Journal of Plant Biology, September 2008, 51(5) : 379-385

Effects of Surrounding Pastureland on Jilmoe Moor Vegetation in Mt. Odae National Park, Korea

Youngseob Shin[1], Soyoung Kim[2], Taehwan Hwang[3], and Yeonsook Choung[1]*
[1]Department of Biology, Kangwon National University, Chuncheon 200-701, Republic of Korea
[2]Dongsung Engineering Co., LTD., Seongnam 462-807, Republic of Korea
[3]Bukhansan National Park Office, Korea National Park Service, Seoul 121-050, Republic of Korea

Jilmoe Moor, a montane peatland found in Mt. Odae National Park, Korea, has been influenced by a surrounding pastureland for more than 30 years. Here, we used multivariate analyses to study the vegetation structure at that Moor. Four distinct communities were consistently separated (82.2% of the total variance): two wetland communities -- *Sphagnum palustre* (SP) and *Persicaria nepalensis – Persicaria thunbergii* (PNPT). In addition, we recorded two invaded upland communities: *Phleum pratense* (PP) and *Festuca ovina – Artemisia feddei* (FOAF). Of those pasture species, timothy (*Phleum pratense*) was most dominant in all wetland communities except SP. Our data demonstrate that the pasture has affected the settlement and expansion of two pasture communities on the moor by acting as a propagule source and also through the input of nutrients in the form of fertilizer and waste from cattle. Moreover, this enrichment of the moor habitat may have facilitated replacement of the original wetland community. That is, its unusually high levels of phosphorus and potassium may have resulted in the dominance of *Persicaria nepalensis,* and *P. thunbergii*, which often occur on nutrient-rich sites. Therefore, proper policies should be enacted to restore Jilmoe Moor as a montane peatland by eliminating the effect of the surrounding pasture.

Keywords: invasive species, montane moor, national park, pasture, peatland, vegetation

As transitional zones, wetlands connect terrestrial ecosystems to aquatic ecosystems (Mitsch and Gosselink, 1993; Succow and Joosten, 2001). Their physical environments are diverse, varying according to the way in which water is supplied as well as by the nutrient content of those waters (Miyawaki, 1977; Wilmanns, 1978; Kim and Han, 2005). The structure and function of each wetland have unique characteristics as a result of complex interactions among the surrounding vegetation, the dispersal of seeds from other wetlands, seed germination, growth rates, the amount of seeds produced by vegetation in the wetland, pathogens, competition, and life history (van der Valk, 1981).

Due to its high moisture content, wetland soil is generally anaerobic or has a low amount of oxygen. Accordingly, wetlands accommodate the unique vegetation that is suited to such conditions (Cylinder et al., 1995). However, the presence of such highly adapted species makes wetlands particularly susceptible to changes in water level and water quality. In addition, as the moisture content of a wetland decreases, such sites can become vulnerable to invasion by upland species. Furthermore, if a drop in the wetland water level is coupled with an influx of topsoil from the surrounding land, the successional process can be accelerated (Park, 2001).

The classification of a wetland varies based on regional characteristics and recognition. Moors are often categorized as high, transitional, or lower moors, depending on the plants that comprise the peat, the amount of peat, and the overall plant groups that are present (Miyawaki et al., 1978; Ryou, 2004).

Son and Park (1999) have explained that the morphogenetic environment of Jilmoe Moor is formed in its high etchplain, which uplifted during the Tertiary period. This site is composed of thermokarst; therefore, its relief is irregular due to locally differential freezing and thawing of the soil. However, it is more likely that this irregular relief on a small scale has resulted from differential peat accumulation. Such diverse microtopography causes differences in water level, water and soil nutrient contents, and decomposition throughout the moor, resulting in a variety of plant communities with different species compositions.

Jilmoe Moor, at Mt. Odae National Park, is classified as a high moor (Son and Park, 1999). This site, surrounded by a pasture run by the Samyang Livestock Co. (Fig. 1), has been influenced by that pastureland for more than 30 years. The pasture was established on what was originally forested land in 1972, before the region was designated as a national park in 1975.

Montane wetlands are very rare in Korea because of topography; only five moors are registered as Wetland Protection Areas by the Ministry of Environment: Yong, Moojechi, Hwaeom, Sinbulsan, and Sinanjangdo (Ministry of Environment, 2005). Those montane wetlands in national parks include Wangdeungjae at Mt. Jiri (Kim and Lee, 2005), Sohwangbyeongsan, and Jilmoe.

Jilmoe Moor has been investigated several times, during routine monitoring of activity in national parks (Korea National Park Service, 2000, 2001, 2004, 2007; Ryou 2004). However, no multivariate analyses have been conducted to explain its vegetation structure. Furthermore, no studies have evaluated in detail how that moor has been affected by the surrounding pastureland. Therefore, our research utilized multivariate analyses to elucidate the vegetation structure that developed on the surface of this moor, as well as the influence of the nearby pastureland.

*Corresponding author; fax +82-33-251-3990
e-mail yschoung@kangwon.ac.kr

METHODS

Study Site

Jilmoe Moor is located in Mt. Odae National Park, at an elevation of 1,050 m. The site is in the southeast portion of the park on the main ridge of the Baekdudaegan Mountains, which connects Mt. Sohwangbyeong to Mt. Maebong (Figure 1). This moor covers 0.27 ha (Korea National Park Service, 2001). In 2004, the Korea National Park Service installed a boundary fence for protection, enclosing a total of 1.23 ha that included the core area of the moor (Korea National Park Service, 2004).

The annual average temperature is 6.4°C and annual precipitation is 1,717 mm, as recorded at the Daegwallyeong weather station, 10.4 km away from Jilmoe moor (Gangwon Regional Meteorological Administration, 2008). However, because that station is at an elevation of 772 m, it is likely that the actual temperature of the moor is slightly lower. That low temperature and poor water evaporation allow the wetland to be sustained (Son and Park, 1999). Son and Park (1999) have reported that the water supply at Jilmoe comes primarily from precipitation, in the form of snow, rain, and fog. It is also likely that some of the influx is from groundwater and runoff. The average soil pH is 5.9 while that of the open water is 6.7 (Choung et al., 2005), thus defining the moor as a minerotrophic fen (Mitch and Gosslink, 1993). It also has a deep peat layer (to 80 cm), indicating that it formed over a long period of time (Korea National Park Service, 2007).

Topographically, two waterways that developed weakly from the northern ridge run from the north to the south through the moor. Because they pass through the middle, elevations are higher on the east and west sides of the moor. In addition, the overall land surface is irregular, giving the appearance of a very complex mosaic of vegetation.

Organic content and chemical properties were analyzed in air-dried samples of topsoil collected at 10 cm deep from sphagnum and non-sphagnum stands. Levels of organic matter as well as concentrations of total nitrogen and exchangeable cations (Na^+, Mg^{2+}, K^+, Ca^{2+}) were all greater in the sphagnum stands (Table 1). However, the concentration of available P, as determined using the Bray I method (Buurman et al., 1996), was greater in the non-sphagnum stands. Vegetation in the sphagnum stands was dominated by *Sphagnum palustre*, forming mainly small peat hummocks, whereas the dominant vegetation in the non-sphagnum stands was consisted of the species such as *Persicaria nepalensis*, *P. thunbergii*, and *Phleum pratense*.

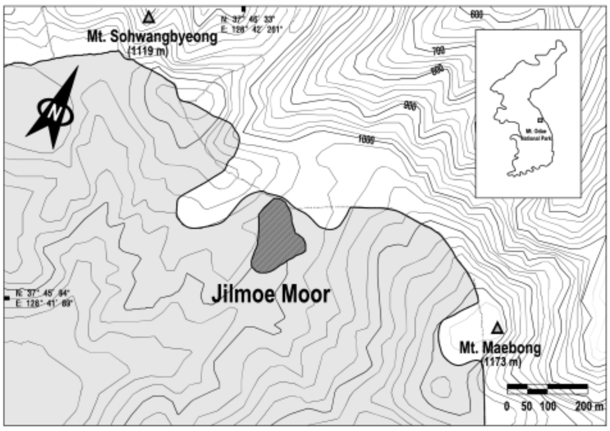

Figure 1. Location and topography of Jilmoe Moor in Odae National Park. Site is surrounded by pasture (grey-shaded) run by Samyang Livestock Co. Dotted line indicates main ridge of Baekdudaegan Mountains by Act on Protection of Baekdudaegan Mountains.

Table 1. Soil chemical properties of Jilmoe Moor at Mt. Odae National Park. Values are means. Standard errors and number of samples are shown in parentheses

Property	Sphagnum stands		Non-sphagnum stands	
Soil pH	5.8	(0.1, 6)	6.0	(0.1, 10)
Organic matter (%)	26.5	(7.8, 9)	8.2	(1.5, 9)
Total nitrogen (mg g^{-1})	4.7	(0.8, 8)	2.7	(0.5, 10)
Available phosphorus (μg g^{-1})	3.3	(1.0, 8)	6.0	(1.3, 10)
Exchangeable Na^+ (μg g^{-1})	59.4	(12.5, 4)	54.3	(6.1, 4)
Exchangeable Mg^{2+} (μg g^{-1})	113.4	(38.9, 4)	55.4	(9.9, 4)
Exchangeable K^+ (μg g^{-1})	235.5	(99.9, 4)	91.2	(13.8, 4)
Exchangeable Ca^{2+} (μg g^{-1})	656.3	(118.5, 4)	439.0	(53.9, 4)

Soil pH values from both types of stands were measured in water (soil:water=1:5, w/v), while organic water content was estimated as the loss on ignition, and total N was evaluated via the micro-Kjeldahl method. Exchangeable cations were analyzed by ICP (inductively coupled plasma) atomic emission spectroscopy (Leeman PS950; Leeman Labs) after samples were extracted with ammonium acetate.

Vegetation Survey

Vegetation was surveyed in early September 2004. Four line transects (T1 to T4) were established in the core area of the moor. Because each transect was set from the north to the south end of the fence, it also included that transition zone between moor and pastureland. Transect lines were 20 m apart, with lengths of 40 m (T1), 64 m (T2), 78 m (T3), and 82 m (T4).

Due to the small-scale heterogeneous vegetation structure of the moor, plots of 50 cm×50 cm were spaced at 2 m along each transect, for a total of 132 plots. The species in each plot were recorded, and their coverage was visually evaluated according to 12 classes, by percentages: +, <1; 1, 1 to 5%; 2, 5 to 10%; 3, 10 to 20%; 4, 20 to 30%; 5, 30 to 40%; 6, 40 to 50%; 7, 50 to 60%; 8, 60 to 70%; 9, 70 to 80%; 10, 80 to 90%; and 11, 90 to 100%. The median of each class was used to calculate coverage. Species identification followed that of Lee (1996). Here, we referred to all hydrophytes, wetland plants, and facultative wetland plants as 'wetland species'.

Data Analysis

Cluster analysis (CA) served to categorize the plots into groups while ordination was used to evaluate those groups in the multi-dimensional space and to confirm our findings from the CA. This form of classification results in discrete units, whereas ordination is a type of gradient analysis.

Therefore, the combination of CA and ordination is a powerful method for interpreting inner vegetation patterns, particularly when the same distance measure is used (Gould, 2007).

CA was conducted with Sorenson distance measure and a flexible beta linkage method ($\beta = -0.25$). Indicator species analysis (ISA) was used to prune the dendrogram of the cluster analysis by running ISA with different numbers of groups as cutoffs, then choosing the cutoff level by selecting the group with the lowest p-value (McCune and Grace 2002). We also performed ISA to determine the significant indicator species for groups, using Monte Carlo permutations (999 randomizations).

Non-metric multi-dimensional scaling (NMS) was run (with 250 permutations) as one of the ordination analyses, using the same Sorensen distance measure as for the CA to ensure consistency. All plots were overlaid on the NMS space according to community groups derived from our CA and ISA.

Vegetation cover for each species was transformed by using the arcsine-square root. Rare species, i.e., with less than 5% frequency, were deleted. All analyses were conducted using PC-ORD (Version 5; McCune and Grace 2002).

RESULTS

Species Composition

A total of 80 plant taxa were found within the investigated plots. Among them, 73 were herbaceous and 7 were woody. *Phleum pratense*, or timothy, had the highest relative coverage (RC: 26%) and the greatest relative frequency (RF: 8.4%) (Table 2). Therefore, it had the highest importance value (IV: 17.2%). Originating in Europe and Siberia, timothy is a representative plant cultivated in the pastures of Korea. *Festuca ovina* and *Arundinella hirta* also were dominant, with IVs of 6% and 4.1%, respectively. Among the wetland plants (WP), *Persicaria nepalensis* (IV of 7.1%) was most dominant. However, *Sphagnum palustre,* a well-known indicator species of peatland, as well as *Juncus effuses* var. *decipiens* and *Persicaria thunbergii*, both hydrophytes, also were dominant in some plots. Overall, 25 wetland species accounted for 43.8% of the total IV, while 55 upland species occupied 56.2%.

The characteristic distributions of plants in heterogeneous microhabitats can be determined based on the distribution of major species along line transects. In T1, *Persicaria thunbergii* and *P. nepalensis* were dominant in plots with high

Table 2. Dominant wetland and upland plant species of Jilmoe Moor at Mt. Odae National Park

Species class	Species	C (%)	RC (%)	F (%)	RF (%)	IV (%)
UP	*Phleum pratense*	31.8	26.0	0.7	8.4	17.2
WP	*Persicaria nepalensis*	10.1	8.2	0.5	6.0	7.1
UP	*Festuca ovina*	10.0	8.2	0.3	3.8	6.0
WP	*Sphagnum palustre*	8.1	6.6	0.2	2.6	4.6
WP	*Juncus effusus* var. *decipiens*	5.7	4.6	0.4	4.4	4.5
UP	*Arundinella hirta*	5.2	4.2	0.3	4.0	4.1
WP	*Persicaria thunbergii*	5.0	4.1	0.3	4.0	4.0
UP	*Plantago asiatica*	3.1	2.6	0.4	5.1	3.9
WP	*Polytrichum commune*	6.5	5.3	0.2	1.9	3.6
WP	*Lycopus maackianus*	1.7	1.4	0.5	5.5	3.5
UP	*Artemisia feddei*	3.5	2.8	0.3	3.3	3.1
WP	*Rumex acetosella*	2.6	2.1	0.3	3.8	2.9
WP	*Salix gracilistyla*	4.6	3.8	0.1	1.4	2.6
WP	*Viola verecunda*	0.3	0.3	0.4	4.7	2.5
WP	*Ostericum maximowiczii*	1.5	1.2	0.3	3.6	2.4
UP	*Muhlenbergia japonica*	2.7	2.2	0.1	1.6	1.9
WP	*Ostericum sieboldii*	1.3	1.1	0.2	2.3	1.7
WP	*Scirpus karuizawensis*	2.2	1.8	0.1	1.4	1.6
UP	*Athyrium yokoscense*	2.0	1.6	0.1	1.6	1.6
UP	*Chrysanthemum zawadskii* var. *latilobum*	1.7	1.4	0.1	1.3	1.3
UP	*Aster ciliosus*	1.0	0.8	0.1	1.5	1.2
UP	*Potentilla freyniana*	0.2	0.1	0.2	2.0	1.1
UP	*Agrimonia pilosa* var. *coreana*	0.6	0.5	0.1	1.5	1.0
UP	*Geranium thunbergii*	0.2	0.2	0.2	1.8	1.0

WP: hydrophytes, wetland plants, and facultative wetland plants; UP: upland plants;
F: frequency; C: coverage; RF: Relative frequency; RC: Relative coverage.
IV: Importance value (RF+RD/2) 1.0 is shown

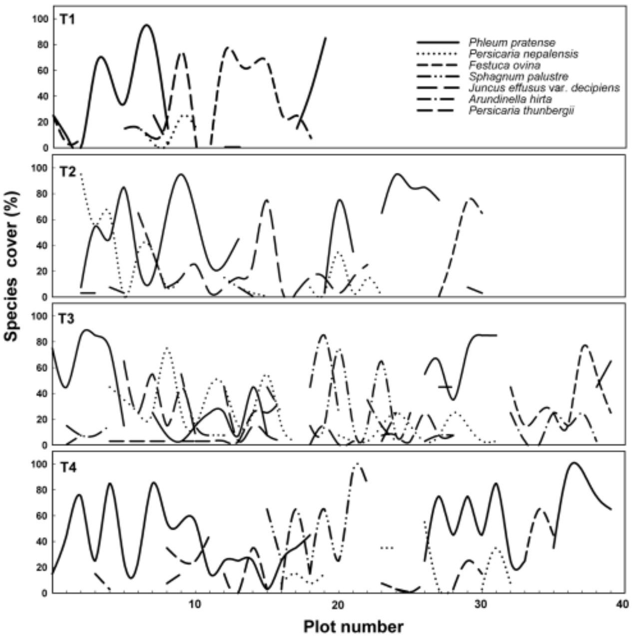

Figure 2. Vegetation cover by 7 most dominant species over 4 transects at Jilmoe Moor in Mt. Odae National Park.

water levels, such as waterways or water pits, while *Festuca ovina* and *Phleum pratense* were dominant at the eastern and western edges, respectively, where the elevation was high (Figure 2). Wetland plants, such as *Persicaria nepalensis*, *P. thunbergii*, and *Juncus effuses* var. *decipiens,* formed mixed or pure stands. *Phleum pratense* comprised mixed stands with *Persicaria nepalensis* at the western edge, where the water level was high, while the former occurred as a pure stand at the eastern edge of the moor. *Festuca ovina* also formed a pure stand at that eastern edge. In T3, which contained many tributaries of those primary waterways, small peat hummocks had developed, making the pattern of vegetation distribution more complicated. For example, *Persicaria nepalensis*, *Juncus effuses* var. *decipiens*, and *Sphagnum palustre* were often found alternately or together in the same plots. However, in microsites at the eastern and western edges of the transect, where the water level was low, *Phleum pratense* and *Festuca ovina* occurred separately. Conversely, *Phleum pratense* formed mixed stands with *Persicaria nepalensis*, *Juncus effuses* var. *decipiens*, and *P. thunbergii,* even in microsites where the water level was high. In T4, *Sphagnum palustre* was notably dominant in plots in the middle of the transect, where the water level was high. However, *Phleum pratense* formed pure stands in micro-

Table 3. Species composition and selected indicator species of four defined plant communities. Species with an average importance value (IV) >1% for all four communities are shown; among those species, significant indicators are only shown with their indicator values (IndVal) ($p \leq 0.05$).

Species	FOAF		PP		PNPT		SP	
	IV	IndVal	IV	IndVal	IV	IndVal	IV	IndVal
Phleum pratense	12.2		40.9	51	23.9		2.4	
Persicaria nepalensis	1.2		3.2		17.4	59	6.0	
Festuca ovina	22.1	79	1.5		0.5		2.0	
Plantago asiatica	6.3		9.2	36	1.6		1.5	
Sphagnum palustre	0.2				5.4		12.7	40
Juncus effuses var. *decipiens*	0.5		1.6		8.5		7.6	28
Arundinella hirta	5.4		2.2		3.6		5.9	
Polytrichum commune	1.1		5.1		0.2		10.2	25
Persicaria thunbergii	0.2				11.1	55	3.9	
Lycopus maackianus	1.0		2.6		6.1	29	5.2	
Rumex acetosella	7.4	37	6.1				0.7	
Artemisia feddei	9.7	58	2.4		0.7		0.4	
Viola verecunda	1.5		4.0		2.6		3.6	
Ostericum maximowiczii	0.4		1.9		3.1		5.3	33
Salix gracilistyla	0.6				1.6		8.2	26
Muhlenbergia japonica	1.0		1.5		0.9		5.0	16
Athyrium yokoscense	0.4		0.7		0.8		5.2	26
Ostericum sieboldii			0.7		4.1	24	2.1	
Scirpus karuizawensis			1.0		1.8		3.9	15
Chrysanthemum zawadskii var. *latilobum*	5.0	32	0.6					
Aster ciliosus	3.5	25	1.8					
Potentilla freyniana	1.4		2.7	17	0.6		0.6	
Agrimonia pilosa var. *coreana*	2.3	14	1.8				0.5	
Geranium thunbergii	1.9		1.7		0.5		0.4	

FOAF: *Festuca ovina – Artemisia feddei* community, PP: *Phleum pratense* community, PNPT: *Persicaria nepalensis – P. thunbergii* community, SP: *Sphagnum palustre* community.

sites at high elevations, i.e., at the edges of the transect. That species also was found in mixed stands with *Persicaria thunbergii* and *P. nepalensis* in some microsites that had high water levels.

Multivariate Analysis of Vegetation Structure

Our CA and ISA results revealed that the Jilmoe moor has four plant communities (Chaining at 1.02%) that were formed by different associations between wetland and upland species (Table 3). However, *Phleum pratense*, a pasture species, was dominant in three of those communities, while the peatland moss, *Sphagnum palustre,* was dominant in one.

Community 1 had 13 significant indicator species, including *Festuca ovina* and *Artemisia feddei,* whereas Community 2 had four significant indicator species, including *Phleum pratense*. Community 3 had five significant indicator species, including *Persicaria nepalensis* and *P. thunbergii*, and Community 4 had 10 significant indicator species, including *Sphagnum palustre* (Table 3). Based on those dominant indicator species, we named Community 1 *Festuca ovina – Artemisia feddei* (FOAF); Community 2, *Phleum pratense* (PP); Community 3, *Persicaria nepalensis – Persicaria thunbergii* (PNPT); and Community 4, *Sphagnum palustre* (SP).

The spatial distribution of those investigated plots were all significant from Axis 1 through 6; Axes 1 through 3 were recommended for further explanation in NMS (Figure 3; mean stress of the third axis was 16.08, Monte Carlo test $p < 0.01$). Axis 1 of the NMS explained 24.9% of the total variance, whereas Axis 2 explained 37.0% and Axis 3, 20.3%. In all, these three explained 82.2% of the total variance.

To compare the analytical data obtained via CA and NMS, and to infer the possible environmental factors, we overlaid the four communities classified by CA on the NMS, and found clear distinctions among them (Figure 3). This indicated that the four have become unique because of their specific microhabitats.

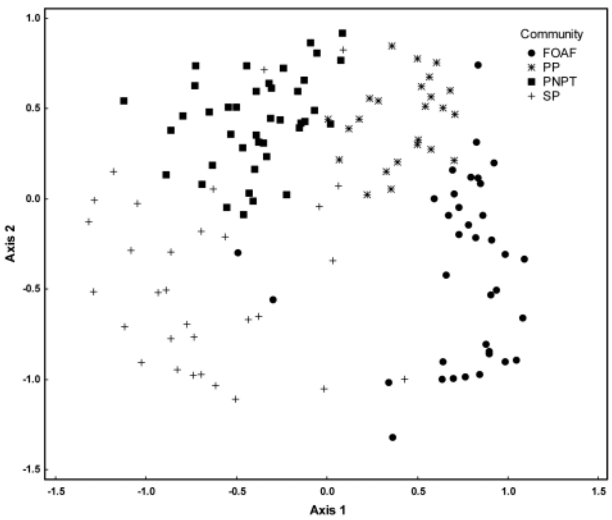

Figure 3. Spatial distribution of 132 plots by NMS ordination at Jilmoe Moor in Mt. Odae National Park. Symbols represent 1 of 4 different community types determined by cluster analysis. ● FOAF: *Festuca ovina – Artemisia feddei*, * PP: *Phleum pratense*, ■ PNPT: *Persicaria nepalensis – P. thunbergii*, + SP: *Sphagnum palustre*.

For example, Axis 1 contained two wetlands communities on the left, SP and PNPT, while two upland communities, FOAF and PP, were located on the right side. Conversely, Axis 2, which was more important than Axis 1 because it explained a higher amount of the total variance, contained the SP and FOAF communities on its lower side and the PNPT and PP communities on its upper side. The SP community on the lower side of Axis 2 occupied the peat hummock in the middle of the wetland, while the FOAF community was found on the edges of the wetland, where the elevation was high. Conversely, the PNPT communities were distributed in or near waterways, allowing those plant roots to be constantly submerged. The PP communities occupied broad areas, from near waterways to the wetland edge.

DISCUSSION

The mountains of Korea are generally steep, with complex relief. Therefore, montane moors rarely develop, and when they do they are usually very small (Korea National Park Service, 2007). As a result, they are isolated from each other, which results in their unique characteristics (Choung et al., 2005).

Applying CA, NMS, and ISA for our multivariate vegetation analyses, we identified four distinct communities: two upland (PP and FOAF) and two wetland (SP and PNPT) (Figure 3). The PP and FOAF communities, which comprise species generally found in pastureland (Table 3), commonly occur at transition zones with low water levels connecting moor to pasture (Table 3). In particular, *Phleum pratense*, a pasture plant, dominates in both the PNPT wet community and the PP upland community. *Persicaria nepalensis* and *P. thunbergii*, which are dominant within the wet PNPT community, are common in areas of Korea with rich nutrient sources and frequent changes in water level from rivers, lakes, and valleys. The high phosphate concentration in soils of the non-sphagnum stands, which included those of the PNPT, PP, and FOAF communities, may explain the prevalence of species such as *Phleum pratense*, *Persicaria nepalensis*, and *P. thunbergii* (Table 1). The SP community is another wet community that dominantly occupied the peat hummock. *Sphagnum palustre* is a major indicator species of peatland. For example, *Sphagnum* becomes dominant in oligotrophic areas that are acidic and are fed primarily by precipitation. These results also showed that soils of the sphagnum stands are more acidic and lower in available phosphate compared with non-sphagnum stands. Therefore, *Sphagnum* becomes the major component in hummocks, contributing to peat accumulation (Succow and Joosten, 2001). That genus is dominant in Yong Moor at Mt. Daeam (Choi and Koh, 1989), Soomeungol Moor at Mt. Jeombong (Ryou 2004), Neoreungol Moor at Mt. Jeombong (Choung et al., 2005), and Sohwangbyeongsan Moor (Choung et al., 2005; Korea National Park Service, 2007). At Jilmoe Moor, the SP community also has been invaded by timothy (Table 3), but is less affected than the PNPT community perhaps because of its relatively low pH and phosphate concentration (Table 1).

The high levels of available phosphorus and exchangeable potassium in the soil may have exacerbated the disturbance of the vegetation here. When compared with 12 other montane moors in Gangwon Province, e.g., Yong, Neoreungol, Sohwangbyeongsan, and Simjeokri, concentrations of those two elements are unusual high in the soils of both sphagnum and non-sphagnum stands at Jilmoe Moor (Choung et al., 2005). Furthermore, the available phosphate concentration is a critical factor affecting species composition in montane moors (Choung et al., 2005). These unusually high levels may have been caused by agricultural runoff from the surrounding pasture. In addition, cattle footprints were observed in the moor, which suggests that their excrement impacts that area. This nutrient-rich environment may have facilitated both the replacement of original wetland species and invasions by pasture species. *Persicaria nepalensis*, *P. thunbergii*, *Juncus effusus* var. *decipiens*, *Ostericum maximowiczii*, and *Viola verecunda*, which are the dominant wetland species at Jilmoe, are commonly found in eutrophicated wetlands, but are rare in oligotrophic habitats (Choung et al., 2005).

Ryou (2004) previously evaluated the vegetation of Jilmoe Moor, concluding that this is a substitute community comprised of secondary vegetation. Conversely, the closest wetland to Jilmoe -- the Sohwangbyeongsan moor -- is less nutrient-rich and is dominated by oligotrophic species such as *Carex cruta* and *C. dispalata* (Choung et al., 2005; Korea National Park Service, 2007). Sohwangbyeongsan moor is relatively protected from the influence of the pasture.

It is common for upland species to co-exist in montane wetlands. For example, Lee (2007) has reported that the frequency of wetland species compared with upland species at Gyeongsangnam-do is 15~21%. At Jilmoe Moor, that percentage is 31%, indicating that it has a higher ratio of wetland species at the latter location. Nevertheless, the number of species is not as important as the practical dominance by upland species in quantity, particularly when those are pasture plants.

Jilmoe Moor has been left without care for more than 30 years, during which time the surrounding pasture has become a tourist attraction. Although the moor became part of a national park in 1975, its wetland since then has been exposed to grazing cattle, as well as their excrement, fertilizer from the pasture, the influx of pasture plant species, and tourists. Although a fence was installed in 2004 to prevent cattle and tourists from entering, an investigation in 2006 showed that the moor soil had much higher contents of available phosphorus and exchangeable potassium than those of other high montane wetlands (Choung et al., 2005).

The International Union for Conservation of Nature (IUCN, 1994) has designated national parks as Category II for the management of protected regions. Such sites are defined as "natural areas of land and/or sea designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities". Because Jilmoe Moor is a montane wetland located within a national park, it should be managed in accordance with its value as part of that park system as well as preserving its value as a very rare moor.

For those reasons, it is essential that Jilmoe be protected from the influence of pastureland. In the long term, to facilitate natural succession, the surrounding property, which is government-owned, should not be used. Invading pasture species, such as timothy, should be removed as soon as possible. Furthermore, to return the moor to an oligotrophic state, the fence should be extended upstream of the waterway to prevent the excrement of grazing cattle from contaminating the waters. Finally, the use of fertilizer should be banned within a certain boundary around this moor.

ACKNOWLEDGEMENTS

We thank Drs. WC Lee and KO Yoo for helping to identify collected plant specimens. We also thank Dr. KY Joo and two anonymous reviewers for critical review of the manuscript. This work was supported by the Ministry of Environment as 'Survey of Natural Resources in Mt. Odae National Park in 2004'. Chemical analyses were performed by using the resources of the Central Laboratory of Kangwon National University.

Received June 27, 2008; accepted July 29, 2008.

LITERATURE CITED

Buurman P, Van Lagen B, Velthorst EJ (1996) Manual for Soil and Water Analysis. Backhuys Publishers, Leiden, The Netherlands

Choi KR, Koh JK (1989) Studies on moor vegetation of Mt. Daeam, east-central Korea. Kor J Ecol 12(4): 237-244

Choung Y, Joo KY, Park DS, Shin Y, Kim S, Lee YT, Seo B, Lee JH (2005) Distribution, Characteristics and Conservation Status of Some Montane Moors in Gangwon Province, Korea. Kangwon Regional Environmental Technology Development Center Press, Chuncheon, Korea

Cylinder PD, Kenneth MB, Ellyn MD, Albert IH (1995) Wetlands Regulation: A Complete Guide to Federal and California Programs. Solano Press, Point Arena, CA, USA

Gangwon Regional Meteorological Administration (2008) The Weather of Gangwon Province. http://gangwon.kma.go.kr/index.php.

Gould AJ (2007) A Habitat-based Approach to the Conservation of Rare Vascular Plants in the Northern Rocky Mountains of Alberta. Ph.D. Thesis. University of Alberta, Edmonton, AB, Canada

IUCN (1994) Guidelines for Protected Area Management Categories. IUCN, Gland.

Kim JG, Lee YW (2005) Recent history and environmental changes in Wandeungjae moor of Mt. Jiri. Kor J Ecol 28(3): 121-127

Kim JW, Han SU (2005) Moor vegetation of Mt. Shinbul in Yangsan. Kor J Ecol 28(2): 85-92

Korea National Park Service (2000) Report of Wetland Monitoring in Mt. Odae National Park. Korea National Park Service, Seoul

Korea National Park Service (2001) Monitoring Report on Natural Resources of Mt. Odae National Park. Korea National Park Service, Seoul

Korea National Park Service (2004) Monitoring Report on Natural Resources of Mt. Odae National Park. Korea National Park Service, Seoul

Korea National Park Service (2007) Monitoring Report on Natural Resources of Mt. Odae National Park. Korea National Park Service, Seoul

Lee WC (1996) Standard Illustrations of Korean Plants. Academy-book, Seoul

Lee M-K (2007) Present Status and Conservation Strategy of the Mountainous Wetlands in Ulsan City and Gyeongsangnamdo Province. M.Sc. Thesis. Gyeongsang National University, Jinju, Korea

McCune B, Grace JB (2002) Analysis of Ecological Communities. Mjm Software Design, Gleneden Beach, OR, USA

Ministry of Environment (2005) Annual Report. Ministry of Environment, Seoul

Mitsch WJ, Gosselink JG (1993) Wetlands. Van Nostrand Reinhold Company, New York

Miyawaki A (1977) Vegetation of Japan. Gakuken, Tokyo

Miyawaki A, Okuda S, Mochizuki R (1978) Handbook of Japanese Vegetation. Shibundo, Tokyo

Park JK (2001) Water table variation of Yongnup located at Daeam-san, Yanggu-gun. J Geomorph Assn Kor 8(2): 35-49

Ryou SH (2004) Studies on Vegetation and Successive Dynamics of Moors in Montane Zone, Korea. Ph.D. Thesis. Chungnam National University, Daejeon, Korea

Son MW, Park K (1999) Morphogenetic environment of Jilmoe Bog in the Odae Mountain National Park. Kor Comm Region Geogr 5(2): 133-152

Succow M, Joosten H (2001) Moorkunde. E. Schweizerbart'sche Verlagbuchhandung, Stuttgart

van der Valk AG (1981) Succession in wetlands: A Gleasonian approach. Ecol 62(3): 688-696

Wilmanns O (1978) Ökologische Pflanzensoziologie. UTB, Quelle and Meyer, Heidelberg