* L., and *Lysimachia vulgaris* var. *davurica* to invade.

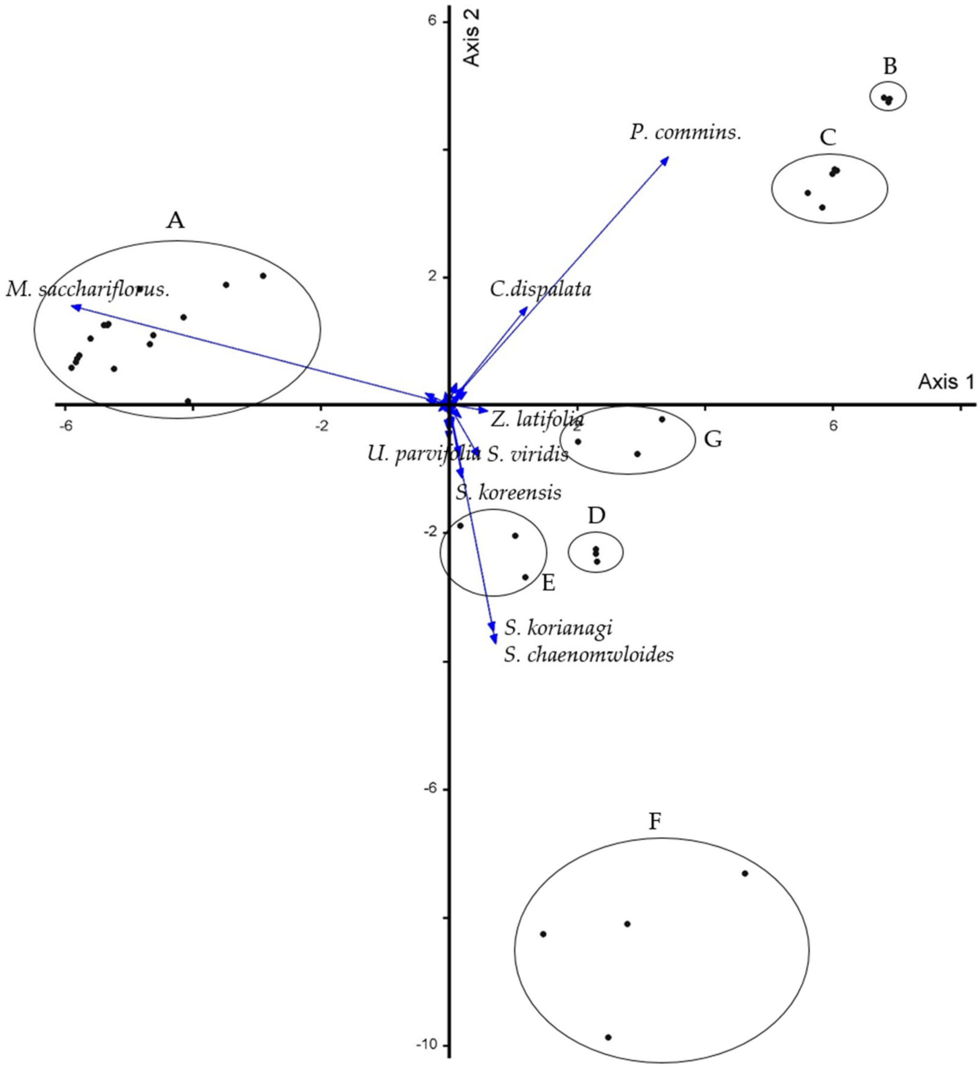

Figure 4. PCA plot of vegetation of the survey area (A: *M. sacchariflorus* community; B: *P. communis-C. dispalata* community; C: *P. communis* community; D: *S. viridis* community; E: *U. parvifolia* community; F: *S. koriyanagi-S. chaenomeloides* community; G: *Z. latifolia* community).

3.4. Distribution Characteristics of *Pterygopleurum neurophyllum*

Pterygopleurum neurophyllum, an endangered species, did not appear in communities other than the *Miscanthus sacchariflorus* community (Table 5). *P. neurophyllum* appeared in only 6 plots out of 16 *M. sacchariflorus* plots. The habitat of *P. neurophyllum* had the same site as that of *M. sacchariflorus*, and it is considered that they share the same habitat. Moreover, the distribution of *P. neurophyllum* was relatively located at the edge in the *M. sacchariflorus* communities. Although *P. neurophyllum* and *M. sacchariflorus* share the same habitat, *P. neurophyllum* appeared in locations where the soil was more compacted and dried owing to visitors.

The results showed that the *Phragmites communis* community where *Pterygopleurum neurophyllum* was not found was adjacent to the *Miscanthus sacchariflorus* community. Although *P. neurophyllum* was not observed in the *P. communis* community, it is assumed that it could grow in it. This finding seems to be related to the previously mentioned slightly raised mounds and the necromass of *M. sacchariflorus* and sand sediment. Unlike herbaceous plant communities, woody plant communities such as the *Ulmus parvifolia* community and the *Salix koriyanagi–Salix chaenomeloides* community form a canopy. Therefore, the light is blocked, and it is difficult for *P. neurophyllum* to grow. The *Zizania latifolia* community grows in shallow water, and the distribution of *P. neurophyllum* indicates that it is not able to grow in deep water habitats. In the case of the *Setaria viridis* community, since it grows in a somewhat dry wetland, it is not suitable for the growth of *P. neurophyllum*.

Table 5. *Miscanthus sacchariflorus* community vegetation table of study area.

		***Miscanthus sacchariflorus* Community**																	
No.		s7	s8	s10	s12	s15	s22	s26	s29	s30	s33	s5	s6	s13	s14	s18	s19		
Height (m)		1.5	2	2	2	2.5	2.3	1.8	1.6	2	2	1.2	2	2	2	2.3	2		
Mean of Height (m)						1.97 (±0.3)								1.91 (±0.37)					
Coverage (%)		95	100	100	100	100	100	95	95	100	100	85	65	80	80	70	85		
Mean of Coverage (%)						98.5 (±2.6)								77.5 (±8.2)					
Number of occurring species		10	7	8	3	3	8	5	5	5	3	9	13	11	10	8	9	r-NCD value (%)	
Mean number of occurring Species						5.7 (±2.45)								10 (±1.78)					
unit		A-1										A-2						A1	A2
Character species of community																			
Miscanthus sacchariflorus	H	8	9	9	9	9	9	9	9	9	9	8	7	8	8	7	8	100	100
Companions																			
Phragmites communis	H	3	1	1	1						2	2		1	1	3		4.49	10.14
Carex dispalata								1										0.11	0.00
Zizania latifolia	H												3					0.00	1.09
Persicaria perfoliata	H	2	1	1	1	1		2	1	2	1				1	1	2	12.13	4.35
Pterygopleurum neurophyllum	H											1	1	1	1	3	3	0.00	21.74
Lespedeza cuneata	H	1	1	1			1					1		1		1	1	1.80	5.80
Humulus japonicus	H		1	1									1					0.45	0.36
Rosa multiflora	H						1					1	1	1			1	0.11	5.80
Paederia scandens	H	1	1	1					1	1		1	1					2.81	1.45
Persicaria lapathifolia	H	1					1		1	1				1				1.80	0.36
Salix koreensis	T2	1																0.11	0.00
Carex thunbergii var. *appendiculata*	H											2	1					0.00	2.17
Actinostemma lobatum	H		1	1		1		1										1.80	0.00
Persicaria nodosa	H	1																0.11	0.00
Persicaria sagittata	H						1											0.11	0.00
Ambrosia trifida	H												1					0.00	0.36
Galium dahuricum var. *tokyoense*	H						1	1		1			1					1.01	0.36
Carex dimorpholepis	H	1															1	0.11	0.36
Hemarthria sibirica	H													2	1	1	1	0.00	7.25
Achyranthes japonica	H								1			1			1			0.11	1.45
Mosla dianthera	H	1																0.11	0.00
Conyza canadensis	H														1			0.00	0.36
Artemisia princeps	H			1			1						2	1	1		2	0.45	8.70
Potentilla anemonefolia	H													1	1	1	1	0.00	5.80
Acalypha australis	H												1					0.00	0.36
Carex neurocarpa	H															1		0.00	0.36
Bromus japonicus	H													1				0.00	0.36
Agropyron tsukushiense var. *transiens*	H													1				0.00	0.36
Conyza sumatrensis	H														1			0.00	0.36
Lysimachia vulgaris var. *davurica*	H											1						0.00	0.36
Acer tataricum subsp. *ginnala*	H												1					0.00	0.36
Glycine soja	H												1					0.00	0.36
Rubus parvifolius	H						1											0.11	0.00

H: herb.

The vegetation table that summarizes the ground cover class (Classes 1 to 9) using the combined cover degree showed that the cover and ground cover rate of *Miscanthus sacchariflorus*, the dominant species of the *M. sacchariflorus* community(A-1) where *Pterygopleurum neurophyllum* did not appear, were 8–9 and 98.5% (±2.6%), respectively. The cover and ground cover rate of the *M. sacchariflorus* community(A-2) where *P. neurophyllum* appeared were 7–8 and 77.5% (±8.2%), respectively, which were relatively low (Table 5). The low ground cover rate of the *M. sacchariflorus* community where *P. neurophyllum* appeared provided conditions for the growth and maintenance of *P. neurophyllum* and increased the appearance probability. *P. neurophyllum* did not grow in a community with dense *M. sacchariflorus*, and it seemed that *P. neurophyllum* was distributed as a refugee in areas with low density of *M. sacchariflorus*. Moreover, due to this, more sunlight entered into the community, increasing the number of emerged species, and the species compositions of the communities were different as a result. In fact, the number of emerged species in the *M. sacchariflorus* community without *P. neurophyllum*(A-1) was 5.7 ($\pm$2.45) and that in the *M. sacchariflorus* community with *P. neurophyllum*(A-2) was 10 ($\pm$1.78), implying that the latter had five more species and different species composition. This suggests that the growth of species in the *M. sacchariflorus* community was difficult and the composition of the community was simplified.

According to the analysis of the relative contribution of the *Miscanthus sacchariflorus* community with or without *Pterygopleurum neurophyllum*, *M. sacchariflorus* showed the highest relative contribution (100), followed by *Persicaria perfoliata* (12.13), and *Phragmites communis* (4.49) in the *M. sacchariflorus* community without *P. neurophyllum*. Other emerged species showed a relative contribution of $\leq$1. By contrast, the relative contribution of *M. sacchariflorus* (100) was the highest, followed by *P. neurophyllum* (21.74), *P. communis* (10.14), and *Artemisia princeps* (8.70) in the *M. sacchariflorus* community with *P. neurophyllum*. In addition, *Hemarthria sibirica*, *Rosa multiflora*, and *Potentilla anemonefolia* showed relative contributions of $\geq$5. It appeared that it was difficult for other species to grow in the *M. sacchariflorus* community without *P. neurophyllum* owing to the particularly high dominance of *M. sacchariflorus*. Conversely, as the dominance of *M. sacchariflorus* was relatively lower in the *M. sacchariflorus* community with *P. neurophyllum*, other species such as *P. neurophyllum* and *H. sibirica* could grow. According to the result of this study, the influence of *M. sacchariflorus* was very strong, and its dominance was very high. *P. neurophyllum* was distributed in rather weak *M. sacchariflorus* community edge. It distributed sporadically in individual units. Overall, the influence of *P. neurophyllum* was very weak, and it will likely be forced out in the future. Moreover, if the current situation continues, the remaining *P. neurophyllum* will be simpler, and it will be difficult to maintain *P. neurophyllum* individuals as the density of *M. sacchariflorus* increases over time.

3.5. Conservation and Restoration Direction of Pterygopleurum neurophyllum

Conservation and restoration of endangered species' habitats are very important tasks in the modern society from the viewpoint of improving biodiversity, securing biological sovereignty, and providing ecosystem services. The conservation of endangered species is an essential task in the modern age when living organisms are national property. The current threat to the native habitat of *Pterygopleurum neurophyllum* is the extremely high dominance of the dominant species. This study conducted vegetation analysis in the Wondong wetland, the native habitat of *P. neurophyllum*, and found seven vegetation communities. Among them, *P. neurophyllum* was scattered or distributed at the individual level in the *Miscanthus sacchariflorus* community. The distribution of *P. neurophyllum* was determined by the difference in the dominance of the dominant species within the community: The difference between the community with and without *P. neurophyllum*. First, *P. neurophyllum* was not found where *M. sacchariflorus* was highly dominant. Second, owing to the geographical limitations of the Nakdong River backswamp, the site was submerged for several days due to flooding during the rainy season. Therefore, disturbance occurs in the Wondong wetland, which may affect the distribution and sustainability of *P. neurophyllum*. Third, anthropogenic threats were inherent, such as visitors and human interference due to development. After eliminating and resolving these three threat factors, the direction of conservation and restoration can be established. In order to solve the first problem, the density of *M. sacchariflorus* must be controlled. It is necessary to remove *M. sacchariflorus* so that *P. neurophyllum* can proliferate. This is because *P. neurophyllum* does not grow in communities with high dominance of *M. sacchariflorus*. As the second threat is a natural problem, it is difficult to prevent flooding through additional development or other means. Preventing it is not appropriate because it may collapse the entire wetland ecosystem, including changes in the waterways of the Wondong wetland. Instead, ex situ conservation should be promoted propagation and restoration utilizing seeds and individuals of *P. neurophyllum*. Third, conservation policies should be established by using an active administrative approach. The original habitat of *P. neurophyllum* should be protected from human disturbance by designating endangered wildlife conservation areas and installing fences and information boards. In summary, for the conservation of the study site, it is necessary to establish physical conservation measures such as habitat restoration by controlling the density of *M. sacchariflorus* and biological conservation measures such as ex situ conservation through propagation.

4. Conclusions

This study analyzed the flora, life form, and vegetation of the emerged species in the backswamp of the Nakdong River in Yangsan-si (Gyeongsangnam-do) the native habitat of *Pterygopleurum neurophyllum*, an endangered Class II plant. Vegetation analysis was performed using the phytosociological method of the Zürich-Montpellier School along with a traditional classification method and a mathematical statistical classification method. Regarding the flora of this study site, 82 taxa were identified: 28 families, 65 genera, 72 species, 2 subspecies, and 8 varieties. The life form was of Th-R_5-D_4-e type, and many annual plants appeared owing to the characteristics of the site. There were seven communities by traditional classification method and PCA anaylsis: *Miscanthus sacchariflorus* community, *Phragmites communis* community, *Ulmus parvifolia* community, *Phragmites communis*–*Carex dispalata* community, *Zizania latifolia* community, *Setaria viridis* community, and *Salix koriyanagi*–*Salix chaenomeloides* community. The character species was analyzed as eight species (*M. sacchariflorus, P. communis, C. dispalata, U. parvifolia, Z. latifolia, S. viridis, S. koriyanagi, S. chaenomeloides,* and *S. koreensis*). In particular, *M. sacchariflorus* showed a high relative contribution (100) and dominated at a very high rate in the *M. sacchariflorus* community. *P. neurophyllum* was distributed in a part of the *M. sacchariflorus* community. It seemed that its distribution was related to the density, dominance, and ground cover rate of *M. sacchariflorus*. In fact, the dominance and ground cover rate of *M. sacchariflorus*, the dominant species in the *M. sacchariflorus* community without *P. neurophyllum*, were 8–9 and 98.8% (±2.8%), respectively, which were relatively higher than those of *M. sacchariflorus*, the dominant species in the *M. sacchariflorus* community with *P. neurophyllum*, in which the dominance and ground cover rate were 7–8 and 77.5% (±8.2%), respectively. *P. neurophyllum* appeared in the *M. sacchariflorus* communities with relatively low dominance of *M. sacchariflorus*.

In this study, we analyzed vegetation, flora, and vegetation characteristics among many factors in the native habitat of *Pterygopleurum neurophyllum*. The distribution of species is determined by many factors. As mentioned above, it is necessary to investigate environmental factors such as soil, light quantity, and moisture conditions that may affect the distribution characteristics of *P. neurophyllum*, in addition to the results of this study. Nevertheless, the results of this study are meaningful in that they reveal the vegetation characteristics of *P. neurophyllum*. Further studies are warranted by utilizing continuous monitoring.

Author Contributions: Conceptualization, H.J.P. and S.K.; Data curation, H.B.P. and P.B.K.; Formal analysis, S.K. and J.E.H.; Funding acquisition, N.Y.K.; Investigation, C.W.L.; Methodology, J.A.; Supervision, N.Y.K.; Validation, J.A. and B.-D.L.; Visualization, H.B.P.; Writing—original draft, H.J.P.; Writing—review & editing, H.J.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by National Institute of Ecology (NIE), grant number NIE-C-2021-46.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. The vegetation table of study area.

		A																B					C			D			E			F			G			
Plot no.		7	8	12	15	26	29	30	22	10	33	18	19	13	14	5	6	16	20	21	24	27	23	3	32	9	11	34	28	31	11	1	2	37	4	17	31	25
Survey area (m²)		2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	5 × 5	5 × 5	5 × 5	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	5 × 5	5 × 5	5 × 5	5 × 5
Height (m)		1.5	2	2	2	2.5	2.3	1.8	1.6	2	2	1.2	2	2	2	2.3	2	1.8	1.8	1.8	2.5	2.5	1.8	2	2	5.5	6	5	1.5	1.8	1.7	0.8	1	1	4.5	4.5	3.5	3.5
Coverage (%)		95	100	100	100	100	100	95	95	100	100	85	65	80	80	70	85	95	95	95	100	95	95	95	90	75	70	75	90	90	95	65	90	80	70	95	65	65
Character species of community																																						
Miscanthus sacchariflorus	H	8	9	9	9	9	9	9	9	9	9	8	7	8	8	7	8									3	1	2		1						1	1	2
Phragmites communis	H	3	1	1	1						2	2		1	1	3		8	8	9	9	9	8	8	8	2	1	1	2	1	1				3		1	
Carex dispalata	H							1															7	7	7													
Ulmus parvifolia	T2																									8	8	8										
Zizania latifolia	H												3						2										8	8	9							
Setaria viridis	H																															7	8	8				
Salix koriyanagi	T2																									1									7	8	7	7
Salix chaenomeloides	T2																																		7	7	7	7
Companions																																						
Pterygopleurum neurophyllum	H											1	1	1	1	3	3																					
Persicaria perfoliata	H	2	1	1	1	1		2	1	2	1				1	1	2	5			1	1	2	1	1	1	1	1		1	1	1	2	1	1		1	1
Lespedeza cuneata	H	1	1	1			1					1		1		1	1		1										1			1			1	1		
Humulus japonicus	H		1	1									1					1								2	1					1	1	1	1			1
Rosa multiflora	H						1					1	1	1			1					1				1	2	1				1		2		2	1	
Paederia scandens	H	1	1	1					1	1		1	1									1		1			1									1	1	
Persicaria lapathifolia	H	1					1		1	1				1					2			1						1							1	2	1	
Actinostemma lobatum	H		1	1		1		1										1	1	1		1	1						1		1							
Persicaria nodosa	H	1																														3		2				
Artemisia princeps	H			1			1						2	1	1		2																					
Ambrosia trifida	H												1													1		1				1						
Galium dahuricum var. *tokyoense*	H						1	1		1			1									1			1		1							1				
Carex dimorpholepis	H	1															1			1				1	1	1									1	2		
Hemarthria sibirica	H													2	1	1	1						1	1										1				
Kummerowia striata	H																															1	1	2				
Ambrosia artemisiifolia	H																		1	1												1	1	1				
Echinochloa crusgalli	H																															1		1				
Achyranthes japonica	H								1			1			1						1															1		
Mosla dianthera	H	1																														1	1					1
Persicaria maackiana	H																		2					1	1				1			1						
Rumex nipponicus	H																		1		1											1	1	1				
Conyza canadensis	H														1																	1	1		1			
Carex thunbergii var. *appendiculata*	H											2	1													1									1	1		1

Table A1. *Cont.*

		A																B					C			D			E			F			G			
Plot no.		7	8	12	15	26	29	30	22	10	33	18	19	13	14	5	6	16	20	21	24	27	23	3	32	9	11	34	28	31	11	1	2	37	4	17	31	25
Survey area (m^2)		2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	5 × 5	5 × 5	5 × 5	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	2 × 2	5 × 5	5 × 5	5 × 5	5 × 5
Height (m)		1.5	2	2	2	2.5	2.3	1.8	1.6	2	2	1.2	2	2	2	2.3	2	1.8	1.8	1.8	2.5	2.5	1.8	2	2	5.5	6	5	1.5	1.8	1.7	0.8	1	1	4.5	4.5	3.5	3.5
Coverage (%)		95	100	100	100	100	100	95	95	100	100	85	65	80	80	70	85	95	95	95	100	95	95	95	90	75	70	75	90	90	95	65	90	80	70	95	65	65
Commelina communis	H																															1	1	2				
Phyllanthus ussuriensis	H																															1						
Potentilla anemonefolia	H													1	1	1	1																1					
Acalypha australis	H												1																				1					
Bidens bipinnata	H																																1	1				
Amaranthus patulus	H																																1					
Chenopodium album	H																								1							1						
Salix koreensis	T2	1																																	2	4	2	1
Carex neurocarpa	H															1																						
Bromus japonicus	H													1																								
Agropyron tsukushiense var. *transiens*	H													1																						1		
Conyza sumatrensis	H														1																							
Amorpha fruticosa	S																																			1		
Viola lactiflora	H																																			1		
Lysimachia vulgaris var. *davurica*	H											1																										
Acer tataricum subsp. *ginnala*	H												1																				1					
Glycine soja	H												1																									
Persicaria hydropiper	H																		1					1	1	1												
Galium spurium var. *echinospermum*	H																			1																		
Scirpus radicans	H																						1	2	1													
Rubus parvifolius	H						1																															
Persicaria sagittata	H						1																	1			1			1								
Eclipta prostrata	H																																1					
Juncus effusus var. *decipiens*	H																																	1				
Rorippa palustris	H																															1						
Xanthium canadense	H																																1					
Dioscorea batatas	H																															1						
Cyperus microiria	H																																					
Cosmos bipinnatus	H																															1						

A: Miscanthus sacchariflorus community; B: Phragmites communis community; C: Phragmites communis-Carex dispalata community; D: Ulmus parvifolia community; E: Zizania latifolia community; F: Setaria viridis community; G: Salix koriyanagi-Salix chaenomeloides community. T2: subtree; S: shrub; H: herb.

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