



Growth environment characteristics of the habitat of *Epilobium hirsutum* L., a class II endangered wildlife species

Kwang Jin Cho^{ID}, Hyeong Cheol Lee^{ID}, Sang Uk Han^{ID}, Hae Seon Shin^{ID} and Pyoung Beom Kim*^{ID}

National Institute of Ecology, Changnyeong 50303, Republic of Korea

ARTICLE INFO

Received October 25, 2023

Revised November 17, 2023

Accepted November 17, 2023

Published on December 26, 2023

*Corresponding author

Pyoung Beom Kim

E-mail normal@nie.re.kr

Background: As wildlife habitats are being destroyed and growth environments are changing, the survival of animals and plants is under threat. *Epilobium hirsutum* L., a species that inhabits wetlands, has held legally protected status since 2012. However, no specific measures are currently in place to protect its habitat, leading to a decline in remaining populations as a result of land use change and human activities.

Results: The growth environment (including location, climate, land use, soil, and vegetation) of the five habitat sites (Samcheok, Taebaek1, Taebaek2, Cheongsong, Ulleung) of *E. hirsutum* L. was investigated and analyzed. These habitats were predominantly situated in flat areas with gentle south-facing slopes, at an average altitude of 452.7 m (8–726 m) above sea level in Gangwon-do and Gyeongsangbuk-do. The average annual temperature ranged 11.5°C (9.2°C–12.9°C), whereas the average annual precipitation ranged 1,304.5 mm (1,062.7–1,590.7 mm). The surrounding land use status was mainly characterized by mountainous areas, and human interference, such as agricultural land and roads, was commonly found in proximity to these natural habitats. Soil physicochemical analysis revealed that the soil was predominantly sandy loam with a slightly high sand content. The average pH measured 7.64, indicating an alkaline environment, and electrical conductivity (EC) averaged 0.33 dS/m. Organic matter (OM) content averaged 66.44 g/kg, available phosphoric acid (P₂O₅) content averaged 115.73 mg/kg, and cation exchange capacity (CEC) averaged 23.43 cmolc/kg. The exchangeable cations ranged 0.09–0.43 cmol⁺/kg for potassium (K), 10.23–16.21 cmol⁺/kg for calcium (Ca), 0.67–4.94 cmol⁺/kg for magnesium (Mg), and 0.05–0.74 cmol⁺/kg for sodium (Na). The vegetation type was categorized as *E. hirsutum* community with high numbers of *E. hirsutum* L., *Persicaria thunbergii* (Siebold & Zucc.) H. Gross, *Phragmites japonica* Steud., *Humulus japonicus* (Siebold & Zucc.), and *Bidens frondosa* L.. An ecological flora analysis, including the proportion of lianas, naturalized plants, and annual herbaceous plants, revealed that the native habitat of *E. hirsutum* L. was ecologically unstable.

Conclusions: Analysis of the habitat of *E. hirsutum* L., a class II endangered wildlife species, provided essential data for local conservation and restoration efforts.

Keywords: ecoflora, ecology, ecosystems, endangered wildlife, *Epilobium hirsutum* L.

Introduction

In recent years, wildlife habitats have encountered damage and environmental changes due to factors such as environmental pollution, climate change, and various development projects (land use change for urbanization, factory construction, resort construction, etc.), posing a threat to the survival of animals and plants (Forman 2001; Ko 2009; Rho and Choung 2006). In 2004, the enactment of the Wildlife and Plant Protection Act established a legal framework for the protection of wildlife and plants, consolidating regulations that had been dispersed across vari-

ous law such as Natural Environment Conservation Act, Animals and Birds Protection and Hunting Control Act (Bang and An 2005). Under this framework, the Ministry of Environment (ME) of Korea has been legally preventing the extinction of endangered wildlife and systematically conserving their habitats. With the implementation of the Wildlife and Plant Protection Act, the number of endangered wildlife species expanded to 221 species (Bang and An 2005), and this number has continued to increase over the years, with 282 species designated and managed as of 2022 (Korea Law Information Center 2023).

Meanwhile, *Epilobium hirsutum* L., a perennial herba-



ceous plant of the family Onagraceae (Lee 1996), was designated as a class II endangered wildlife species in 2012 (Korea Law Information Center 2023). However, specific measures for protecting its natural habitat are lacking, leading to a population decline due to human-induced damage such as wetland filling, cultivation, and riverbank maintenance (KNA 2021). Information on the growth environment of this target plant is crucial in establishing conservation strategies for endangered wildlife and restoring its native habitat (Song et al. 2009). In Korea, surveys and studies have been conducted on endangered wildlife and rare plants, such as *Pedicularis hallaisanensis* Hurus., *Polygonatum stenophyllum* Maxim., *Mankyua chejuense* B.Y.Sun et al., and *Viola websteri* Hemsl., to investigate their habitat location, soil composition, and vegetation structure (Kim et al. 2018; Lee et al. 2012; Song et al. 2009, 2010). Research on *E. hirsutum* L. has focused on seasonal variations in reproduction, physiological responses to soil moisture and organic matter (OM) (Lee et al. 2018), seed germination characteristics (Cho 2019), cultivation in smart farms (Park 2020), and the development of habitat creation plans (Kim 2022). In addition, location information for growth sites has been documented via flora surveys in specific areas (Jang et al. 2019; Kim et al. 2022). However, research on the growing environment of the *E. hirsutum* L. is limited.

Therefore, this study aimed to identify the soil, vegetation, and surrounding land use status of the *E. hirsutum* L., providing essential baseline data for conservation and restoration efforts both at domestic and international levels.

Materials and Methods

Investigation areas

Based on a literature review, two regions in Gangwon-do (Singi-myeon, Samcheok-si and Sangsami-dong, Taebaek-si) and two regions in Gyeongsangbuk-do (Juwangsan-myeon, Cheongsong-gun and Ulleung-eup, Ulleung-gun) were selected as study areas for habitat environment analysis (Fig. 1).

Growing environment analysis

For analyzing the growth environmental conditions, environmental factors such as altitude, slope, and slope direction were identified. For this survey, continuous numerical map data at a scale of 1:5,000 provided by the National Geographic Information Institute (NGII) of the Ministry of Land, Infrastructure, and Transport were utilized (NGII 2023), and they were analyzed using quantum geographic information system (QGIS), an open-source program. Furthermore, the meteorological data were analyzed using

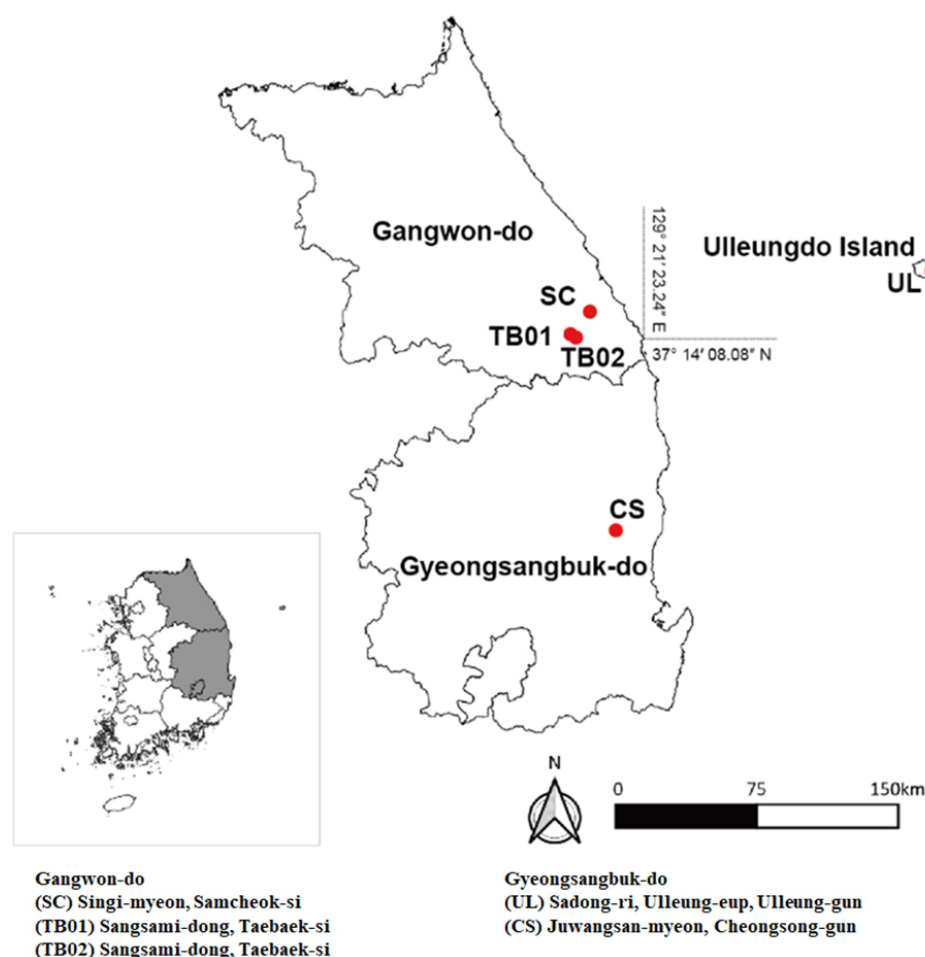


Fig. 1 Location and geographical data of survey sites. UL: Ulleung; SC: Samcheok; TB01: Taebaek1; TB02: Taebaek2; CS: Cheongsong.

data from the Korea Meteorological Administration's (KMA) National Climate Data Center for the last 20 years (2003–2022) for the following locations closest to the survey site: Hwangji-dong, Taebaek-si and Singi-ri, Singi-myeon, Samcheok-si and Sangui-ri, Budong-myeon, Cheongsong-gun and Sadong-ri, Ulleung-gun (KMA 2023).

Current land use status analysis

The current land use status was investigated within a 500 m radius of the survey point. Regarding the land use data, the most recent land cover classification map provided by the ME (ME 2023) was used, and the entire process was analyzed and mapped using QGIS.

Soil survey

Soil samples were collected from five locations where vegetation surveys were conducted. An aliquot was taken from a depth of approximately 20 cm below the surface, and the sample was subsequently dried and stored at room temperature. The samples were analyzed by the Foundation for the Commercialization of Agricultural Technology for ten categories: particle size composition, pH, electrical conductivity (EC), OM content, available phosphoric acid (P_2O_5), exchangeable potassium (K), exchangeable calcium (Ca), exchangeable magnesium (Mg), exchangeable sodium (Na), and cation exchange capacity (CEC).

Vegetation survey

The vegetation survey was conducted following phytosociological methods, which take into consideration habitat and species composition (Braun-Blanquet 1965; Kim and Lee 2006). Qualitative and quantitative data collection for species was conducted by categorizing strata within the survey area and recording the list of species along with their abundance in each stratum. The decision of the coverage was determined using the combined cover degree with ranks ranging 1–9 (Kim and Lee 2006; Westhoff and Van der Maarel 1973). Quantitative comparisons of emergent species were performed using the relative net contribution degree (r-NCD). In addition to the phytosociological vegetation survey, detailed study methods, field surveys, and indoor analyses were employed to derive vegetation types, adhering to the phytosociological vegetation survey and assessment method (Kim and Lee 2006). Furthermore, species composition was analyzed based on the flora obtained from the vegetation survey data. This analysis involved the determination of the number of occurring species, dormancy form (Lee 1996), climbing plant species, naturalized plants (Lee et al. 2011; Ryu et al. 2017) and the calculation of naturalized ratio using naturalized plants (Numata 1975). Climbing plants were categorized as liane form species within Lee's (1996) growth forms. Species and scientific names adhered to the National Inventory of Biological Resources (National Institute of Biological Resources 2020).

Results and Discussion

Growing environment characteristics

The natural habitat of *E. hirsutum* L. is primarily located on southeastern, southwestern, and northwestern slopes with an average altitude of 452.7 m (ranging 8–726 m) and average inclination of 8.6° (ranging 1°–25°) (Table 1). It was found to be observed in a horizontal manner in agricultural ditches of river headwaters and tributaries in Gangwon-do and the northern regions of Gyeongsangbuk-do. In addition, it was found on the edge of the mountainous area adjacent to the coast in Ulleung.

The average annual temperature of the native sites was 12.7°C in Samcheok, 9.2°C in Taebaek, 11.2°C in Cheongsong, and 12.9°C in Ulleung, and the average annual precipitation was 1,269.9 mm in Samcheok, 1,294.8 mm in Taebaek, 1,062.7 mm in Cheongsong, and 1,590.7 mm in Ulleung, with Ulleung having the highest values for both average annual temperature and average annual precipitation (Table 2). The higher mean annual precipitation in Ulleung county compared with other areas is likely attributable to greater winter snowfall compared with those regions (Lee 1979). This variation may have influenced the mean annual precipitation. Although the average summer temperatures in the study area did not considerably differ, there were notable differences in average winter temperatures. The average winter temperature in Taebaek and Ulleung exhibited a difference of 6.2°C. *Epilobium hirsutum* L. is a nondormant seed species and is not considerably influenced by temperature. It has a germination rate of approximately 90% under light conditions, with uneven germination rates under dark conditions (Cho 2019). All the sites in this study were located in open, sunny conditions with high light levels and relatively high soil OM content. Given the germination characteristics of the species, these conditions are considered suitable for the continued growth of the species unless direct disturbances affecting habitat degradation occur.

Land use characteristics

Analysis of land use around the Ulleung habitat, situated at the edge of the forest near the coast, revealed that water bodies covered the largest area (41.4%), followed by forest (26.8%) and grassland (16.0%). In Samcheok habitat, located along Muryeong Stream on Ulmi Mountain, and in Cheongsong habitat, adjacent to Jubang Stream within Juwangsang National Park, forest areas were predominant, occupying 62.9% and 63.3%, respectively, whereas the proportion of agricultural areas was relatively low at 4.3% and 13.5%, respectively. Conversely, Taebaek habitat, located near agricultural waterways, exhibited a higher distribution ratio in agricultural areas (39.7%–40.9%) compared with forests (15.5%–18.1%). However, satellite image confirmation of grassland areas (32.3%–35.3%) revealed that

Table 1 Vegetation table of *Epilobium hirsutum* community

Running No.	1	2	3	4	5	r-NCD	Dormancy form
Site No.	UL	SC	TB01	TB02	CS		
Height of herb layer (m)	1.5	1.7	1.5	1.6	1.7		
Coverage of herb layer (%)	95	95	100	95	95		
Area (m ²)	6	4	3	2	4		
Slope direction	SE	SW	SE	SE	NW		
Inclination (°)	25	5	1	2	10		
Altitude (m)	8	100	726	726	251		
Number of species	11	19	15	8	11		
Differential species of community							
<i>Epilobium hirsutum</i> L.	3	3	7	4	4	100.0	G
Companion species							
<i>Persicaria thunbergii</i> (Siebold & Zucc.) H. Gross	-	-	2	8	7	48.6	HH (Th)
<i>Phragmites japonica</i> Steud.	4	6	-	-	2	34.3	HH
<i>Humulus japonicus</i> Siebold & Zucc. ^a	-	2	-	1	7	28.6	Th
<i>Bidens frondosa</i> L. ^b	-	2	2	5	-	25.7	Th
<i>Oenanthe javanica</i> (Blume) DC.	3	-	1	1	-	14.3	HH
<i>Artemisia indica</i> Willd.	-	2	-	2	1	14.3	Ch
<i>Commelina communis</i> L.	-	1	3	-	1	14.3	Th
<i>Boehmeria spicata</i> (Thunb.) Thunb.	-	7	-	-	3	19.0	Ch
<i>Persicaria japonica</i> (Meisn.) H. Gross ex Nakai	-	-	4	1	-	9.5	HH
<i>Amphicarpaea bracteata</i> subsp. <i>edgeworthii</i> (Benth.) H. Ohashi ^a	-	-	3	-	2	9.5	Th
<i>Angelica dahurica</i> (Fisch. ex Hoffm.) Benth. & Hook. f. ex Franch. & Sav.	-	-	2	-	3	9.5	G
<i>Setaria viridis</i> (L.) P. Beauv.	1	2	-	-	-	5.7	Th
<i>Cerastium glomeratum</i> Thuill. ^b	-	1	2	-	-	5.7	Th

Accidental species that observed in a single site (combined cover degree, r-NCD value, dormancy form): No. 1: *Ampelopsis brevipedunculata* (Maxim.) Trautv.^a 9 8.6 N, *Equisetum arvense* L. 3 2.9 G, *Pueraria lobata* (Willd.) Ohwi^a 3 2.9 Ch, *Petasites japonicus* (Siebold & Zucc.) Maxim. 2 1.9 H, *Cyperus amuricus* Maxim. 2 1.9 Th, *Rumex crispus* L.^b 1 1.0 H, *Portulaca oleracea* L. 1 1.0 Th, No. 2: *Dactylis glomerata* L.^b 6 5.7 H, *Festuca arundinacea* Schreb.^b 4 3.8 H, *Boehmeria platanifolia* Franch. & Sav. 3 2.9 Ch, *Impatiens textori* Miq. 2 1.9 Th, *Dendranthema boreale* (Makino) Ling 2 1.9 H, *Synurus deltoides* (Aiton) Nakai 2 1.9 G, *Erigeron annuus* (L.) Pers.^b 1 1.0 Th (w), *Oenothera biennis* L.^b 1 1.0 Th (w), *Nasturtium officinale* W.T. Aiton^b 1 1.0 HH, *Stellaria aquatica* (L.) Scop. 1 1.0 Th (w), No. 3: *Geranium sibiricum* L. 7 6.7 H, *Sedum sarmentosum* Bunge 5 4.8 H, *Cnidium monnieri* (L.) Cusson 3 2.9 Th (w), *Vicia japonica* A. Gray^a 2 1.9 G, *Galinsoga quadriradiata* Ruiz & Pav.^b 2 1.9 Th, *Chenopodium album* L. 1 1.0 Th, No. 4: *Phalaris arundinacea* L. 2 1.9 HH, No. 5: *Mentha canadensis* L. 2 1.9 G, *Oplismenus undulatifolius* (Ard.) Roem. & Schult. 1 1.0 H. UL: Ulleung; SC: Samcheok; TB01: Taebaek1; TB02: Taebaek2; CS: Cheongsong; r-NCD: relative net contribution degree; G: geophyte; HH: hydatophyte; Th: therophyte; Ch: chamaephyte; N: nanophanerophyte; H: hemicryptophyte; -: not applicable.

^aLiane, ^bnaturalized plant.

Table 2 20 years of meteorological data from the *Epilobium hirsutum* L. habitats area

Site	Mean temperature for 20 yr (°C)	Winter-time mean temperature (°C)	Mean minimum temperature of the coldest month (°C)	Summer-time mean temperature (°C)	Mean maximum temperature of the hottest month (°C)	Mean precipitation for 20 yr
SC	12.7	1.1	Jan. 2011, -8.4	23.3	Aug. 2013, 32.7	1,269.9
TB	9.2	-3.4	Jan. 2011, -13.8	20.6	Aug. 2013, 29.7	1,294.8
CS	11.2	-1.4	Jan. 2011, -13.4	22.7	Aug. 2010, 32.3	1,062.7
UL	12.9	2.8	Jan. 2011, -3.2	22.2	Aug. 2013, 29.8	1,590.7

SC: Samcheok; TB: Taebaek; CS: Cheongsong; UL: Ulleung.

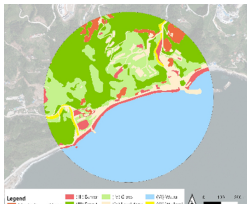
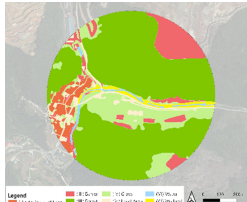
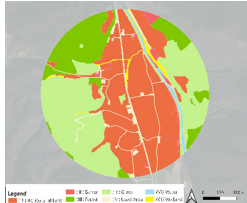
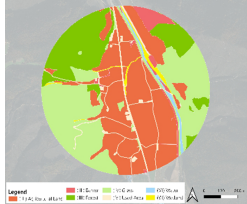
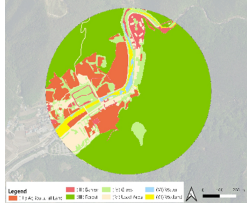
the proportion of forest areas was indeed higher, as some areas appeared cut forest sites (Table 3). *Epilobium hirsutum* L.'s natural habitat is primarily characterized by mountainous terrain, and ongoing human interference, including residential, agricultural, road, and commercial developments, can potentially result in damage. Therefore, it is crucial to regularly monitor *E. hirsutum* L. populations and consider proactive on-site conservation strategies, such as access restrictions, protective fencing, and informative

signage for promotion and management.

Soil properties

Following soil physicochemical analysis, it was found that the soils at the survey locations were predominantly sand, silt, and clay, with average proportions of 56.78%, 32.26%, and 10.96%, respectively (Table 4). The soil was predominantly sandy loam with a slightly high sand content. Analysis of the chemical properties of the soil re-

Table 3 Land use status of the survey area (radius 500 m)

Site	Legend	Area (m ²)	Ratio (%)	Map
UL	I	26,966	3.4	
	II	29,419	3.7	
	III	210,292	26.8	
	IV	125,507	16.0	
	V	60,371	7.7	
	VI	325,309	41.4	
	VII	7,501	1.0	
SC	I	33,641	4.3	
	II	84,626	10.8	
	III	494,470	62.9	
	IV	114,472	14.6	
	V	31,681	4.0	
	VI	10,876	1.4	
	VII	15,600	2.0	
TB01	I	320,960	40.9	
	II	16,462	2.1	
	III	121,916	15.5	
	IV	277,052	35.3	
	V	28,199	3.6	
	VI	10,302	1.3	
	VII	10,474	1.3	
TB02	I	311,956	39.7	
	II	28,297	3.6	
	III	142,208	18.1	
	IV	253,612	32.3	
	V	28,264	3.6	
	VI	10,143	1.3	
	VII	10,886	1.4	
CS	I	105,990	13.5	
	II	25,713	3.3	
	III	496,868	63.3	
	IV	80,383	10.2	
	V	51,958	6.6	
	VI	6,677	0.8	
	VII	17,777	2.3	

UL: Ulleung; SC: Samcheok; TB01: Taebaek1; TB02: Taebaek2; CS: Cheongsong.

Table 4 Soil texture of the habitats of *Epilobium hirsutum* L.

Site	Sand (%)	Silt (%)	Clay (%)	Texture
UL	53.7	36.8	9.5	Sandy loam
SC	78.5	16.6	4.9	Loamy sand
TB01	40.2	44.7	15.1	Laom
TB02	57.3	30.6	12.1	Sandy loam
CS	54.2	32.6	13.2	Sandy loam
Average	56.78	32.26	10.96	Sandy loam

UL: Ulleung; SC: Samcheok; TB01: Taebaek1; TB02: Taebaek2; CS: Cheongsong.

vealed that the pH averaged 7.64 (ranging 6.90–8.30), indicating that the soil was slightly alkaline. This pH level is higher than the average pH of 5.5 in Korean forest soil (Jeong et al. 2002) and the average pH of 6.3 in river sediment soil (Jang et al. 2019). It is also similar to the pH range (ranging 6.49–7.28) of streamside-growing *P. stenophyllum* Maxim. (Song et al. 2009). The EC averaged 0.33 dS/m, which is within the average range for stream sediment soils

analyzed by Zhang et al. (2011). By region, the soil at Cheongsong-gun was found to have slightly higher EC (0.50 dS/m), while the values for other survey areas were not significantly different (ranging 0.27–0.33 dS/m). The average OM content of the sediment was 66.44 g/kg, which was much higher than the average value of river sediments of 8 g/kg (Zhang et al. 2011). It tended to be slightly higher than the river wetlands, Bangujeong Wetland in Gokseong-gun (av-

erage 59.91 g/kg) and Omcheon Reedbed Wetland in Jangheung-gun (average 41.13 g/kg) (NIE 2022). Specifically, Samcheok had the highest value of 110.16 g/kg compared with other regions, whereas Ulleung had the lowest value of 26.20 g/kg (Table 5). The natural settlement and growth of wet vegetation in rivers are believed to influence soil OM content (NIE 2022). In the case of Samcheok, the number of species in the habitat was higher than that in other areas, and the incidence of herbaceous plants with large plant parts was also greater, suggesting that the development of such vegetation influenced OM content. The lower OM content in Ulleung was attributed to the habitat's location on a steep slope along the mountain's margins and the presence of adjacent building construction, creating an unfavorable environment for OM accumulation in the soil. The P_2O_5 , the form of phosphorus that can be taken up or used by plants, averaged 115.73 mg/kg (ranging 8.43–295.32 mg/kg), with significant regional variations. Notably, it was found to be high in Taebaek1 (295.32 mg/kg) and Ulleung (185.26 mg/kg), likely as a result of the influence of artificially applied fertilizers and manure due to the presence of cultivated land and livestock farms in these areas.

Vegetation characteristics

Five vegetation datasets were obtained from Taebaek-si, Samcheok-si, and Ulleung-gun, where the *E. hirsutum* L. grows. Through these data, the *E. hirsutum* community consisting of 40 taxa (20 and 38 genus, 39 species, 1 subspecies; averaging 12.8 species per site) was classified. *Epilobium hirsutum* community was characterized by the presence of *E. hirsutum* L. itself, and plant species contributing remarkably with relative cover values of ≥ 20.0 , including *Persicaria thunbergii* (Siebold & Zucc.) H. Gross,

Phragmites japonica Steud., *Humulus japonicus* (Siebold & Zucc.), and *Bidens frondosa* L., commonly found in riparian wetlands (Table 1). The dormancy form of plant species appearing in *E. hirsutum* community was identified by therophytes (Th, Th [w], HH [Th]) accounting for 40.0%, followed by hemicryptophytes (H) with 20.0%, and geophytes (G) with 15.0% (Table 6). Moreover, *E. hirsutum* community exhibited a relatively high composition ratio of liane plants (5 species, 12.5%), naturalized plants (9 species, 22.5%), and annual plants (16 species, 40.0%) (Table 7). This composition was higher than the percentage of naturalized plants in Korea cultivated fields where anthropogenic interference is frequent (Kim et al. 2016) and slightly lower than the annual herbaceous plants composition ratio in orchards (Kim et al. 2019). The proximity of this community to roads, factories, residences, and cultivated land provides circumstantial evidence that the habitat of *E. hirsutum* L. is unstable.

Conclusions

This study investigated and analyzed the growth environments of the endangered wild plant species, *E. hirsutum* L., in five natural habitats. *Epilobium hirsutum* L. was

Table 7 Floral characteristics of *Epilobium hirsutum* community

Floral characteristics	Total
No. of taxa	40
No. of annual plant	16
No. of liane	5
No. of naturalized plant	9
Naturalized index (%)	22.5

Table 5 Chemical properties of soil in the habitats of *Epilobium hirsutum* L.

Site	pH (1:5)	EC (dS/m)	OM (g/kg)	P_2O_5 (mg/kg)	CEC (cmolc/kg)	Ex. K (cmol ⁺ /kg)	Ex. Ca (cmol ⁺ /kg)	Ex. Mg (cmol ⁺ /kg)	Ex. Na (cmol ⁺ /kg)
UL	7.60	0.27	26.20	185.26	27.22	0.43	10.23	4.94	0.74
SC	8.30	0.29	110.16	8.43	12.52	0.09	15.24	0.67	0.10
TB01	7.60	0.28	66.55	295.32	25.84	0.28	13.03	3.73	0.05
TB02	7.80	0.33	58.44	53.27	21.38	0.22	12.99	1.84	0.10
CS	6.90	0.50	70.86	36.37	30.20	0.24	16.21	2.36	0.23
Mean $\pm$ SD	7.64 $\pm$ 0.45	0.33 $\pm$ 0.09	66.44 $\pm$ 26.89	115.73 $\pm$ 108.44	23.43 $\pm$ 6.15	0.25 $\pm$ 0.11	13.54 $\pm$ 2.08	2.71 $\pm$ 1.49	0.24 $\pm$ 0.26

EC: electrical conductivity; OM: organic matter; CEC: cation exchange capacity; Ex.: exchangeable; UL: Ulleung; SC: Samcheok; TB01: Taebaek1; TB02: Taebaek2; CS: Cheongsong; SD: standard deviation.

Table 6 Dormancy form of the vascular plants in the *Epilobium hirsutum* community

Dormancy form ^a	Perennial					Annual		
	Ch	G	H	HH	N	Th	Th (w)	HH (Th)
No. of taxa	4	6	8	5	1	11	4	1
Ratio (%)	10.0	15.0	20.0	12.5	2.5	27.5	10.0	2.5

^aCh: chamaephyte; G: geophyte; H: hemicryptophyte; HH: hydathophyte; M: microphanerophyte; MM: megaphanerophyte; N: nanophanerophyte; Th: therophyte.

observed in open, well-lit river sediment areas, and along embankments in agricultural regions. Organic matter content of the sediments was generally high, with the exception of the Ulleung-do habitat, which had steeply sloping mountainous margins. However, the areas surrounding the native habitat were characterized by the presence of agricultural fields, roads, factories, and residences, with ongoing farming activities (Table 3). This situation highlighted the need for active management measures to mitigate artificial interference. The vegetation type was characterized by *E. hirsutum* community, with the species composition comprising plant species commonly found in riparian wetlands. Furthermore, the ecological characteristics of the plant species within the community confirmed the unstable nature of *E. hirsutum* L.'s habitat.

Abbreviations

CEC: Cation exchange capacity
EC: Electrical conductivity
KLIC: Korean Law Information Center
KMA: Korea Meteorological Administration
KNA: Korea National Arboretum
ME: Ministry of Environment
NGII: National Geographic Information Institute
NIBR: National Institute of Biological Resources
NIE: National Institute of Ecology
OM: Organic matter
QGIS: Quantum geographic information system
r-NCD: Relative net contribution degree

Acknowledgements

Not applicable.

Authors' contributions

KJC conducted the field survey, performed the analysis and wrote the manuscript. HCL and SUH conducted the field survey and reviewed the manuscript. HSS analyzed the land use status and wrote the manuscript. PBK conducted field surveys, analyzed weather data and soil properties and wrote manuscripts. KJC received a research grant. All authors have read and approved the final manuscript.

Funding

This research was supported by a grant from the National Institute of Ecology (NIE-A-2022-20).

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

References

- Bang SW, An SY. Development of red list categories and criteria for the protection of endangered species in Korea. Sejong: Korea Environment Institute; 2005.
- Braun-Blanquet J. Plant sociology: the study of plant communities. London: Hafner; 1965.
- Cho JS. Seed germination characteristics according to environmental condition and chemical treatment of two Onagraceae species. J Agric Sci Res. 2019;35(2):139-45.
- Forman RTT. Land Mosaics: the ecology of landscapes and regions. Cambridge: Cambridge University Press; 2001.
- Jang HD, Leem H, Han S, So S. Floristic study of Juwangsan National Park in Korea. Korean J Plant Reour. 2019;32(4):379-406. <https://doi.org/10.7732/kjpr.2019.32.4.379>
- Jeong JH, Koo KS, Lee CH, Kim CS. Physico-chemical properties of Korean forest soils by regions. J Korean Soc For Sci. 2002;91(6):694-700.
- Kim JW, Lee YK. Classification and assessment of plant communities. Seoul: World Science; 2006.
- Kim LK, Choi SD, Choo GC, Hwang BY, Gang GH, So LK, et al. Environmental characteristics and floristic study of endangered *Pedicularis hallaisanensis* habitats. J Agric Life Sci. 2018;52(6):163-73. <https://doi.org/10.14397/jals.2018.52.6.163>
- Kim MH, Cho KJ, Oh YJ, Yang D, Lee WJ, Park S, et al. Life form and naturalization characteristics of naturalized plants in upland fields of South Korea. Korean J Environ Biol. 2016;34(2):63-72. <https://doi.org/10.11626/KJEB.2016.34.2.063>
- Kim MH, Nam HK, Eo J, Song YJ. Floristic features of orchards in South Korea. Korean J Environ Biol. 2019;37(4):447-66. <https://doi.org/10.11626/KJEB.2019.37.4.447>
- Kim Y. A study on the creation of alternative habitats of endangered plant *Epilobium hirsutum* L. [master's thesis]. Daegu: Kyungpook National University; 2022.
- Kim YC, Chae HH, Park YC, Lee SM. Floristic characteristics of vascular plants in the Goyangsan Mtn.(Jeongseon-gun) and Munraesan Mtn.(Jeongseon-gun) area. Korean J Environ Ecol. 2022;36(3):220-56. <https://doi.org/10.13047/KJEE.2022.36.3.220>
- Korea Law Information Center. Wildlife protection and management act. In: Endangered wildlife. 2023. <https://www.law.go.kr/%EB%B2%95%EB%A0%B9%EC%95%BC%EC%83%9D%EC%83%9D%EB%AC%BC%EB%B3%B4%ED%98%B8%EB%B0%8F%EA%B4%80%EB%A6%AC%EC%97%90%EA%B4%80%ED%95%9C%EB%B2%95%EB%A5%A0>. Accessed 11 Apr 2023.
- Korea Meteorological Administration. Meteorological data (2003~2022). 2023. <https://data.kma.go.kr/data/grnd/selectAsosRltmList.do?pgm-No=36>. Accessed 24 Aug 2023.
- Korea National Arboretum (KNA). The National Red List of vascular plant in Korea. Pocheon: KNA; 2021.
- Ko RS. The research of policy on forest biodiversity conservation to the

- effect of climate change [master's thesis]. Seoul: Korea University; 2009.
- Lee BS. The distribution of the fresh snowfall in South Korea. *J Geogr Educ.* 1979;9:224-35. <https://kiss.kstudy.com/Detail/Ar?key=410195>
- Lee EP, Lee SI, Han YS, Lee SY, You YH, Cho YY. Effect of moisture and nutrient of soil on reproductive phenology and physiological response of *Epilobium hirsutum* L., an endangered plant. *J Wetl Res.* 2018;20(1):27-34. <https://doi.org/10.17663/JWR.2018.20.1.027>
- Lee KM, Shin JH, Jeong HM, Kim HR, Kim JH, Shin DH, et al. Characteristics of vegetation structure and habitat of *Mankyua chejuense* (Ophioglossaceae), endangered plant in Korea. *J Wetl Res.* 2012;14(1):35-45. <https://doi.org/10.17663/JWR.2012.14.1.035>
- Lee WT. *Lineamenta florae Koreae*. Seoul: Academy Press; 1996.
- Lee YM, Park SH, Jung SY, Oh SH, Yang JC. Study on the current status of naturalized plants in South Korea. *Korean J Plant Taxon.* 2011;41(1):87-101. <https://doi.org/10.11110/kjpt.2011.41.1.087>
- Ministry of Environment. Land cover map. 2023. <https://egis.me.go.kr/map/map.do>. Accessed 10 Aug 2023.
- National Geographic Information Institute. Seamless digital topographic map (1:5,000). 2023. <http://data.nsdi.go.kr/dataset/20190710ds00002>. Accessed 10 Aug 2023.
- National Institute of Biological Resources. National list of indigenous species of Korean peninsula. 2020. https://species.nibr.go.kr/home/mainHome.do?cont_link=010&subMenu=010003&contCd=010003007. Accessed 1 May 2020.
- National Institute of Ecology (NIE). Intensive survey on the inland wetland ('22). Seoecheon: NIE; 2022.
- Numata M. *Naturalized plants*. Tokyo: Dai Nippon printing Co.; 1975.
- Park JH. The relationships between vegetative succession and soil characteristics on the floodplain in large river ecosystem, and growth of *Epilobium hirsutum* L., Korean endangered hydrophyte in the closed smart farm [PhD dissertation]. Gongju: Kongju National University; 2020.
- Rho P, Choung HL. Alternatives of the Korean nationwide survey on natural environments to promote biodiversity conservation. *J Environ Policy.* 2006;5(3):25-56.
- Ryu TB, Kim JW, Lee SE. The exotic flora of Korea: actual list of neophytes and their ecological characteristics. *Korean J Environ Ecol.* 2017;31(4):365-80. <https://doi.org/10.13047/KJEE.2017.31.4.365>
- Song J, Lee GY, Kim N, Yi JS. Vegetation structure and site environment of natural habitat of an endangered plant, *Viola websteri*. *J Korean For Soc.* 2010;99(3):267-76.
- Song JM, Lee GY, Yi JS. Growth environment and vegetation structure of natural habitat of *Polygonatum stenophyllum* maxim. *J For Sci.* 2009;25(3):187-94.
- Westhoff V, Van der Maarel E. The Braun-Blanquet approach. In: Whittaker RH, editor. *Ordination and classification of plant communities*. Hague-Boston-London: Dr. W. Junk; 1973. p.167-726.
- Zhang YS, Sonn YG, Park CW, Hyun BK, Moon YH, Song KC. Soil physical and chemical characteristics of river-bed sediments in river basins. *Korean J Soil Sci Fertil.* 2011;44(6):963-9.