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Characterization of High Elevation Central Appalachian Wetlands

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Abstract

We characterized 20 high elevation wetlands in the central Appalachian Mountains in West Virginia and Maryland, in terms of vegetation, soils, hydrology, and geology. Plant species were distributed along soil chemical (pH, conductivity) and physical (organic matter depth) gradients across sites. Topography and geology appear to explain differences among these wetlands, as reflected by soil and chemistry measures and vegetation distribution. Our work provides substantial quantitative baseline data for these uncommon high elevation wetlands, emphasizing the importance and diversity of these isolated systems.

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Cover Photos, from left: Alder Bog, Yellow Creek, and Main Bog; photos by Karen Francl.

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Summary

We characterized 20 high elevation wetlands in the central Appalachian Mountains in West Virginia and Maryland. We performed woody and herbaceous vegetation surveys by estimating cover percentage in plots (10 x 10 m) and subplots (1 x 1 m), documented soil profiles and texture within each vegetation plot, measured water chemistry parameters, monitored hydrology with piezometers, and investigated geologic influences at each site. Plant species were distributed along soil chemical (pH, conductivity) and physical (organic matter depth) gradients across sites. Topography and geology explain the presence and condition of these wetlands, as all sites were situated within natural basins, and 17 of 20 sites were underlain primarily by sandstone that impedes drainage and creates a perched water table. The remaining sites contained a greater proportion of limestone, which was reflected by differences in vegetation and soil chemistry. Our research emphasizes the importance of small (< 5 ha) wetlands, often overlooked and unprotected, that support as many wetland plants as their larger counterparts on a per-unit-area basis. Our work provides substantial quantitative baseline data for these high elevation wetlands, providing a foundation for understanding the structure and function of these systems.

Introduction

Acidic, anoxic, nutrient-poor wetlands are intermittently distributed across cool environments of the northern United States and Canada. Plant and animal matter production exceeds the annual decomposition rate in these wetlands. Wetlands with these climate conditions and plant communities are locally abundant in portions of the central Appalachian Mountains (restricted in this discussion to east-central and northern West Virginia and western Maryland west of the Allegheny Front).

Despite similar plant communities in northern boreal bogs and fens and central Appalachian wetlands, the ontogeny of these regions' wetlands is quite different. Unlike the wetlands of the north, central Appalachian wetlands were not influenced directly by continental glacial recession (Ingham 1996). Continental glaciers from the Wisconsin Ice Age did not extend any farther south than Pennsylvania in the Appalachian region. However, at high elevations (≥800 m), the climatological conditions of cooler air and soil temperatures and greater precipitation mimic the environment of wetlands at more northern latitudes (Rigg and Strausbaugh 1949). The locally cool climate acts as a refuge for many northern plant species that were trapped as the last continental glaciers receded. Several species reach their southernmost extent in these central Appalachian wetlands (Fortney 1975, Ingham 1996).

Fens and bogs are common throughout large portions of the northern United States. However, these categories fail to adequately describe or "match" conditions found farther south in the central and southern Appalachians (Moorhead and Rossell 1998). Typically, bogs of the northern United States and Canada are defined by acidic conditions (pH ≤4.1) and an ombrotrophic (precipitation-fed) nature. Bog vegetation primarily consists of *Sphagnum* mats, cranberries (*Vaccinium* spp.), and other types of low-lying herbaceous plants (Core 1966). Classic northern fens are slightly less acidic and are minerotrophic (groundwater-fed). Dominant vegetation includes sedges (*Carex* spp.), rushes (*Juncus* spp.) and several shrub species (Core 1966, Walbridge 1994). Central and southern Appalachian wetlands are mostly minerotrophic, and therefore classified as fens, but they support vegetation more similar to bog flora (Moorhead and Rossell 1998). Additionally, these bogs and fens lack the distinct concentric zonation of plant communities found in many northern kettle bogs. Indeed, southern Appalachian wetlands have been described as an "irregular mosaic," more patchy than patterned (Wieder et al. 1981, Moorhead and Rossell 1998). Vegetational studies of central Appalachian wetlands, such as Big Run Bog (Tucker County, WV) support this description (Muzika et al. 1996), and attribute plant distributional patterns to water chemistry differences across the site (Wieder et al.1981, Walbridge 1994).

An important difference between northern boreal bogs and central Appalachian wetlands is their original state prior to anthropogenic activity. Rather than existing as open, floating *Sphagnum* mats, many central Appalachian wetlands (e.g., Canaan Valley, Tucker County, WV) were forested, red spruce (*Picea rubens*)-dominated wetlands prior to timber harvests of the late 1800s through the 1920s (Clarkson 1993). Additionally, balsam fir (*Abies balsamea*) and rosebay rhododendron (*Rhododendron maximum*) thickets were common in the wetland canopy and understory, respectively, whereas the forest floor consisted of wetland mosses atop a deep, rich organic layer (Fortney 1993). Logging, mostly clearcutting, exposed the organic soils, and subsequent fires burned and removed the organic layers. As a result, rock outcrops dominated these formerly forested wetland landscapes (Fortney 1975). Tree removal also created isolated pockets of raised water tables, so formerly dry sites were too wet to sustain tree regeneration, instead supporting shrub-scrub and open wetlands. Currently, open wetlands, often beaver (*Castor canadensis*) influenced, have reappeared on the landscape, mainly in high elevation alluvial areas (Fortney 1993, Walbridge 1994). Therefore, it is likely that many central Appalachian wetlands are geologically young or drastically altered from their natural state more than a century ago. In very few exceptions, like Cranberry Glades (Pocahontas County, WV), the lack of local logging minimized disturbance to the organic layer, which extends more than 2 m below the surface, markedly deeper than logged, "young" wetlands (Darlington 1943). Additionally, portions of The Glades (Garrett County, MD) have been reported to contain peat deposits greater than 3 m[1].

The vegetation, soils, and hydrology of a few large bogs and fens in West Virginia (< 10 sites) have been studied in the past (Darlington 1943, Gibson 1970, Walbridge 1994, Wieder 1985). Dominant plant associations and short-term plant succession have been thoroughly mapped in a two wetlands (Edens 1973, Walbridge 1994). Wieder (1985) and Yavitt (1994), working at Big Run Bog, also examined the local wetland biogeochemistry concluding that differences in vegetative structure result from surface soil chemistry

[1]Feller, D. 2003. Personal communication. Wildlife Biologist, Maryland Department of Natural Resources, 10775 Savage River Road, Swanton, MD 21561.

(i.e., calcium, nitrogen, and magnesium concentrations and pH) variation at Big Run Bog. Walbridge's (1994) research at Big Run and three other wetlands in the area support this relationship between plant species composition, pH, and cation concentrations.

Other wetland soil chemistry studies in the region have been cursorial, typically documenting nothing more than pH and soil water temperature. Soil classification maps are available for all counties in West Virginia and Maryland (USDA Soil Conserv. Serv. 1959, USDA Soil Conserv. Serv. 1982, USDA Natural Resources Conserv. Serv. 2002a). However, due to scaling and poor-quality aerial photographs used to make maps, soil surveys often classify wetlands less than 2 ha according to dominant terrestrial, xeric soils surrounding the area (Wakeley 1994). Those large enough to be recognized (e.g., Canaan Valley and Cranberry Glades) are generally classified as muck and peat soils that are acidic and poorly drained (Ingham1996, Moorhead and Rossell 1998). Darlington's (1943) work at Cranberry Glades showed great variation in peat depth, from 0.3 to 2.3 m across the site, and peat type, including fine peat, *Sphagnum* peat, and sedge peat.

Ingham (1996) performed a regional wetland survey that examined general vegetation, soil, climatic, and geologic conditions among 20 central Appalachian wetlands, but limited research to qualitative comparisons. Additionally, Diehl (1981) qualitatively examined the influence of geologic factors on the presence and formation of nearly 50 wetlands throughout West Virginia. Until now, few large-scale studies have been undertaken that quantitatively assess the relationship of vegetation, soils, hydrology, and geology of central Appalachian bogs and fens.

Our goal was to survey high-elevation central Appalachian wetlands and to provide baseline data for each component that defines them as wetlands: hydrophytic vegetation, hydric soils, and periodic flooded conditions during the growing season (Cowardin et al.1979). We wanted to determine how variable these systems were, and if and how they differed chemically and hydrologically. To accomplish this task, we quantified vegetation structure, monitored water levels with piezometers, and measured several soil components (type, texture, chemistry, and vertical profile) at 20 wetlands in northern West Virginia and western Maryland. Additionally, we examined general geologic and topographic patterns to determine how the formation of these wetlands, underlying rock layers, and placement on the land influence basic wetland parameters.

The scarcity of information in nearly all aspects of ecological concern provides countless research opportunities in central Appalachian wetlands (Moorhead and Rossell 1998). Once these habitats have been thoroughly examined for floral composition and physical and chemical parameters, informed management decisions can be made regarding legal protection of these sites.

Materials and Methods

Site Selection

Twenty sites were selected for this study (Fig. 1, Table 1). Sites were identified from literature reviews and an examination of topographic quadrangle maps. Site selection was based on accessibility and permission to work on private and public lands. Seventeen sites in Randolph and Tucker Counties, WV, plus three in Garrett County, MD and/or Preston County, WV, were qualitatively categorized according to relative geographic placement on the landscape (Big Run Bog, Canaan Loop Road, Canaan Valley, Dolly Sods, Maryland/TNC, and Otter Creek), and referred to as such in the text. Several of the sites, including Big Run Bog, Alder Run, and Cranesville Swamp, have been studied in the past (Robinette 1964, Gibson 1970, Walbridge 1994). However, many of the selected areas are small, isolated habitats that have received little attention. The West Virginia sites are located on federal- or state-owned land, including the Monongahela National Forest (14 sites), Canaan Valley National Wildlife Refuge (two), and Canaan Valley Resort State Park (one). The three wetlands in Garrett County, MD are owned by The Nature Conservancy. Initially, all sites appeared to be isolated depressional wetlands, but several sites also contained flowing water (creeks and seeps less than 2 m wide), and therefore likely were influenced by alluvial inputs.

Vegetative Surveys

To determine the presence and relative importance of hydrophytic vegetation, we followed Tiner (1999) and Reed's (1988) characterization techniques, incorporating weighted values for each species, based on its degree of wetland obligation. We sampled vegetation at each wetland using plots and subplots, modified from Walbridge's (1994) nested-plot design. At each site, we selected two to twenty-four 10 x 10 m plots as most representative of community structure. The number of plots per site was based on a combination of wetland size and visible habitat diversity. The small sites were sampled at approximately 1-2 plots/ha. Because the larger sites could not be sampled with this same intensity, plots representing each physiognomic type

Table 1.—Locality information for 20 wetland sites in West Virginia and Maryland, surveyed in 2001-2002

Site name	Code	County[a]	Geographic cluster	Latitude (North)	Longitude (West)	Elevation (m)	Area (ha)	Owner
Canaan Valley State Park, Abe Run Trail	ABER	Tucker	Canaan Valley	39° 00.930'	79° 27.800'	960	3.0	State of West Virginia
Alder Run	ALDR	Tucker	Dolly Sods	39° 01.710'	79° 19.200'	1164	5.0	USDA Forest Service
Canaan Valley NWR, Beall Tract	BEAL	Tucker	Canaan Valley	39° 04.273	79° 24.776'	954	1.2	USDI Fish and Wildlife Service
Big Run Bog	BIGR	Tucker	Big Run Bog	39° 07.017'	79° 34.554'	982	15.0	USDA Forest Service
Condon Run	COND	Randolph	Otter Creek	38° 56.540'	79° 40.000'	918	3.0	USDA Forest Service
Cranesville Swamp	CRSW	Preston	Maryland/TNC	39° 31.981'	79° 29.199'	794	225.0	The Nature Conservancy
Fisher Springs Run	FISH	Tucker	Dolly Sods	39° 00.890'	79° 19.510'	1158	25.0	USDA Forest Service
The Glades	GLAD	Garrett, MD	Maryland/TNC	39° 33.426'	79° 16.969'	775	240.0	The Nature Conservancy
Hammel Glade	HAMM	Garrett, MD	Maryland/TNC	39° 29.419'	79° 21.797'	737	20.0	The Nature Conservancy
Canaan Valley NWR, Herz Tract	HERZ	Tucker	Canaan Valley	39° 02.268'	79° 25.358'	983	10.0	USDI Fish and Wildlife Service
High Ridge	HIGH	Tucker/ Randolph	Dolly Sods	38° 57.647'	79° 21.235'	1216	28.0	USDA Forest Service
Canaan Loop, Main Rd.	MAIN	Tucker	Canaan Loop Road	39° 04.371’	79° 28.363’	1111	30.0	USDA Forest Service
Moore Run	MOOR	Randolph,	Otter Creek	39° 00.072'	79° 39.623'	991	2.0	USDA Forest Service
Canaan Loop, North Rd.	NORT	Tucker	Canaan Loop Road	39° 04.140'	79° 29.059'	1076	15.0	USDA Forest Service
Canaan Loop, Powerline	POWR	Tucker	Canaan Loop Road	39° 04.959'	79° 27.784'	1099	0.08	USDA Forest Service
Canaan Loop, Red Run	REDR	Tucker	Canaan Loop Road	39° 04.125'	79° 29.455'	1085	0.4	USDA Forest Service
Canaan Loop, Trail 1 (101)	TRL1	Tucker	Canaan Loop Road	39° 05.197'	79° 28.896'	1038	0.4	USDA Forest Service
Canaan Loop, Trail 2 (109/108)	TRL2	Tucker	Canaan Loop Road	39° 04.823'	79° 28.847’	1067	0.2	USDA Forest Service
Canaan Loop, Trail 3 (109/701)	TRL3	Tucker	Canaan Loop Road	39° 04.466'	79° 29.487	1085	1.3	USDA Forest Service
Yellow Creek	YELL	Randolph	Otter Creek	38° 57.742'	79° 40.600'	952	2.5	USDA Forest Service

[a]West Virginia unless otherwise noted

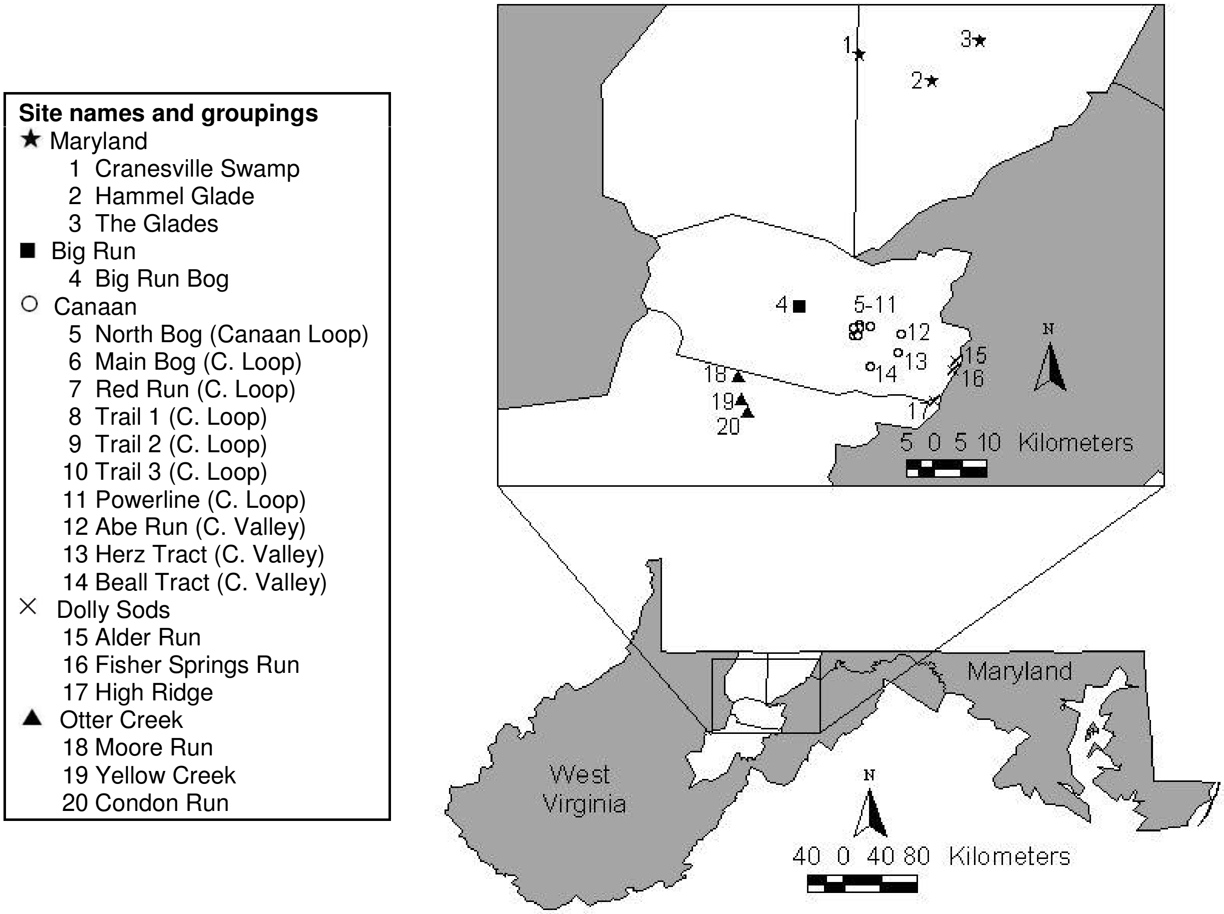

Figure 1.—Twenty high elevation wetland study sites in the Allegheny Mountains of Preston, Tucker, and Randolph counties, West Virginia and Garrett County, Maryland. Symbols refer to groups of sites geographically clustered, and referred to as such in text.

(i.e., shrub-scrub, open mossy, open grassy, and forested patches) were surveyed. At least two plots of each recognizable community type were sampled. Within these plots, we visually estimated cover percentage for each woody species (Walbridge 1994). Nine 1 m x 1 m subplots were randomly selected within each plot, and cover percentage for herbs, vines, and mosses was estimated.

When possible, all plants were identified to species, and taxonomy followed the PLANTS database (Strausbaugh and Core 1978, USDA Natural Resources Conserv. Serv. 2002b. *Sphagnum* moss was identified to genus only. If a plant was rare or easily identifiable by sight, photographs served as voucher specimens. If a plant species was common, a specimen was collected and prepared as an herbarium specimen. Voucher specimens of pressed plants were deposited in the herbarium at the University of Georgia. Several moss specimens also were placed in the herbarium at West Virginia University.

Vegetation was analyzed using weighted averages for each species, where each species is assigned an appropriate ecological indicator value, ranging from one (obligate wetland species occurring more than 99 percent of the time in wetlands) to five (obligate upland species found in nonwetlands more than 99 percent of the time) (Reed 1988). If Reed (1998) did not assign a value to a species, as in the case of nonvascular plants, we assigned an appropriate value, based on literature review and values assigned to other closely related species. For example, all *Sphagnum* mosses were considered obligate wetland species. A weighted average was calculated for each site:

$$W_s = \Sigma(C_{is})(E_i) / \Sigma C_{is}$$

Where:

W_s = weighted average, or vegetative index value, for site s
C_{is} = percent cover for each species i at site s,
E_i = ecological index value for species i.

The result was a weighted average of the site, ranging from one to five. Weighted averages typically are less than 2.0 in wetlands. For borderline averages (2.0–2.5), it is necessary to use soil and hydrology parameters to confirm that a site is a wetland (Tiner 1999).

To further analyze vegetation data, we calculated the importance value (*I*) for each species, which equally weighs its relative dominance and relative frequency (Cox 1996). Dominance refers to the basal area covered by a species (as estimated by the cover percentage within each plot), and frequency to the fraction of plots containing the particular species. Relative values are the proportions for each species of the total for all species.

Soil Surveys

In our characterization surveys, we followed the hydric soil morphology characters (soil color) explained by Wakeley (1994), and supported by the USDA Soil Conservation (1991) such as reduced, saturated conditions result in gray-colored, low-chroma soils and the accumulation of organic matter (surface organic layer greater than 20 cm). Within the established 10 x 10 m vegetation plots (2-22/site), we obtained soil profile information for the surface and subsurface layers (2 plots at the Glades were not sampled for soils because recent acid mine drainage restoration construction filled in these areas). We documented the depth, color (using a Munsell Soil Color Chart), and particle size distribution of each horizon to 1 m below the surface (Kollmorgen Corporation1992). We measured the depth to gray mottles and gray matrix to determine the extent of reduced conditions in the soil. In measuring depth of organic matter, we noted the percent of samples with organic layers deeper than 20 cm (a histic epipedon) (Hurt et al. 2003). We also calculated the percentage of samples with organic layers greater than 40 cm, which would classify as histosols under the U.S. soil classification system (Soil Survey Staff 1998a, Hurt et al. 2003).

From each point at which a soil profile was recorded, we collected a soil sample at ca. 10 cm below the surface. So that a minimum of three soil samples were taken from each site, additional randomly selected points were sampled at four of the smaller sites. Samples were dried at 70° C for 48 hours, or until thoroughly dry. Particle-size analysis was completed following the hydrometer method (Gee and Bauder 1982). Carbon and nitrogen percentages were analyzed on a NC 2100 soil analyzer (C.E. Elantech, Inc., Lakewood, NJ), which uses a gas-chromatographic approach to quantitatively determine concentrations. We compared percentage of clay to percentage of organic carbon in each sample to further classify the soils as organic, mineral, or mucky mineral (Hurt et al. 2003). County soil maps also were analyzed to determine the proportion of sites that were classified as containing wetland soils (USDA Soil Conserv. Serv. 1959, USDA Soil Conserv. Serv. 1982).

To estimate organic matter from each sample, we examined our carbon percentage results. Literature suggests that soil type and depth of sample influence percentage of carbon, which can be 40–59 percent of the organic carbon (Nelson and Sommers 1982, Orlov 1985, Jenkinson 1988). In surface humic soils, the range is typically 50–55 percent, and slightly less in subsoils[2] (Orlov 1985). Because our samples were obtained at 10 cm below the surface, we used a conservative estimate of 48 percent in our calculations.

In early August 2001, we used a YSI 600XL with a 610DM data logger to obtain water chemistry readings (YSI Inc., Yellow Springs, Ohio). Readings were taken at two or more representative spots within each wetland, and averaged for each site. At each site, we measured pH, conductivity (mS/cm), dissolved oxygen (saturation percentage), temperature (°C), and redox potential (ORP, mV). To avoid bias from rainfall (Allan 1995), data were recorded at all sites within a 36-hour period, which occurred at least 48 hours after any measurable precipitation.

Because dissolved oxygen and temperature fluctuate throughout the day (Allan, 1995), we modified our readings from all sites to estimate dissolved oxygen and temperature at 1200 h, so that all sites could be compared without temporal bias. To create a standard curve for oxygen and temperature throughout the day, we recorded temperature and dissolved oxygen at a small, stagnant creek on the Herz Tract (Canaan Valley NWR, Tucker County, WV). We recorded dissolved oxygen and temperature at 2-hour intervals (0600 to 1800 h) on the day immediately following the 36-hour recording period. No rainfall occurred during this period.

Hydrological Monitoring

Criteria for wetland hydrology dictate that surface saturation or inundation must exist for 5 percent or more of the year (Wakeley 1994). To be considered flooded or saturated, the water table must be within ca. 15–46 cm of the surface, with the specified depth depending on soil drainage class and permeability (Wakeley 1994). To account for yearly variability, we

[2]Morris, L. 2002. Personal communication. Professor, University of Georgia Warnell School of Forest Resources, Athens, GA 30602.

monitored changes in the water table depth at each site for two growing seasons. At each site, we installed a piezometer, which was constructed of 5.2-cm-diameter PVC with one end covered with water-permeable double-folded landscaping fabric. A PVC cap was added to the other end to prevent rainfall from entering the pipe. Inside this pipe, we placed a 2.6-cm-diameter PVC pipe as a dip-stick to measure the maximum water level height since last measurement. The piezometer was placed no more than 1 m deep, slightly projecting from the surface (Morrison 1983). One instrument was positioned in a representative area of each wetland (most common microhabitat within the site), at least 10 m from edge habitat and avoiding hummocks and direct stream channels. If an impenetrable layer, such as a hard rock or clay layer, was reached prior to 1 m deep, the piezometer was established atop this layer. Using water-finding paste to gauge current depth, and ground cork particles to gauge maximum water levels since the last measurement, piezometer readings were taken a minimum of every 14 days from June to August 2001, and checked once every 28 days thereafter through September 2002, unless snowfall prevented access. Previous wetland work indicated that sampling every 28 days results in an average error in daily stage estimates of less than 0.05 m and 5 percent of the actual daily values (Shaffer et al. 2000). For the purposes of comparing these wetlands, monthly sampling provided a representative description of water level fluctuations, allowing us to examine intra- and inter-seasonal trends and to infer if areas are continually flooded for 5 percent of the year.

Piezometer trends were qualitatively compared to rainfall data from the 2001 and 2002 growing seasons, as recorded at the USDA Forest Service weather station on Bearden Knob (Canaan Heights, Tucker County, WV; elevation ca. 1150 m) , and to long-term (1980-1990) precipitation trends obtained from the National Oceanic and Atmospheric Administration station for Canaan Valley (elevation ca. 955 m) (Stephenson 1993).

Geologic Analyses

The underlying geology of each site was determined through an analysis of state geologic maps of West Virginia and Maryland (Cardwell 1968, Maryland Geological Survey 2000). Site-specific geologic information also was obtained through published data (Robinette 1964, Diehl 1981, Ingham 1996). Dominant, secondary, and tertiary rock groups and formations were recorded for each site. Quantitative analyses were not performed, due to the scale, age, and questionable accuracy of the maps. U.S. Geologic Survey topographical quadrangle maps (1:24,000) were examined to study trends in elevation within and surrounding each site.

Statistical Analyses

Principal components analyses were performed using NTSYS-pc version 2.02i (Applied Biostatistics, Inc. 1998). Plot and subplot plant data, measured in proportions (*I*-values), were standardized using the default methods in NTSYS. Initially, separate principal components analyses were performed using the *I*-values for each species for woody (plot) and herbaceous (subplot) data (Ludwig and Reynolds 1988). However, the first principal components of woody and herbaceous analyses were strongly correlated ($r = 0.922$, $P < 0.001$). Therefore, we performed a single principal components analysis for all vegetation data, giving equal weight to the woody and herbaceous *I*-values. For these analyses, we calculated correlations among variables, then extracted the first three principal components from the correlation matrix. We chose to examine the first three axes in all cases because the eigenvalues typically began to level off at relatively low values at the fourth principal component. Scatter diagrams were created by plotting each site's projection value for a particular component. Although we violated the assumption of normality in the data, we chose not to attempt data transformation because this often makes the interpretation of principal components difficult (Isebrand and Crow 1975).

Pearson product-moment correlations ($\alpha = 0.05$), performed using SYSTAT 8.0 (SPSS, Inc. 1998), examined relationships among vegetation projection values for each site, wetland indices, and all soil chemistry measures (e.g., pH, dissolved oxygen, redox potential). We also compared these values to the average depth of the organic layer and average piezometer recordings.

Results

Vegetation Surveys

We documented 50 species of trees, shrubs, and woody vines in 133 plots and 130 species of herbs, mosses, and liverworts in 1197 subplots (Appendix 1). Of these plants, 41 were classified as wetland-obligate species and 23 were wetland facultative (Appendix 1) (Reed 1988). Wetland index values were averaged for plot and subplot data to equally weigh the influence of woody and herbaceous plants. Values ranged from 1.69-3.29, with the smaller, isolated sites rating higher (i.e., fewer wetland-obligate species) than the larger, more open sites (Table 2). However, wetland size did not influence the average number of woody ($r = -0.201$; $P = 0.396$) and herbaceous ($r = -0.165$; $P = 0.486$) plants per plot and subplot, respectively (Table 2).

Table 2.—Vegetative measurements for 20 wetland sites in West Virginia and Maryland, collected in 2001. Wetland index value based on averaged plot and subplot values.

Site	Plots sampled	Herbaceous species	Woody species	Mean herbaceous species/plot	Mean woody species/plot	Wetland index
ABER	5	44	14	7.8	5.4	2.82
ALDR	6	18	10	5.6	5.0	1.90
BEAL	4	39	7	6.0	4.0	2.07
BIGR	8	27	13	4.5	5.0	1.69
COND	4	26	10	5.6	6.0	2.12
CRSW	10	28	15	4.4	5.6	1.80
FISH	12	32	19	5.7	6.1	1.92
GLAD	24	47	18	3.7	3.9	2.04
HAMM	6	11	6	3.7	2.8	1.95
HERZ	8	25	7	4.4	3.4	2.20
HIGH	8	44	17	5.9	5.6	1.99
MAIN	10	21	16	3.7	8.0	1.93
MOOR	4	13	12	3.8	6.8	1.82
NORT	8	26	14	5.1	6.8	2.19
POWR	2	13	9	4.1	7.5	3.29
REDR	3	15	9	5.1	8.7	2.06
TRL1	2	16	10	5.1	7.0	2.91
TRL2	2	11	7	3.2	5.0	2.37
TRL3	3	13	9	3.0	7.0	2.08
YELL	4	15	6	2.9	3.5	2.02

In a principal components analysis of the combined vegetation plot and subplot data, the first component explained 20.4 percent of total character variance, and separated out Abe Run (Canaan Valley State Park, Tucker County, WV) from the remaining 19 (Fig. 2). Abe Run contained several disturbance-tolerant species not restricted to wetland habitats, as well as additional species unique to this site. Twenty-eight species exhibited loadings above 0.98 (representative species listed in Fig. 2). No plant species exhibited similar high loadings on the negative end of the axis, but herbs and mosses with the most negative loadings included *Sphagnum* moss (eigenvalue of -0.3853), cottongrass (*Eriophorum virginicum*, -0.2377), and ground pine (*Lycopodium obscurum*, -0.1933). Trees and shrubs with the most negative loadings included groundberry (*Rubus* sp., -0.4337), possumhaw (*Viburnum nudum*, -0.2828), black chokeberry (*Photinia melanocarpa*, -0.2537), and velvetleaf huckleberry (*Vaccinium myrtilloides*, -0.2528).

The second component explained 10.5 percent of the variance, and separated High Ridge (Dolly Sods, Tucker/Randolph County, WV) from the remaining sites. Eighteen plant species exhibited loadings above 0.90; however, no patterns were apparent among the remaining 19 sites loaded on this axis. The third component comprised 8.3 percent of the character variance, and separated sites on a geographical basis. Canaan Loop Road sites clustered at the positive end of the axis, whereas the Maryland sites were located toward the negative end of the axis. Several representative species most common at the Maryland sites, all with loadings of -0.6965, included black cherry (*Prunus serotina*), intermediate woodfern (*Dryopteris intermedia*), blackgum (*Nyssa sylvatica*), smartweed (*Polygonum persicaria*), and common oats (*Avena sativa*). Oats, however, were planted at the site as part of an acid mine drainage remediation effort. Species most often found at the Canaan Loop Road sites include red spruce (0.6531), lichens (0.6546), hygrohypnum moss (*Hygrohypnum eugyrium*, 0.5902), bracken fern (*Pteridium aquilinum*, 0.5830), possumhaw (*Viburnum nudum*, 0.5621), velvetleaf huckleberry (0.5082), and ground pine (*Lycopodium obscurum*, 0.4868).

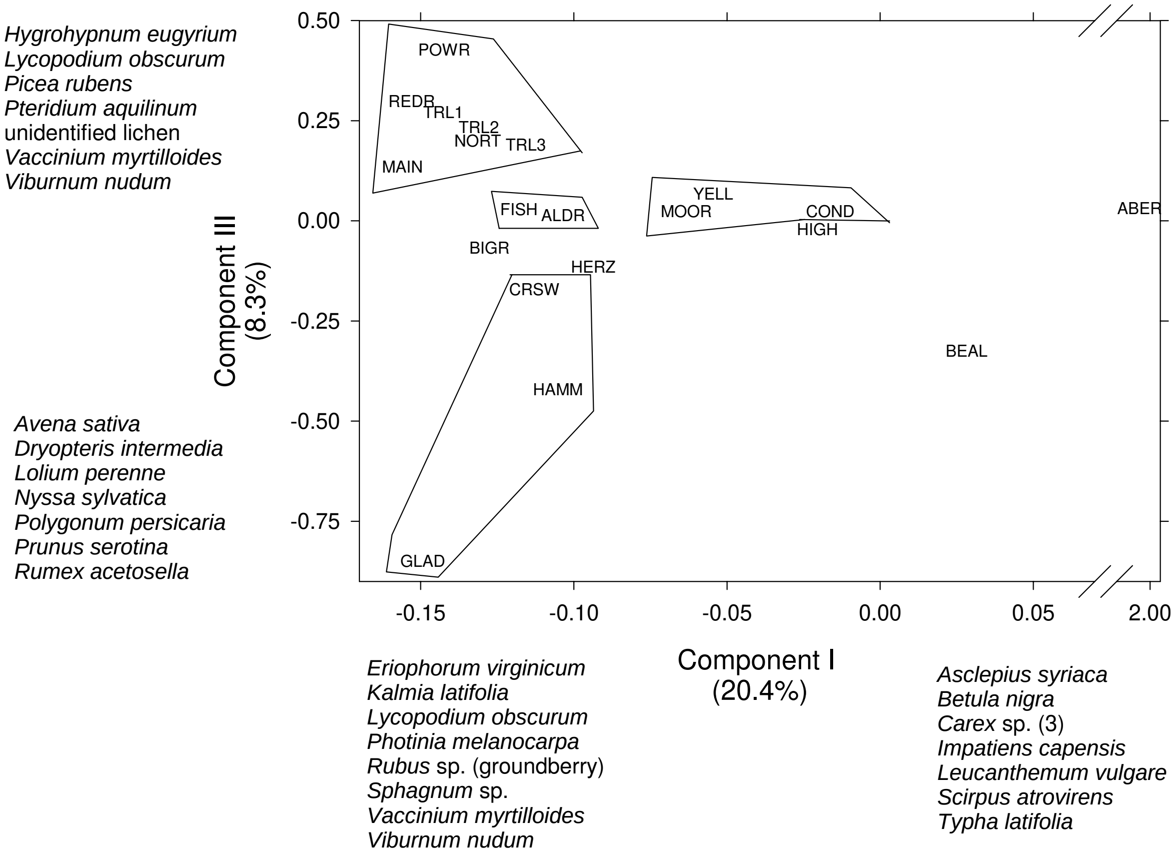

Figure 2.—Principal components analysis of combined vegetation plot and subplot data collected in 2001, evaluating *I*-values of each plant species at the 20 high elevation wetlands. Encircled sites indicate those geographically close to one another. Plant species exhibiting high positive or negative loadings are listed on appropriate axes.

Soil and Water Analyses

Several mean chemistry measures varied considerably across sites, including soil pH (3.14–5.80), redox potential (-24 – +370 mV), and dissolved oxygen (6.9–110.7 percent; Table 3). Organic matter ranged from 20.3–75.6 percent, and trends were evident across sites (Table 4). Sites with flowing water, the Beall Tract (Canaan Valley NWR, Tucker County, WV) and Condon Run (Otter Creek, Randolph County, West Virginia), had lower organic matter. Sites with ponded water, seeps, or no visible surface water had higher organic matter.

Soil profiles were recorded for 2–22 points per site, one in each vegetation plot (Table 5). Because depth to grey matrix matched the depth just beyond the organic layer for nearly every sample, we assumed in further discussions that reduced conditions exist for all mineral soils directly underlying the organic layer. The depth of the organic layer was greater than 20 cm in plots at 19 of 20 sites and in 77.7 percent of all samples. The only wetland lacking a 20-cm organic layer was the Powerline site (Canaan Loop Road, Tucker County, WV), which was the smallest (0.08 ha) of the sites. The organic-layer depth was greater than 40 cm (a histosol) in plots at 12 of the 20 sites and in 30.0 percent of all samples.

Analyzing particle size, nine soil textural classes were documented. Sandy clay loam and sandy loam were found most often in the 130 samples (Table 5). In comparing clay percentage to organic carbon percentage within each sample, 9.3 percent were mineral soil, 25.6 percent were mucky mineral, and 65.1 percent were organic (Fig. 3). Only Condon Run and the Beall Tract (both containing creeks) produced samples that were entirely mineral or mucky mineral soils. All samples from four wetlands from the Canaan Loop Road complex (Main, Red Run, Trail 3, and Powerline) were organic. In comparison with other soil analyses, three of these four sites (excluding Main) lacked histosols (organic layer greater than 40 cm), and the Powerline site had an even shallower (4-8 cm) organic layer. The remaining 13 sites contained mixtures of mineral and organic soils.

Table 3.—Average water chemistry measures for 20 wetland sites in West Virginia and Maryland in August 2001. Temperature and dissolved oxygen are standardized to approximate readings at 1200.

Site	Temperature (°C)	DO (% saturation)	pH	Conductivity (mS/cm)	ORP (mV)
ABER	14.8	110.7	5.80	0.141	149.1
ALDR	24.2	97.1	3.68	0.023	255.8
BEAL	11.4	79.1	4.23	0.010	249.7
BIGR	22.7	43.2	3.68	0.034	220.1
COND	17.5	18.4	3.95	0.022	234.9
CRSW	18.5	18.0	4.16	0.035	-3.7
FISH	20.4	31.7	4.82	0.018	134.8
GLAD	23.0	102.3	4.72	0.249	115.6
HAMM	17.3	18.6	5.89	0.133	-24.0
HERZ	21.9	35.7	4.49	0.091	128.7
HIGH	22.1	24.9	5.21	0.025	68.1
MAIN	21.3	53.6	4.43	0.051	251.7
MOOR	18.4	69.4	3.83	0.020	275.6
NORT	21.8	45.0	4.46	0.049	229.1
POWR	25.2	73.2	3.15	0.056	370.0
REDR	17.8	52.6	3.14	0.027	271.5
TRL1	21.6	47.2	3.41	0.012	306.2
TRL2	16.4	59.2	3.21	0.044	320.9

Table 4.—Soil and hydrology measures for 20 sites in West Virginia and Maryland, measured in 2001-2002. Average water table depth computed from measures taken May 2001 – June 2002. Remaining averages based on 3 - 24 soil samples analyzed per site. Categories ">20 cm organic" and ">40 cm organic" refer to percentage of plots with organic depth greater than 20 and 40 cm, respectively.

Site	% Carbon	% Nitrogen	C:N ratio	% Organic matter	Organic depth (cm)	>20 cm organic (%)	>40 cm organic (%)	Mean water table depth (cm)
ABER	18.4	0.96	19.2	38.4	31	100	20	-18.1
ALDR	24	1.37	17.5	50.0	33	100	17	-15.9
BEAL	9.7	0.63	15.4	20.3	20	50	0	-5.1
BIGR	18.7	0.98	19.1	38.9	38	88	38	-0.9
COND	11	0.55	20.1	23.0	52	100	75	-6. 0
CRSW	36.3	1.98	18.3	75.6	74	100	90	-26.8
FISH	19	1.11	17.1	39.5	30	100	0	-9.9
GLAD	27.9	1.59	17.6	58.2	52	91	50	-15.8
HAMM	15.7	1.2	13.1	32.7	55	100	33	-24.3
HERZ	17.4	0.86	20.2	36.2	15	13	13	-13. 0
HIGH	19.3	1.52	12.7	40.1	26	63	13	-15.9
MAIN	33.5	1.3	25.8	69.8	25	63	25	-10.9
MOOR	18.2	0.88	20.7	37.9	39	100	50	-11.4
NORT	20.2	0.88	22.9	42.0	20	50	0	-9
POWR	26.8	1.28	21.0	55.9	6	0	0	-10.8
REDR	30.1	1.33	22.6	62.6	21	100	0	-8.9
TRL1	13.3	0.72	18.5	27.7	17	50	0	-14.8
TRL2	18.8	1.05	17.9	39.2	25	50	0	-17.2
TRL3	24.4	1.37	17.8	50.8	19	33	0	-7.3
YELL	18.6	0.89	20.9	38.8	40	100	75	-11

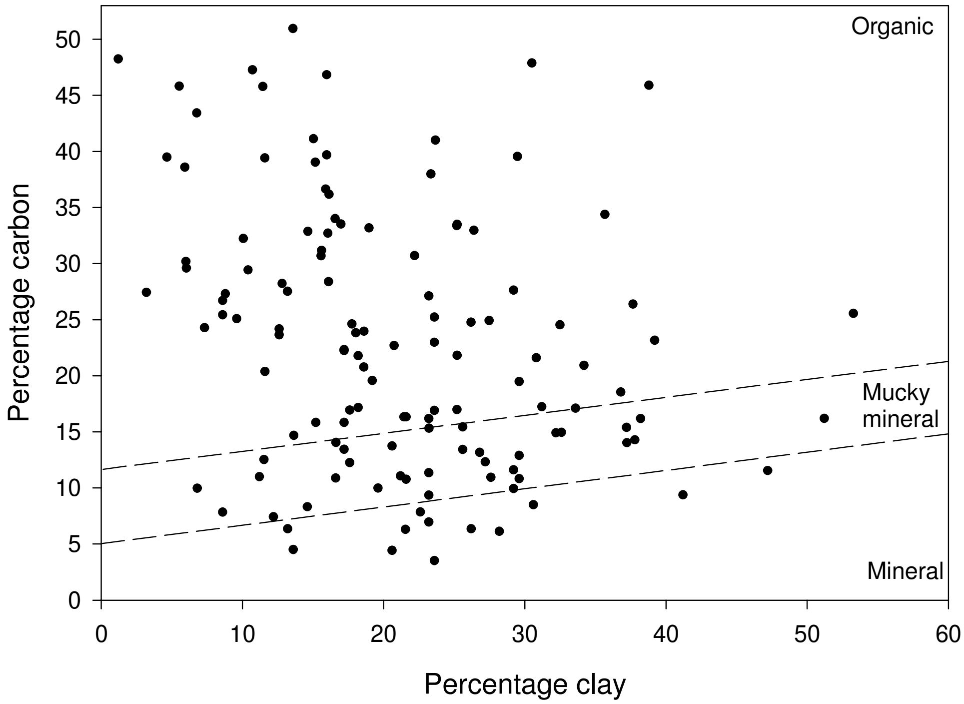

Figure 3,—Percentage organic carbon versus percentage clay for 130 soil samples collected at 10 cm depth in 2001 from the 20 high elevation wetland sites. Soil samples are classified as organic, mineral, or mucky mineral.

Table 5.—Soil texture distribution for 20 wetland sites in West Virginia and Maryland, collected in 2001. Numbers refer to proportion of plots in which textural class existed.

	Clay		Loam					Sand	
Site	clay	sandy clay	clay loam	silty clay loam	sandy clay loam	loam	sandy loam	loamy sand	sand
ABER	–	–	–	–	0.400	–	0.400	0.200	–
ALDR	–	–	–	–	0.333	–	0.667	–	–
BEAL	–	–	–	–	1.000	–	–	–	–
BIGR	–	–	–	0.125	0.625	–	0.250	–	–
COND	–	–	–	–	0.250	–	0.500	0.250	–
CRSW	–	0.200	–	–	0.300	–	0.300	0.200	–
FISH	0.083	0.250	–	–	0.500	–	0.167	–	–
GLAD	–	–	–	–	0.364	–	0.364	0.091	0.182
HAMM	–	–	–	–	–	–	0.667	0.167	0.167
HERZ	0.250	0.250	0.125	–	0.125	–	0.250	–	–
HIGH	–	–	–	–	0.500	0.125	0.250	–	0.125
MAIN	–	–	–	–	0.375	–	0.500	0.125	–
MOOR	0.250	–	–	–	0.250	–	0.250	0.250	–
NORT	–	–	–	–	0.500	–	0.500	–	–
POWR	–	0.333	–	–	0.667	–	–	–	–
REDR	–	–	–	–	–	–	0.333	0.667	–
TRL1	–	–	–	–	1.000	–	–	–	–
TRL2	–	–	–	–	0.333	–	0.333	0.333	–
TRL3	–	–	–	–	–	–	0.667	–	0.333
YELL	–	–	–	–	0.500	–	–	0.500	–

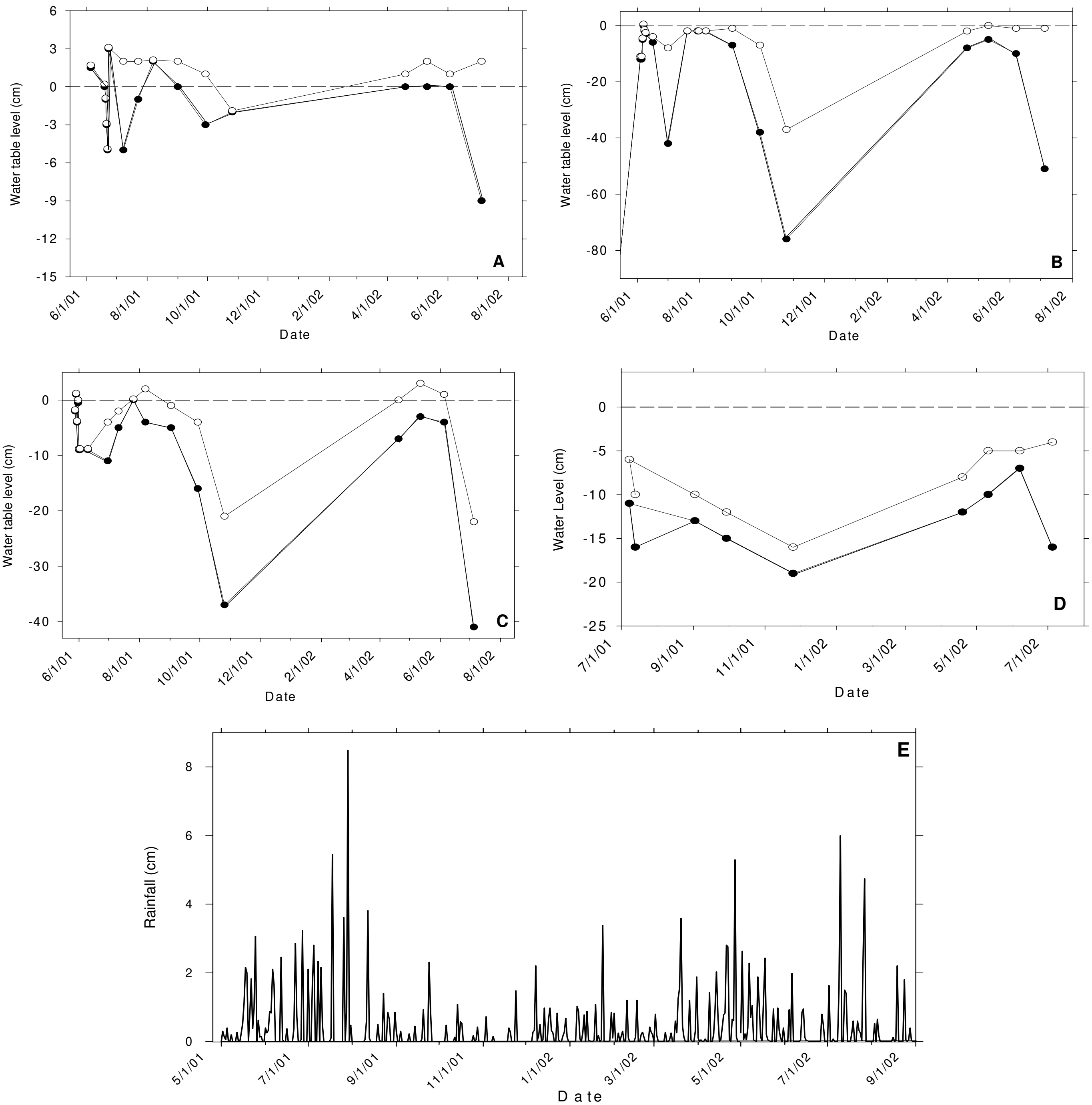

Figure 4.—Water table depth versus time for four wetland sites in the Allegheny Mountains of West Virginia and Maryland, monitored May 2001 – September 2002: (A) BIGR, (B) HERZ, (C) TRL3, and (D) ABER (see text). Solid circles, connected by solid line, indicate current readings taken on specified dates. Open circles plotted above solid circles indicate highest level reached since last reading. Dashed horizontal line indicates soil surface. Also plotted is rainfall hydrograph (E) for sampling period.

Hydrological Measures

Considerable interseasonal variation (Fig. 4B, 4C) to almost no variation (Fig. 4A, 4D) was observed. Eight of the 20 sites showed a marked height decrease (-30 cm) in the water table outside of the growing season. Three sites (Herz Tract, High Ridge, and Trail 2) fell below -50 cm. Using the most restrictive definition of 15 cm from the surface for 5 percent of the year, then 19 of 20 sites met the requirements for a wetland in 2001 and 2002. At the remaining site, Cranesville Swamp, the water table remained approximately 20 cm below the surface for most of the 2001 growing season but met the requirement in the 2002 growing season. Additionally, several areas within 10 m of the installed piezometer remained flooded for a large portion of both seasons.

Long-term precipitation trends revealed that 2001 and 2002 were drier than the long-term average of 134 cm of precipitation per year (Stephenson 1993). The hydrologic years of 2000 (May 2000 – April 2001), 2001 (May 2001 – April 2002) and 2002 (May 2002 – April 2003) recorded 98, 118, and 123 cm of precipitation, respectively. When examining day-by-day records of precipitation for the periods in which piezometers were installed and monitored, it is unclear whether wetland water levels responded to specific rain events (Fig. 4E).

Geologic Interpretation

Fifteen of the study wetlands were dominated by underlying layers from the Pottsville Group, that contain a sandstone and shale layer that is highly erosion-resistant (Table 6, Appendix 2). Two sites in Canaan Valley contained an older sandstone layer from the Pocono group. The three remaining sites, Abe Run, Cranesville Swamp, and Hammel Glade (Garrett County, MD), contained rock from the Greenbrier Group, that includes a significant amount of limestone mixed with sandstone and shale. In an examination of topographical and soil maps, several trends were noted. All sites were situated within small basins, up to 30 m lower in elevation than surrounding landscapes. Additionally, many of the sites were located near the headwaters of streams. Only one site of the 17 examined for mapped soils in West Virginia contained muck and peat—Fisher Springs Run (Dolly Sods, Tucker County, WV). The remaining sites were designated as a variety of series that contain poorly draining and/or acidic soils. These include the Lickdale (deep, poorly-drained soils in upland depressions), Blago (deep, poorly-drained soils formed in acidic conditions and sandstone weathering), and Brinkerton (deep, somewhat poorly drained soils developed in acidic material) series.

Table 6.—Principle underlying geology for 20 wetlands in West Virginia and Maryland. Primary layer indicates that which dominates by wetland area. Secondary and tertiary layers, if present, are found in increasingly smaller portions of the site. Appendix 2 lists code descriptions.

Site	Primary layer	Secondary layer	Tertiary layer
ABER	Mg		
ALDR	Ppv		
BEAL	Mp		
BIGR	Pa	Pk	
COND	Pnr	Pk	
CRSW	Mg	Mp	Mmc
FISH	Pc		
GLAD	Pc	Ppv	Pa
HAMM	Mg	Mmc	Mp
HERZ	Mp		
HIGH	Pk	Pa	Pc
MAIN	Ppv		
MOOR	Pnr	Pk	
NORT	Ppv		
POWR	Ppv		
REDR	Ppv		
TRL1	Ppv		
TRL2	Ppv		
TRL3	Ppv		
YELL	Pnr	Pk	

Comparison Among Vegetation, Soils, and Hydrology

Pearson's correlations revealed significant positive relationships among several vegetative variables (principal components loadings) and water chemistry variables (i.e., pH, dissolved oxygen, conductivity), indicating chemical gradients along vegetative community types (Table 7). Water chemistry factors were closely correlated to one another. For example, increases in pH corresponded to an increase in conductivity and a decrease in redox potential (Table 7). Additionally, pH readings were negatively correlated to average water table depth and the C:N ratio (table 7). Organic matter depth was negatively correlated to the wetland vegetative index, indicating that sites with deeper organic layers contained a greater proportion of wetland-obligate or wetland-facultative species (Table 7). Organic depth also was related positively to the third principal component of the vegetation analysis, indicating a relationship between soil composition and vegetative community composition (Table 7).

In a principal components analysis of vegetation, soils, and hydrology compared in Table 7, the first component explained 33.0 percent of total character variance (figure 5). Variables with high negative loadings for this first component include pH (-0.7324), and conductivity (-0.8433). Water-table depth (0.6395), ORP (0.6996), and the third component of the vegetation PCA (0.7736) exhibited high positive loadings for this component. This component separated out the three Maryland sites, plus Abe Run, from the remaining

Table 7.—Correlation analysis of soil, hydrology, and vegetation measures from 20 wetland sites in West Virginia and Maryland, 2001-2002. Correlation (*r*) listed for each pair with *P*-value in parentheses (*P* ≤ 0.1 in bold).

	Vegetation				Soils and Hydrology								
	Veg. PC III	Veg PC II	Veg. PC I	Wetland Index	ORP	Temp.	Cond'y	DO%	pH	C:N Ratio	Avg. %N	Avg. %C	Organic Depth
Soils/Hydrology													
Mean water depth	0.276	0.028	-0.184	-0.075	**0.489**	0.091	-0.377	-0.008	**-0.388**	0.354	**-0.540**	-0.299	**-0.474**
	(0.238)	(0.907)	(0.438)	(0.752)	**(0.029)**	(0.704)	(0.101)	(0.973)	**(0.091)**	(0.126)	**(0.014)**	(0.201)	**(0.035)**
Organic depth	**-0.595**	0.094	0.007	**-0.530**	**-0.505**	-0.194	0.296	-0.148	0.268	-0.246	0.349	0.173	
	(0.006)	(0.695)	(0.976)	**(0.016)**	**(0.023)**	(0.413)	(0.204)	(0.533)	(0.254)	(0.295)	(0.132)	(0.467)	x
Mean %C	0.057	0.193	-0.156	-0.128	-0.158	**0.378**	0.159	0.028	-0.129	**0.394**	**0.838**		
	(0.811)	(0.415)	(0.510)	(0.590)	(0.507)	**(0.100)**	(0.503)	(0.906)	(0.588)	**(0.085)**	**(0.001)**	x	
Mean %N	-0.210	-0.126	-0.153	-0.224	**-0.505**	0.338	0.241	-0.094	0.136	-0.159			
	(0.375)	(0.598)	(0.520)	(0.342)	**(0.023)**	(0.145)	(0.306)	(0.693)	(0.568)	(0.503)	x		
C:N Ratio	**0.481**	**0.477**	-0.026	0.130	**0.542**	0.205	-0.103	0.166	**-0.441**				
	(0.032)	**(0.033)**	(0.912)	(0.585)	**(0.013)**	(0.386)	(0.664)	(0.485)	**(0.052)**	x			
pH	**-0.518**	-0.279	**0.479**	-0.150	**-0.755**	-0.241	**0.483**	-0.086					
	(0.019)	(0.233)	**(0.033)**	(0.529)	**(0.001)**	(0.306)	**(0.031)**	(0.718)	x				
DO%	-0.161	0.216	**0.446**	0.296	**0.468**	-0.058	**0.405**						
	(0.499)	(0.360)	**(0.049)**	(0.204)	**(0.038)**	(0.807)	**(0.077)**	x					
Conductivity	**-0.662**	0.235	0.307	0.102	-0.330	0.070							
	(0.001)	(0.318)	(0.188)	(0.669)	(0.155)	(0.770)	x						
Temperature	0.177	-0.070	**-0.409**	0.073	0.093								
	(0.455)	(0.771)	**(0.073)**	(0.758)	(0.697)	x							
ORP	**0.553**	0.214	-0.106	**0.399**									
	(0.011)	(0.366)	(0.657)	**(0.081)**	**x**								
Vegetation													
Wetland Index	0.443	0.150	0.356										
	(0.051)	(0.529)	(0.123)	x									
Veg. PC I	0.000	0.000											
	(1.000)	(1.000)	x										
Veg. PC II	0.000												
	(1.000)	x											

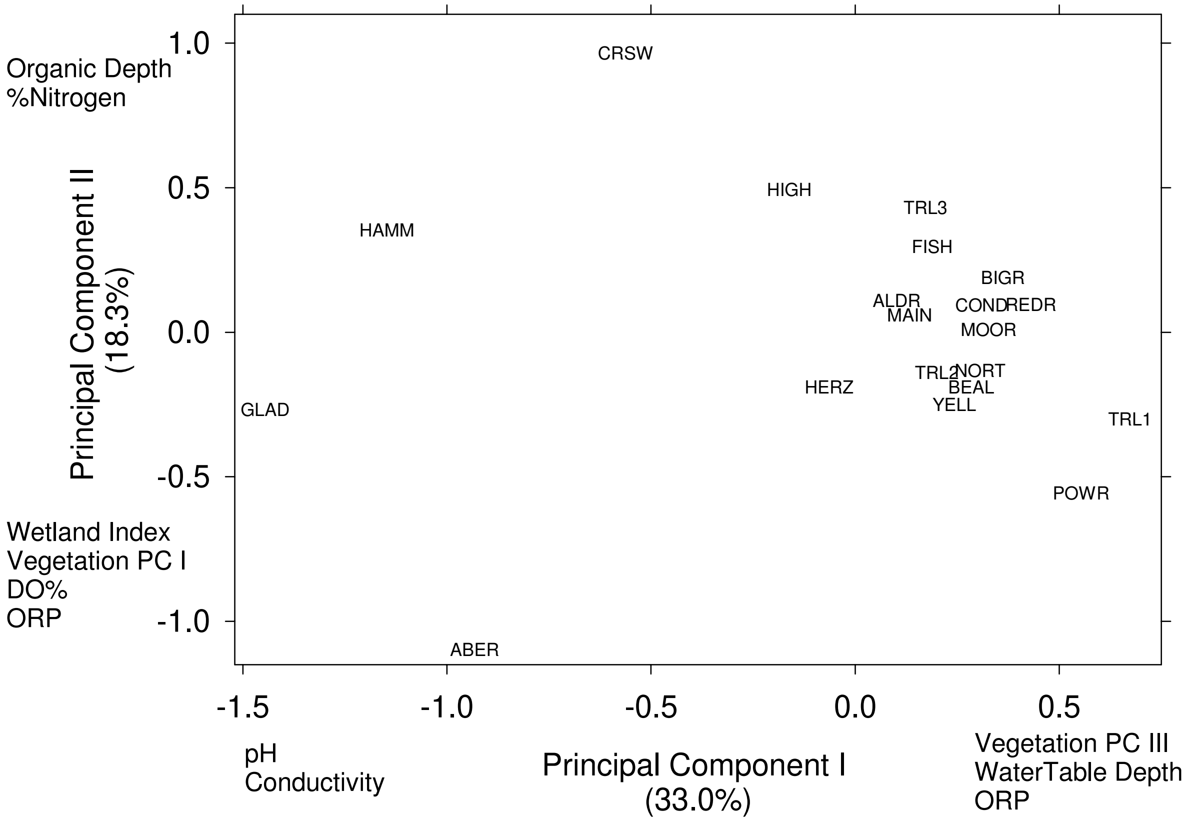

Figure 5.—Principal components analysis of vegetation, soils, and hydrology at the 20 wetland sites. Variables exhibiting high positive or negative loadings listed on appropriate axes.

wetlands. The second component explained 18.3 percent of total character variance. Nitrogen percentage (0.5049) and the organic layer depth (0.4676) exhibited high positive loadings on this axis, whereas percent dissolved oxygen (-0.7318), ORP (-0.5315), wetland index (-0.7021), and the first component of the vegetation PCA (-0.5929) had high negative loadings. This component separated Abe Run and Cranesville Swamp (at opposite extremes) from the remaining sites. The third component explained 14.7 percent of total character variance, but no major trends among sites or among variables were evident.

Discussion

Assessment of Current Data

When examining vegetation, soils, and hydrology as a whole, all sites fit the biological definition of a wetland (Cowardin et al. 1979). Nearly all sites (18 of 20) exhibited wetland vegetative index values less than 2.5, and those with values more than 2.5 met all hydrology and hydric soils requirements. Topography and geology appear to be the driving factors for the presence and condition of these wetlands. Topographically, all sites were situated within locally concave pockets, which provide a pooling site for precipitation and encourage growth of wetland-obligate and wetland-facultative vegetation. Geologically, 17 of the 20 sites are underlain by a hard sandstone and shale layer that impedes drainage and encourages water table levels to be near the soil surface. The remaining three sites, Abe Run, Hammel Glade, and Cranesville Swamp, also contain limestone, which typically is associated with less acidic soils. This was true for Abe Run and Hammel Glade, whose soil pH readings were markedly higher (5.80 and 5.89, respectively) than other sites. However, at the sample sites chosen for Cranesville Swamp, Pocono Sandstone overlaid the Mauch Chunk (limestone) layer. Therefore, the direct influence of limestone was not represented in the soil pH.

Piezometer data revealed that most sites are hydrologically similar. Nearly all wetlands maintained a water table at or near the surface for substantial portions of the 2001 and 2002 growing seasons. Hydrologic data indicate that these study years, and the few preceding them, were relatively dry when compared to long-term trends. Though we acknowledge that the difference in elevation between recording stations at Canaan Valley and Beardon Knob might account for some of the differences in precipitation, the recent years were still markedly drier than normal. Thus, despite the lower precipitation recorded in each year, these sites still maintained water table levels at appropriate levels for typical wetlands.

It appears that even sites greatly influenced by limestone contain an underlying clay or rock layer that maintained a perched water table. Therefore, bedrock might not directly influence the presence of a wetland in all cases, but clearly affects localized soil chemistry (Webb et al. 1997).

Webb et al. (1997) acknowledged that bedrock type influences water chemistry and soils. Because vegetation communities partially are driven by soil properties, one would observe an indirect relationship between the bedrock layer and vegetation distribution. Indeed, we found that many of these study sites are similar for a number of vegetation, soils, and hydrology parameters.

These wetlands exhibited a great deal of intrasite variability, in terms of soil texture, organic-layer depth, and nutrient concentrations. Even sites smaller than 2 ha contained up to three soil textural classes and a variable range of organic depths (e.g., 5-30 cm at Beall Tract, 27-100+ cm at Hammel Glade). Similarly, Darlington (1943) found 2 m differences in peat depth across Cranberry Glades. Intrasite variation could be attributed to many physical and geological factors recorded at our sites, including direct input from creeks, local underlying rock types, or slight elevational changes, which would influence depth to the water table. The frequency of fire also would regulate peat accumulation in these systems. It is possible that sizeable within-site differences could be found with additional survey work that examined the organic layer below 1 m.

Previous estimates of peatland area failed to acknowledge the presence of histosols in West Virginia, indicating that many of the smaller wetlands examined here were overlooked (Soil Survey Staff, 1998b). However, the presence of histosols at more than half the sites (including six sites less than or equal to 5 ha) illustrates the lack of small-scale scrutiny.

Therefore, wetland size appears to be an influential factor in delineating wetlands, but fails to acknowledge the equally important smaller sites that show similar wetland soil characteristics. Additionally, vegetative assessments showed that wetland size did not influence the number of species per unit area or the diversity index, emphasizing that small wetlands should not be overlooked in preservation efforts.

Wetlands: Past and Present

A review of the geologic literature available for this region supports our findings for the presence and formation of these wetlands. Diehl's (1981) examination of 49 wetlands in the unglaciated Allegheny Plateau (west-central West Virginia) and the Allegheny Mountain (eastern West Virginia) provinces revealed that hard sandstone layers directly underlie the majority of sites within our study area. These wetlands often are at headwaters of mature rivers that travel across originally flat-lying strata. Typically, water flows across these horizontal, unsloped strata until a basin is eroded away and water ponds up. The basin reaches its maximum depth when eroding strata, such as Mauch Chunk or Greenbrier limestone, are removed and less penetrable sandstone layers are exposed (Diehl 1981). Given the low permeability of some sandstones, the water table becomes perched and can reach the surface.

Given the stable geology of the systems, one must examine other factors that have shaped the current state of these wetlands. Logging of red spruce forests a century ago markedly altered the landscape. Additionally, wetlands in the Dolly Sods Scenic Area and Cranesville Swamp were influenced by livestock grazing, fire, beaver activity, and anthropogenic species introductions (Fortney 1975). Furthermore, the impact of exotic insects such as the balsam woolly adelgid, (*Adelges piceae*) or hemlock woolly adelgid, (*Adelges tsugae*), heavy deer browse on saplings, and recent human activities, such as coal mining and subsequent acid-mine drainage, inhibits some species' ability to sustain healthy populations (Michael 2000). One site in particular, the Glades, has been notably impacted by acid mine drainage and is currently undergoing long-term remediation (West Virginia Department of Environmental Protection 1997).

Validation for Wetland Preservation

When Fortney (1975) studied the plant communities of Canaan Valley, he found that some wetland habitats contained the highest plant species diversity. Speckled alder (*Alnus incana*) thickets, such as those found at Alder Run (Dolly Sods, Tucker County, WV), High Ridge, and the Glades, commonly contained at least 45 associated species of herbaceous vegetation. Other associations dominated by meadowsweet (*Spiraea alba*) or shrubby St. John's wort (*Hypericum densiflorum*), such as Herz Tract, may contain fewer plant species, but provide sufficient cover and nesting sites for several uncommon small mammals (Fortney 1993), including meadow jumping mice (*Zapus hudsonius*) and southern bog lemmings (*Synaptomys cooperi*). Wetlands containing open water, including Moore Run (Otter Creek, Randolph County, West Virginia) and Fisher Springs, also are valuable sites for breeding herpetofauna (Semlitsch and Bodie 1998).

In our study, we found that small, isolated wetlands exhibit hydrological and soil characteristics similar to larger, recognized sites and serve as patchily distributed refugia for wetland-obligate species in the area. Semlitsch and Bodie (1998) address the importance of small wetlands in the Southeast, emphasizing that they are not expendable if regional biodiversity is to be maintained. Sites smaller than 1.2 ha comprised 46.4 percent of the 371 Carolina bays examined, and nearly 90 percent were less than 4.0 ha. Similar high proportions were found in Maine wetlands, in which 62 percent of the sites were < 4.05 ha (Gibbs 1993). Small wetlands such as these are significant contributors to amphibian species richness and diversity, and harbor large numbers of wetland plants and aquatic insects with limited dispersal abilities (Semlitsch and Bodie 1998). The destruction of such habitats would increase dispersal distances between suitable sites and likely isolate these plants and animals from larger wetlands serving as source populations. As local extinction rates increased, genetic diversity could decline (Semlitsch and Bodie 1998). Lower genetic diversity would mean that the ability of a species to adapt to changing environmental conditions also would decrease (Hansen et al. 2001).

Legal Implications

Isolated wetlands are considered some of the most important and threatened ecosystems in the country (Osmond et al. 1995). Unfortunately, few state or federal laws protect them. Since a 2001 U.S. Supreme Court's decision (*Solid Waste Agency of Northern Cook County v. U.S. Army Corp of Engineers*), Section 404 of the Clean Water Act no longer protects isolated wetlands such as those examined in this study (Bedford and Godwin 2003). Because the U.S. Army Corps of Engineers lacks jurisdiction over isolated sites, like those in this study, any further regulation must be the responsibility of the states (through Section 404(g)), which may implement their own permit programs over non-navigable waters (Osmond et al. 1995). However, no recognized statutes or programs in West Virginia have been created explicitly to protect isolated wetlands as has been done in many states (Christie and Hausman 2003), unless affected by acid mine drainage from coal-mining operations (West Virginia Annotated Code § 22-11-7a, 2001). In Maryland, state wetlands law is limited to navigable waters, and reiterates similar restrictions of the federal Clean Water Act.

Due to the lack of explicit legal protection of isolated wetlands, it is important to determine how central Appalachian wetlands should be protected. The selected study sites are either government-owned (e.g., part of the Monongahela National Forest, Canaan Valley National Wildlife Refuge, Canaan Valley Resort State Park) or privately owned by The Nature Conservancy. Both owner-types protect the sites through government regulations or self-regulated policies. However, many privately owned wetlands exist within this region and do not fall under any protection guidelines (Diehl 1981, Ingham 1996). Currently, the conventional method to preserving wetlands regionally on private property is for private conservation groups, such as The Nature Conservancy, or governmental agencies to purchase the land. In 2002, the USDI Fish and Wildlife Service purchased a large parcel in Canaan Valley from Allegheny Power, increasing the refuge's total wetlands to 2175 ha[3]. However, not all wetlands can be or should be purchased and preserved by public means. Potentially beneficial programs include educating private landowners in the utility of these wetlands (e.g., floodwater storage and filtration of heavy metals and organic materials) or exploring potential future financial incentives through mitigation banking or carbon sequestration.

Conclusions

Although other researchers have studied several of these wetlands previously, our study is the first to compare a large number of sites on a quantitative basis. Many of the quantitative differences could be explained qualitatively in terms of geology and topography. These two factors combined to create favorable conditions for wetlands. Variability in geology led to differentiation among vegetative communities and soil and water properties.

These data support previous research, in that central Appalachian fens and bogs are similar to boreal bogs and fens of the northern United States and Canada. There exists an overlap of many vegetative species and chemical characteristics. However, all study sites from the central Appalachians lacked the concentric zonation of many northern bogs and exhibited a greater degree of within-site variation in terms of soil texture, organic depth, and distribution of vegetation. Moorhead and Rossell's (1998) description of southern Appalachian sites as an "irregular mosaic" also appears to fit these 20 central Appalachian wetlands (Wieder et al. 1981).

Based upon the survey of vegetation, soils, and hydrology, we conclude that all sites qualify as wetlands.

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[3]Sturm, K. 2003. Personnal communication. Wildlife Biologist, U.S. Fish and Wildlife Service, Canaan Valley National Wildlife Refuge, HC 70 Box 200, Davis, WV 26260.

Future management decisions should incorporate the impacts on these isolated systems when making landscape-level changes. Furthermore, wetland size should not be a determining factor in decisions to preserve sites, as we have shown that small wetlands are just as important ecologically as thelarger counterparts. Localized management efforts, such as removing invading upland or exotic species or minimizing foot traffic in these wetlands, might be necessary. However, in most cases simple preservation and protection may be the best tool to sustain or reach desired conditions.

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Appendix 1

Plants collected in vegetation surveys in 2001 at 20 wetlands in West Virginia and Maryland. Names listed in accordance with PLANTS database (USDA—NRCS, 2002). Values indicate ecological indicator values used in weighted analyses.

Family	Scientific name	Author	Value
Non-vascular plants			
Amblystegiaceae	*Hygrohypnum eugyrium*	(Schimp. in B.S.G.) Loeske	
Dicranaceae	*Dicranum scoparium*	Hedw.	
Fontinalaceae	*Fontinalis dalecarlica*	Schimp. in B.S.G.	
Hypnaceae	*Hypnum imponens*	Hedw.	
Lepidoziaceae	*Bazzania trilobata*	(L.) Gray	
Leucobryaceae	*Leucobrym albidum*	(Brid. ex P. Beauv.) Lindb.	
Leucobryaceae	*Leucobrym glaucum*	(Hedw.) Angstr.	
Polytrichaceae	*Polytrichum commune*	Hedw.	
Scapaniaceae	*Scapania undulata*	(L.) Dumort.	
Sphagnaceae	*Sphagnum capillifolium*	(Ehrh.) Hedw.	1.00
Sphagnaceae	*Sphagnum fallax*	(Klinggr.) Klinggr.	1.00
Sphagnaceae	*Sphagnum palustre*	L.	1.00
Sphagnaceae	*Sphagnum* sp.		1.00
Vascular plants			
Aceraceae	*Acer pensylvanicum*	L.	4.00
Aceraceae	*Acer rubrum*	L.	3.00
Aquifoliaceae	*Ilex montana*	Torr. & Gray ex Gray	
Aquifoliaceae	*Ilex verticillata*	(L.) Gray	1.67
Aquifoliaceae	*Nemopanthus mucronatus*	(L.) Loes.	1.00
Araceae	*Arisaema triphyllum*	(L.) Schott	2.33
Araceae	*Orontium aquaticum*	L.	1.00
Araceae	*Symplocarpus foetidus*	(L.) Salisb. ex Nutt.	1.00
Asclepiadaceae	*Asclepias syriaca*	L.	4.33
Aspleniaceae	*Asplenium montanum*	Willd.	5.00
Asteraceae	*Achillea millefolium*	L.	4.00
Asteraceae	*Symphyotrichum praealtum* var. *praealtum*	(Poir.) Nesom	2.00
Asteraceae	*Symphyotrichum puniceum* var. *puniceum*	(L.) A.& D. Löve	1.00
Asteraceae	*Eupatorium fistulosum*	Barratt	2.00
Asteraceae	*Euthamia graminifolia*	(L.) Nutt.	3.00
Asteraceae	*Leucanthemum vulgare*	Lam.	5.00
Asteraceae	*Solidago rugosa*	P. Mill	3.00
Asteraceae	*Solidago uliginosa*	Nutt.	1.00
Balsaminaceae	*Impatiens capensis*	Meerb.	2.00
Betulaceae	*Alnus incana* ssp. *rugosa*	(L.) Moench (Du Roi) Clausen	2.00
Betulaceae	*Betula lenta*	L.	4.00
Betulaceae	*Betula nigra*	L.	2.00
Caprifoliaceae	*Viburnum dentatum*	L.	3.00
Caprifoliaceae	*Viburnum nudum*	L.	1.00
Caryophyllaceae	*Galium obtusum*	Bigelow	1.67
Caryophyllaceae	*Stellaria graminea*	L.	4.33
Clusiaceae	*Hypericum canadense*	L.	2.00
Clusiaceae	*Hypericum densiflorum*	Pursh	2.67

Continued

Appendix 1—continued.

Family	Scientific name	Author	Value
Clusiaceae	*Hypericum ellipticum*	Hook	1.00
Clusiaceae	*Hypericum mutilum*	L.	2.00
Clusiaceae	*Hypericum punctatum*	Lam.	3.33
Clusiaceae	*Hypericum* sp.		
Clusiaceae	*Triadenum virginicum*	(L.) Raf.	1.00
Convolvulaceae	*Ipomoea* sp.		
Cyperaceae	*Carex atlantica* ssp. *atlantica*	Bailey	1.67
Cyperaceae	*Carex baileyi*	Britt.	1.00
Cyperaceae	*Carex brunnescens*	(Pers.) Poir.	2.00
Cyperaceae	*Carex canescens*	L.	1.00
Cyperaceae	*Carex debilis*	Michx.	3.00
Cyperaceae	*Carex echinata*	Murr.	1.00
Cyperaceae	*Carex folliculata*	L.	1.00
Cyperaceae	*Carex gynandra*	Schwein.	1.00
Cyperaceae	*Carex hirtifolia*	Mackenzie	
Cyperaceae	*Carex interior*	Bailey	1.00
Cyperaceae	*Carex leptalea*	Wahlenb.	1.00
Cyperaceae	*Carex lurida*	Wahlenb.	1.00
Cyperaceae	*Carex normalis*	Mackenzie	4.00
Cyperaceae	*Carex pauciflora*	Lightf.	1.00
Cyperaceae	*Carex rostrata*	Stokes	1.00
Cyperaceae	*Carex scoparia*	Schkuhr ex Willd.	2.00
Cyperaceae	*Carex stipata*	Muhl. ex Willd.	1.00
Cyperaceae	*Carex trisperma*	Dewey	1.00
Cyperaceae	*Carex vesicaria*	L.	1.00
Cyperaceae	*Eleocharis tenuis*	Willd.) J.A. Schultes	1.67
Cyperaceae	*Eriophorum virginicum*	L.	1.00
Cyperaceae	*Rhynchospora alba*	(L.) Vahl	1.00
Cyperaceae	*Scirpus atrocinctus*	Fern.	1.67
Cyperaceae	*Scirpus cyperinus*	(L.) Kunth	1.67
Dennstaedtiaceae	*Pteridium aquilinum*	(L.) Kuhn	4.00
Droseraceae	*Drosera rotundifolia*	L.	1.00
Dryopteridaceae	*Dryopteris cristata*	(L.) Gray	1.67
Dryopteridaceae	*Dryopteris intermedia*	(Muhl. ex Willd.) Gray	4.00
Dryopteridaceae	*Dryopteris marginalis*	(L.) Gray	4.33
Dryopteridaceae	*Dryopteris* x *boottii*	(Tuckerman) Underwood (pro sp.)	2.00
Dryopteridaceae	*Onoclea sensibilis*	L.	2.00
Ericaceae	*Epigaea repens*	L.	
Ericaceae	*Gaultheria hispidula*	(L.) Muhl. ex Bigelow	2.00
Ericaceae	*Gaultheria procumbens*	L.	4.00
Ericaceae	*Kalmia latifolia*	L.	4.00
Ericaceae	*Rhododendron maximum*	L.	3.00
Ericaceae	*Vaccinium angustifolium*	Ait.	4.00
Ericaceae	*Vaccinium corymbosum*	L.	2.33
Ericaceae	*Vaccinium macrocarpon*	Ait.	1.00
Ericaceae	*Vaccinium myrtilloides*	Michx.	3.00
Ericaceae	*Vaccinium oxycoccos*	L.	1.00
Ericaceae	*Vaccinium pallidum*	Ait.	2.33
Fabaceae	*Trifoluim* sp.		

Continued

Appendix 1—continued.

Family	Scientific name	Author	Value
Fagaceae	*Quercus rubra*	L.	4.33
Gentianaceae	*Gentiana linearis*	Froel.	1.00
Hamamelidaceae	*Hamamelis virginiana*	L.	4.00
Iridaceae	*Sisyrinchium angustifolium*	P.Mill.	2.33
Juncaceae	*Juncus brevicaudatus*	(Engelm.) Fern.	1.00
Juncaceae	*Juncus canadensis*	J. Gay ex Laharpe	1.00
Juncaceae	*Juncus effusus*	L.	1.67
Juncaceae	*Juncus subcaudatus*	(Engelm.) Coville & Blake	1.00
Juncaceae	*Juncus* sp.		
Juncaceae	*Luzula acuminata*	Raf.	3.00
Lamiaceae	*Lycopus uniflorus*	Michx.	1.00
Liliaceae	*Veratrum viride*	Ait.	1.67
Lycopodiaceae	*Lycopodium clavatum*	L.	3.00
Lycopodiaceae	*Lycopodium obscurum*	L.	4.00
Nyssaceae	*Nyssa sylvatica*	Marsh	3.00
Oenagraceae	*Ludwigia palustris*	(L.) Ell.	1.00
Oleaceae	*Fraxinus pennsylvanica*	Marsh	2.00
Onagraceae	*Oenothera fruticosa*	L.	3.00
Ophioglossaceae	*Ophioglossum vulgatum*	L.	2.00
Orchidaceae	*Cypripedium acaule*	Ait.	4.33
Orchidaceae	*Habenaria clavellata*	(Michx.) Luer	3.67
Orchidaceae	*Spiranthes cernua*	(L.) L.C. Rich.	2.00
Osmundaceae	*Osmunda cinnamomea*	L.	2.00
Oxalidaceae	*Oxalis stricta*	L.	5.00
Pinaceae	*Abies balsamea*	(L.) P. Mill.	3.00
Pinaceae	*Picea abies*	(L.) Karst.	
Pinaceae	*Picea rubens*	Sarg.	4.00
Pinaceae	*Pinus resinosa*	Soland.	4.00
Pinaceae	*Pinus rigida*	P. Mill	4.00
Pinaceae	*Pinus strobus*	L.	4.00
Pinaceae	*Tsuga canadensis*	(L.) Carr.	4.00
Poaceae	*Agrostis gigantea*	Roth	2.33
Poaceae	*Anthoxanthum odoratum*	L.	4.00
Poaceae	*Avena sativa*	L.	N/A
Poaceae	*Brachyelytrum erectum*	(Schreb. ex Spreng.) Beauv.	N/A
Poaceae	*Calamagrostis canadensis*	(Michx.) Beauv.	1.67
Poaceae	*Danthonia spicata*	(L.) Beauv. ex Roemer & J.A. Schultes	4.00
Poaceae	*Dichanthelium acuminatum*	(Sw.) Gould & C.A. Clark	2.00
Poaceae	*Dichanthelium clandestinum*	(L.) Gould	2.67
Poaceae	*Dulichium arundinaceum*	(L.) Britt.	1.00
Poaceae	*Glyceria melicaria*	(Michx.) F.T. Hubbard	1.00
Poaceae	*Glyceria striata*	(Lam.) A.S. Hitchc.	1.00
Poaceae	*Lolium perenne*	L.	4.33
Poaceae	*Phalaris arundinacea*	L.	2.00
Poaceae	*Phleum pratense*	L.	4.00
Polemoniaceae	*Polemonium vanbruntiae*	Britt.	2.00
Polygonaceae	*Polygonum persicaria*	L.	2.00
Polygonaceae	*Polygonum sagittatum*	L.	1.00

Continued

Appendix 1—continued.

Family	Scientific name	Author	Value
Polygonaceae	*Rumex acetosella*	L.	5.00
Ranunculaceae	*Caltha palustris*	L.	1.00
Rosaceae	*Amelanchier laevis*	Wieg.	2.33
Rosaceae	*Crataegus* sp.		
Rosaceae	*Dalibarda repens*	L.	3.00
Rosaceae	*Photinia floribunda*	(Lindl.) Robertson & Phipps	2.00
Rosaceae	*Photinia melanocarpa*	(Michx.) Robertson & Phipps	3.00
Rosaceae	*Potentilla norvegica*	L.	4.00
Rosaceae	*Potentilla simplex*	Michx.	4.33
Rosaceae	*Prunus serotina*	Ehrh.	4.00
Rosaceae	*Prunus* sp.		
Rosaceae	*Rosa multiflora*	Thunb. ex Murr.	4.00
Rosaceae	*Rubus–blackberry group*		
Rosaceae	*Rubus–dewberry group*		2.00
Rosaceae	*Spiraea alba*	Du Roi	1.67
Rosaceae	*Spiraea tomentosa*	L.	2.33
Salicaceae	*Populus tremuloides*	Michx.	
Salicaceae	*Salix alba*	L.	2.00
Salicaceae	*Salix nigra*	Marsh	1.67
Salicaceae	*Salix sericea*	Marsh	1.00
Sarraceniaceae	*Sarracenia purpurea*	L.	1.00
Sparganiaceae	*Sparganium erectum* ssp. *stoloniferum*	(Graebn.) Hara	1.00
Thelypteridaceae	*Thelypteris palustris*	Schott	1.67
Thelypteridaceae	*Thelypteris simulata*	(Davenport) Nieuwl.	2.00
Typhaceae	*Typha latifolia*	L.	1.00
Betulaceae	*Betula alleghaniensis*	Britt.	3.00
Ulmaceae	*Ulmus* sp.		
Violaceae	*Viola* sp.		

Appendix 2

Key to geologic codes and dominant rock types within each group or formation. Geologic periods and rock strata listed from youngest to oldest in geologic time. General lithology also listed for each category (as described by Webb et al. 1997).

Geologic Period	Group	Formation	General Lithology	Code
Upper Pennsylvanian	Conemaugh		67% Shale/clay; 28% Sandstone; 4% Coal; 1% Limestone	Pc
Middle Pennsylvanian		Allegheny	63% Sandstone, 22% Shale/clay, 10% Coal, 5% Limestone	Pa
Lower Pennsylvanian	Pottsville		Sandstone (some conglomeratic), Shale, Coal	Ppv
Lower Pennsylvanian	Pottsville	Kanawha	73% Sandstone, 21% Shale/clay, 4% Coal, 0-2% Limestone	Pk
Lower Pennsylvanian	Pottsville	New River	72% Sandstone, 23% Shale/clay, 5% Coal	Pnr
Upper Mississippian	Mauch Chunk		63% Shale/clay, 33% Sandstone, 4% Limestone	Mmc
Middle Mississippian	Greenbrier Limestone		94% Limestone, 4% Shale/clay, 2% Sandstone	Mg
Lower Mississippian	Pocono		Sandstone, shale	Mp

Francl, K.E.; Ford, W.M.; and Castleberry, S.B. 2004. **Characterization of high elevation central Appalachian wetlands.** Res. Pap. NE-725. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 26 p.

We characterized 20 high elevation wetlands in the central Appalachian Mountains in West Virginia and Maryland, in terms of vegetation, soils, hydrology, and geology. Plant species were distributed along soil chemical (pH, conductivity) and physical (organic matter depth) gradients across sites. Topography and geology appear to explain differences among these wetlands, as reflected by soil and chemistry measures and vegetation distribution. Our work provides substantial quantitative baseline data for these uncommon high elevation wetlands, emphasizing the importance and diversity of these isolated systems.

Key Words: bog, central Appalachian Mountains, fen, geology, hydric soils, hydrophytic vegetation, wetland characterization

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