Plant Species Assemblages and Vegetation Composition of Wetlands Within an Upland Forest

Man Kyu Huh*, Hak Young Lee[1] and Sung Gi Moon[2]

Department of Molecular Biology, Dongeui University, Busan 607-714, Korea
[1]*Department of Biology, Chonnam National University, Gwangju 500-737, Korea*
[2]*Department of Biology, Kyungsung University, Busan 608-736, Korea*

Abstract − Small wetlands in an upland matrix can support diverse vegetation composition that increase both local and regional species richness. In this study we characterize the full range of wetland vegetation in an upland forest landscape at Dumyeong-ri, Gijang-gun, Busan. This wetland index can be calculated with species data, or with community type data as performed. Classified community types were used to describe vegetation at three wetlands and adjacent areas. The communities contained 28 species of vascular plants and 28 species were identified four plant community types. The *Pinus densiflora* type was dominated by *Pinus densiflora* and contained only four species. None of the plots had high proportion of standing water. The *Carpinus laxiflora* type had high obligate upland species (OU) and facultative upland species (FU). The *Rhododendron mucronulatum* type grew in over half of the plots included *Pinus densiflora* and *Alnus japonica*. Some species bother swampy areas adjacent to site C. The *Miscanthus sacchariflorus* type consisted of seasonal wetlands. The three sites contained nine species with the strongest indicator species being *Miscanthus sinensis* var. *purpurascens*, *Miscanthus sinensis*, *Echinochloa crus-galli*, and *Sagittaria aginashi*. This type had the highest proportions of obligate wetland species. Plant species richness averaged 5.069. Shannon-Weaver index of diversity also varied among the community types (F=22.7, df=4, 115), with the types FU having significantly higher value (2.746) than the others (1.057 for type FW and 1.600 for type OU). Regional plans including all of the diverse types of wetland vegetation in upland forests will contribute substantially to the conservation of plant diversity.

Key words : cluster analysis, community types, species richness, wetlands

INTRODUCTION

Wetlands are the link between land and water and are some of the most productive ecosystems in the world. In temperate deciduous forests, wetland habitats are both abundant and widely varied, including permanent and seasonal ponds, glades, streamsides, and other small wetlands (Brooks *et al.* 1998; Palik *et al.* 2003). However, despite the abundance and ecological importance of wetlands within forested landscapes, many aspects of their biology remain unknown. While seasonal pools have gained attention as crucial habitat for amphibians and invertebrates (Semlitsch and Bodie 1998; Paton 2005), the vegetation composition of these and other forest wetlands have not been fully described (Colburn 2004; Palik *et al.* 2007).

The Yangsan and Ilkwang provinces in Busan, Korea are fortunate to have many small local wetlands. A few previous studies of the plant community of small wetlands in eastern Korean forests have focused on the lists of plant and animal species. However, these studies often defy simple classification; the distinctions among wetland types remain largely arbitrary and inconsistent, and the floras of different wetland features in a landscape often substantially overlap. To under-

* Corresponding author: Man Kyu Huh, Tel. 051-890-1529, Fax. 051-890-1521, E-mail. mkhuh@deu.ac.kr

stand how small wetlands contribute to regional plant diversity, we need to consider all the wet areas in a landscape and to identify them based on the vegetation itself.

The wetlands can contribute disproportionately to landscape-level diversity because they often have high levels of both local species richness (α diversity) and spatial variation in plant community (β diversity; Wright *et al.* 2002; de Meester *et al.* 2005). In addition, wet habitat patches surrounded by uplands may support distinctive species assemblages, different from those of large-scale wetlands (Colburn 2004; de Meester *et al.* 2005). These communities often include regionally rare species, and they can serve as refugia for wetland specialists in landscapes where major wetlands are destroyed, degraded, or absent (Williams *et al.* 2004; Nicolet *et al.* 2004). As human activities such as pollution and drainage continue to threaten small isolated wetlands, it is critical to make a full assessment of their conservation value (Tiner 2003; Nicolet *et al.* 2004; de Meester *et al.* 2005).

In this study we characterize the full range of wetland vegetation in an upland forest landscape at Dumyeong-ri, Gijang-gun. To include a wide variety of wet habitats typical of temperate deciduous forests and minimally impacted by human activity, we consider the range of wetlands within a topographically diverse, old growth *Carpinus laxiflora* BL.-*Pinus densiflora* Siebold et Zucc. forest in northern Busan, Korea. Specifically, we assess five community types among assemblages, a classification of four vegetation types, and species diversity.

MATERIALS AND METHODS

1. Study site

The study area is located at Dumyeong-ri, Gijang-gun, which is administering by Busan city as a part of the Memorial Park (Fig. 1). The geographical location is 129° 06′28″E, 35° 18′05″N. The mountain has a diversity of vegetation, most dominated by pine, oak, and alder. The mountain has three wetlands and their elevation ranges from 220 m to 230 m. The wetlands are waste field and rounded an oak-pine ecosystem. Another major feature is a swamp on swallow peat deposits and the wet sites include poorly drained areas along streams. Although farmers have utilized these wetlands as rice fields, they have failed to cultivate rice or crop because of continuous spring out and bad draining.

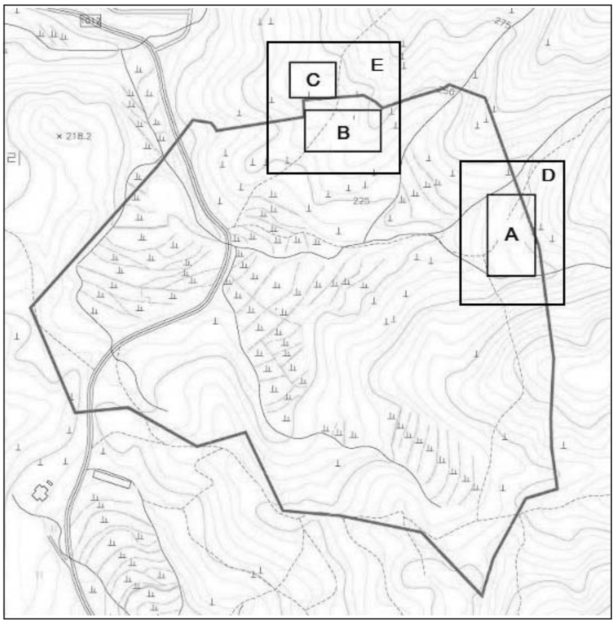

Fig. 1. The locations of wetland communities. Wetlands are shown quadrilaterals and a red polygon is a part of the Memorial Park. Wetlands (A, B, and C) are at the northeast and north center. D and E are the circumferences of wetlands. The marginal polygon (red line) is planned as a development district by Busan-si.

2. Vegetation sampling

The study was conducted on the wetlands at Dumyeong-ri and their circumferences between April 2006 and November 2007. We collected samples For sampling, wet areas were divided into 20 m × 20 m segments, with each segment sampled separately. We sampled the vegetation of each site in two ways. First, we listed the identity and cover of all vascular plant species present at the site, using the percentage cover classes 0 to < 1, 1 to < 5, 5 to < 25, 25 to < 75, and 75 to 100. To obtain area-based samples, we also recorded species present within 1 × 1 m plots located every other meter along transects (Table 1). Transects were aligned with the longest axis of each site, and their length varied with the size of the sites. Total 100 plots were surveyed.

3. Data analysis

The identification of characteristic or indicator species is estimated by the Reed' classification (1988). He described species "probability of occurrence in wetlands" as opposed to upland habitats, with obligate wetland species having a percentage probability of occurrence in wetlands (OW) > 99; facultative wetland species (FW), 67 ∼ 99; facultative species

(F), 34～66; facultative upland species (FU), 1～33; and obligate upland species (OU), <1. To define groups of plant community. First, we conducted a hierarchical, agglomerative cluster analysis with Sørensen (Bray-Curtis) similarities based on percentage cover classes, using the flexible beta linkage method with $\beta = -0.25$ in the program PC-ORD (McCune and Mefford 1999; Flinn *et al.* 2008). We then used the indicator species analysis of Dufrêne and Legendre (1997) to choose an appropriate number of groups from the cluster analysis and to describe the resulting community types. This method calculates indicator values for each species in each group as the product of the species' mean abundance in that group relative to other groups and the proportion of sites in that group where it is present (Flinn *et al.* 2008). By comparing the results of indicator species analysis at multiple levels of clustering, we chose the minimum number of groups that maximized the average significance of indicator values and the number of species with significant indicator values.

Table 1. Sites description of wetland communities on Dumyeong-ri

Site	Aspect	Area (m^2)	No. of plots
A	SE	65.03	18
B	NW	56.33	14
C	NW	17.79	11
D	SE	112.60	24
E	NW	225.84	33

The Shannon-Weaver index of diversity was used to characterize species richness and abundance (Shannon and Weaver 1949). It was calculated as:

$$H' = -\sum_{i=1}^{s} (pi)(\ln pi)$$

where s is the total number of species and pi is the proportion of all individuals in a sample that belong to the ith species.

Table 2. Indicator values of plant species for four types of wetland communities on Dumyeong-ri, Gijang-gun, Korea. The values range from 0 (no indication) to 100 (perfect indication, i.e., the species is always present in that community type and never present in others)

Species	Vegetation composition			
	Pd	Cl	Rm	Ms
Pinus densiflora Siebold et Zucc.	67	13	15	0
Pinus thunbergii Pal.	64	8	12	0
Larix leptolepis (S. et Z.) Gordon	7	37	3	0
Cedrus deodara (Roxb.) Loudon	11	5	4	0
Alnus japonica Steud.	9	79	6	0
Alnus hirsuta (Spach). Rurr.	11	50	2	0
Alnus firma S. et Z.	13	33	5	0
Carpinus laxiflora BL.	0	75	3	0
Quercus acutissima Carruth.	11	0	11	0
Quercus variabilis BL.	1	0	7	0
Quercus dentata Thunb.	3	0	21	0
Quercus aliena BL.	1	0	18	0
Pueraria thunbergiana Benth.	0	0	5	8
Rubus crataegifolius Bunge	0	0	22	0
Robinia pseudo-acacia L.	2	0	1	0
Rhus trichocarpa Stokes	21	4	3	0
Rhododendron mucronulatum Turcz.	7	7	64	0
Rhododendron yedoense var. *poukhanense* (Lev.) Nakai	4	11	34	0
Rosa multiflora Thunb.	0	0	1	9
Echinochloa crus-galli (L.) Beauz.	0	0	0	71
Sagittaria aginashi Makino	0	0	0	42
Alopecurus aequalis var. *amurensis* (Kom.) Ohwi	0	0	0	10
Miscanthus sacchariflorus Benth.	0	0	0	92
Miscanthus sinensis Andress.	0	0	0	80
Miscanthus sinensis var. *purpurascens*	0	0	0	88
Pseudosasa japonica Makino	2	0	0	0
Scirpus triqueter L.	0	0	0	7
Carex humilis var. *nana* Leyss	13	2	8	0

Notes: The community types are abbreviated as Pd: *Pinus densiflora*, Cl: C*arpinus laxiflora*, Rm: *Rhododendron mucronulatum* and Ms: *Miscanthus sacchariflorus*. The indicator values combine species' relative frequency and relative abundance across groups, expressed as percentages of perfect indication (Dufrêne and Legendre, 1997). For each species in each community type, the indicator value is the product of the species mean abundance in that type relative to other types and the proportion of sites in that type where it is present. The table shows only species with indicator values significant at $P < 0.05$. Categories include OU: Obligate upland species, FU: Facultative upland species, F: Facultative species, FW: Facultative wetland species and OW: Obligate wetland species.

RESULTS

The three wetlands (A, B, and C) and two rounded areas (D and E) communities contained 28 species of vascular plants (Table 2). These included no species listed as threatened or rare in Korea. Only several species were considered susceptible species in the wetlands of being listed: *Echinochloa crus-galli*, *Sagittaria aginashi*, *Alopecurus aequalis* var. *amurensis*, and *Scirpus triqueter*. Indicator values of plant species for four types of vegetation composition on Dumyeong-ri, Busan, Korea. The values range from 0 (no indication) to 100 (perfect indication, i.e., the species is always present in that community type and never present in others).

From the cluster analysis, 28 species were identified four vegetation compositions (Fig. 2). This level of grouping retained about 42.5% of the information in the dendrogram. Overall pairwise comparisons showed significant differences in species composition among all groups (overall $t = -30.3$, $P < 0.0001$, chance-corrected within-group agreement $A = 0.11$).

The *Pinus densiflora* type was dominated by *P. densiflora* and contained only four species. None of the plots had high proportion of standing water.

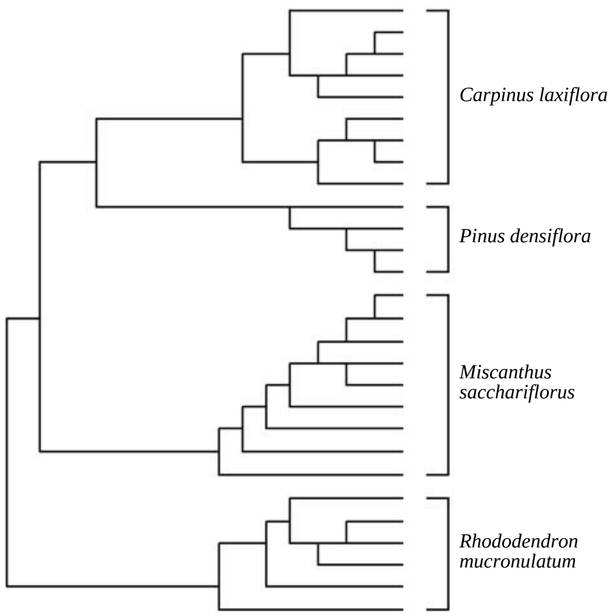

Fig. 2. Dendrogram of the results of hierarchical, agglomerative cluster analysis, grouping 28 wetland plant communities into four vegetation compositions, named for the species with the highest indicator value.

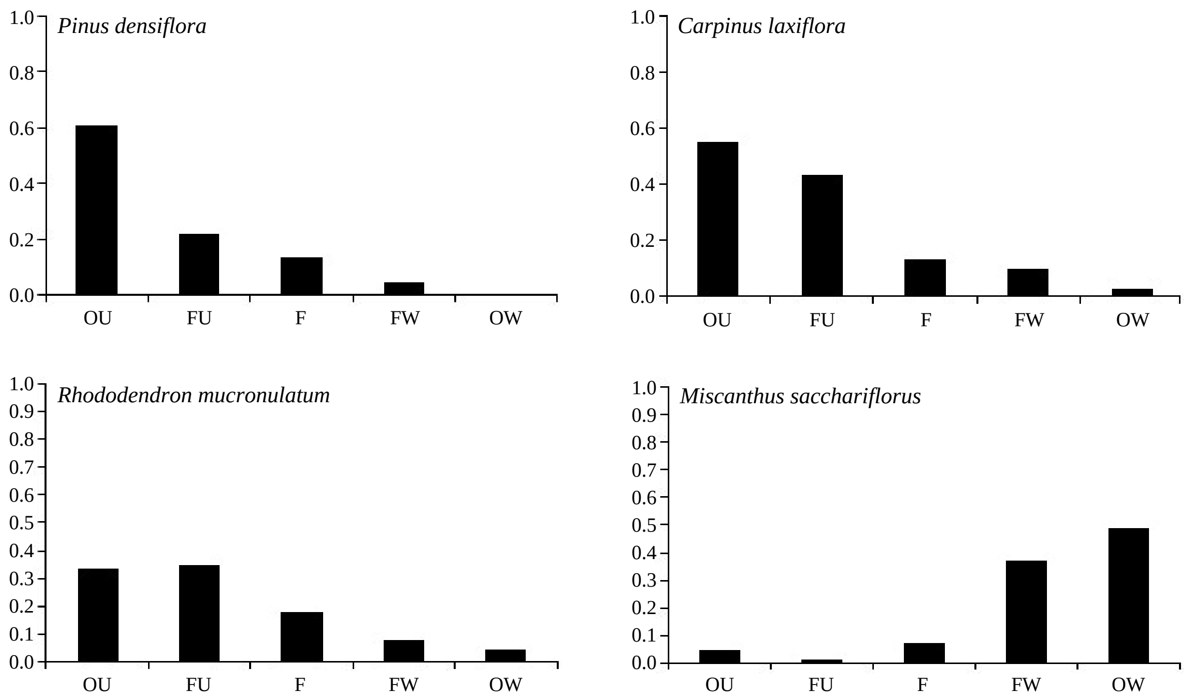

Fig. 3. Histograms showing the proportions of the plant species in five types of wetland communities, named for the species with the highest indicator value, that belong to each National Wetlands Inventory indicator category (Reed 1988). OU, FU, F, FW, and OW are same as Table 2.

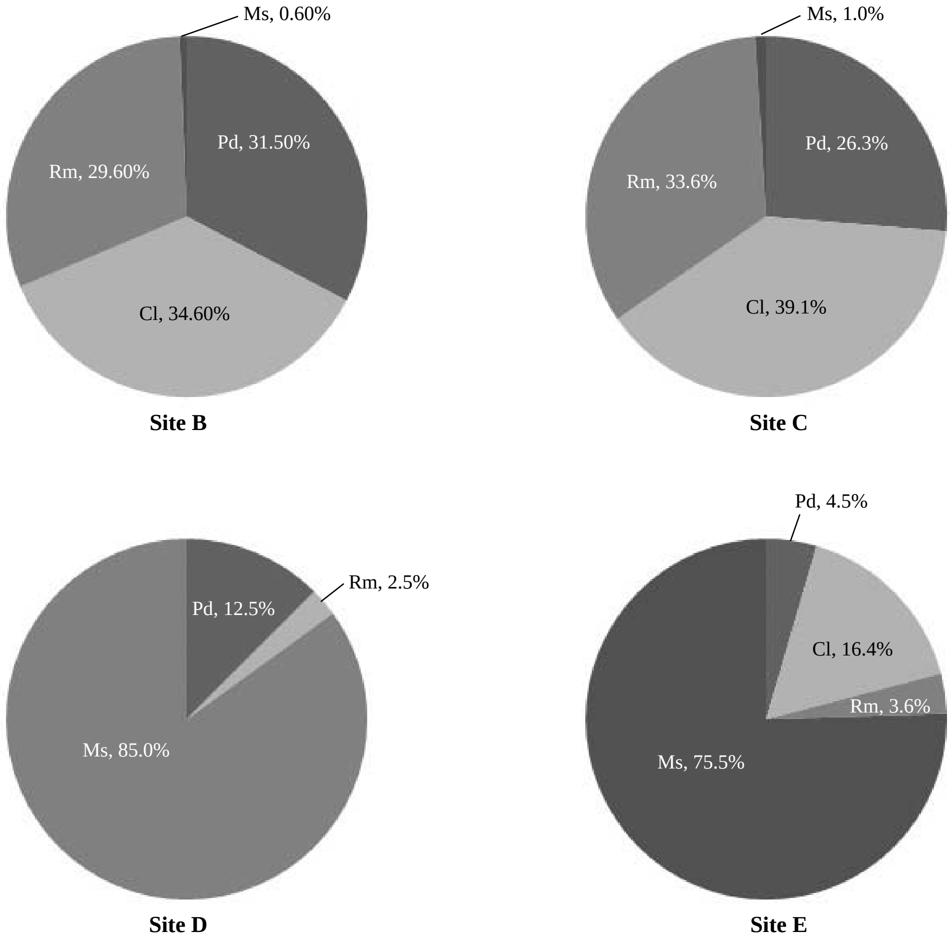

Fig. 4. Diagrams showing the proportions of the four types in four sites. Site A was only occupied the type *Miscanthus sacchariflorus* and thus omitted the diagram.

The *Carpinus laxiflora* type had high obligate upland species (OU) and facultative upland species (FU) (Fig. 3). This type trees and shrubs had greater cover that in the other types.

The *Rhododendron mucronulatum* type grew in over half of the plots and *Pinus densiflora* and *Alnus japonica* were growed as mixed plants with this type plants.

The *Miscanthus sacchariflorus* type consisted of seasonal wetlands. The three sites contained nine species with the strongest indicator species being *Miscanthus sinensis* var. *purpurascens*, *Miscanthus sinensis*, *Echinochloa crus-galli*, and *Sagittaria aginashi* (in order of descending indicator values; Table 2). This type had the highest proportions of obligate wetland species (Fig. 3).

Wetlands are often thought of as areas where there is water with many plants. However, Sites A, B, and C were lower number of species than those of both rounded area, D and E. The wetland communities were streamsides and easy glades dominated by *Miscanthus sacchariflorus*, with nine species. *Miscanthus sinensis* covered more than 25% of each wetland site. In area E, trees and shrubs had greater cover than in the other types, especially *Pinus densiflora*, *Pinus thunbergii*, and *Rhododendron yedoense* var. *poukhanense*. *Carex humilis* var. *nana* was the strongest indicator species in site A. *Alnus japonica* and *Carpinus laxiflora* bordered site D. In addition, genus *Quercus* occurred mainly in this type. Some species were common throughout wet places, yet not indicative of a particular type. For example, *Pueraria thunbergiana* occurred at 13 of the 100 plots.

The communities of three wetlands and their circumferences contained 28 species. These species sorted into vegetation types in part according to hydrological features, with most seasonal ponds clustering together, respectively (Fig. 3).

All individuals of 28 species of four vegetation composi-

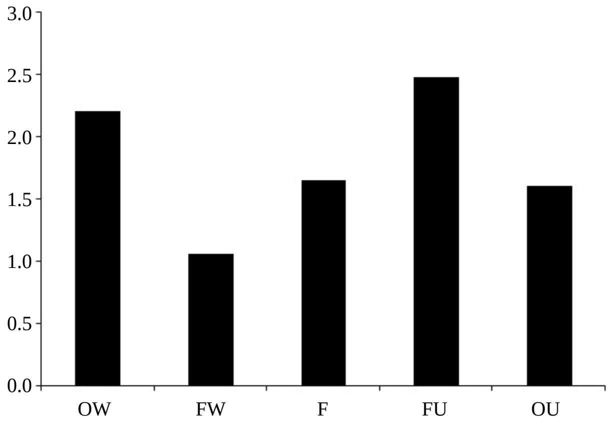

Fig. 5. Species diversity index in five types of the wetlands and their circumferences.

tions were identified five plant communities (Fig. 4). Proportion rates of sites A and B were very similar to each other. Wetlands were shown the relative individual density or abundance across sites. Site A was only occupied the type *Miscanthus sacchariflorus* and thus omitted the diagram.

Plant species richness averaged 5.069. At this spatial scale, the most species-rich site was *Carpinus laxiflora* type and the least species-rich site was the wet site A. Species richness differed significantly among the five community types ($F=6.8$, $df=4$, $P<0.05$). Shannon-Weaver index of diversity also varied among the community types ($F=22.7$, $df=4, 115$, $P<0.001$), with the types FU having significantly higher value (2.746) than the others (1.057 for type FW and 1.600 for type OU) (Fig. 5).

Shannon-Weaver index of diversity also varied among the sites with the sites D (1.350) and E (1.390) having significantly higher value than the wetland sites (0.0 for site A, 0.490 for site B, and 0.879 for site C).

DISCUSSION

The main good provided by the high wetlands is water, as well as some of the most relevant ecosystem functions and environmental services related to water resources (including water storage, flow regulation, hydroelectric generation, and others). Actually, one of the most important services is a permanent supply of drinking water for human use, fresh water for agricultural land irrigation, and hydroelectric generation. In fact, many cities depend on the high wetlands due to these fundamental services. Similarly, a substantial part of the agricultural production of the lower region depends on the high Dumyeong-ri watersheds, including the wetland systems, as a basic source of water.

The wetlands and wetland complexes maintain a unique biological diversity and are characterized by a high level of plants (Keiper *et al.* 2002). Plant diversity is often an indicator of the level of disturbance in a wetland. Describe the diversity of plant species in the wetland, recognizing that different community types have different levels of diversity. Wetlands with many species of trees, shrubs, grasses, sedges and wild flowers are rated high. Wetlands with monotypic stands of reed canary grass or cattail are rated low.

Wet places cover a very small proportion of the landscape of at Dumyeong-ri, Busan (the area sampled is ~2% of the park). Small and surrounded by upland forests, the wet areas in this study contained as many upland species as wetland species. At the same time, wet places on Dumyeong-ri provided habitat for many wetland plants that would not otherwise occur in an upland forest landscape. For example, they supported species such as *Miscanthus sinensis* var. *purpurascens*, *Miscanthus sinensis*, *Echinochloa crus-galli*, and *Sagittaria aginashi* species, which grow elsewhere in the region in habitats like riverside marshes.

27.3% of the species in our wetlands were facultative upland species, 21.8% obligate wetland species, 15.6% facultative wetland species, 9.3% facultative species, and 22.0% obligate upland species. It is similar to the American National Wetlands Inventory classification, 29% of the species in our wetlands were facultative upland species, 22% obligate wetland species, 17% facultative wetland species, and 16% each facultative species and obligate upland species (Reed 1988).

Land use within the wetland alters the soils and vegetation, affecting the relationships among ground water discharge, recharge and evapotranspiration (Bohn *et al.* 2007). Development and intensive use reduce the wetland's ability to maintain its normal hydrologic regime. Ground water is a constant source of water to a wetland, establishing the base flow. Ground water fed wetlands typically have rich plant diversity and can support a variety of wildlife. Springs, seeps, or plant indicators indicate groundwater interaction.

This study has several important implications for the design and management of reserves and other forest lands. First, it demonstrates that wetlands within upland forests are indeed rare in Korea. Thus the three high wetlands are valuable resource for the conservation of plant diversity and academic research. Second, they are lying areas where enough water collects to support water-loving plants. Wetlands include the area covered by water and the adjacent area of lush water-loving plants. This has increased the amount of soil moisture available for crop and forage production. Third, wetlands provide great volumes of food that attract many animal species. These animals use wetlands for part of or all of their life-cycle. Dead plant leaves and stems break down in the water to form small particles of organic material called “detritus.” This enriched material feeds many small aquatic insects and amphibians that are food for larger predatory reptiles, birds, and mammals.

Wetlands, once perceived as worthless land, are now recognized as a necessary component of a vital landscape. However, due to draining and filling we have lost many of our wetlands. In Korea, farmers have converted many wetlands into rice fields or orchards. Especially, the loss of wetlands in upland forests can have undesirable effects on the landscape, such as erosion, flooding, habitat loss and deterioration of water quality. While natural wetland systems are being destroyed nationwide, the wetlands restored or created to compensate for these losses are commonly not evaluated or contain large percentages of non-wetland acreage. At the present time we do not have established methodology that can uniformly evaluate a wetland’s function, or that is useful for providing guidelines that enhance wetland restoration/creation success.

REFERENCES

Bohn TJ, DP Lettenmaier, K Sathulur, LC Bowling, E Podest, KC McDonald and T Friborg. 2007. Methane emissions from western Siberian wetlands: heterogeneity and sensitivity to climate change. Environ. Res. Lett. 2, 045015 (9 pp).

Brooks RT, J Stone and P Lyons. 1998. An inventory of seasonal forest pools on the Quabbin Reservoir watershed, Massachusetts. Northeastern Naturalist 5:219-230.

Colburn EA. 2004. Vernal pools: Natural history and conservation. McDonald and Woodward, Blacksburg, Virginia, USA.

de Meester L, S Declerck, R Stoks, G Louette, F van de Meutter, T de Bie, E Michels and L Brendonck. 2005. Ponds and pools as model systems in conservation biology, ecology and evolutionary biology. Aquatic Conservation: Marine & Freshwater Ecosystems 15:715-725.

Dufrêne M and P Legendre. 1997. Species assemblages and indicator species: The need for a flexible asymmetrical approach. Ecological Monographs 67:345-366.

Flinn KM, MJ Lechowicz and MJ Waterway. 2008. Plant species diversity and composition of wetlands within an upland forest. Am. J. Bot. 95:1216-1224.

Keiper JB, WE Walton and BA Foote. 2002. Biology and ecology of higher diptera from freshwater wetlands. Annual Review of Entomology 47:207-232.

McCune B and MJ Mefford. 1999. PC-ORD: Multivariate analysis of ecological data, version 4.25. MjM Software Design, Gleneden Beach, Oregon, USA.

Nicolet P, J Biggs, G Fox, MJ Hodson, C Reynolds, M Whitfield and P Williams. 2004. The wetland plant and macroinvertebrate assemblages of temporary ponds in England and Wales. Biological Conservation 120:261-278.

Palik B, R Buech and L Egeland. 2003. Using an ecological land hierarchy to predict the abundance of seasonal wetlands in northern Minnesota forests. Ecological Applications 10:189-202.

Palik B, D Streblow, L Egeland and R Buech. 2007. Landscape variation of seasonal pool plant communities in forests of northern Minnesota, USA. Wetlands 27:12-23.

Paton PWC. 2005. A review of vertebrate community composition in seasonal forest pools of the northeastern United States. Wetlands Ecology and Management 13:235-246.

Reed PB Jr. 1988. National list of plant species that occur in wetlands: National summary. Biological Report 88. U.S. Fish and Wildlife Service, Washington, D.C., USA. Website http://www.fws.gov/nwi/plants.htm.

Semlitsch RD and JR. Bodie. 1998 . Are small, isolated wetlands expendable? Conservation Biology 12:1129-1133.

Shannon CE and W Weaver 1949. The Mathematical Theory of Communication. pp. 326, University Illinois Press, Urbana, IL.

Tiner RW. 2003. Geographically isolated wetlands of the United States. Wetlands 23:494-516.

Williams P, M Whitfield, J Biggs, S Bray, G Fox, P Nicolet and D Sear. 2004. Comparative biodiversity of rivers, streams, ditches and ponds in an agricultural landscape in Southern England. Biological Conservation 115:329-341.

Wright JP, CG Jones and AS Flecker. 2002. An ecosystem engineer, the beaver, increases species richness at the landscape scale. Oecologia 132:96-101.

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