Vegetation of geographically isolated montane non-alluvial wetlands of the southern Blue Ridge of North Carolina

by
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ABSTRACT

WICHMANN, BRENDA LYNN. Vegetation of geographically isolated montane non-alluvial wetlands of the southern Blue Ridge of North Carolina. (Under the direction of Thomas R. Wentworth.)

The ecological significance of montane non-alluvial wetlands in the southern Blue Ridge region of North Carolina is well known. However, there is relatively little quantitative documentation of these community types. In particular, our understanding of montane, peat-forming wetlands is based primarily on qualitative data, and there has been no previous comprehensive classification and description of these community types. In this study, species composition and vegetation-environment relationships are described for the geographically-isolated, non-alluvial wetlands of the southern Blue Ridge region of North Carolina. A hierarchical classification is presented for 12 community types within 2 broad vegetation classes based on 136 vegetation plots spanning the range of the southern Blue Ridge region of North Carolina. Hierarchical cluster analysis was used to delimit community types, and non-metric multidimensional scaling was subsequently used to help differentiate the community types identified by the cluster analysis. Although some of these community types fit well within currently recognized community concepts, others fit poorly within existing concepts, pointing to a need for definition of new types and/or significant refinement of types currently recognized. The 2 broad vegetation classes and 12 community types are discussed, each with a description of composition, related community concepts, and environmental context. Compositional variation among the types is most strongly associated with elevation, soil pH, soil nutrient availability, and soil cation exchange capacity.
DEDICATION

To my late Grandmother, Virnette Colleen Herrmann, whom, I believe, cultivated my passion for botany at a very early age. When I was as young as 4 years old, she explained to me why I should not pick the wild flowers…because they will not make seed for baby flowers to grow and one day all the flowers will be gone. Here’s to all the wonderful moments spent with my grandmother, especially those at ‘Endlich’ (at last), which I cherish the most.

To the late Robert Gardener, a dear friend and mentor with whom I spent countless hours in the garden learning and chatting. My dear friend left this world, after a long fight, during the summer of 2006, while I was away collecting data for the research presented in this thesis. To Rob, an amazing person with good spirits, who always knew how to have fun, and who had exceptional talent in the garden. Good-bye my friend. I miss our Saturday mornings together and will always cherish the memories.

Virnette C. Herrmann
November 15, 1928 - December 11, 1993

Robert K. Gardner
May 6, 1949 – August 2006
I am western girl disjunct in the South. I was born and raised outside of Denver, Colorado (Westminster, 80021) and spent a lot of time in the Rocky Mountains. My parents are wonderful. My brother and sister are wonderful. I grew up in a supportive and loving family. My grandparents, aunts, cousins, sister, brother, mom and dad made my life enjoyable and exciting. Determination and excellence were encouraged, always with support. Adventure and fun were typical. We spent time together, outdoors and indoors. I have fond memories of the Rocky Mountains, camping, fishing, relaxing, and botanizing. I cherish the memories of my grandmother, whom I believe, along with my father, cultivated my passion for botany at a very young age. I've always been a dedicated and passionate person, reaching for the stars with all my might. I was a passionate and serious athlete and that taught me a lot. My youthful aspirations were to excel both academically and athletically. My parents encouraged and supported both academic and athletic excellence; success at both (and all) endeavors was expected to be possible with determination and hard work. My family is the reason that I am where I am today. I would have never made it here without them. My parents spent their life encouraging my dreams (along with those of my brother and sister), weekends were spent at the soccer field, and money was spent on my education and soccer career. So long as I can remember, I've wanted to be both an Olympic soccer player and a professional botanist. My parents never told me to expect anything less. I generally succeeded. I played soccer at the collegiate level (DI, Southern Conference, Wofford College) and I became a botanist. I only wish my family were not so far away. I am still passionate about athletics, soccer in particular. I will play soccer so as long as I can
run. I understand the importance of athletics to society, accepting the environmental impacts that such activities have on the earth. I will always be a passionate botanist, no matter where my career might take me. I love adventure and discovery and hope only for more of both. I love my husband and our cats. I love my parents and my brother and my sister. I love my friends and my local community. My life is enjoyable. If I should discover, describe, and name a new plant taxon, I will have lived.
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INTRODUCTION

Vegetation description and classification, as well as the interpretation of vegetation-environment relationships, play key roles in scientific research, conservation, and natural resource management (Peet et al. 1998). Vegetation classification systems provide conceptual frameworks for understanding ecological and evolutionary relationships among species and environment from local to regional scales (Carr et al. *in press*). The information embedded in such systems is essential to scientists interested in a better understanding of how vegetation varies through time and with respect to local conditions (Peet et al. 1998). The same information informs professionals working to document patterns of biodiversity, to determine its current status, to predict its responses to global environmental change, and to identify the most effective approaches for *in situ* conservation and sustainable use (Gaston 2000).

Geographically isolated montane non-alluvial wetlands of the southern Blue Ridge region of North Carolina are endangered ecosystems (Noss et al. 2005) that support high biological diversity and numerous disjunct and regionally rare species (Richardson and Gibbons 1993). These are small wetlands, surrounded by terrestrial vegetation, occurring in localized areas where hydrology dominated by seepage, high water table, or paludification allows for the development of *Sphagnum* moss and the accumulation of peat or muck soils (Weakley and Schafale 1994, Schafale and Weakley 1990, and Moorhead et al. 2000). These wetlands occupy four principal landscape positions: headwater regions of small streams, stream valleys no longer subject to flooding, slopes intercepting the water table and subject to constant seepage from groundwater, and isolated locations over resistant rock strata.
(Moorhead et al. 2000, Weakley and Schafale 1994, and Walbridge 1994). They span six degrees of latitude and are found across an elevation range of 1,800 m; each wetland has distinct geological, chemical, and physical characteristics (Moorehead and Rossell 1998), creating a situation fostering high floristic variation at both local and regional scales.

The soil chemistry and plant assemblages of these peat-accumulating wetlands resemble the bogs and fens found in the northern latitudes of North America and Europe, but their ontogeny is quite different and they were not influenced directly by continental glacial recession (Ingham 1996 in Francl et al. 2004, Warren et al. 2004, and Thompson et al. 2007).

The unique combination of climatological and geological components typical of the southern Blue Ridge region of North Carolina help to explain the formation of peat-accumulating wetlands south of their general regional climatic limit (40° N. latitude). Cooler air and soil temperatures and increased precipitation, often leading to areas of precipitation exceeding evapotranspiration typical of high elevations (> 800m) of the southern Blue Ridge region, mimic northern climates (Francl et al. 2004 in Thompson et al. 2007); the typical acidic substrate and localized areas with high connectivity to groundwater encourage the formation of Sphagnum-dominated wetlands (Halsey et al. 2000).

Non-alluvial wetlands are rare in the southern Blue Ridge region, not only because of relatively recent loss through human modification of the landscape (~90% since European settlement) but also because the generally steep and topographically mature landscape typical of the region is not favorable for extensive wetland formation (Halsey et al. 2000 and Weakley and Schafale 1994). Nonetheless, these small, rare ecosystems support great biological diversity, are themselves highly varied in composition, provide critical habitat for
several species of native plants and animals, some of which are rare in the Southeast
(Thompson et al. 2007, Comer et al. 2005, Weakley and Schafale 1994, Richardson and
Gibbons 1993, and Murdock 1994). The flora they support includes a high concentration of
rare taxa, southern Appalachian endemics, and regionally disjunct taxa (Billings and

Much of our understanding of the vegetation of montane non-alluvial wetlands of the
southern and central Appalachian highlands is based on work conducted outside of the Blue
Ridge region, in the Appalachian Plateau and Ridge and Valley regions of Virginia and West
Virginia (e.g., Byers et al. 2007 and Francl et al. 2004). Relatively little work has been
conducted on the wetlands in the southern Blue Ridge region. What we do know of these
southern wetlands is based primarily on information from plant species lists that often focus
primarily on rare or dominant taxa (e.g., Smith 1993, Boufford and Wood 1975, Gaddy 1981,
and from studies conducted in a few key research sites (Tucker 1967; Shafer 1984, 1986, and
1988; Mowbray and Schlesinger 1988; Stewart and Nilsen 1993; Pittillo 1994; Delcourt and
Delcourt 1997; Almon 1998; Riggsbee 1999; Rossell and Wells 1999; Moorhead et al. 2000;
Moorhead 2001; Warren et al. 2004; Warren et al. 2007; and Rossell et al. 2008). Cursory
studies in the southern Blue Ridge region and more comprehensive studies in the
Appalachian Plateau and Ridge and Valley regions have documented the distinctiveness of
individual wetlands and the wide range of compositional variation found among wetland sites
These same studies indicate that findings from the few carefully-studied sites represent only
a small subset of the variation in vegetation and underlying environmental conditions found in montane non-alluvial wetlands spanning the southern Appalachian region. Moreover, the small pockets that these wetlands occupy are spatially isolated from one another (Weakley and Schafale 1994), with the consequence that chance events such as seed dispersal, habitat colonization, and survivorship have led to considerable compositional variation in vegetation. No previous work has provided quantitative documentation of the vegetation composition of the non-alluvial wetlands found throughout the southern Blue Ridge region at either local or regional scales.

The focus of this study is geographically isolated montane non-alluvial wetlands of the southern Blue Ridge region of North Carolina. In regional literature, these habitats are often referred to as ‘bogs’, (e.g., Schafale and Weakley 1990, Pittillo 1994, and Richardson and Gibbons 1993), though this usage is not consistent with more common, international use of the term to refer to more ombrotrophic peatlands. Schafale and Weakley (1990) divided the montane non-alluvial wetlands of North Carolina into six major types: 1) Swamp Forest-Bog Complex, 2) Southern Appalachian Bog, 3) Southern Appalachian Fen, 4) High Elevation Seep, 5) Spray Cliff, and 6) Upland Pool. Except for Spray Cliffs and Upland Pools, these wetland types are geographically isolated, have hydrology dominated by seepage, high water table, or paludification, and accumulate relatively large amounts of peat or muck under Sphagnum moss (Schafale and Weakley 1990 and Weakley and Schafale 1994). This study includes montane, non-alluvial wetlands within the scope of Schafale and Weakley’s (1990) Swamp Forest-Bog Complex, Southern Appalachian Bog, Southern Appalachian Fen, and High Elevation Seep.
We present a quantitative classification and description of the vegetation of montane non-alluvial wetlands occurring throughout the southern Blue Ridge region of North Carolina. Our objective was to describe plant community types based on floristic assemblages alone, and then place the compositional variation in vegetation in an environmental and geographic context by examining underlying environmental gradients correlated with the observed differences in vegetation patterns. Community types are described by their dominant and diagnostic plant species, facilitating field identification.

We use the results of this study to develop proposals for revision or elaboration of the community types recognized in the U.S. National Vegetation Classification (NVC) and the North Carolina Natural Heritage Program (NCNHP). The resultant characterization and classification of the vegetation of the montane non-alluvial wetlands North Carolina will provide a better overall ecological understanding of these rare systems and should guide future preservation, conservation, management, and restoration decisions.

**METHODS**

**Study Area**

The study area spanned the southern Blue Ridge region of North Carolina (Figure 1). This region occupies the Southern section of the Blue Ridge Province, the easternmost belt of mountains in the Appalachian Highlands physiographic division of eastern North America (Fenneman 1928 and Guyot 1861). The Blue Ridge province is geologically and ecologically complex (Soltis et al. 2006) with remarkable physical structure and general altitude (Guyot 1861). It is characterized by mature mountains composed of crystalline rocks
of pre-Cambrian to early Cambrian origin and defined as the broader portion south of the Roanoke River whose summits do not indicate a peneplain (Fenneman 1928). Within North Carolina, the Blue Ridge region extends about 350 km along a southwest to northeast axis and reaches a width of 130 km with a total area of around 22,000 km² (Guyot 1861, McNab and Avers 1996, and Peet et al. 2003). Elevations vary abruptly from around 300 m at the base of Blue Ridge Escarpment to 2000 m atop highest peaks (Peet et al. 2003).
The landscape of the southern Blue Ridge region of North Carolina is ancient, built by a series of collisional events in the Paleozoic and an extensional event in the Late Triassic (Matmon 2003). In this ancient landscape, active tectonics ceased long ago and there were no glaciations, thereby giving topography time to adjust to lithology (rock composition) and structure (Matmon 2003). Thus, the landscape is in a relative steady state (Matmon 2003), has well developed drainage systems (Halsey et al. 2000) with no natural lakes and few depression wetlands.

The soils of the region are largely derived from mica gneiss, similar felsic rocks, and acidic metasedimentary rock units (Peet et al. 2003). Ancient weathering and acidic substrate characteristic of the region are reflected in the soils, which are typically poor in phosphorus, calcium, and magnesium, and are acidic, generally with a pH less than 5.0 in all horizons (Peet et al. 2003). Exceptions are found in areas with soils derived from igneous bedrock containing high levels of mafic minerals (Peet et al. 2003).

The climate of the southern Blue Ridge region varies considerably with local topography and elevation (Newell 1998, McNab and Avers 1996), but is generally humid, and its average annual precipitation far exceeds evapotranspiration (Muller and Grymes III 1998). Precipitation averages 1000-1300 mm annually, although totals may be considerably higher along portions of the Blue Ridge escarpment (up to 2000 mm) and on the highest peaks (up to 2000 m) (McNab and Avers 1996). Precipitation is nearly equally distributed throughout the year and relatively little occurs as snow, which may cover only the highest elevations until spring (McNab and Avers 1996, Sankovski and Pridnia 1995). Mean monthly temperatures range from 3° C in January to 24° C in July (McNab and Avers 1996).
SITE SELECTION

The geographic and ecological scope of this study includes all geographically isolated non-alluvial wetlands within the southern Blue Ridge region of North Carolina. Sample sites were distributed across the region to capture the range of variation associated with both elevation and geography (Figure 2). Candidate sites were identified by various sources, including the North Carolina Natural Heritage Program (NHP) and regional natural resource professionals. Priority was given to sites with at least one NHP Natural Community Element Occurrence classified as “Southern Appalachian Bog” (Schafale and Weakley 1994) and ranked as excellent (A) or good (B). In a few cases, sites ranked as fair (C) were considered, specifically if a site had at least one known occurrence of a federally listed (LE or LT) or special concern (FSC) plant or animal. A site was defined as an individual area of wetland vegetation, geographically separated from additional areas of wetland vegetation by terrestrial vegetation. Determination of geographical separation was based on field observation and/or interpretation of Digital Orthophoto Quarter Quads (DOQQS) in a Geographic Information System (GIS). A site does not, necessarily, correspond to the spatial extent of a Significant Natural Heritage Area SNHA as defined by NHP. In total I recorded 90 plots from 49 sites distributed across 11 counties in North Carolina (Appendix 1). For the analysis I also included 53 plots from the Carolina Vegetation Survey (CVS) database (archived by the North Carolina Botanical Garden) that were classified as “Montane non-alluvial wetlands,” increasing the sample size to 143 plots from 68 sites distributed across 12 counties in North Carolina (Appendix 1). Original plot data, including plot locations (with
latitudes and longitudes), collected for this project are part of the Carolina Vegetation Survey database and are archived as such.

FIELD METHODS

Vegetation plots established for this project were 10m² in size (10 x 10m or 5 x 20m) to correspond to the standard observation unit (i.e., quadrat or module) of the Carolina Vegetation Survey (CVS) protocol (Peet et al. 1998). In one instance (plot 73-09-007), a 1000m² or 20 x 50 m plot configuration with multiple 100m² subplots was used (Peet et al. 1998). At each site, at least one 100m² (10 x 10m or 5 x 20 m) plot was established within

Figure 2. Distribution of sampling sites across the southern Blue Ridge region of North Carolina.
an area of relatively homogeneous vegetation. At compositionally diverse sites, more than one plot was typically established. However, the primary objective was to capture the range of variation found across the region with the consequence that the number of plots established in any one site was generally limited and not sufficient to capture the full range of vegetation variation found throughout the wetland area. Vegetation was recorded following the CVS protocol (Peet et al. 1998). Within each 10m² plot, four nested subquadrats or “subplots” were inventoried: all vascular plant taxa were identified and given values indicating presence in different sized quadrats in a nest (presence, depth: 1-5) and abundance (cover class, scale: 1-10) (Peet et al. 1998). Aerial cover (as a measure of abundance) was estimated at the scale of the plot (depth: 1) using the CVS cover-class scale (1 = trace, 2 = <1%, 3 = 1-2%, 4 = 2-5%, 5 = 5-10%, 6 = 10-25%, 7 = 25-50%, 8 = 50-75%, 9 = 75-95%, 10 = 95-100). The presence and abundance of *Sphagnum* spp. were recorded at the scale of the plot (depth: 1, 100m²). Percentage total covers (scale: 0 – 100%) of litter, decaying wood, bryophytes (including *Sphagnum* spp. and other mosses), visible surface water, and exposed muck were recorded at the scale of the plot (depth: 1, 100m²). Plots were inventoried during the late-vernal to aestival growing season (May-August) over a two-year period (2006-2007). Geographic coordinates (as estimated using a Garmin Extrex Legend H GPS Navigator Global Positioning System with an accuracy of ≤10m) and photographs were taken at one corner of each plot. Often a gnome (37 cm in height) was placed in the photograph for scale. The elevation of each plot was determined by from USGS digital elevation maps through use of a Geographic Information System.
Plant taxa were identified to the most finely resolved taxonomic level possible (i.e., specific, subspecific and/or varietal, where appropriate). Some taxa were treated with reduced taxonomic resolution because of problems with consistent field identification. Taxon concepts and authorities follow the Manual of the Vascular Flora of the Carolinas, Virginia, Georgia, and surrounding areas, working draft of 7 April 2008 (Weakley 2008). Voucher specimens of selected species of conservation value will be deposited at the North Carolina State University herbarium (NCSC).

A soil sample was collected from the top 10-20 cm of mineral or organic (peat or muck) soil found below the humic or bryophyte layer. When possible, a second soil sample was collected approximately 50 cm below ground surface. Soil depth was measured at the inner corner of each nested subquadrat (see Peet et al. 1998 for details). Soil samples were analyzed by Brookside Laboratories, Inc., New Knoxville, Ohio using the Mehlich III extraction technique. Total cation exchange capacity, percentage humic matter, pH, estimated nitrogen release (N ppm), easily extractable Phosphorus (P ppm), exchangeable cations (Ca, Mg, K, Na ppm), percentage base saturation, extractable micro-nutrients (Fe, Mn, B, Cu, Zn, Al ppm), soluble sulfur, and bulk density values were determined for each sample. Extractions were carried out using the Mehlich III method (Mehlich 1984) and percentage humic matter was determined by loss on ignition. Soil texture was determined and quantified as percentage sand (2 mm – 63 μm), silt (63– 2 μm) and clay (< 2 μm).

QUANTITATIVE ANALYSIS

Standardization of Data
Analysis included 142 plots, 90 that I personally sampled during the summers of 2006 and 2007 and 52 sampled by the Carolina Vegetation Survey between 1993 and 1999 (Appendix A). Plots I sampled were all 100 m² except one plot (117-09-007), which was 1000 m² in size (Appendix A). Plots sampled by the Carolina Vegetation Survey ranged in size from 100 m² to 1000 m² (Appendix A). To accommodate for the variation in spatial extent and number of intensive modules sampled (i.e., quadrats with presence and abundance data recorded, see Peet et al. 1998), we determined the geometric mean percentage cover of each cover class for all intensive modules inventoried in a plot and calculated an average value across the entire plot. In most cases, plots were a single 100m² module in size and thus no such calculations were necessary. We similarly standardized soil values by determining a single value for each measured variable for each plot. In the case of multiple module plots, we averaged all soil values measured from intensive modules to obtain a single plot value for each measured variable. Prior to analysis, we used our field experience to assign each plot to one of three possible a priori classification groups: 1) bog or fen, 2) seep, or 3) forested bog. This provided a subjective clustering or grouping of vegetation which we then used to evaluate quantitative results as suggested by Gauch and Whittaker (1981).

Differences in botanical nomenclature due to sampling date and preference of data recorders were standardized to follow Weakley’s Flora of the Carolinas, Virginia, Georgia, and surrounding areas, working draft of 7 April 2008 (Weakley 2008). In cases where nomenclatural relationships were not synonymous as a one to one relationship, a composite taxon was created to include all possible component taxa. Composite taxa, typically of broad
taxonomy, were also created to accommodate vegetative specimens that could not be identified to the most finely resolved taxonomic level (e.g., the composite taxon ‘Chelone [glabra + obliqua]’ accommodates indistinguishable vegetative specimens of the petiolate Chelone spp., while allowing precise recognition of vegetative specimens of the sessile species, Chelone cuthbertii).

**Vegetation classification and characterization**

Our approach to vegetation classification was to apply a combination of ordination and clustering techniques to partition samples into floristically similar groups. Once potential groups were identified, we calculated several summery statistics based on concepts of constancy and fidelity to evaluate the consistency and distinctiveness of each group and to aid in selecting nominal taxa. We also ranked taxa by prevalence (*sensu* Curtis 1959) and subsequently determined homoteneity (*sensu* Curtis 1959) for each vegetation class and community type to provide an indication of compositional variability among plots within a recognized group.

We calculated a dissimilarity matrix for the complete data set (142 plots x 493 taxa) representing inter-sample similarity in species abundances among plots Sørensen (Bray-Curtis) distance metric. We used a hierarchical, agglomerative Sørensen-based cluster analysis and the flexible-beta group linkage (Lance and Williams 1967) with a $\beta = -0.25$ to partition samples in a manner that minimized within group sum of squares relative to between group differences (McCune and Grace 2002). We used PC-ORD software, version 5.0 (McCune and Mefford 2006) to conduct these analyses.
An initial cluster analysis of the complete data set (142 plots x 493 taxa) revealed that the data were very heterogeneous. We, therefore, identified and removed outlier samples in the dataset and subsequently partitioned the data set into finer-scale data subsets. We identified plots that fell greater than 2.0 standard deviations above the mean for average Sørensen (Bray-Curtis) distance as outliers in the data set (142 plots x 493 taxa) and removed these plots prior to further analyses. Six plots were removed, bringing the dataset to 136 plots (Appendix A). We then performed cluster analysis on the new data set (136 plots x 477 taxa) to partition the data into finer-scale data subsets. We also used Nonmetric Multidimensional Scaling (NMS) ordination to summarize compositional similarity among the plots. We also manually adjusted group membership of individual plots during cluster analysis of the data set. Eight plots proved problematic, falling in clustered groups inconsistent with a priori classification. We ultimately re-assigned these plots (Appendix A) from their initial group to another group after evaluating the statistical interpretability of each affected group with and without the questionable plots, by examining the plots in ordination space, and by reviewing a priori classification. Finally, after examining the results of fine-tuned the manually-adjusted cluster analysis and ordination, we chose to partition the dataset into two groups or data subsets, which we call “vegetation classes”. Acceptance of two groups as vegetation classes provided recognizable and distinct floristic assemblages that were ecologically interpretable and provided a hierarchical framework comparable to existing classifications of montane non-alluvial wetlands.

Once the vegetation classes were determined, we treated data associated with each vegetation class as independent data sets and each was analyzed as such. Data set I
contained 83 plots and 313 taxa. Data set II contained 53 plots and 385 taxa. For each data set we performed multiple hierarchical, agglomerative cluster analyses using various measures of distance. Ultimately, a Sørensen-based cluster analysis and the flexible-beta group linkage (Lance and Williams 1967) with a $\beta = -0.25$ provided the most interpretable groups for both data subsets.

Data set II proved problematic, not yielding groups that were easily recognizable and distinct. To mediate this problem, we deleted two taxa, *Acer rubrum* L. var. *rubrum* and the composite taxon *Betula* sp. (subgenus *Betulenta*; *Betula lenta* L. var. *lenta + B. alleghaniensis*). Because we were unable to confidently distinguish between *Betula lenta* L. var. *lenta* and *Betula alleghaniensis* Britton in the field, we felt that we may have been obscuring inter-plot similarities by lumping the two taxa. Hybridization and vegetative variability is common among birches (Järvinen 2004), and Weakley (2008) suggests that these taxa may occupy different elevation gradients. Similarly, we felt *Acer rubrum* L. var. *rubrum*, one of the most ubiquitous trees in North Carolina and one with weedy abilities (Weakley 2008), may have been obscuring inter-plot similarities because it was found in nearly every plot. Ultimately, removal of the taxon *Acer rubrum* L. var. *rubrum* and the composite taxon representing *Betula lenta* L. var. *lenta* and *B. alleghaniensis* resulted in groups that were easily recognizable and distinct. Once groups were accepted, both taxa were put back into the data set prior to calculation of summary statistics.

After examining the results of cluster analysis for each data set, we accepted the most ecologically interpretable dendrogram for each vegetation class, which presented recognizable and distinct floristic assemblages that we call “communities.” To evaluate the
consistency and distinctiveness of each community we calculated summary statistics based on taxon-specific measures of constancy (*sensu* Curtis 1958), fidelity, and mean abundance. Constancy represents the percentage of plots in a community in which a taxon occurs. Fidelity represents the degree to which a taxon is confined in a community. We also identified diagnostic taxa (*sensu* Curtis 1958) by calculating taxon-specific indicator values. For each taxon in each community, two indicator values were calculated. The first, which we call Indicator Value (IV) represents taxa that are both constant and relatively confined to a community and does not consider abundance. The second, which we call Scaled Indicator Value (IVS), represents taxa that are both constant and relatively confined to a community and is adjusted by mean abundance so as to synthesize taxon-specific information of constancy, fidelity, and mean abundance (Fleming et al. 2006).

**Relationship of vegetation to the environment**

The relationship between species composition and major environmental gradients was explored using non-metric multidimensional scaling (NMS) ordination of our response matrices of Sørensen distance. Nonmetric multidimensional scaling (NMS; Kruskal 1964) was implemented in the program PC-ORD 5.0 using the slow and thorough autopilot approach followed by a final run using the manual approach (McCune and Medford 2006). The configuration file from the preliminary run and one real run was used for the final run. The final NMS run consisted of two dimensions with no step-down in dimensionality. The ordination was VARIMAX rotated to optimize axis placement such that axis 1 accounted for the majority of the solution.
RESULTS

We identified 12 communities within 2 vegetation classes based on analyses of 136 plots containing a total of 477 plant taxa. Within vegetation class I, we identified 4 communities based on 53 plots (Appendix B.1). Within vegetation class II we identified 8 communities and 83 plots (Appendix B.2). We identified vegetation classes from the manually adjusted Sørensen flexible-beta cluster solution that was ecologically interpretable, corresponded to the a priori classification, and displayed a stable, two-dimensional solution using Nonmetric Multidimensional Scaling (NMS) ordination.

Vegetation classes were identified to provide broad categories of non-alluvial wetlands that differ primarily in vegetation structure and are comparable to broad vegetation groups previously recognized by Schafale and Weakley (1990). Communities represent finer divisions of vegetation classes that are more compositionally homogeneous and reflect environmental gradients of elevation and properties of soil. Our classification is a first approximation of a geographically broad classification based on quantitative data. Our classification system of 12 communities in 2 vegetation classes provides a hierarchical framework comparable to classifications of montane non-alluvial wetlands by Schafale and Weakley (1990) and presents community types that are readily distinguishable by field practitioners.

Vegetation classes were named using existing terminology in plant community classification. We used a standard naming strategy for community types, largely consistent with usage in the U.S. National Vegetation Classification (NVC; NatureServe 2009). Community names include diagnostic taxa that characterize and distinguish individual
communities and typically have both high constancy (> 40%) and consistently high cover (>4). Diagnostic taxa occurring in the same stratum (tree, shrub, herb, nonvascular) are separated by a hyphen (-), and those occurring in different strata are separated by a slash (/). Taxa occurring in the uppermost stratum are listed first, followed successively by those in the lower strata. The order of taxon names within the stratum generally reflects decreasing levels constancy and/or abundance. Names were selected at the author’s discretion based on calculated indicator values, constancy, and existing NVC names (Appendix B.1 and Appendix B.2).

We describe the two vegetation classes and individual communities below in terms of community structure, species composition, and associated environmental variables. First we explain the difference between the two vegetation classes and how these compare to previously recognized vegetation groups. We then compare and contrast each community within each vegetation class based on environmental gradients of elevation and properties of soil. This is followed by detailed descriptions of each community within each vegetation class. Communities are described in terms of community structure and species composition. Community descriptions are presented in order of descending constancy for each of four recognized strata layers: Canopy, Shrub, Herbaceous, and Bryophyte.

VEGETATION CLASSES

We recognize two vegetation classes, 1) SATURATED FORESTS AND SEEPS and 2) BOGS AND FENS, which are differentiated primarily based on the presence or abundance of large canopy trees. SATURATED FORESTS AND SEEPS represent areas of saturated
soils having an abundance of canopy trees growing within a complex of ridges and sloughs, or small (< 0.5 ha) areas of saturated soils that receive shading from overhanging canopy trees of adjacent forests. BOGS AND FENS, in contrast, represent relatively large (> 0.5 ha) areas of saturated soils, which are typically open, generally flat or slightly sloping, and lack shading from overhanging canopy trees of adjacent forest.

The SATURATED FORESTS AND SEEPS vegetation class we describe includes Schafale and Weakley’s (1990) concepts of Swamp Forest-Bog Complexe and High Elevation Seep. The BOGS AND FENS vegetation class we describe included Schafale and Weakley’s (1990) concepts of Southern Appalachian Bogs and Southern Appalachian Fen.

**Vegetation class 1: SATURATED FORESTS AND SEEPS**

The SATURATED FORESTS AND SEEPS vegetation class occurs throughout the southern Blue Ridge region of North Carolina at elevations ranging from 600 m to over 1735 m. This vegetation class represents a large, broad group of montane non-alluvial wetland community types, which are distinctive in having large canopy trees contributing to vegetation composition. Canopy trees may be rooted within the wetland or overhanging from more terrestrial zones on community edges. Communities recognized within this vegetation class occupy poorly drained bottomlands of small streams, relatively steep slopes of groundwater discharge (Weakley and Schafale 1994), and/or broad and gently sloping areas among stream headwaters. Soils may be permanently saturated to intermittently dry or seasonally to semipermanently saturated, a result of constant to regular seepage and high water table (Weakley and Schafale 1994).
We recognized 4 community types within the SATURATED FOREST AND SEEPS vegetation class based on results of cluster analysis and NMDS ordination (Figures 3 and 4). Compositional differences among the 4 vegetation classes are most strongly associated with variation in elevation (Elv), soil depth, soil cation exchange capacity (CEC), soil nutrients (represented by calcium (Ca), potassium (K) and zinc (Zn)), and exchangeable Calcium to Magnesium ratios (Ca/Mg) (Figure 4, Appendix C). The **Low Elevation Saturated Forest (1.4)** occupies lower-elevation areas of deeper soil characterized by lower nutrient availability, lower total cation exchange capacity, and lower exchangeable Calcium to Magnesium ratios (Ca/Mg) (Figure 4). In contrast, the **High Elevation Seep (1.1)** community occupies higher-elevation areas of relatively shallow soils that are characterized by higher nutrient availability, higher total cation exchange capacity, and higher exchangeable Calcium to Magnesium ratios (Ca/Mg) (Figure 4). The **High Elevation Saturated Forest (1.3)** and the **High Elevation Sedge Seep (1.2)** occupy intermediate to higher-elevation areas of relatively shallow soils that are characterized by intermediate to higher nutrient availability and total cation exchange capacity (CEC) (Figure 4). The **High Elevation Sedge Seep (1.2)** differs from the **High Elevation Saturated Forest (1.3)** and the **Low Elevation Saturated Forest (1.4)** by occupying areas of soils characterized by higher exchangeable Calcium to Magnesium ratios (Ca/Mg) (Figure 4).

### 1.1 High Elevation Seep (8 plots)

*Betula spp. / Viburnum cassinoides / Athyrium asplenoides*
The **High Elevation Seep** community occupies relatively small zones of seepage at high elevations (1115 – 1730 m) on slopes ranging from 3 – 33°. Examples occur primarily in the southern portion of the study area, in Macon, Haywood, Jackson, and Transylvania Counties. Two examples occur in the northern portion of the study area, in Avery and Watauga Counties.

Vegetation composition is highly variable. This community occupies wetland zones that are often small (< 0.01 ha) with the consequence that surrounding vegetation of more upland or forested areas is often included in plots and thus contributes to community composition. The canopy is typically dominated by *Betula* spp. (**alleghaniensis/lenta**) in association with a variable composition of deciduous and evergreen trees such as *Fagus grandiflora, Aesculus flava, Abies fraseri, Acer rubrum, Acer saccharum, Picea rubens, Prunus pensylvanica, Magnolia acuminata var. acuminata, Quercus montana* and/or *Fraxinus* spp. Shrub composition may include *Rhododendron maximum, Rhododendron catawbiense, Rubus allegheniensis, Amelanchier* spp. (**arborea/laevis**), *Vaccinium erythrocarpum, Hamamelis virginiana* var. *virginiana*, and/or *Viburnum cassinoides*. The herbaceous layer typically includes *Athyrium asplenioides* in association with *Eurybia chlorolepis, Oclemena acuminata, Dennstaedtia punctilobula, Angelica triquinata, Prenanthes* sp., *Chelone* spp. (**oblique/glabra**), *Viola cucullata*, and/or *Arisaema triphyllum*. Additional less common herbaceous taxa may include *Carex ruthii, Agrostis altissima, Oxalis montana, Veratrum virginicum, Diphylelia cymosa, Carex flexuosa, Glyceria melicaria*, and/or *Solidago curtisii* (Appendix A). *Sphagnum* spp. are generally present as scattered patches.
Figure 3. Hierarchical cluster solution of non-alluvial wetlands of the southern Blue Ridge region of North Carolina in the SATURATED FORESTS AND SEEPS vegetation class. The dendrogram shows divisions and final community grouping identified using Sørensen-based cluster analysis and the flexible-beta group linkage (Lance and Williams 1967) with a $\beta = -0.25$. Communities are represented by their numbers: 1.1 High Elevation Seep, 1.2 High Elevation Sedge Seep, 1.3 High Elevation Saturated Forest, 1.4 Low Elevation Saturated Forest.
Figure 4. Two-dimensional NMDS ordination showing association between community types and environmental gradients in the SATURATED FORESTS AND SEEPS vegetation class. The direction of each vector indicates the direction of maximum correlation, and the length is the strength of the correlation. **CEC** indicates total cation exchange capacity (meg/100 g); **Soil Depth** indicates depth of soil (cm); **Elv** indicates Elevation (m); **Ca**, **K**, and **Zn** represent soil micronutrients (ppm); and **Ca/Mg** indicates the exchangeable Ca to Mg ratio.
Communities are represented by their numbers: 1.1 High Elevation Seep, 1.2 High Elevation Sedge Seep, 1.3 High Elevation Saturated Forest, 1.4 Low Elevation Saturated Forest.
The **High Elevation Seep** as described here fits within the broad concept of High Elevation Seep recognized by Schafale and Weakley (1990) (Appendix D). The **High Elevation Seep** as described here is a broad concept that includes the NVC associations CEGL004293 and CEGL004296 (NatureServe 2009) (Appendix D). The composition found among seepage zone of higher elevation areas of the southern Blue Ridge region of North Carolina is highly variable and more samples are needed to fully understand the compositional diversity found within and among sites. As described here, the **High Elevation Seep** community includes a broad range of compositional variation. As more data are collected it is likely that this community will be split into more than one community.

1.2 **High Elevation Sedge Seep (4 plots)**

*Betula* spp. / *Carex ruthii* – *Avenella flexuosa* / *Sphagnum* spp.

The **High Elevation Sedge Seep** is currently known only from two sites in Haywood County, North Carolina. Examples occur as relatively small zones of seepage on slopes ranging from 2 – 7°. The average elevation is 1,685 m.

Vegetation composition is generally graminoid-dominated but coverage from shrubs and trees is common, particularly around seep margins, due to the small nature of wetland zones. Canopy trees may include *Betula (alleghaniensis/lenta)*, *Acer rubrum*, and/or *Sorbus americana*. Shrub composition is variable but typically includes *Hypericum densiflorum* and *Lyonia ligustrina* var. *ligustrina*, *Amelanchier* spp. (*arborea/laevis*), *Rhododendron maximum*, *Aronia melanocarpa*, *Rhododendron catawbiense*, and *Viburnum cassinoides*. The trailing sub-shrub, *Rubus canadensis*, is also common. *Carex ruthii* is the characteristic
graminoid in association with *Avenella flexuosa*, *Carex crinita* s.l. (includes *C. mitchelliana* and *Carex gynandra*), *Carex flexuosa*, *Juncus* ssp., *Oclemena acuminata*, *Osmunda cinnamomea* var. *cinnamomea*, *Scirpus* ssp., *Calamagrostis cinnoides*, *Juncus gymnocarpus*, and *Solidago patula* var. *patula*. *Sphagnum* ssp. are characteristic and typically abundant (Appendix D).

The **High Elevation Sedge Seep** as described here fits well within the concept of the NVC Association CEGL007697 (NatureServe 2009) and within Schafale and Weakley’s (1990) broad concept of High Elevation Seep. The vegetation composition found among seepage zones of the higher elevation areas of the southern Blue Ridge region of North Carolina is highly variable and more sampling is needed to fully understand the compositional diversity found within and among site. There is potential that this community is more widespread and could occur in locations outside of Haywood County, North Carolina (Appendix D).

### 1.3 High Elevation Saturated Forest (12 plots)

*Picea rubens* / *Rhododendron maximum* / *Osmunda cinnamomea* var. *cinnamomea*.

The **High Elevation Saturated Forest** occurs scattered throughout the mountains of North Carolina at high elevations (1060 m to 1475 m). Examples occur in the northern and southern portion of the southern Blue Ridge region of North Carolina in Avery, Ashe, Jackson, Transylvania, and Watauga counties.

Vegetation composition is variable, dependent on canopy and shrub coverage. Widely scattered trees and thick patches of shrubs are typical, interspersed with relatively
small patches of herbaceous and bryophyte-dominated zones. *Picea rubens* is a typical canopy tree in association with *Acer rubrum, Betula* spp. (*alleghaniensis/lenta*), *Tsuga canadensis*, *Sorbus americana*, and/or *Pinus rigida*. *Rhododendron maximum* and *Kalmia latifolia* are characteristically abundant in association with *Viburnum cassinoides, Ilex verticillata, Aronia melanocarpa*, and *Amelanchier* spp. (*arborea/laevis*). The trailing sub-shrub *Rubus hispidus* is typically present. Characteristic herbaceous components include *Maianthemum canadense, Osmunda cinnamomea* var. *cinnamomea, Arisaema triphyllum, Carex leptalea* var. *leptalea, Solidago patula* var. *patula, Mitchella repens*, and *Viola macloskeyi* var. *macloskeyi*. Additional herbaceous taxa may include *Trillium undulatum, Symphyotrichum puniceum* var. *puniceum, Impatiens* spp. (*capensis/pallida*), *Packera aurea, Galium* spp. (*tinctoria/triflora*), *Carex trisperma* var. *trisperma*, and *Platanthera clavellata* (Appendix D).

The **High Elevation Saturated Forest** as described here is broader than the concept of Swamp Forest-Bog Complex (Typic Subtype) recognized by Schafale and Weakley (1990) (Appendix D). The **High Elevation Saturated Forest** as described here is a broad concept that includes the NVC associations CEGL006277 and CEGL003667 (NatureServe 2009) (Appendix D). The composition found among saturated forests of lower elevations of the southern Blue Ridge region of North Carolina is highly variable and more sampling is needed to fully understand the compositional diversity found within and among sites. As described here, the **High Elevation Saturated Forest** community includes a broad range of compositional variation. As more data are collected it is likely that this community will be split into more than one community.
1.4 Low Elevation Saturated Forest (28 plots)

*Acer rubrum / Viburnum cassinoides /Osmunda cinnamomea var. cinnamomea.*

The **Low Elevation Saturated Forest** occurs throughout the southern Blue Ridge region at lower elevations, ranging from 630 to 1120 m. Examples occur in poorly drained bottomlands, generally with visible microtopography of ridges and sloughs or depressions (Schafale and Weakley 1990), or in gently sloping to relatively flat stream headwaters. Examples are located in the northern mountains in Ashe and Alleghany Counties and in the southern mountains in Transylvania, Henderson, and Jackson Counties. One example occurs in Yancy County.

Vegetation composition is typically tree and shrub-dominated, interspersed with relatively small patches of herbaceous and bryophyte-dominated zones. Canopy trees may occur widely scattered throughout wetlands or may be confined to edges of smaller wetland openings. Canopy composition is quite variable among sites but *Acer rubrum* is a characteristic dominant in association with *Nyssa sylvatica* and *Pinus strobus*. Additional canopy associates may include *Quercus alba, Quercus rubra var. rubra, Tsuga canadensis,* and *Liriodendron tulipifera var. tulipifera*. Vines such as *Smilax glauca* and/or *Smilax rotundifolia* are often present. Shrubs are typically present but composition is variable among sites. Typical shrubs may include *Kalmia latifolia, Viburnum cassinoides, Amelanchier* spp. (*arborea/laevis*), *Rhododendron maximum, Alnus serrulata, Ilex verticillata, Vaccinium corymbosum, Lyonia ligustrina var. ligustrina, Rhododendron* spp. (subgenus Hymenanthes), and *Prunus serotina var. serotina*. The trailing sub-shrub *Rubus*
hispidus is often present. Herbaceous composition is highly variable among sites, dependent primarily upon geographic location and canopy coverage. Larger canopy openings often result in a relatively abundant herbaceous layer typically dominated by Sphagnum spp. and sedges such as Carex folliculata and/or Carex intumescens. Smaller canopy gaps or shaded zones of seepage areas support a less abundant herbaceous layer that typically includes small clumps of Sphagnum spp., sedges, and ferns such as Osmunda cinnamomea var. cinnamomea and/or Thelypteris noveboracensis. In areas with limited canopy gaps, low depressions, and zones of seepage, the herbaceous layer is less abundant and composition is highly variable. Additional herbaceous components may include Galium spp. (tinctorum/triflorum), Impatiens spp. (capensis/pallida), Medeola virginiana, Symplocarpus foetidus, Galax urceolata, Lycopus virginicus, and Mitchella repens. Occasionally this community supports the rare forbs Dalibarda repens and Helonia bullata or the carnivorous Sarracenia purpurea var. montana. (Appendix D).

The Low Elevation Saturated Forest as described here fits within the broad concept of Swamp Forest-Bog Complex (Typic Subtype) recognized by Schafale and Weakley (1990) (Appendix D). The Low Elevation Saturated Forest as described here is a broad concept that includes the NVC associations CEGL007565, CEGL003667, CEGL003918, CEGLE008438 (NatureServe 2009) (Appendix D). The composition found among saturated forests of lower elevations of the southern Blue Ridge region of North Carolina is highly variable and more samples are needed to fully understand the compositional diversity found within and among site. As described here, the Low Elevation Saturated Forest community
includes a broad range of compositional variation. As more data is collected it is likely that this community will be split into more than one community.

**Vegetation class 2: BOGS AND FENS**

The BOGS AND FENS vegetation class occurs throughout the southern Blue Ridge region at elevations ranging from 620 m to 1,400 m. This vegetation class represents a large, broad group of montane non-alluvial wetland communities that are open areas dominated by shrubs and/or graminoids, lacking canopy trees of considerable abundance. Communities recognized within this vegetation class occupy the headwater regions of small streams, rounded and gently sloping mountain peaks, and broad valleys of small rivers and streams.

We recognize 8 community types within the BOGS AND FENS vegetation class based on results of cluster analysis and NMS ordination (Figures 5 and 6). Compositional differences among the 8 vegetation classes groups are most strongly associated with variation in elevation (Elv), soil depth, soil texture (represented by Clay and Sand), soil pH, soil nutrient availability (represented by magnesium (Mg), and base saturation (Figure 6). The **Disturbed Bog (2.1)** occupies lower-elevation areas of deeper soil characterized by higher clay content, lower nutrient availability, lower base saturation, and lower pH (Figure 6). In contrast, the **High Elevation Valley Fen (2.8)** occupies higher-elevation areas of shallow soils characterized by higher sand content, higher nutrient availability, higher base saturation, and higher pH (Figure 6). The **Shrub Bog (2.2)** and the **High Elevation Mosiac Bog (2.4)** are positioned along the left side of Axis 1 of the NMDS ordination and are not associated with variation in measured environmental variables (Figure 6). When compared to the **Disturbed Bog (2.3)**, the **Acidic Bog (2.3)** occupies areas of higher soil nutrient availability, higher base
saturation, and higher soil pH. However, when compared to the High Elevation Valley Fen (2.8), the Acidic Bog (2.3) occupies areas of lower soil nutrient availability, lower base saturation, and lower soil pH. The Mosiac Bog (2.5) is similar to the High Elevation Valley Fen (2.8) in that it occupies areas of relatively higher soil nutrient availability, higher base saturation, and higher soil pH when compared to all other communities except the Mountaintop Fen (2.6) which also occupies areas of relatively higher soil nutrient availability, higher base saturation, and higher soil pH. The difference between the Mountaintop Fen (2.6) and High Elevation Valley Fen (2.8) is not associated with variation in measured environmental variables as it is positioned on the right side of Axis 1 of the NMDS ordination (Figure 6). Similarly, variation in measured environmental variables does not explain compositional differences of the Low Elevation Bog (2.7) which is positioned near the middle of Axis 2 and on the right side of Axis 1 of the NMDS ordination (Figure 6).

2.1 Disturbed Bog (13 plots)

*Alnus serrulata / Juncus effusus – Persicaria sagittata*

The Disturbed Bog community represents herbaceous bogs that are recovering from current to relatively recent disturbance activities, such as active pasturing, active beaver activity, recent impoundment, and tree/shrub removal. Examples occur throughout the southern Blue Ridge region and over a wide range of elevation (635 to 1,450 m).

Vegetation composition in the Disturbed Bog is highly variable. The herbaceous layer is typically the dominant stratum, but scattered shrubs, including *Alnus serrulata, Spiraea*
tomentosa, and \textit{Salix sericea} are occasional. The herbaceous layer is characteristically
dominated by \textit{Juncus} spp. (\textit{effusus} ssp. \textit{solutus/pylai}) and \textit{Persicaria sagittata} in association
with \textit{Galium} sp. (\textit{tinctorum/triflorum}), \textit{Impatiens} spp. (\textit{capensis/pallida}), \textit{Carex lurida}, \textit{Carex}
\textit{(acuminatus/canadensis/subcaudatus)}, and \textit{Eupatorium perfoliatum}. Additional herbaceous
taxa may include \textit{Scirpus} spp., \textit{Carex echinata} ssp. \textit{echinata}, \textit{Viola macloskeyi} var. \textit{pallens},
\textit{leptalea}, \textit{Dichanthelium dichotomum}, \textit{Lycopus uniflorus}, \textit{Solidago} spp., \textit{Carex atlantica},
\textit{Carex crinita} s.l. (includes \textit{C. gynandra} and \textit{C. mitchelliana}), \textit{Leersia virginica}, \textit{Eleocharis}
tenuis var. \textit{tenuis}, \textit{Glyceria striata} var. \textit{striata}, \textit{Rhynchospora capitellata}, \textit{Agrostis perennans}
s.l., \textit{Mimulus ringens} var. \textit{ringens}, \textit{Leersia oryzoides}, and \textit{Vernonia noveboracensis}.
\textit{Symplocarpus foetidus} may be present in the northern counties (i.e., Ashe, Alleghany
Counties) of the southern Blue Ridge region of North Carolina (Appendix A).

The \textbf{Disturbed Bog} is comparable, but more broadly defined than the NVC
associations CEGLE004112, CEGL004510, and CEGL008433 (NatureServe 2009)
(Appendix D). The \textbf{Disturbed Bog} does not fit well within Schafale and Weakley (1990)
community concepts (Appendix D).

\textbf{2.2 Shrub Bog (14plots)}


The \textbf{Shrub Bog} occurs at higher elevations ranging from 980-1,250 m. Examples
occur in the southern mountains, along the broad floodplain of the Nantahala River (Jackson
and Clay Counties), and in the northern mountains in broad areas of stream headwaters and along tributaries to the Linville River (Avery County).
Figure 5. Hierarchical cluster solution for non-alluvial wetlands of the southern Blue Ridge region of North Carolina in the BOGS AND FENS vegetation class. The dendrogram shows divisions and final community grouping identified using Sørensen (Bray-Curtis) based cluster analysis and the flexible-beta group linkage (Lance and Williams 1967) with a $\beta = -0.25$. Communities are represented by their numbers: 2.1 Disturbed Bog, 2.2 Shrub Bog, 2.3 Acidic Bog, 2.4 High Elevation Mosiac Bog, 2.5 Mosiac Bog, 2.6 Bluff Mountain Fen, 2.7 Low Elevation Bog, and 2.8 High Elevation Valley Bog.
Figure 6. Two-dimensional non-metric multidimensional scaling (NMS) ordination showing association between community types and environmental gradients in the BOGS AND FENS vegetation class. The direction of each vector indicates the direction of maximum correlation, and the length is the strength of the correlation. Elv indicates Elevation (m), Mgppm represents soil micronutrients, pH represents soil pH, Clay and Sand indicate soil texture (%), Soil Depth indicates depth of soil (cm), and BaseSaturation indicates soil base saturation. Communities are represented by their numbers: 2.1 Disturbed Bog, 2.2 Shrub Bog, 2.3 Acidic Bog, 2.4 High Elevation Mosiac Bog, 2.5 Mosiac Bog, 2.6 Bluff Mountain Fen, 2.7 Low Elevation Bog, and 2.8 High Elevation Valley Bog.
Composition is highly variable in the **Shrub Bog**, which may be primarily shrub-dominated or may have patches of shrub and herb dominated zones. *Sphagnum* spp. are typically abundant. A canopy is largely lacking, although small trees and saplings of *Acer rubrum*, *Betula* sp. (*lenta/alleghaniensis*), and *Tsuga canadensis* may be present. Shrubs are common and may dominate large areas or occur in small patches. Typical shrubs include *Viburnum cassinoides*, *Salix sericea*, *Lyonia ligustrina* var. *ligustrina*, *Rosa palustris*, and *Ilex verticillata*. *Sambucus canadensis*, *Rhododendron maximum*, *Spiraea alba* and/or *Ilex verticillata* may also be present and occasionally locally dominant. Herbaceous composition is variable and is typically comprised of a mixture of forbs and sedges. The dwarf shrub *Rubus hispidus* and the fern *Osmunda cinnamomea* var. *cinnamomea* are often present. Characteristic forbs include *Arisaema triphyllum* var. *stewardsonii*, *Impatiens (capensis/pallida)*, *Juncus* spp. (*effusus* ssp. *solutus/pylaei*), *Galium* spp. (*tinctorum/triflorum*), *Persicaria sagittata*, *Solidago patula* var. *patula*, and *Viola macloskeyi* var. *pallens*. Common sedges may include *Carex echinata* ssp. *echinata*, *Carex leptalea* var. *leptalea*, *Carex atlantica*, *Carex* spp. (section Ovales), *Carex lurida*, *Scirpus cyperinus* s.l. (includes *S. atrovirens*, *S. georgianus*, *S. hattorianus*, and *S. polyphyllus*), *Juncus* spp. (*acuminatus/canadensis/subcaudatus*), and *Luzula echinata*. Additional common herbaceous associates may include *Epilobium coloratum*, *Houstonia serpyllifolia*, *Symphyotrichum puniceum* var. *puniceum*, *Galium asprellum*, *Sphenopholis pensylvanica*, *Mimulus ringens* var. *ringens*, *Viola primulifolia*, *Rubus hispidus*, and *Clematis virginiana* (Appendix B.2).
The Shrub Bog as described here is included in the NVC association CEGL003915 (NatureServe 2009) but the Shrub Bog is more broadly defined (Appendix D). The Shrub Bog is more narrowly defined than Schafale and Weakley’s (1990) concept of Southern Appalachian Bog (Northern Subtype) and Southern Appalachian Bog (Southern Subtype) (Appendix D).

2.3 Acidic Bog (9 plots)


The Acidic Bog occupies elevations ranging from 1,020 to 1,315m. Examples occur in the northern mountains (Avery and Watauga counties) in wide, relatively flat areas of stream headwaters and in the southern mountains, in the broad valley of Panthertown Creek (Jackson County). One example occurs in Macon County, North Carolina.

The vegetation composition of the Acidic Bog is typically herb-dominated but small, dense clusters of shrubs and stunted trees are commonly widely scattered throughout, creating a mosaic or zoned pattern. *Acer rubrum* is characteristically present as seedlings or small saplings and stunted individuals of *Betula* spp. (alleghaniensis/lenta), *Pinus strobus*, *Quercus rubra* var. *rubra*, and/or *Tsuga canadensis* may be present. Shrub composition is variable. Typical shrubs may include *Lyonia ligustrina* var. *ligustrina*, *Viburnum cassinoides* var. *cassinoides*, *Kalmia latifolia*, and *Rhododendron maximum*. Herbaceous composition is variable and may include *Carex echinata* var. *echinata*, *Scirpus expansus*, *Viola macloskeyi* var. *pallens*, *Galium* spp. (tinctorum/triflorum), *Juncus* spp.
(acuminatus/canadensis/subcaudatus), Osmunda cinnamomea var. cinnamomea, Solidago patula var. patula, Juncus spp. (effusus ssp. solutus/pylaei), Symphyotrichum puniceum var. puniceum, Hypericum densiflorum, Carex crinita s.l. (includes C. gynandra and C. mitchelliana), Carex leptalea var. leptalea, Carex lurida, Holcus lanatus, Lycopus uniflorus, Epilobium leptophyllum, Glyceria striata var. striata, Chelone cuthbertii, Impatiense sp. (capensis/pallida), Scirpus spp., Solidago altissima var. altissima, Drosera rotundifolia var. rotundifolia and/or Hypericum muticum var. muticum (Appendix A).

The **Acidic Bog** as described here contains elements of the NVC association CEGL004158 (NatureServe 2009) but substantial revision is needed to better synonymize these concepts (Appendix D). The **Acidic Bog** is comparable, but more broadly defined, than the NVC associations CEGL003915, CEGL003916, and CEGL 4156 (Appendix D). The **Acidic Bog** occurs in both the northern and southern portions of the study region and is comparable to Schafale and Weakley’s (1990) concepts of Southern Appalachian Bog (Northern Subtype) and Southern Appalachian Bog (Southern Subtype) (Appendix D).

### 2.4 High Elevation Mosaic Bog (5 plots):

*Vaccinium simulatum / Osmunda cinnamomea var. cinnamomea – Oclemena acuminata / Sphagnum spp. - Polytrichum spp.*

The **High Elevation Mosaic Bog** is restricted to the flat headwater region of Beech Creek at an elevation of approximately 1,400 m.

Community composition is characterized by patches of relatively small and often dense clusters of shrubs and trees that create a mosaic or zoned pattern scattered among a
thick herbaceous and bryophyte layer of *Sphagnum* spp. Characteristic trees include *Betula* spp. (*alleghaniensis*/*lenta*), *Picea rubens* and *Tsuga canadensis*. Additional trees may include *Acer rubrum*, *Pinus strobus*, and *Tsuga canadensis*. *Vaccinium simulatum* is a characteristic shrub in association with *Rhododendron maximum*, *Aronia melanocarpa*, *Kalmia latifolia*, and/or *Salix sericea*. Other shrub associates may include *Viburnum cassinoides*, *Rubus* spp. (*R. allegheniensis*, *R. argutus*, and/or *R. canadensis*), *Sambucus canadensis* and *Amelanchier* spp. (*A. arborea* or *A. laevis*). Characteristic herbs include *Oclemena acuminata* and *Chamerion platyphyllum*. Typical dominant taxa of the herbaceous layer includes *Juncus* spp. (*effusus* ssp. *solutus*/*pylæi*), *Osmunda cinnamomea* var. *cinnamomea*, *Scirpus* spp. (may include *S. cyperinus*, *S. atrovires*, *S. cyperinus*, *S. georgianus*, *S. hattorianus* and/or *S. polyphyllus*), *Solidago patula* var. *patula*, and *Viola macloskeyi* var. *pallens*. Additional herbaceous dominants may include *Carex atlantica*, *Impatiens* sp. (*I. capensis* and/or *I. pallida*), *Lycopus uniflorus* *Platanthera clavellata*, *Potentilla canadensis*, and *Solidago* spp.

The **High Elevation Mosaic Bog** is comparable to the NVC association CEGL004158 (NatureServe 2009) but substantial revision is needed. Currently, the concept of **High Elevation Mosaic Bog** as described here is more narrowly defined than the NVC association CEGL004158. Similarly, Schafale and Weakley’s (1990) concept of Southern Appalachian Bog (Northern Subtype) is comparable to, but broader than, the concept of **High Elevation Mosaic Bog** presented here (Appendix D).

The **High Elevation Mosaic Bog** is most comparable to the NVC associations CEGL003913 and CEGL004158 but the **High Elevation Mosaic Bog** occupies a different
geographic scope and has less floristic variation than these associations (NatureServe 2009) (Appendix D). Revisions are needed to improve synonymy among concepts. The Mosaic Bog is falls within the concept of Schafale and Weakley’s (1990) Southern Appalachian Bog (Northern Subtype) (Appendix D).

2.5 Mosaic Bog (12 plots)

Salix sericea / Osmunda cinnamomea var. cinnamomea - Carex echinata ssp. echinata / Sphagnum spp.

The Mosaic Bog occurs in the northern mountains at higher elevations, ranging from 1228 to 1291m. Examples occur along broad areas of tributaries leading to Long Hope Creek (Ashe Co., Watauga Co.), in the broad headwater regions of Kentucky Creek (Avery Co.), and in the broad floodplain of the Linville River (Avery County).

The Mosaic Bog is characterized by small, dense clusters of shrubs and stunted trees that are widely scattered among a thick herbaceous and bryophyte layer, creating a mosaic or zoned pattern. Acer rubrum may be present as seedlings or small saplings and stunted individuals of Tsuga canadensis and Picea rubens may be present. Shrub composition is variable and typically reduced to small patches of relatively short (< 1-2 m) individuals. Shrubs present may include Salix sericea, Lyonia ligustrina var. ligustrina, Kalmia latifolia, Viburnum cassinoides, Rosa palustris, Vaccinium corymbosum, Amelanchier spp. and (arborea/laevis). The dwarf shrubs Vaccinium macrocarpon and Rubus hispidus are typically present. The herbaceous layer dominates composition and is composed of a variety of graminoids, forbs, and the fern Osmunda cinnamomea var. cinnamomea. Typical
graminoids include Carex echinata ssp. echinata, Juncus spp. (acuminatus/canadensis/subcaudatus), Eriophorum virginicum, Carex leptalea var. leptalea, Juncus effusus s.l. (includes J. pylaei), Scirpus expansus and Carex crinita s.l. (includes C. gynandra and C. mitchelliana), Eriophorum virginicum, Eleocharis tenuis, and Sphenopholis pensylvanica. Common forbs that may be present include Solidago patula var. patula, Houstonia serpyllifolia, Drosera rotundifolia var. rotundifolia, Epilobium leptophyllum, Viola macloskeyi var. pallens, Oxypolis rigidior, Platanthera clavellata, Viola cucullata, Packera aurea, Eupatorium perfoliatum, Scirpus spp. (atrovirens/cyperinus/georgianus/hattorianus/polyphyllus), Clematis virginiana, Linum striatum, Parnassia asarifolia, Rhynchospora capitellata, Persicaria sagittata, Dryopteris cristata, Symphyotrichum puniceum var. puniceum, Lycopus uniflorus, Fragaria virginiana, and Lilium grayi.

The Mosaic Bog is most comparable to the NVC associations CEGL003913 and CEGL004158 but the Mosaic Bog is broader in floristic variation and in geographic scope than these associations (NatureServe 2009). The Mosaic Bog also also has elements of the NVC associations CEGL003915 (NatureServe 2009) (Appendix D). Revisions are needed to improve synonymy among concepts. The Mosaic Bog is falls within the concept of Schafale and Weakley’s (1990) Southern Appalachian Bog (Northern Subtype) (Appendix D).

2.6 Mountaintop Fen (4 plots)

Cladium mariscoides – Solidago uliginosa var. uliginosa / Sphagnum spp.
The **Mountaintop Fen** is restricted to one site, Bluff Mountain, located in Ashe County at an elevation of 1,370 m. This community type represents a unique assemblage of vegetation, distinctive in lacking canopy coverage, having minimal scattered shrubs, and having a dominance of graminoids, particularly the sedge *Cladium mariscoides*. Shrubs that may be present in small patches of low abundance or concentrated near wetland edges include *Alnus serrulata*, *Kalmia latifolia*, and *Rhododendron* sp. (subgenus Hymenanthes). *Acer rubrum* and/or *Acer saccharum* may occasionally contribute to the shrub composition. The herbaceous layer is dominated by graminoids and other forbs, which vary spatially in abundance and composition. *Cladium mariscoides* is a characteristic dominant throughout the herbaceous layer in association with *Carex atlantica*, *Drosera rotundifolia* var. *rotundifolia*, *Eriophorum virginicum*, *Linum striatum*, *Lycopus uniflorus*, *Parnassia grandifolia*, *Rhynchospora capitellata*, *Sanguinaria canadensis*, *Solidago uliginosa* var. *uliginosa*, *Hydrophyllum canadense*, and *Xyris torta*. Additional common herbaceous taxa include *Oxypolis rigidior*, *Rhynchospora alba*, *Juncus* spp. (*acuminatus/canadensis/subcaudatus*), *Triantha glutinosa*, *Carex leptalea* var. *leptalea*, *Carex stricta*, *Utriculatia cornuta*, *Osmunda regalis* var. *spectabilis*, *Gentiana* sp., *Houstonia serpyllifolia*, *Carex buxbaumii*, *Osmunda regalis* var. *spectabilis*, and *Linum striatum*. Other typical herbs found throughout but usually not as dominants include *Drosera rotundifolia* var. *rotundifolia*, *Lycopodium clavatum*, *Hydrophyllum canadense*, *Xyris torta*, *Oxypolis rigidior*, *Juncus* sp., *Osmunda regalis* var. *spectabilis*, *Tofieldia glabra*, *Houstonia serpyllifolia*, *Gentiana* sp., *Solidago patula* var. *patula*, *Viola cucullata*, *Packera aurea*, *Eleocharis tenuis*, *Dichanthelium dichotomum*, and *Platanthera lacera*. 
The **Mountaintop Fen** as described here is consistent with Schafale and Weakley’s (1990) concept of Southern Appalachian Fen and the NVC association CEGL004167 (NatureServe 2009) (Appendix D). Revisions are needed to improve synonymy among concepts.

## 2.7 Low Elevation Bog (11 plots)

*Lyonia ligustrina var. ligustrina – Aronia arbutifolia / Eriophorum virginicum – Solidago patula var. patula / Sphagnum spp.*

The **Low Elevation Bog** occurs at lower elevations from about 800 m to 1,200 m. Examples occur in Ashe, Alleghany, Yancy, and Burk Counties.

The **Low Elevation Bog** is generally open and herb-dominated but patches of shrubs may occur. Mats of *Sphagnum* spp. are common. Trees such as *Acer rubrum, Liriodendron tulipifera* var. *tulipifera*, and *Pinus strobus* may be widely scattered throughout or dominate on edges but typically contribute little to to overall abundance. Herbaceous composition is variable, but graminoids such as *Eriophorum virginicum, Juncus* spp., *Dichanthelium lucidum, Carex leptalea, Carex atlantica*, and *Carex echinata* ssp. *echinata* and *Rhynchospora capitellata* are common. Characteristic forbs include *Solidago patula* var. *patula* and *Vernonia noveboracensis*. Additional herbaceous associates may include *Drosera rotundifolia* var. *rotundifolia, Viola primulifolia, Osmunda regalis* var. *spectabilis, Eriocaulon decangulare* var. *decangulare, Pogonia ophioglossoides, Scirpus expansus*, and *Symphyotrichum puniceum* var. *puniceum*. Less common herbaceous taxa that may be present include *Eupatorium perfoliatum, Lycopus uniflorus, Oxypolis rigidior, Osmunda*
and Viola cucullata.

The **Low Elevation Bog** is most comparable to the NVC associations CEGL003916 and CEGL004158 but also has elements of CEGL003915 (NatureServe 2009) (Appendix D). Revisions are needed to improve synonymy among concepts. The **Low Elevation Bog** is falls within the concept of Schafale and Weakley’s (1990) Southern Appalachian Bog (Northern Subtype) (Appendix D).

### 2.8 High Elevation Valley Fen (15 plots)

*Carex echinata* spp. *echinata – Vaccinium macrocarpon / Sphagnum* spp.

The **High Elevation Valley Fen** occurs within the amphibolite region of the southern Blue Ridge region of North Carolina at higher elevations, ranging from 1303 to 1342 m. Examples are found in headwater basins and valley bottoms of the Long Hope Creek (Ashe Watauga Counties) and a headwater basin of Howards Creek (Avery County).

The **High Elevation Valley Fen** is predominately herbaceous but may contain scattered patches of low shrubs, usually not reaching more than 1 meter in height, particularly *Rosa palustris* and *Lyonia ligustrina* var. *ligustrina*, and occasionally *Salix sericea*. *Acer rubrum* is occasionally present as small saplings. The dwarf shrub *Vaccinium macrocarpon* is characteristically present and locally dominant. Herbaceous composition is
somewhat variable, but *Carex echinata* ssp. *echinata*, *Carex leptalea* var. *leptalea*, *Solidago patula* var. *patula*, and *Houstonia serpyllifolia* are characteristic dominants in association with less dominant taxa such as *Juncus* spp. (*acuminatus/canadensis/subcaudatus*), *Drosera rotundifolia* var. *rotundifolia*, and *Oxypolis rigidior*. Additional herbaceous dominants may include *Packera aurea*, *Schizachyrium scoparium*, *Eriophorum virginicum*, *Rhynchospora capitellata*, *Rhynchospora alba*, *Parnassia asarifolia*, and *Thelypteris palustris* var. *pubescens*. Less common herbaceous associates may include *Juncus effusus* s.l. (includes *J. pylaei*), *Pogonia ophioglossoides*, *Viola cucullata*, *Galium asprellum*, *Epilobium leptophyllum*, *Carex buxbaumii*, *Linum striatum*, *Scirpus* spp., *Eleocharis tenuis* var. *tenuis*, *Luzula echinata*, *Viola macloskeyi* var. *pallens*, and *Hypericum mutilum* var. *mutilum*. *Sphagnum* spp. are typically dominant.

The **High Elevation Valley Fen** is comparable to the NVC association CEGL004157 (NatureServe 2009). The **High Elevation Valley Fen** includes more floristic variation and is a slightly broader geographic scope than CEGL004157 (Appendix D). In contrast, Schafale and Weakley’s (1990) concept of Southern Appalachian Bog (Northern Subtype) is broader in both floristic variation and geographic range then the concept of **High Elevation Valley Fen** presented here (Appendix D).

**DISCUSSION**

This study provides a comprehensive classification and description of montane non-alluvial wetlands of the southern Blue Ridge region of North Carolina. The use of detailed, quantitative vascular plant data from standard plots allows partitioning of community types
based on vegetation data alone, in addition to a comprehensive assessment of distinctive community characteristics. The resultant descriptions of communities in terms of elevation and soil characteristics should assist in field identification of communities.

Our approach both correlates and contrasts with previous classifications of montane non-alluvial wetlands. By providing a hierarchical framework of vegetation classes and communities, we provide correlation at the highest level (vegetation classes), but at the finer-scale of the community our approach often contracts with previous classifications. Previous classifications have been based on qualitative data. This study presents a first approximation of a geographically broad classification based on quantitative data. The addition of new data in the future will doubtless suggest modifications to the classification presented herein. However, conservation workers and land managers require a classification system that is relevant to the geographic scope and variation of their region yet is manageable in terms of ease community recognition. The vegetation classification of Schafale and Weakley (1990) has heretofore provided such a classification, albeit a subjective one based on qualitative observation rather than quantitative field data. It is hoped that this work will also become a useful reference for scientists and land managers working within the southern Blue Ridge region of North Carolina and surrounding states.

Our study is comparable to the U.S. National Vegetation Classification (NVC; NatureServe 2008), but indicates that substantial revision is needed to more accurately describe the non-alluvial wetlands of the southern Blue Ridge region. While some types are currently described such that they are compatible with communities described in this study, most types are only vaguely comparable (see Appendix D). The NVC classification spans
the entire United States, is derived from both qualitative and quantitative information, and strives for more narrowly defined and homogeneous units (associations) with the goal of providing a framework for precise documentation of ecological context and biodiversity significance (see Federal Geographic Data Committee 2008, Jennings et al. 2009). Communities of the present study span more floristic variation and reflect a more even coverage than NVC community “associations”. Moreover, our classification is more practical and identifiable for the typical user.

To facilitate crosswalks between classifications, we identified NVC associations that currently describe montane non-alluvial wetlands of North Carolina. We highlight those that can be compared to the communities of this study (Appendix D). We anticipate that the data collected and communities defined in this study will be used to refine or define the vegetation associations of the NVC following the U.S. Federal Data Committee standards (Federal Geographic Data Committee 2008) and the Ecological Society of America guidelines (Jennings et al. 2009).

**CONCLUSION**

This study provides the first quantitative and comprehensive description of the vegetational variation found among non-alluvial wetlands spanning the broad geographic range of the southern Blue Ridge region of North Carolina. Results of this study indicate that vegetational composition varies with elevation and soil nutrients while geography seems less important. However, disturbance from flooding (e.g., resulting from beaver activity) and
anthropogenic alteration create a recognizable compositional variation that crosses environmental gradients.

The communities described in this study differ substantially from those described in the current National Vegetation Classification (NVC, NaturServe 2009). This result points to the importance of quantitative data in community description, especially for insular communities. The vegetational variation of insular communities is high compared to that of communities that occur more widely in the landscape as repeatable patterns. Because non-alluvial wetlands of the southern Blue Ridge region are geographically isolated from one another, the chance for dispersal between them is limited. Thus each individual wetland is maintained largely by local processes. Each wetland thus has its own unique assemblage of vegetation that is often only vaguely comparable to that of the next wetland.

Due to the insular nature and relatively high vegetational variation found among non-alluvial wetlands of the southern Blue Ridge region, it is imperative that each and every wetland be quantitatively inventoried to gain a comprehensive understanding of these systems. The data collected in this study were obtained from a significant number of sites and represent the variation found among them. However, sites remain that have not been sampled and more sampling is needed to better understand the variation found within sites. Data are particularly lacking for the lower elevation non-alluvial wetlands found south of the Asheville Basin, particularly in the drainage basin of the French Broad River. Further, the SATURATED FORESTS AND SEEPS vegetation class represents a relatively small sample of the very large and extensive range of variation in vegetation assemblages found scattered throughout seeps and saturated forests of the southern Blue Ridge region of North Carolina.
Additional sampling of vegetation assemblages that falls within this broadly defined vegetation class is needed to better understand the compositional variation found therein. The results of this study provided much needed baseline data to help guide management decisions and to detect changes over time as a result of management and impacts of climate change (Parry et al. 2007). Appropriate methods of management of montane non-alluvial wetlands of the southern Blue Ridge region are very poorly developed because these ecosystems are differ greatly from those in the surrounding landscape. It is likely that new and unusual (relative to the surrounding landscape) approaches are needed to effectively manage and conserve the southern non-alluvial wetlands.

Finally, the quantitative data collected and described here, when combined with that of Virginia and West Virginia (e.g., Fleming et al. 2006, Byers et al. 2007), will provide a better overall comprehensive understanding of southern and central Appalachian montane non-alluvial wetlands.
REFERENCES


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APPENDICES
APPENDIX A

Plot Data
Appendix A. Listing of plots analyzed in this project, including Carolina Vegetation Survey (CVS) Plot ID code, Plot ID code used in this project, data Collector, Plot Size (m²), County of occurrence, Site Number, and Community code. Bolded Plot ID numbers indicate those plots that were treated in analysis of Vegetation Class I but initially clustered with Vegetation Class II. Data are in ascending order of plot ID. CVS Plot ID codes are unique and have three parts: project number, team number, and plot number. Plot ID codes used in this project are also unique and are condensed (to 7 characters) from the CVS Plot ID codes. Many data collectors contributed to the CVS data base and their identity (where Collector = CVS) may be determined from Carolina Vegetation Survey archives. Plots where Collector = Wichmann were inventoried by the author and assistants specifically for this project. Data were collected from 68 Sites distributed across 12 Counties in North Carolina (Fig. 2). A guide to communities referenced by Community codes may be found in Appendix D.

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APPENDIX B.1

Vegetation data for the SATURATED FORESTS AND SEEPS vegetation class
Appendix B.1. Listing of taxa by community type for vegetation class I, SATURATED FORESTS AND SEEPS. Each community type is represented by its number. For each community type, the number of plots, mean elevation (m), mean soil depth (cm), mean bryophyte cover class (CC) and mean species richness (per 100 m²) are indicated. All taxa present in a community type are listed; a line separates prevalent taxa from non-prevalent taxa. Taxa are listed in alphabetical order after sorting in descending order of Constancy (C) and then Cover Class (CC). The typical stratum occupied by each taxon is indicated (T=tree, S=shrub, SS=subshrub, H=herb, V=vine). Calculated values of Frequency (FQ), Mean Cover (MC), Relative Cover (RC), Fidelity (FI), Indicator Value (IV) and Scaled Indicator Value (IVS) are also given for each taxon. Boldface values (C>60, CC>4, IV>30, IVS>15) indicate taxa that are considered characteristic and/or abundant in written descriptions of communities and in community names.

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Mean elevation (m): 1215
Mean soil depth (cm): 99
Mean Bryophyte Cover (CC): 6
Mean sp richness/100 m²: 40

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APPENDIX B.2

Vegetation data for the **BOGS AND FENS** vegetation class
Appendix B.2. Listing of taxa by community type for vegetation class II, BOGS AND FENS. Each community type is represented by its number. For each community type, the number of plots, mean elevation (m), mean soil depth (cm), mean bryophyte cover class (CC) and mean species richness (per 100 m²) are indicated. All taxa present in a community type are listed; a line separates prevalent taxa from non-prevalent taxa. Taxa are listed in alphabetical order after sorting in descending order of Constancy (C) and then Cover Class (CC). The typical stratum occupied by each taxon is indicated (T=tree, S=shrub, SS=subshrub, H=herb, V=vine). Calculated values of Frequency (FQ), Mean Cover (MC), Relative Cover (RC), Fidelity (FI), Indicator Value (IV) and Scaled Indicator Value (IVS) are also given for each taxon. Boldface values (C>60, CC>4, IV>30, IVS>15) indicate taxa that are considered characteristic and/or abundant in written descriptions of communities and in community names.

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Mean soil depth (cm): 102  
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Mean soil depth (cm): 86  
Mean Bryophyte Cover (CC): 6  
Mean sp richness/100 m²: 49

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APPENDIX C

Soil data
Appendix C. Soil nutrients and textural properties averaged across plots within vegetation classes (1.0 and 2.0) and within community types (1.1, 1.2, etc.). See text for full names of vegetation classes and community types. Specific soil variables are as follows: pH, percent base saturation (BS), total cation exchange capacity (CEC; meq/100g), exchangeable cations (Ca, Mg, K; ppm), easily extractable P (ppm), easily extractable micronutrients (Al, Cu, Fe, Mn, Zn; ppm), ratio of exchangeable Ca to Mg (Ca/Mg), percent organic matter (OM; weight loss by ignition), sand, silt, and clay (percent by weight of mineral soil).

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APPENDIX D

Relationship of recognized communities
Appendix D. Communities recognized in the SATURATED FORESTS AND SEEPS and BOGS AND FENS vegetation class are compared with currently recognized associations in the National Vegetation Classification (NVC; NatureServe 2009) and by Schafale and Weakley (1990). Communities are matched at four levels: “<” indicates a concept is narrower than a currently defined concept, “=” indicates two concepts are approximately equal, “>” indicates a concept is broader than a currently defined type, and “> <” indicates the concepts overlap with a currently defined concept, having some unique elements not found in the other. Certainty is ranked on a scale of one to three with 1 being least certain and 3 being most certain. Group numbers and names follow those presented in the text of the document. The number of samples for each community is listed in parentheses after the community name.

<table>
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<tr>
<th>Community</th>
<th>Certainty</th>
<th>NVC CEGL</th>
<th>NVC Name</th>
<th>Shafale and Weakley Name</th>
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<tr>
<td>1.1 High Elevation Seep (8)</td>
<td>3</td>
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<td>Impatiens (capensis, pallida) - Monarda didyma -</td>
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<td>Rudbeckia laciniata var. humilis Herbaceous Vegetation</td>
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<td></td>
<td>3</td>
<td>&gt; 4296</td>
<td>Diphylleia cymosa - Saxifraga micranthidifolia - Laportea canadensis Herbaceous Vegetation</td>
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<td>1.2 High Elevation Sedge Seep (4)</td>
<td>3</td>
<td>= 7697</td>
<td>Carex gynandra - Platanthera clavellata - Drosera</td>
<td>= High Elevation Seep</td>
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<td></td>
<td></td>
<td>rotundifolia - Carex ruthii - Carex atlantica / Sphagnum spp.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Herbaceous Vegetation</td>
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<td>1.3 High Elevation Saturated Forest (12)</td>
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<td>Picea rubens - (Tsuga canadensis) / Rhododendron</td>
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<td>maximum Saturated Forest</td>
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<td></td>
<td></td>
<td>Picea rubens - (Tsuga canadensis) / Rhododendron maximum</td>
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<td>Low Elevation Saturated Forest (28)</td>
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<td><em>Tsuga canadensis - Acer rubrum</em> - <em>(Liriodendron tulipifera, Nyssa sylvatica)</em> / <em>Rhododendron maximum</em> / <em>Sphagnum spp.</em> Forest</td>
<td>Swamp Forest-Bog Complex (Typic Subtype)</td>
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<tr>
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<td></td>
<td>2 &gt; 3667</td>
<td><em>Picea rubens - (Tsuga canadensis)</em> / <em>Rhododendron maximum</em> Saturated Forest</td>
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<td></td>
<td>2 &gt; 3918</td>
<td><em>Alnus serrulata - Viburnum nudum var. nudum</em> - <em>Chamaedaphne calyculata</em> / <em>Woodwardia areolata</em> / <em>Sarracenia rubra ssp. jonesii</em> Shrubland</td>
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<tr>
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<td>2 &gt; 8438</td>
<td><em>Glyceria striata - Carex gynandra - Chelone glabra</em> - <em>Symphyotrichum puniceum - Sphagnum spp.</em> Herbaceous Vegetation</td>
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<td>Disturbed Bog (13)</td>
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<td><em>Juncus effusus - Chelone glabra - Scirpus spp.</em> Southern Blue Ridge Beaver Pond Herbaceous Vegetation</td>
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<td>3 &gt; 4112</td>
<td><em>Juncus effusus</em> Seasonally Flooded Herbaceous Alliance</td>
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<td><em>Sparganium americanum - Epilobium leptophyllum</em> Herbaceous Vegetation</td>
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<td>Shrub Bog (14)</td>
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<td><em>Alnus serrulata - Kalmia carolina - Rhododendron catawbiense</em> - <em>Spiraea alba - Carex folliculata - Lilium grayi</em> Shrubland</td>
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<td>2 &gt;</td>
<td>3915 Alnus serrulata - Kalmia carolina - Rhododendron catawbiense - Spiraea alba / Carex folliculata - Lilium grayi Shrubland</td>
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<td>3916 Alnus serrulata - Rhododendron viscosum - Rhododendron maximum / Juncus gymnocarpus - Chelone cuthbertii Shrubland</td>
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<td>4156 Carex (atlantica, echinata, leptalea, lurida) - Solidago patula Herbaceous Vegetation</td>
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<tr>
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<td>2 &gt; &lt;</td>
<td>3915 Alnus serrulata - Kalmia carolina - Rhododendron catawbiense - Spiraea alba / Carex folliculata - Lilium grayi Shrubland</td>
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<td>Mountaintop Fen (4)</td>
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**ADDITIONAL NVC ASSOCIATIONS ATTRIBUTED TO OR HAVING POTENTIAL TO OCCUR IN NC:**

**Notes:**

<p>| 3909 | Alnus serrulata - Lindera benzoin / Scutellaria lateriflora - Thelypters noveboracensis | Shrubland | Occupies lower elevation seeps which were not targeted as sample sites and were not sampled. |
| 3914 | Alnus serrulata - Rhododendron arborescens / Sarracenia oreaphila - Rhynchospora rariflora | Shrubland | 1 rare example occurs in NC, not sampled |</p>
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<td><em>Rhododendron maximum</em> / <em>Sphagnum</em> spp. Shrubland</td>
<td>Common along wetland edges, not sampled</td>
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<td><em>Alnus serrulata</em> / <em>Sanguisorba canadensis</em> - <em>Parnassia grandifolia</em> - <em>Helenium brevifolium</em> Shrubland</td>
<td>1 degraded example occurs in NC, not sampled</td>
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<td><em>Pinus strubus</em> - <em>Acer ruburm</em> / <em>Spiraea alba var. latifolia</em> / <em>Sanguisorba canadensis</em> Woodland</td>
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