Natural vegetation of the Carolinas: Classification and description of the Piedmont alluvial plant communities of the Cape Fear, Neuse, and Tar-Pamlico River Basins

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Abstract

Floodplain ecosystems have long been known to be home to diverse and highly productive communities. Despite their ecological significance, however, little is known about the vegetation composition and structure of these systems in the Piedmont region. As faced-paced population growth and development disturb lager areas of the North Carolina Piedmont, ecosystem restoration activities are becoming more common and the need for a detailed knowledge of vegetation composition and structure is becoming more critical; however, there is relatively little documentation or understanding of bottomland vegetation types in North Carolina or elsewhere on the southeastern Piedmont. Our understanding of these brownwater bottomlands is based primarily on qualitative data, and there has been no comprehensive, data-based classification and description of these community types. In this report we present a classification based on one-hundred and nineteen collected in the Cape Fear, Neuse, and Tar-Pamlico River basins of the North Carolina Piedmont. Vegetation types were derived using hierarchical cluster analysis, and non-metric multi-dimensional scaling (NMS) was used to help differentiate and characterize the resultant groups. We identify six vegetation groups. While some of these groups fit well within currently recognized community-type concepts, others deviate sharply from established types and point to a need for refinement of currently recognized community concepts. These six groups are discussed below, each with a description of composition, related community concepts, and correlated environmental variation.

I. Introduction

Riparian ecosystems are home to diverse and highly productive communities, in part due to the diversity of habitats found in this landscape. Floodplain plant communities, in particular, have long been known to be one of the most diverse terrestrial habitats on Earth (Nilsson *et al* 1989, Gregory *et al* 1991, Naiman *et al* 1993). In addition to the ecological value of these communities, floodplain vegetation provides many services to the human population including filtration of pollutants, flood and erosion control, fish and wildlife habitat, and a variety of recreational opportunities.

However, few pristine riparian ecosystems remain in the developed world today, particularly in North America (Sharitz and Mitsch 1993). Many of these landscapes have been converted to agriculture, damaged by impoundments, or degraded by the invasion of non-native species. North Carolina rivers have not escaped this trend. As residential and commercial development keeps pace with our growing population, our waterways continue to face new threats, particularly in rapidly developing areas like the Piedmont of North Carolina. According to the Census Bureau, four North Carolina Piedmont cities are included in the list of fifty fastest growing U.S. cities: Cary, Raleigh, Charlotte, and Durham. The effects of this massive growth on our water resources have already been recognized; in 2007, the Neuse River was named America's eighth most endangered river by the American Rivers organization, and The Rivers of Life publication, produced by The Nature Conservancy and various non-profit and state agency partners, listed both the Neuse and Tar Rivers as "hot spots" for at-risk freshwater species (Masters *et al* 1998).

Knowledge of the vegetation composition and structure of these communities can inform management decisions and direct restoration projects in degraded systems. However, the bottomland communities of Piedmont rivers have not previously been well documented and quantitatively described. This report documents the composition and structure of the bottomland vegetation found in one-hundred and nineteen vegetation plots sampled in the Piedmont portions of the Cape Fear, Neuse, and Tar-Pamlico River basins. The goals of this project are to define and characterize the riparian vegetation types of the Piedmont region of these basins, and to use the results to develop proposals for revision or elaboration of the types recognized in the U.S. National Vegetation Classification and the North Carolina Natural Heritage Program's Classification of the Natural Communities of North Carolina. It is our goal and expectation that the classification and description of vegetation types will provide better targets for restoration activities in this area.

II. Background

Thirty-five communities in the U.S. National Vegetation Classification have been attributed to or likely occur in the riparian zone of Piedmont brownwater rivers (NatureServe 2009); these communities are listed in Appendix 1. Eight communities in the Classification of the Natural Communities of North Carolina, Third Approximation, are attributed to Piedmont riparian zones(Schafale and Weakley 1990). These communities are listed in Appendix 2. These classifications, however, are primarily based on qualitative data with little or no quantitative data supporting their descriptions. The goal of this document is to use quantitative data on community composition to evaluate, document, and where appropriate revise the existing classification

III. Field data

During the summers of 2006 and 2007, one-hundred and nineteen vegetation plots were established and recorded in the Piedmont portions of the Cape Fear, Neuse, and Tar-Pamlico River basins. Sample sites were stratified by geographic location within the basin, bedrock composition, geomorphic position, and floodplain width. Sample sites on smaller streams with poor geomorphic development were identified as small stream floodplains, while sites on larger streams were tentatively identified to one of five geomorphic positions in the field. Moving across the floodplain, the five geomorphic positions defined for use in this analysis were: (1) rocky bar and shore, located along the river itself, inside any levee structure, (2)the levee, a raised area running parallel to the river, (3) the backswamp, farther from the river itself, beyond the levee, often flooded for long periods of time when compared to the levee, (4)the terrace, located beyond the backswamp, which are rarely flooded, and (5)the flat, often located parallel to a levee or in the place of a true raised levee in smaller rivers. This setting tends to have features intermediate to the levee and backswamp and intergrades with the two where geomorphology is poorly developed. All plots were located approximately within the twenty-year floodplain of the nearest creek, determined using floodplain maps and the local vegetation composition, with hydrophitic species indicating an area inside the floodplain.

Vegetation was sampled following the Carolina Vegetation Survey (CVS) protocol described in Peet *et al* 1998. Plots were oriented with the long axis parallel to the longitudinal axis of the river. Soil samples were collected at each site and analyzed for texture and nutrients.

IV. Analytical methods

Vegetation data were analyzed using cluster techniques, indicator species analysis, and ordination techniques as implemented PC-ORD (version 5). Group selection was based on two methods of hierarchical cluster analyses: (1) group linkage based on flexible beta (beta=0.25) with a dissimilarity matrix computed using Sorenson distance and (2) group linkage based on Ward's method with a dissimilarity matrix computed using Euclidean distance. Indicator species analysis was used to determine the appropriate number of vegetation groups to recognize, as well as to indentify indicator species in each group. Non-metric, multidimensional scaling (NMS) ordination was used to determine the environmental setting associated with each group identified in the cluster analysis; all ordinations were based on Sorenson distance.

V. Results

Cluster analysis suggested the recognition of six groups (Appendix 3; dendrogram). The herbaceous community is the first break in the dendrogram produced using all plots. These plots were removed from further analyses of forested communities. Although a different level of division into clusters would have been possible, six clusters resulted in groups with approximately the same degree of compositional distinctness as is typically recognized in the US NVC; however, some NVC groups are narrowly defined based upon plots at a single location. The groups here are based upon a large number of plots across a larger geographic area, and allow for some compositional variation within the groups across this area. For the dendrogram presented here, the next cut, which would recognize a seventh group, divides the *Platanus occidentalis-Celtis laevigata-Fraxinus pennsylvanica- Ulmus americana/Acer negundo* forest vegetation type, discussed below, into two groups. While there may be some merit in this division, the two groups resulting from this division diverge primarily based upon a few species that are more common in nutrient rich sites or in different river basins; recognition of two groups here would require a different level of compositional distinctness than is normally recognized in the US NVC. Instead, we recognize compositional variability within the group that is related to the quality of the substrate and geographic location. We present analyses that elucidate the relationship of these two subgroups to substrate and geography below. Recognizing an eighth or ninth group further divides this vegetation group. While this group is large, floristic differentiation of the subgroups does not appear to be strongly correlated with any recorded ecological variable, and therefore, this group is recognized as a heterogeneous vegetation type.

Indicator species analyses supported the division of the forested plots into five groups. An optimum number of clusters was determined based upon maximization of significant indicator values and minimization of average p-values (Dufrene and Legendre 1997; McCune and Grace). A full species matrix, as well as matrices with single occurrence species, two occurrence species, and three occurrence species removed, were used for this analysis; all but the full matrix supported five clusters.

The full matrix, on the other hand, supported 6 clusters, dividing the large levee group as discussed above. A table showing the change of total significant and average p-values at different cluster numbers is displayed in Appendix 4; this table is based upon a vegetation matrix where species that occur in two or fewer plots have been removed.

The forested groups are presented in a non-metric multidimensional ordination space in Appendix 5. Vectors for environmental variables are overlaid on this plot (r^2>0.25). Vegetation plots are grouped by community-type discussed below, with the subgroups of group 6 also displayed in the ordination plot.

A community characterization and description of each vegetation group is presented below. Vegetation type names are based on the naming system used in the U.S. National Vegetation Classification (NatureServe 2007; Jennings et al 2006). Names reflect species with high constancy and high cover; a "-" separates species within the same vertical strata, while a "/" separates species of a different strata. Each community type presented in this document is compared with currently recognized concepts from NVC and NHP's Third Approximation (Appendix 6). A floristic table is presented for each type; the tables include the most common species of each stratum found in each group, ranked by constancy and average cover class values within the group. Average cover class was calculated using only plots where the species was present. Constancy, the percent of plots within a group in which a given species is present, is reported (e.g., a species present in all plots within a group has a constancy value of 100%). A map displaying geographic extent is also presented for each group, and a summary table of soil data by vegetation type is found in Appendix 7.

The vegetation types presented here appear to be driven by a combination of geomorphic position, substrate, geographic location, and floodplain width. The geomorphic landscape of most Piedmont brownwater rivers is not very well developed due to the resistant metamorphic and granitic bedrock dominant in this region. The resulting landscape is dominated by comparatively narrow floodplains where geomorphic positions are not as well developed as in the Coastal Plain. The Triassic Basin region of the Piedmont, however, is characterized by sedimentary bedrock, allowing wider floodplains and a better developed geomorphic landscape as rivers travel through this region; the larger floodplains of this region result in more variation between the environmental settings of each geomorphic position. Several vegetation types presented below are associated with floodplains of a particular width (often correlated with substrate), moving along a continuum from narrow floodplains found along smaller streams on resistant bedrock to larger floodplains found within the Triassic Basins. Compositional variation within the groups presented below is driven by substrate quality and successional status.

I. Herbaceous vegetation

1) *Justicia americana* herbaceous vegetation. This community occurs on rocky bottomed rivers and are heavily dominated by herbaceous cover from water willow, *Justicia americana* (Appendix 8). Occasional tree cover is contributed by overhanging bottomland species that may include *Platanus occidentalis, Fraxinus pennslyvanica,* and *Betula nigra.* Nine plots, distributed across the three river basins, were included in this analysis. The geographic distribution of this group is shown in Appendix 9. This group closely matches community concepts already recognized in both NVC and NHP's third approximation (Appendix 6).

II. Small stream (narrow floodplain) forests

2) *Liquidambar styraciflua – Liriodendron tulipifera* small stream forest. This closed canopy forest is dominated by *Liquidambar styraciflua, Liriodendron tulipifera, Acer rubrum,* and a wide variety of bottomland tree species (Appendix 10); the narrow floodplains associated with this type result in less species-sorting compared to larger floodplains where geomorphic features are better developed and the inclusion of more species that are often upland in character. The subcanopy is dominated by *Carpinus caroliniana, Ulmus alata, Ostraya virginiana,* and *Acer floridanum,* while the shrub layer tends to be relatively sparse. Exotic species commonly associated with this type include *Eleagnus umbellata, Lonicera japonica,* and *Microstegium vimineum.* The description of this group is based upon seventeen plots distributed across the three river basins (Appendix 11). This group is approximately equal to the *Liquidambar styraciflua – Liriodendron tulipifera / Lindera benzoin / Arisaema triphyllum* Forest of the NVC, although the group described here includes various *Carya* species not mentioned the description of the NVC type. This type fits within the Piedmont alluvial forest described in the Third Approximation.

3) *Ilex opaca- Quercus nigra* forest. This closed canopy forest is dominated by *Ilex opaca, Quercus nigra, Liquidambar styraciflua, Carpinus caroliniana,* and *Acer rubrum* (Appendix 12). The twelve plots included in this type are primarily located along the fall-line in the Tar-Pamlico river basin; many are on small streams, but a few are on the Tar River itself in areas where the floodplain is narrow (Appendix 13). Soils associated with this group are relatively nutrient-poor, sandy soils. This group is similar to the *Nyssa biflora – Quercus nigra – Quercus laurifolia – Pinus taeda / Ilex opaca – Carpinus caroliniana* Forest of the NVC, which is also indicated to occur on small streams of the lower Piedmont. However, while the group recognized here is dominated by the title species and bottomland oaks indicated in the NVC description, it does not "always include substantial" *Nyssa biflora* or *Taxodium distichum* as required by the NVC. The NVC-type may warrant revision to reflect this difference. There appears to be no good match for this group in the Third Approximation.

III. Bottomland forests

4) *Quercus* phellos – Quercus pagoda – Quercus michauxii bottomland forest. This closed canopy forest is dominated by bottomland oak species *Q. phellos, Q. michauxii,* and *Q. pagoda* in addition to other common bottomland species, including *Liquidambar styraciflua, Acer rubrum* and *Fraxinus pennslyvanica* (Appendix 14). *Quercus alba, Quercus lyrata,* and *Quercus nigra* are also present in some plots of this group. The shrub stratum is primarily a mix of *Carpinus caroliniana* and *Ilex decidua.* This vegetation type is correlated with the backswamp and terrace geomorphic positions and nutrient poor soils. Dominance of particular oak species indicates the hydrologic regime at smaller scales; *Q. lyrata*, for example, reflecting wetter, sometimes small depressions within the larger flat bottomland topography . Eighteen plots are included in this group; most are located within the Triassic Basins, where the sedimentary bedrock has allowed the development of wider floodplains with a range of geomorphic settings. Geographic distribution is shown in Appendix 15. The group presented here approximates the NVC community type *Quercus pagoda - Quercus phellos - Quercus lyrata - Quercus michauxii / Chasmanthium latifolium* Forest (Appendix 4) This group fits within the Piedmont swamp forest described by NHP, but is a more narrowly circumscribed group with the oak species occupying the dominant canopy position. This suggests that the NHP type is too broad in composition while the NVC types may be too narrow in geographic setting, as this type appears to occur outside of the Triassic Basins.

5) *Acer rubrum – Fraxinus pennsylvanica* bottomland swamp forest. The mostly closed canopy of this vegetation type is heavily dominated by both *Acer rubrum* and *Fraxinus pennslyvanica,* in addition to other common bottomland trees including *Liquidambar styraciflua, Quercus phellos,* and *Carpinus caroliniana* (Appendix 16). The sparse shrub stratum is primarily composed of *Ilex decidua*, and the relatively robust vine layer is dominated by *Toxicodendron radicans, Campsis radicans,* and *Smilax* spp. The herbaceous stratum is dominanted by *Saururus cernusu, Boehmaria cylandrica,* and a variety of *Carex* species. This vegetation type is found in the backswamp geomorphic landscape position, well-distributed among all three river basins (Appendix 17). Ordination results indicate that this type is associated with high-clay content in the A horizon and relatively infertile soils. While the NVC recognizes a variety of red maple-green ash swamp forests, they are difficult to differentiate based upon the current descriptions and none are recognized in North Carolina. The closest fit is *Acer rubrum - Fraxinus pennsylvanica - Ulmus americana / Boehmaria cylindrica* Forest, which recognized in Virginia and more northerly states; it should likely also be recognized in North Carolina. This vegetation type fits within the Third Approximation Piedmont swamp forest.

6) *Platanus occidentalis – Celtis laevigata – Fraxinus pennslyvanica – Ulmus americana / Acer negundo* levee forest. This closed canopy forest is dominated by *Platanus occidentalis, Celtis laevigata, Fraxinus pennsylvanica, Ulmus [americana + rubra],* and *Liquidambar styraciflua* (Appendix 18). *Acer negundo* is the dominant sub-canopy species, in addition to *Acer floridanum* and *Carpinus caroliniana.* This groups is based upon a large group of plots, forty four in total; while the dominant trees are found in most sites, there is much variation in this group. In cluster analyses, this group had a tendency to split into two sub-groups (floristic tables and soil average are presented for the subgroups for comparison; Appendix 7, 19, and 20). Ordination within the larger group of forty-four levee plots indicate that nutrient differences between the subgroups and influence of an east-west geographic gradient may be driving this split (Appendix 21). This suggests compositional differences across river basin boundaries. This type tends to be found on the levee, where geomorphic positions are well-developed, or flats along the river where geomorphology is not well-developed, as is true in most Piedmont areas. The larger group is well distributed across the three sampled basins (Appendix 22).

This type approximates three NVC types and fits within the Piedmont levee forest of the Natural Heritage Program. Floristically, it is very close to the *Platanus occidentalis – Celtis laevigata – Fraxinus pennsylvanica / Lindera benzoin – Ilex decidua / Carex retroflexa* Forest (CEGL 7730) described in the NVC; however, this type is primarily described as a coastal plain group based upon plots in the

Congaree Swamp. It is noted that it may also occur in the lower Piedmont and adjacent regions; the plots that form the group recognized here are found across the North Carolina Piedmont, perhaps indicating that this NVC type should be expanded to include these occurrences. Additionally , this group closely approximates the *Celtis laevigata – Fraxinus pennsylvanica – Acer negundo – (Juglans nigra) / Asimina triloba / Carex grayi* Forest (CEGL 4740), which is also currently described as a coastal plain vegetation type. Finally, the group described here also approximates the *Platanus occidentalis-Liquidamabr styraciflua / Carpinus caroliniana – Asimina triloba* Forest of the NVC ; this group is described as related to CEGL 7730 described above, but likely to be found in upper and inner Piedmont areas. The major difference between the group described here and this final NVC group is the dominance of *Acer negundo* as a subcanopy tree; *Acer negundo* is explicitly mentioned as a subcanopy tree in the first two NVC groups listed.

VI. Discussion and future directions

The community characterization presented above is based upon data collected within the Piedmont portion of the Cape Fear River, Neuse, and Tar-Pamlico river basins. While some types appear to be compositionally consistent across the study area, floristic composition of some bottomland communities tends to vary from basin to basin. Additional plot data from surrounding watersheds will help determine the general applicability of these types across all Piedmont river basins of North Carolina and will help determine the appropriate level of coarseness for conservation and restoration purposes. Coverage across a larger number of river basins will allow us to better examine compositional variation of widely distributed types across basin boundaries. To this end, in the summer of 2008, plot data will be collected in the Piedmont portion of the Yadkin and Catawba River basin. Data from the Yadkin basin is particularly important for this classification, as the Yadkin basin holds the largest percentage of Piedmont acreage for any North Carolina river basin. This data will also help determine the appropriate revisions to both the U.S. National Vegetation Classification and the N.C. Natural Heritage Program's classification schemes.

VII. Literature Cited

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