



Baseline Vegetation Mapping of National Capital Region Parks in Maryland, Virginia, West Virginia, and the District of Columbia

Part 1—Final Report



View of the Potomac River from the Paw Paw Bends, Chesapeake, and Ohio Canal.

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Baseline vegetation mapping of National Capital Region parks in Maryland, Virginia, West Virginia, and the District of Columbia: Part 1—final report

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Preface

This is Part 1 of a 7-part final report, *Baseline Vegetation Mapping of National Capital Region Parks in Maryland, Virginia, West Virginia, and the District of Columbia*.

The baseline vegetation classification and maps of the National Capital Region parks were developed as one unit, which increased the robustness of the analyses. One result from this approach is that the final report is large and exceeds 1,000 pages. The main report, Part 1, describes the methods and processes with summary results. The report continues presenting detailed results in Parts 2 through 7 with supporting geodatabases, vegetation and accuracy assessment plots databases, plot photos, and other files within one project file stored on NPS Integrated Resource Management Applications (IRMA) website (<https://irma.nps.gov/datastore>).

The individual park vegetation descriptions were compiled as a regional report (Part 2) and divided for convenience into park specific reports (Parts 2B through 2L) with mapped vegetation posters as Adobe PDF files. Vegetation and map class names used in these keys correspond to the map class names used in the NCR vegetation maps and accuracy assessment (Part 7. Accuracy Assessment Contingency Tables). These names will not match the primary names used in the vegetation descriptions (Part 2 and 2B through 2L) when nomenclature has changed within the USNVC and ITESC. A crosswalk highlighting all nomenclature changes is provided in Part 3. Nomenclature Changes of USNVC and ITESC for NCR Plant Communities.

Abstract

The National Park Service (NPS) National Capital Region (NCR), the Virginia Natural Heritage Program (VANHP), NatureServe, and Natural Heritage Programs in Maryland, Pennsylvania, and West Virginia, completed the vegetation classification and mapping of eleven parks, totaling 29,968 hectares (74,053 acres) in the NPS NCR. Upon the completion of the vegetation characterization and mapping, NatureServe finalized this process by conducting a thematic accuracy assessment of the resulting the vegetation map. Field observations were collected at 1,561 locations across the eleven parks to analyze the map classes observed in the field against those on the map. Overall map accuracy for 66 map classes was 80.59% (Kappa statistic of 79.23%). The final vegetation maps included a total of 110 map classes that were used to characterize 109 USNVC associations plus other land cover across the 11 parks. These 110 map classes can be separated into four categories: individual USNVC associations (n=80), composite map classes primarily comprised of another 30 USNVC associations (n=11), special feature map classes (n=9), and National Land Cover Database map classes (n=10). Of the 109 USNVC associations, 106 were identified during the classification effort and three were added during the mapping effort; 55 represented upland and 54 wetland or riparian vegetation.

Executive Summary

The National Park Service (NPS) Vegetation Mapping Inventory Program (VMI) supports the classification, description, and mapping of existing vegetation in national park units for the NPS Natural Resource Inventory and Monitoring (I&M) Network. With support from NPS VMI and the NPS National Capital Region (NCR), the Virginia Natural Heritage Program (VANHP) along with NatureServe and ecologists from the National Park Service and Natural Heritage Programs in Maryland, Pennsylvania, and West Virginia, have completed the vegetation classification and mapping of eleven parks, totaling 29,968 hectares (74,053 acres) in the NPS NCR. Upon the completion of the vegetation characterization and mapping of the NCR, NatureServe finalized this process by conducting a thematic accuracy assessment of the resulting vegetation maps.

The VANHP led the NCR vegetation classification and mapping process. Ecologists from NatureServe and the Natural Heritage Programs in Virginia, Maryland, West Virginia, and Pennsylvania all contributed information relating to the occurrence and distribution of known U.S. National Vegetation Classification ([USNVC](http://usnvc.org), <http://usnvc.org>) associations or plant communities in the study area. Supplemental data was reviewed from related work, including studies by Lea (2000), Gawler (2004), and Fleming (2007). Data gaps were identified and areas lacking sufficient plot data to confidently define a natural or seminatural USNVC association were targeted for additional field work. No early successional vegetation was targeted for sampling. Sampling plans for NCR parks were largely based on a preliminary analysis of existing vegetation data in the region, a regional rapid assessment study done by Lea (2004), and other park studies (e.g., Fleming and Weber 2003, Coulling 1999, Rawinski 1995). To fill the data gaps, a total of 578 quantitative vegetation plots were collected in natural and seminatural vegetation within and in the vicinity of NCR parks from 2003 to 2006. In addition, supplementary data were gathered from other projects and initiatives in the region to form a regional dataset of 3,005 plots. The plot dataset was partitioned into subregional datasets and subsequent smaller datasets for classification analyses. All datasets were imported from Microsoft Access into the software program PC-ORD (version 5.04; McCune and Mefford 1999) for multivariate numerical analyses. Ultimately, 1,972 of the initial 3,005 plots were used to define the primary natural and seminatural USNVC associations for the NCR. Qualitative ‘observation points’ were collected to assist in documenting vegetation types not targeted for quantitative vegetation plots.

After the vegetation classification was completed, the VANHP mapped the vegetation of NCR parks. Mapping was informed by all observation and plot data collected or gathered for the vegetation classification. Additional field observations were also collected as a part of the mapping process. Ancillary data used to help inform the mapping process included geologic, wetland, and soil maps, and the National Elevation Dataset (NED). ESRI ArcGIS software (version 9.2) was used to develop the vegetation maps. All digitizing and attributing map classes to polygons was conducted on two Windows XP desktop workstations that were networked for file sharing. The Leica StereoAnalyst extension (version 9.1) for ArcMap was loaded on one workstation (Dell Precision Workstation 690) to enable stereoscopic viewing and editing. Specialized hardware included a stereo-enabled video card (nVidia Quadro FX 4500), a Stereographics Monitor Zscreen mounted on a 21-inch CRT

monitor (NEC AccuSync 120), and polarized glasses supplied with the Zscreen. Properly oriented, overlapping image tiles could be viewed in stereo when used in combination with Leica Photogrammetry Suite Block files (*.blk) providing the necessary parameters. Through using these tools and datasets, VANHP delineated boundaries around different types of vegetation occurring on park lands and classified these different areas into map classes. Vegetated map classes were based on the USNVC association level when possible and when not, they were based on coarser-level ecologically defined map classes (COMP), e.g., shale barren woodlands (COMP_SBWO). The National Landcover Database (NLCD) classification was used to create map classes for non-vegetated areas. The USNVC association-level map was then converted into a map of terrestrial ecological systems following the International Terrestrial Ecological Systems Classification (ITESC) (Comer et al. 2003).

At the finest level, the final NCR vegetation map included a total of 110 map classes that were used to characterize 109 USNVC associations, four USNVC cultural subtypes, one park special, plus other land cover across the 11 parks (Tables 8, 9, 11, and 12). These 110 map classes can be separated into four categories: individual USNVC associations (n=80), composite map classes primarily comprised of another 30 USNVC associations (n=11), special feature map classes (SF) (n=9), and NLCD map classes (n=10).

The classification and mapping efforts for NCR resulted in a total of 109 USNVC associations (code begins with CEG), 4 USNVC cultural subtypes (code begins with CEST), 1 park special (code begins with CEPS), and 24 ecological systems (code begins with CES) (Tables 6–12). Of the 109 USNVC associations, 106 were identified during the classification effort and three were added during the mapping effort; 55 represented upland and 54 wetland or riparian vegetation.

A thematic accuracy assessment (AA) of map classes was completed to provide the probability that a given place on the ground or on the map is mapped correctly. Field observations collected at 1,561 locations across the eleven parks were summarized into a series of contingency tables to analyze the map classes observed in the field against those on the map. In the final analysis, overall map accuracy for 66 map classes was 80.59% (Kappa statistic of 79.23%). Thirty-eight (38) of the 66 individual map classes had accuracy of 80% or above in the 90% confidence interval for both producers and user's accuracy.

In addition to this project report, the NCR vegetation classification and mapping project developed and provided other important data including vegetation descriptions, vegetation map geospatial data, map class descriptions, field keys to USNVC associations and other map classes, photo interpretation keys, a database with vegetation classification and AA observation data, digital images of vegetation classification and AA field observation areas, vegetation observation data collection forms, and contingency tables listing AA results. These are all provided as separate documents.

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Introduction

General Background

Effective management of natural resources in our national parks depends on park managers having access to comprehensive, scientifically credible and defensible information on species and habitats found in the parks. Vegetation classifications and maps can form the foundation for resource management activities in national parks and are recognized by the National Park Service (NPS) as one of twelve basic data sets needed for every park with significant natural resources (NPS 2003, 2009). Activities as diverse as park planning, fire management, wildlife research, habitat conservation/restoration, cultural landscape inventories, and visitor interpretation all can be informed by the classification and mapping of different types of vegetation. Additionally, a vegetation map that is based on a nationally used and standardized classification system provides a way to assess how an individual park's biodiversity fits into the context of larger geographic areas.

The National Park Service Vegetation Mapping Inventory Program

The NPS Vegetation Mapping Inventory Program (NPS VMI) works to classify, describe, and map existing vegetation communities in more than 270 national park units across the United States. The NPS VMI provides baseline vegetation information for the NPS Natural Resource Inventory & Monitoring Program.

Vegetation Mapping Inventory Program Standards and Guidelines

Since its inception, the NPS VMI has provided guidelines for classifying and mapping vegetation communities on NPS lands and for assessing the accuracy of the resulting maps (The Nature Conservancy and Environmental Systems Research Institute 1994a, 1994b, 1994c, 1994d; Lea and Curtis 2010). These guidelines and other information about the NPS VMI are available online at <https://www.nps.gov/im/vegetation-mapping-inventory.htm>. Products produced as part of the NPS VMI must meet Federal Geographic Data Committee (FGDC) standards for vegetation classification and metadata, and national standards for spatial accuracy and data transfer. These include the following:

- National Vegetation Classification Standard (FGDC 2008).
- Content Standard for Digital Geospatial Metadata (FGDC 1998a).
- Spatial Data Transfer Standard (FGDC 1998b).
- United States National Map Accuracy Standards (U.S. Geological Survey 1999).

Standard spatial data products include aerial photography, map classification or key, spatial databases and map layers of vegetation communities, hardcopy maps of vegetation communities, metadata for spatial data, and complete accuracy assessment of the vegetation map. Vegetation information includes vegetation classifications, dichotomous field keys of vegetation classes, formal descriptions of each vegetation class, ground photos of vegetation classes, and field data in database format. Mapping standards include a minimum mapping unit (MMU) of 0.5 hectares (ha) and classification accuracy of 80% for each map class. The spatial databases are required to have horizontal positional accuracy that meets [National Map Accuracy Standards](#) at the 1:24,000 scale.

The NCR map accuracy standard (1:6,000 scale) meets this national standard at a very fine scale. This means that 90% of well-defined objects such as street intersections that can be precisely located in the NCR vegetation maps are expected to be within 5 m of true position on the ground.

The U.S. National Vegetation Classification (USNVC) Standard

The NPS VMI follows the U.S. Federal Geographic Data Committee's National Vegetation Classification Standard (NVCS) for its vegetation classification and mapping efforts. The NVCS includes standard procedures to support the development and consistent use of a national vegetation classification in the United States and its Trust Territories (USNVC). Consistent use of the USNVC enables the development of uniform statistics about vegetation resources across local, state, and national scales.

Over the past 35 years, the USNVC has been developed and implemented by The Nature Conservancy (TNC), the network of Natural Heritage Programs, and more recently, NatureServe, which coordinates the Natural Heritage Program data. The USNVC is a subset of the larger International Vegetation Classification (IVC). In North America, the IVC consists of the USNVC and the Canadian National Vegetation Classification. Further developments are under way through various local, regional, and national projects.

The USNVC is currently maintained and updated by NatureServe through support from nonprofit organizations, businesses, state agencies, federal agencies, the FGDC, and the Ecological Society of America. Refinements to the classification occur through a peer review process.

Though it has been through several revisions, the USNVC has remained a hierarchical classification, allowing its application at any level of the hierarchy. The hierarchy first separates vegetation into "natural" and "cultural" categories. Natural vegetation occurs spontaneously being shaped by natural biotic and abiotic processes; cultural vegetation is intensively managed and maintained (Faber-Langendoen et al. 2009, 2012, 2014). Natural vegetation includes an eight-level hierarchy, organized into three broad upper levels, three mid-levels, and two fine scale levels. Table 1 outlines the natural vegetation hierarchy and provides definitions of the criteria used to distinguish the layers.

NPS VMI classification and mapping projects primarily focus on the lower, floristic levels of the hierarchy—the Association and Alliance. The alliance is a physiognomically uniform group of plant associations that share dominant or diagnostic species, usually found in the uppermost strata of the vegetation. The association is the finest level of the USNVC. An association is defined as a particular plant community that is relatively homogeneous in composition and structure and occurs in a uniform habitat that repeats across the landscape. For example, Mid-Atlantic Mesic Mixed Hardwood Forest (*Fagus grandifolia*--*Quercus (alba, rubra)*—*Liriodendron tulipifera*/(*Ilex opaca* var. *opaca*)/*Polystichum acrostichoides* Forest) is a common forest association that occurs on well-drained, acidic midslopes in the Piedmont and Coastal Plain of Virginia. USNVC associations are also assigned global rarity ranks that indicate their conservation status and relative risk of extirpation (Grossman et al. 1998). Associations from the USNVC are cross-referenced to communities in state-specific vegetation classifications such as the Natural Communities of Virginia (Fleming et al. 2006), as well as to other regional and national and international classification systems.

Table 1. United States National Vegetation Classification System hierarchy for terrestrial vegetation (Faber-Langendoen et al. 2014).

Hierarchy	Level	Definition	Example
Upper Levels	L1 – Formation Class	Broad combinations of dominant general growth forms adapted to basic moisture, temperature, and/or substrate or aquatic conditions.	Mesomorphic Tree Vegetation (Forest to Open Woodland)
	L2 – Formation Subclass	Combinations of general dominant and diagnostic growth forms that reflect global mega- or macroclimatic factors driven primarily by latitude and continental position or that reflect overriding substrate or aquatic conditions.	Temperate & Boreal Forest & Woodland
	L3 – Formation	Combinations of dominant and diagnostic growth forms that reflect global macroclimatic conditions as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions.	Cool Temperate Forest & Woodland
Mid-Levels	L4 – Division	Combinations of dominant and diagnostic growth forms and a broad set of diagnostic plant species that reflect biogeographic differences in composition and continental differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.	Eastern North American Forest & Woodland
	L5 – Macrogroup	Moderate sets of diagnostic plant species and diagnostic growth forms that reflect biogeographic differences in composition and sub-continental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.	Appalachian - Northeastern Oak – Hardwood - Pine Forest & Woodland
	L6 – Group	A relatively narrow set of diagnostic plant species (including dominants and co-dominants), broadly similar composition, and diagnostic growth forms that reflect regional mesoclimate, geology, substrates, hydrology, and disturbance regimes.	Northeastern Oak - Hickory Forest & Woodland
Lower Levels	L7 – Alliance	A characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation. Alliances reflect regional to subregional climate, substrates, hydrology, moisture/nutrient factors, and disturbance regimes.	White oak – Hickory – White Ash Forest Alliance
	L8 – Association	A characteristic range of species composition, diagnostic species occurrence, habitat conditions and physiognomy. Associations reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes.	Northern Red Oak - Chestnut Oak - Red Hickory / (Eastern Redbud) / (Wreath Goldenrod) Forest

An example of another national classification system is the International Terrestrial Ecological Systems Classification (ITESC) (Comer et al. 2003). This is not a part of the USNVC. This project

reviews and updates the relationships between USNVC associations and ecological systems for NCR. The ITESC allows USNVC associations to be grouped at a coarse scale or landscape level based on their physical setting and ecological processes.

Project Overview

In 2001, the National Capital Region of the NPS and NatureServe began classifying and mapping the vegetation of the region's 11 parks. NatureServe enlisted the Virginia Natural Heritage Program to lead all vegetation classification work and all mapping except for that of Rock Creek Park, which was previously mapped in a separate project by The Nature Conservancy and Aerial Information Systems in 1998. NatureServe ecologists updated and remapped Rock Creek Park based on the robust classification provided by the VANHP. Natural Heritage Programs in Maryland, West Virginia, and independent private sector ecologists were enlisted for field data collection and vegetation classification support and review.

The goal of the classification was to accurately classify the vegetation of 11 NCR parks (Table 2) to the association level of the USNVC. Grouping the parks together allowed for a regional classification as the basis for the vegetation maps. The regional classification used quantitative data collected from all park units, combined with existing supplementary data from throughout the central Blue Ridge, Piedmont, and Inner Coastal Plain.

Table 2. List of National Parks within the National Capital Region (NCR) project area. Note: park area is related to park boundaries used for this project that were current in 2007 with overlapping administrative areas.

Park	Acronym	Park Size (ha)	State	NCR Subregion
Antietam National Battlefield	ANTI	1,318	MD	West
Catoctin Mountain Park	CATO	2,276	MD	West
Chesapeake & Ohio Canal National Historical Park	CHOH	9,045	MD, DC	East & West
George Washington Memorial Parkway	GWMP	2,226	MD, DC, VA	East
Harpers Ferry National Historical Park	HAFE	1,731	MD, VA, WV	West
Manassas National Battlefield Park	MANA	2,074	VA	East
Monocacy National Battlefield	MONO	656	MD	West
National Capital Parks-East	NACE	4,357	MD, DC	East
Prince William Forest Park	PRWI	5,102	VA	East
Rock Creek Park	ROCR	1,129	DC	East
Wolf Trap National Park for the Performing Arts	WOTR	54	VA	East

The goal of the regional vegetation classification and mapping effort was to produce a baseline digital geospatial vegetation database for the 10 NCR parks above except ROCR, and to provide a dichotomous key to the vegetation and descriptions of the vegetation in all 11 parks. Baseline information on plant community composition, and rarity is critical to developing desired conditions

and park management goals relating to native plant communities, nonnative plant and insect species, and effects of deer browse and other disturbances. Identification, description, and mapping of plant communities also provides habitat information important to understanding associated organisms, including animals, bacteria, and fungi. A vegetation map can also allow inferences about the location and abundance of species that are characteristic of each community. Baseline inventories are critical for measuring changes in park biota in response to environmental changes, diseases, pests, and resource management activities (e.g., during this project, the hemlock woolly adelgid (*Adelges tsugae*) and emerald ash borer (*Agrilus planipennis*) have decimated populations of hemlock (*Tsuga* spp.) and ash (*Fraxinus* spp.), respectively). This project classified the vegetation in the context of a national and regional vegetation classification, the USNVC. Having each park's vegetation mapped and attributed to this standard will facilitate the comparison of plant communities among other NPS units in the region and throughout the United States.

The three main components of the National Capital Region vegetation mapping project are as follows: (1) vegetation classification, (2) vegetation mapping, and (3) map accuracy assessment (AA). The success of this study depended on cooperative efforts of several government and private entities. VANHP, NatureServe, and NPS along with ecologists from Maryland, West Virginia and Pennsylvania, worked cooperatively on vegetation data collection, review of the regional vegetation classification, development of the map class descriptions, and field keys to the plant communities and map classes. VANHP took lead responsibility for the vegetation data analysis, development of vegetation maps, field validation and editing of the preliminary maps, and production of final maps. NatureServe ensured that the USNVC standard was followed and entered all new information into the USNVC databases and completed global association descriptions. Table 3 provides a timeline for the major processes involved with the vegetation classification and mapping process.

Table 3. National Capital Region Vegetation Classification and Mapping project timeframe.

Task	Timeframe
Project Planning, Imagery Acquisition, GIS, and Rapid Assessments	2001–2003
Preliminary Vegetation Classification and Mapping Planning	2004
Vegetation Plots	2004–2007
Vegetation Classification	2007–2008
Vegetation - Photo Interpretation Training	2006
Map Reconnaissance and Validation	2006–2009
Preliminary Vegetation Polygon Delineation	2007
Vegetation Mapping	2007–2011
Map Verification	2009–2011
Accuracy Assessment Observations	2011–2012
Accuracy Assessment Analyses	2012–2017

National Capital Region Project Area

The National Capital Region project area encompasses 11 park units totaling 29,968 hectares (74,053 acres) in Virginia, West Virginia, Maryland, and the District of Columbia (Table 2). These parks range in size from approximately 54 ha to 9,045 ha, span an area of approximately 10,692 km² (4,128 mile²) and in some cases have overlapping boundaries (Figure 1). The NCR parks encompass a wide range of environmental conditions from urban parks to battlefields to remote forests. The region's increasingly populous and urbanizing landscape plays a significant role in the parks' ecology.

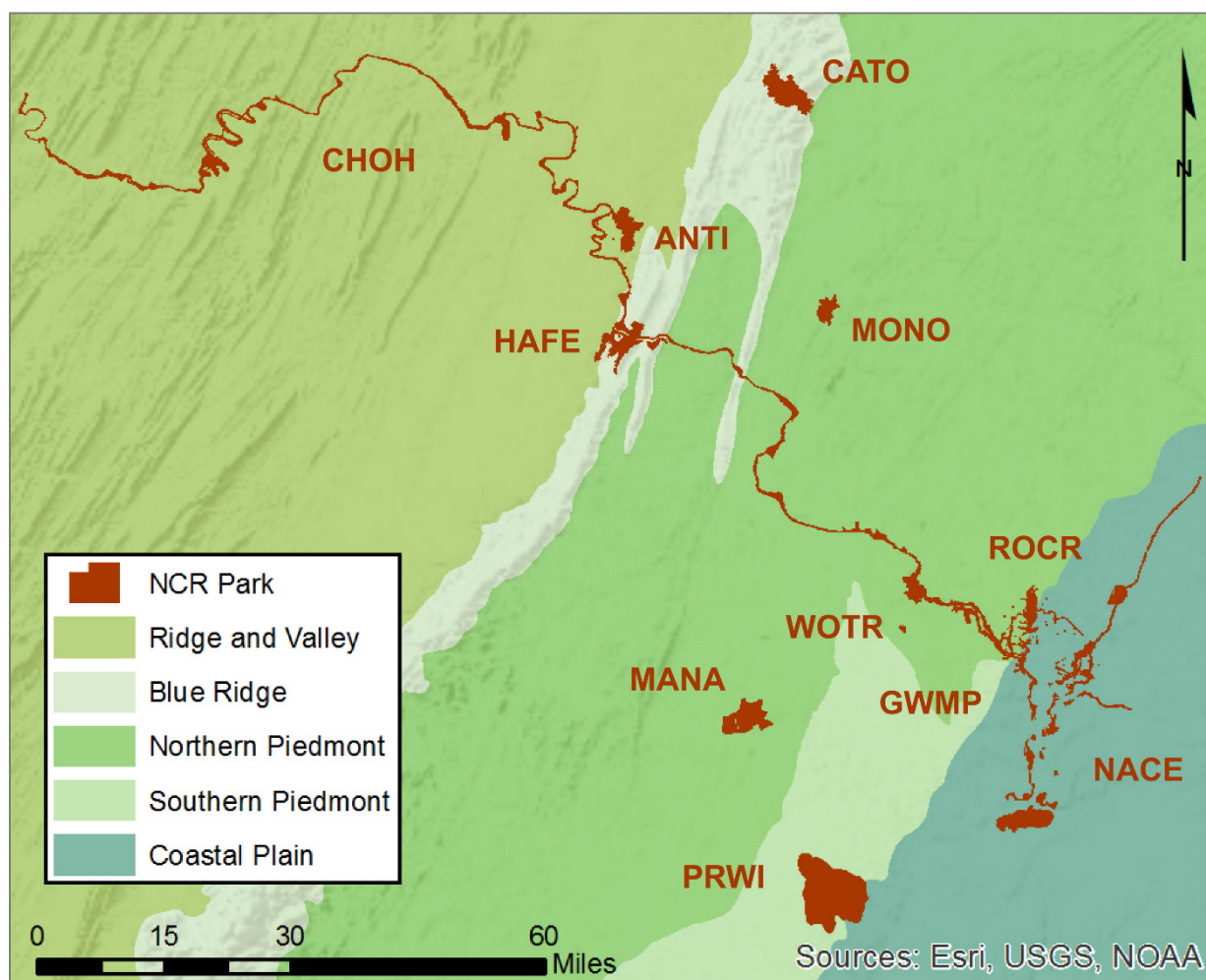


Figure 1. National Capital Region vegetation classification and mapping project area and 11 parks in relation to major ecological regions.

The NCR parks occupy four major ecological regions (US EPA 2013). From east to west, these include the Coastal Plain, the Piedmont (Northern and Southern), the Blue Ridge, and the Ridge and Valley ecoregions (Figure 1). Distribution of the parks creates an almost linear cross-section across these ecoregions.

The Coastal Plain is a broad upland, gently dissected by streams, and locally quite rugged where short, high gradient streams have incised steep ravine systems. This ecoregion is a relatively young

landscape sculpted during the last few million years by the repeated rising and falling of sea level during several cycles of Pleistocene glaciation. The geology largely consists of unconsolidated sediments and soils tend to be sandy, although deposits of terrace gravels, marine clays, and fossiliferous shells are common locally. The Potomac River, a large tidal river that flows southeastward into the Chesapeake Bay, drains all NCR parks except for portions of NACE along the Baltimore–Washington Parkway that drain into the Chesapeake Bay via the Patuxent River.

The upland forests that originally covered much of the Coastal Plain have been extensively cleared or altered, so that in many areas it is now difficult to determine which species and natural communities were historically prevalent. Much of the contemporary forest consists of secondary hardwood and pine-hardwood forests that have developed after repeated cutting or agricultural abandonment. The most mature remnant stands on mesic uplands are characterized by associations of American beech (*Fagus grandifolia*), several oaks (*Quercus* spp.), and American holly (*Ilex opaca* var. *opaca*). Patches of drier oak-dominated forest and steep bluffs with dense forests of chestnut oak (*Quercus prinus*), beech, and mountain-laurel (*Kalmia latifolia*) are fairly common in the dissected inner Coastal Plain. Wetlands of the Coastal Plain are extensive and have fared somewhat better than the province's upland forests, supporting a great variety of natural communities. The diversity of wetlands in this region includes tidal and palustrine swamps; non-riverine, groundwater-saturated flats; seasonally flooded ponds and depressions; seepage slope wetlands; and various tidal and non-tidal aquatic habitats. Rare natural communities in the Coastal Plain ecoregion of NCR parks include calcareous ravine and pitch pine barren (*Pinus rigida*) uplands and pitch pine lowland wetlands.

The Piedmont (Northern and Southern) is a region of low, rolling hills that lie between the Coastal Plain on the east and the Blue Ridge Mountains on the west. It slopes gently eastward punctuated by deeply incised stream valleys to the east and by isolated monadnocks (i.e., abrupt hills rising from a plain) in a western belt adjacent to the main Blue Ridge. The underlying geology consists largely of resistant metamorphic and igneous rocks that have undergone a history of deposition, uplift, deformation, and erosion that is complex and difficult to interpret. Along the eastern border of the Piedmont, known as the Fall Zone, the change in geology from crystalline bedrock to softer unconsolidated sediments of the Coastal Plain has accelerated the down-cutting of streams, creating deeply entrenched valleys with high-gradient flows along the major water courses. Nowhere is this more apparent than in the 15 km long Potomac River gorge west of Washington, D.C., where two NCR parks—the George Washington Memorial Parkway and the C&O Canal National Historical Park—occupy a large part of the landscape.

Most Piedmont forests have a history of repeated cutting, or have regenerated on former agricultural lands, some of which were abandoned more than 150 years ago. Recently disturbed Piedmont forests tend to have a large component of pines and shade-intolerant hardwoods. In the Piedmont region of NCR, Virginia pine (*Pinus virginiana*) and tulip-poplar (*Liriodendron tulipifera*) are prevalent early successional trees. The composition of more mature hardwood forest communities varies with soils and topography. Dry, acidic soils support oak / heath forests, while more basic upland soils usually support oak-hickory forests. White oak (*Quercus alba*) is a ubiquitous dominant in both groups. Mixed forests of American beech, oaks, and tulip-poplar are common in mesic, acidic ravines

throughout the Piedmont forests. More local are rich mesophytic forests, which are generally confined to ravines and river slopes underlain by mafic rocks such as amphibolite, diabase, or gabbro. Forests of silver maple (*Acer saccharinum*), sycamore (*Platanus occidentalis*), American elm (*Ulmus americana*), boxelder (*Acer negundo* var. *negundo*) and other flood-tolerant trees are well developed along rivers and large streams in the region.

Because it has less topographic variation than the Blue Ridge region and less extensive wetlands than the Coastal Plain, the Piedmont has relatively low vegetation diversity and fewer habitats supporting rare vegetation assemblages. Special habitats, however, are not entirely lacking. One of the region's most restricted forest communities—the Northern Hardpan Basic Oak-Hickory Forest—is found on Culpeper Basin uplands with impermeable clay subsoils (hardpans) weathered from fine-grained mafic rocks. Shallow, seasonally flooded upland depressions are also frequently associated with these hardpans. Additional uncommon or rare communities documented in the Piedmont include seepage swamps and several types of river-shore vegetation of the Potomac Gorge area that are shaped by frequent flood-scouring.

The Blue Ridge consists of a narrow, irregularly weathered series of peaks underlain by a core of resistant granites and metabasalts (greenstone), with resistant metasedimentary rocks exposed on the western flank. Although only a small part of NCR park lands is located in the Blue Ridge, they are situated in the dramatic gorge cut through the Blue Ridge by the Potomac River at Harper's Ferry. Most of western NCR lies within the Ridge and Valley ecoregion, which is characterized by long, parallel, narrow, even-crested ridges rising above intervening valleys of varying size. The linear strike-ridges, or sloping hills, are largely underlain by more resistant sandstones, quartzites, and shales; whereas, valleys are largely underlain by less resistant limestones, dolomites, and shales. The most extensive strata of limestone and dolomite in the NCR are located in valleys of the Ridge and Valley ecoregion. The NCR part of Ridge and Valley is drained by the Potomac River and its major tributaries.

Because it is underlain by large areas of base-rich metabasalts and granitic rocks, much of the Blue Ridge supports relatively species-rich oak-hickory forests. By contrast, the matrix forests of the sandstone ridges of the Ridge and Valley are oak forests with heath-dominated shrub layers and relatively low species richness. At low and middle elevations in both provinces, coves, concave slopes, and other protected landforms, which receive abundant moisture, support several types of mixed mesophytic forest vegetation. Sites with fertile soils, especially those weathered from limestone, contain some of the region's richest forests with breathtaking displays of vernal wildflowers growing under mixed hardwood overstories. Rare natural communities in NCR parks located in the Blue Ridge and Ridge and Valley ecoregions include boulderfield forests, shale barrens, alkaline glades, limestone cliffs, and seepage and depression wetlands.

Vegetation Classification

Introduction

Existing site information, literature, and data from previous studies of the NCR were examined at the outset of the project by the Virginia Natural Heritage Program (VANHP) to assess vegetation patterns on the landscape. In addition, VANHP conducted a preliminary classification of vegetation in the Piedmont and inner Coastal Plain of Virginia, Maryland, and District of Columbia (DC) to develop a list of probable plant communities likely to occur throughout the eastern NCR region. This preliminary analysis was based on 1,300 existing plots collected by the Virginia and Maryland Natural Heritage Programs, The Nature Conservancy (1998), Lea (2000, 2002), and Lea and Simmons (2002). A concurrent study of all NCR parks was conducted by Lea (2004) using data collected in 2002 from almost 2,000 rapid assessment observation points. Data collected at each rapid assessment point included location via GPS and a list of dominant and characteristic species in each stratum. In the rapid assessment analysis, each point was subjectively tagged to a probable plant community based on existing USNVC associations, previously published studies from the region (Fleming and Coulling 2001; Fleming 2002), and potential new plant communities (Lee 2004). Information from these preliminary studies provided a starting point for the vegetation classification data collection and analyses described, below.

In early 2004, a meeting was held with all project partners to review the results of the preliminary NCR classification and rapid assessment study. This included ecologists from NatureServe and the Natural Heritage Programs in Virginia, Maryland, West Virginia, Pennsylvania, and NPS. The results of the preliminary classification highlighted the USNVC associations in the study area already well represented by plot data. It also identified data gaps; areas lacking sufficient plot data to confidently define USNVC associations, and existing USNVC associations that were poorly documented with plot data. This vegetation was prioritized during site selection and field data collection for this project. Sampling plans were developed to fill the identified data gaps by developing a list of targeted associations and poorly described vegetation types for each NCR park. These plans were also informed by previous and concurrent studies conducted in the NCR parks and the familiarity of the project ecologists with the parks (e.g., Coulling 1999, Fleming 2007, Fleming and Coulling 2001, Fleming and Weber 2003, Lea 2000, Lea 2004, Lea and Simmons 2002, Rawinski 1995, Steury et al. 2008, Steury 2011, Steury 2004).

Supplemental data from the Potomac Gorge provided by Lea (2000) and Fleming (2007) provided the basis for an unprecedented opportunity to analyze vegetation of depositional bars and related shoreline vegetation along the Potomac River and major tributaries. Approximately 370 plots representing depositional bar and shoreline vegetation were compiled from the above projects and additional data collected elsewhere in the Potomac River watershed during the project.

Additional relevant vegetation classifications were also reviewed to determine their usefulness for the study. A range-wide analysis and classification of shale barren communities by Gawler (2004) was adopted as the standard for the project. Shale barrens were not targeted for sampling.

Methods

Field Data Collection

The purpose of the classification field work was to identify and interpret persistent, late successional plant communities of the National Capital Region. Both qualitative observational data and quantitative plot data were collected to document vegetation in the NCR parks. Site selection was guided by preliminary vegetation analyses, previous experience and reconnaissance, aerial photographs, and maps depicting topography, geology, and soils. Extensive rapid assessment observation point data collected by Lea in 2002 also helped inform the plot locations. Within a targeted site, specific plot locations were chosen subjectively to capture both homogeneous vegetation and a wide range of compositional variation across the larger landscape. Qualitative observational data were collected from already well described late successional plant communities, early successional vegetation, and recently disturbed habitats.

Early successional habitats are spatially, temporally, and compositionally dynamic. Species composition of these habitats is often in flux and subject to stochastic factors. Quantitative plots were not used to sample these areas because groups of plots of heavily modified vegetation (even groups dominated by the same species) usually lack the compositional consistency to allow for ecologically meaningful patterns to be found using quantitative data analysis. In addition to the rapid assessment points described earlier, field crews collected 333 qualitative observation points between 2003 to 2006. These were supplemented by data provided by other projects to form an observational dataset of 519 observations. These qualitative data included the GPS location, list of dominant species, and general description of the habitat at each site.

Relatively undisturbed, late successional vegetation was targeted for quantitative sampling with classification plots. Vegetation and environmental data were collected from 578 quantitative plots established in representative vegetation throughout the NCR parks from 2003 to 2006. Quantitative plots were sampled using the relevé method (*sensu* Peet et al. 1998), following standard procedures employed by VANHP. As a rule, 400 m² (4,312 ft²) plots with 16 m x 25 m (53 ft x 82 ft) configurations were established in forest and woodland vegetation, and 100 m² (1,078 ft²) plots with 8.5 m x 12 m (28 ft x 39 ft) configurations were established in shrubland and herbaceous vegetation. A more linear configuration (mostly 10 m x 40 m [33 ft x 131 ft]) was used to conform to narrow vegetation zones of cliffs, ridge crests, ravines, and stream bottoms.

Vegetation Measurements

To the extent possible, plots were placed in homogeneous stands of vegetation. Environmental ecotones, where plant species composition gradually transitions between two or more plant communities, were avoided. The field form used for the collection of quantitative plot data is presented in Appendix A. Within each plot, the percent cover of each vascular plant taxon was visually estimated as a vertical projection of above-ground biomass onto the full plot area and assigned to one of nine numerical cover classes or categories (Table 4). When species cover differed between spring and summer visits to a plot, the larger of the two cover values was assigned. In addition to this total cover value, cover was estimated for each species in the following height classes:

- herb layer (woody stems < 0.5 m and all herbaceous plants)
- shrub layer (> 0.5 m to 6 m)
- tree layer (> 6 m to 10 m)
- tree layer (> 10 m to 20 m)
- tree layer (> 20 m to 35 m)
- tree layer (> 35 m)

Table 4. Cover class scores used in field sampling and data analysis.

Cover Class	Percent Cover Range	Area of Coverage (in 400 m ² plot)	Cover Class Midpoint (%)
(1)	present outside plot	–	0.05
1	< 0.1%	< 20 cm ²	0.05
2	0.1% to 1%	20 cm ² to 4 m ²	0.55
3	1 to 2%	4 m ² to 8 m ²	1.50
4	2 to 5%	8 m ² to 20 m ²	3.50
5	5 to 10%	20 m ² to 40 m ²	7.50
6	10 to 25%	40 m ² to 100 m ²	17.50
7	25 to 50%	100 m ² to 200 m ²	37.50
8	50 to 75%	200 m ² to 300 m ²	62.50
9	75 to 100%	300 m ² to 400 m ²	87.50

Woody cover in a given layer was defined as the cover of woody plants reaching their maximum height in that layer. The overall cover of mosses, lichens, and liverworts was estimated, but the individual covers of non-vascular taxa were not estimated. Vascular plants characteristic of the stand, but located outside the plot, were recorded parenthetically if visible from the boundary, and assigned a cover class score of “1.” The total vegetative cover in each stratum was also estimated by assignment to the same nine-point scale of cover classes.

In addition to recording presence and cover for all species, stand structure was quantified by measuring the size distribution and vertical stratification of woody plants. The diameter at breast height (1.4 m [4.6 ft]; dbh) of each woody stem (trees, shrubs, woody vines) ≥ 2.5 cm (1 in) dbh and < 40 cm (15.7 in) dbh was measured by size class. Classes used were 2.5 cm to 5 cm, 5 cm to 10 cm, 10 cm to 15 cm, 15 cm to 20 cm, 20 cm to 25 cm, 25 cm to 30 cm, 30 cm to 35 cm, and 35 to 40 cm. Stems ≥ 40 cm (15.7 in) dbh were measured to the nearest 1 cm (0.4 in). The maximum canopy height was measured using a clinometer. Increment cores were extracted from a few selected stands to establish stand ages and examine the relationships between tree size and age. In addition, the annual growth rings on cut trees that had fallen across trails or removed from roadsides were counted, whenever possible.

Environmental Measurements

A standard set of environmental data was measured or estimated at each plot (Table 5). Slope inclination and aspect were measured to the nearest degree from plot center. In plots with variable microtopography, slope was measured at several points and averaged. Elevation was determined to the nearest 10 ft (approximately 3 m) using a topographic map or altimeter. The percent cover of different surface substrates was estimated visually, such that all values summed to 100%.

Topographic position, slope shape (both horizontally and vertically), soil drainage class, soil moisture regime, and inundation were assessed using scalar values. Bedrock geology was determined to the greatest precision possible by using existing geological maps, while the characteristics of surface rocks present in a plot were recorded in the field.

Table 5. Topographic and hydrologic environmental variables recorded at each plot-sampling site.

Category	Values
Topographic Position	• plain / level • toe • lower slope • middle slope • upper slope • crest • ledge / terrace • basin / depression • floodplain - stream bottom - escarpment / face
Inundation	• never • infrequently • regularly, for < 6 mos. • regularly, for > 6 mos. • always submerged by shallow water (< 30 cm) • always submerged by deep water (> 30 cm)
Slope Shape	• vertical (concave, convex, or straight) • horizontal (concave, convex, or straight) • hummock and hollow microtopography • irregular craggy/bouldery microtopography
Measured Aspect	• degrees (flat, or variable)
Measured Slope	• degrees
Soil Drainage Class	• very poorly drained • poorly drained • somewhat poorly drained • moderately well-drained • well-drained • rapidly drained

Table 5 (continued). Topographic and hydrologic environmental variables recorded at each plot-sampling site.

Category	Values
Surface Substrate: % cover	• decaying wood • bedrock • boulders (> 60 cm diam.) • stones (> 25 cm diam.) • cobbles (8–25 cm rounded) • channery (8–25 cm flattened) • gravel • mineral soil • organic matter • water • other
Soil Moisture Regime	• very xeric (moist for negligible time after precipitation) • xeric (moist for brief time) • somewhat xeric (moist for short time) • submesic (moist for moderately short time) • mesic (moist for significant time) • subhygric (wet for large part of growing season; mottles at < 20 cm) • hygric (wet for most of growing season; permanent seepage / mottling) • subhydric (water table at or near surface for most of the year) • hydric (water table at or above surface year round)
Hydrologic Regime	• terrestrial (i.e., not a wetland) • non-tidal (permanently flooded, semipermanently flooded, seasonally flooded, intermittently flooded, temporarily flooded, or saturated)

Soil samples were collected where possible from the top 10 cm (4 in) of mineral soil below the surficial litter and humus. Mineral soil was absent, or not possible to collect, on rock outcrops or riverside boulder bars. As a rule, soil was collected from several locations within a plot and mixed into a composite sample. Depth of surface duff, soil color, and texture were evaluated in the field and recorded on the plot forms. Soil samples collected from plots were oven-dried, sieved (2mm), and analyzed for pH, estimated nitrogen release (ENR), phosphorus (P), soluble sulfur (S), exchangeable cations (calcium [Ca], magnesium [Mg], potassium [K], and sodium [Na] in ppm), extractable micronutrients (boron [B], iron [Fe], manganese [Mn], copper [Cu], zinc [Zn], and aluminum [Al], in ppm), cation exchange capacity (CEC; m.e.q./100g), total base saturation (%TBS), and percent organic matter (%OM). Chemical analyses were conducted by Brookside Laboratories, Inc., New Knoxville, Ohio. Extractions were carried out using the Mehlich III method (Mehlich 1984) and percent organic matter was determined by loss on ignition.

Evidence of any past or ongoing disturbances, including but not limited to logging, fire, nonnative plants, erosion, grazing/browsing, wind or ice damage, hydrologic alterations, chestnut blight, dogwood anthracnose, gypsy moth, and hemlock woolly adelgid, was recorded from each sampling site.

Sampling Site Metadata

Standard metadata, or information about the implementation of the sampling protocol, were recorded at each plot. These included plot numbers, date(s) of sampling, participants, geopolitical locality (county/city), survey site name, USGS quadrangle, plot size and configuration, photographic documentation, and a written description of the plot location. Plots were assigned unique alphanumeric codes, and the data are permanently archived into the PLOTS Database on the NPS IRMA website. A global positioning system (GPS) unit was routinely used to record location data with greater accuracy, usually ≤ 10 m (33 ft) horizontal precision. The GPS data were converted into ArcGIS feature classes and are included in the geodatabases created for each park. This allowed plot locations to be reviewed using several different base layers, e.g., aerial imagery, topographic maps, geology maps, and soil maps.

Data Preparation and Transformation

The analysis used plot data collected specifically for the NCR vegetation mapping project by NatureServe and ecologists from Natural Heritage Programs in Maryland, West Virginia and Pennsylvania. In addition, supplementary data were gathered from other projects and initiatives in the region. Supplementary regional data consisted of all plots in the VANHP database that had been previously assigned to potential plant communities identified in the two preliminary NCR classifications, plus others that were considered potentially related, and many provided by the Maryland Natural Heritage Program.

All plot data were compiled into customized Access databases from which analytical procedures were managed. Separate subregional databases were created for the eastern and western NCR Parks (Table 2). Several major groups (e.g., oak / heath forests) were examined in both the NCR eastern and western subregion classifications since their geographic range extends across the two NCR subregions.

Botanical nomenclature for the entire dataset was reviewed and standardized as individual plant taxa were not always identified to the same taxonomic level in plot sampling. With few exceptions, nomenclature follows the NatureServe/Kartesz (1999) standard. As a rule, taxa were treated at the highest level of resolution possible, but treatment at the subspecific level was not always possible and a few groups of species had to be merged into "pseudospecies." For example, various plots had *Polygonatum biflorum*, *Polygonatum biflorum* var. *biflorum*, or *Polygonatum biflorum* var. *commutatum*; these were merged at the species level. Species richness was calculated for each plot using all taxa (including unidentified spp.) rooted within plot boundaries. However, taxa identified only at generic or higher levels (e.g., "*Carex* sp." or "unidentified woody seedling") were deleted from the dataset prior to analysis to eliminate "noise" and potentially erroneous correlations because the plants were not identified to particular species.

The original dataset for the greater NCR eastern subregion consisted of 2,051 plots (1,253 upland and palustrine wetland plus 798 tidal). To assist in evaluating the initial coarse-scale analyses, each plot was assigned to one of the following six classes to provide the following subsets of the data: (1) Basic Upland Forest, (2) Acidic Upland Forest, (3) Rock Outcrop / Woodland, (4) Alluvial Wetland, (5) Non-Alluvial Wetland, (6) Tidal Wetland.

The original dataset for the greater NCR western subregion consisted of 1,190 plots. Each plot was assigned to one of the following six classes to provide the following subsets of the data: (1) Basic Upland Forest, (2) Acidic Upland Forest, (3) Rock Outcrop / Woodland, (4) Alluvial Forest, (5) Montane Alluvial Forest, (6) Depositional Bar/Shore. All assignments were based on subjective inspection, previous assignment to a Rapid Assessment or Provisional NCR name, or a VANHP ecological group name.

Prior to analysis, most environmental variables were transformed, either to normalize frequency distributions or to assign numeric values to categorical variables. Topographic position and slope were converted to ordinal variables. Aspect was transformed using the cosine method of Beers et al. (1966), using the formula $A' = \cos(45^\circ - A)$ plus 1, where A' = transformed aspect and A = aspect in degrees. This transformation standardizes aspect to a linear variable from 0 (225°; SW, dry, solar-exposed) to 2 (45°; NE, moist, sheltered), and can be used as a surrogate variable for topographic moisture and solar exposure. Surface substrate values were converted to decimals and arcsine transformed to normalize their distributions. The values for organic matter were deleted to avoid collinearity problems with surface substrate; the values for all substrate classes sum to 100, and each can be defined as a linear combination of the others. Values for all soil variables except pH were natural log-transformed to normalize their distributions and make the values more biologically interpretable (Palmer 1993). A calcium: magnesium ratio and a synthetic fertility index (cation exchange capacity X total base saturation / 100) were also calculated for each plot.

A synthetic Topographic Relative Moisture Index (TRMI) was calculated for each plot using a procedure modified from Parker (1982). TRMI is a scalar index ranging from 0 (lowest moisture potential) to 50 (highest moisture potential) and is computed by combining three topographic variables that potentially influence water runoff, evapotranspiration, and soil moisture retention:

- Slope inclination (10-point scale; per Parker [1982])
- Aspect (20-point scale) = Beers-transformed aspect X 10
- Topographic position (20-point scale; per Parker [1982])

Normally, slope shape would be included as an additional 10-point scale but, data on slope shape were not always collected from the NCR plots. Because of this omission, as well as assumptions of the formula that may not apply as well to Piedmont and Coastal Plain topography as to montane topography, this variable was regarded as strictly experimental.

Data Analysis

Each subregional dataset and subsequent smaller datasets were imported from Access into the software program PC-ORD (version 5.04; McCune and Mefford 1999) for multivariate numerical analyses, creating clusters. Cluster analyses produces dendrograms that visually display the relationships of the vegetation plots. The smaller data subsets that generally represented individual plant communities (USNVC associations) were later imported into Excel for calculation of summary statistics (see below). The analytical process was designed to progressively fragment the large datasets into smaller more workable subsets, using cluster analysis to identify groups and statistical analysis to validate those groups. Lastly, ordination analyses were used to examine compositional

gradients between groups and correlations with important environmental gradients. In practice, the process was iterative as increasingly smaller data subsets were identified and analyzed. Groups of increasingly fewer plots were assessed until USNVC association level groups could be identified.

Cluster Analysis

Hierarchical, agglomerative cluster analysis using the Lance-Williams Flexible-Beta linkage method (Lance and Williams 1966, 1967) and the Bray-Curtis dissimilarity measure (Bray and Curtis 1957) was used throughout the project to identify compositionally similar groups of species. The Flexible-Beta method is a generalized sorting strategy, the performance of which varies with user-specified emphasis (beta) on settings for between-group distance. For example, beta settings ranging from the default -0.25 to -0.5 produce optimal results with vegetation data, performing very similarly to minimum-variance clustering, i.e., Ward's method (Ward 1963). The Bray-Curtis coefficient (also known as the Sorensen coefficient) has been used with demonstrable success in a wide range of ecological studies (Beals 1984). Among available measures of ecological "distance," represented as a mathematical dissimilarity between samples, the Bray-Curtis coefficient is a balanced measure that places some emphasis on dominant (i.e., high-cover) species while still giving minor (i.e., low-cover) species weight in the analysis (Gauch 1982).

Cluster analysis of every dataset or subset was run using the Bray-Curtis Co-efficient and four alternative preliminary data treatment protocols:

1. Raw species cover class (values of 1–9).
2. Species cover class is represented as a proportion of the total cover in each plot.
3. The cover class of each species is represented as a proportion of the highest cover class for that species in all the plots in that subset (giving low-cover species more weight in the analysis).
4. The species cover class is represented as a proportion of the total cover in each plot as a proportion of the largest cover class for that species in all the plots in that subset.

In addition, for the eastern NCR dataset a fifth protocol was run using the Relative Euclidian (Chord) distance measure (McCune and Grace 2002) and raw cover class scores. This procedure is conceptually similar to protocol 2 above, except that squared abundance values are relativized such that the sum of squares for each plot=1, and Euclidian distance is used to quantitatively calculate dissimilarity.

After examining the results from all protocols, we accepted the dendrograms that represented consistent groups of vegetation that were most ecologically understandable for each subset of data. Varying the beta setting in Flexible-Beta clustering affects the level at which groups resolve in a dendrogram and can produce subtle changes in group membership. An initial beta setting of -0.25 or -0.5 was used in the analyses but was occasionally varied to -0.375 once the optimal protocol was identified for a given group. Experience has shown that all data treatments will perform similarly in the analyses for a given dataset, and in combination will identify many groups of plots that always cluster together regardless of the protocol used. However, the real advantage of this method is that it will also readily identify those plots or groups of plots whose larger group memberships change

when different protocols are used. Invariably, these plots represent samples that are more problematic (e.g., ecotonal, transitional, heterogeneous) and fit less clearly into classified groups.

Cluster Analysis: Uplands and Palustrine Wetlands

Using these procedures, the initial eastern and western NCR subregional datasets for uplands and palustrine wetlands were progressively fragmented by identifying one or more homogeneous subsets at each iteration, removing those subsets, and re-clustering the remaining plots. This process resulted in 11 subsets for both subregional datasets. More comprehensive cluster, statistical, and ordination analyses were conducted on each subset. In addition, special subsets were assembled to examine potential relationships between groups in different subsets.

The 11 subsets in the eastern NCR subregional dataset contained, roughly, plots of (1) seepage wetlands, (2) alluvial forests, (3) alluvial swamp forests, (4) non-alluvial wetland forests, (5) oak/heath forests, (6) calcareous and hardpan forests, (7) acidic mesic forests, (8) oak-hickory forests, (9) basic mesic forests, (10) outcrop woodland and cliffs, and (11) miscellaneous plant communities.

The 11 subsets in the western NCR subregional dataset contained, roughly, plots of (1) alluvial forests, (2) depositional bars, riverside prairies, aquatic vegetation, (3) acidic dry forests (oak/heath, pine-oak/heath), (4) dry-mesic rich forests, (5) rich mesic forests, (6) oak-hickory and white pine forests, (7) mesic and dry-mesic acidic forests (acidic coves, hemlock, red oak-chestnut oak), (8) montane alluvial forests, (9) rich woodlands and barrens, (10) acidic woodlands, and (11) cliffs.

During the course of analysis, a number of plots were eliminated from each subregional dataset, resulting in a final dataset of 1,253 plots for the eastern NCR subregion and 1,128 plots for the western subregion with some plots included in both subregions. The deleted supplementary plots consisted of NCR plots and VANHP plots. Several large groups of supplementary plots were eliminated because they were iteratively determined to be geographically disparate or unrelated to any NCR plant communities. The remaining NCR plots were removed from the analysis because they performed as outliers, had high cover of widespread and/or invasive species often found in disturbed areas, or were compositionally heterogeneous or unique.

Cluster Analysis: Tidal Wetlands

The Lance-Williams Flexible-Beta linkage method and the Bray-Curtis (Sorensen) dissimilarity measure were also used to identify compositionally similar groups of tidal vegetation in the eastern region of NCR. Cluster analysis of the overall dataset was conducted using raw cover and cover class scores relativized by species maxima, both with beta set at -0.5 . After examining each major branch of each full dendrogram, homogeneous groups or easily identifiable clusters were parsed out and evaluated. All plots representing the same VANHP ecological community group (e.g., Wind-Tidal Oligohaline Marshes, Tidal Bald Cypress Forests and Woodlands) were usually extracted and re-clustered as single subsets, although some final plant communities were identified in the initial dendrogram representing the full data set and others were assembled manually by combining plots from disjunct branches of the entire dendrogram. Cluster analysis using raw cover generally produced the more easily interpretable clusters, but classification of arboreal vegetation (forests,

woodlands, and shrub swamps) was based on analysis using cover relativized by species maxima. During the course of analysis, 23 plots (1 NCR, 22 supplementary) were eliminated, resulting in a final data set of 775 plots. The deleted plots represented outliers and samples of heterogeneous or unique composition. After each remaining plot had been assigned to a final plant community, total frequency and total mean cover were recalculated and diagnostic statistics rerun for the final data set.

Compositional Summary Statistics

Compositional statistics were calculated to evaluate the adequacy of groups recognized in cluster analysis and ultimately to assist in naming and describing the plant communities. This procedure was again conducted separately for the eastern and western subregional NCR datasets. Each cluster had a unique species list built by compiling the cover class data of each species from those plots within the cluster. A zero was inserted for a cover class value if a species did not occur within a particular plot. Total mean cover and total frequency across all plots were determined for every taxon. To compute mean cover, cover class scores were converted to the midpoints of their respective percent ranges, the midpoints were averaged, and resulting values were back-transformed to cover class scores. For each taxon in each group under consideration, the following summary statistics were then calculated:

- Frequency – the number of plots in a group in which a species occurs.
- Mean Cover – back-transformed cover class value corresponding to mean percent cover calculated from midpoint values of cover class ranges. All plots assigned to a group were considered when calculating mean cover, not just those in which a taxon was present; when a taxon was absent from a plot, it was assigned a cover value of 0.
- Relative Cover – the arithmetic difference between mean cover (for a given group of plots) and total mean cover (for the entire data set) ($= \text{Mean Cover} - \text{Total Mean Cover}$). Expressed by plus or minus symbols, this value provides a relative approximation of how much more, or less, abundant a particular species is in a plant community compared to the overall data set.
- Constancy – the proportion of plots in a group in which a species occurs, expressed as a percentage ($= \text{Frequency} / \text{Number of plots in group} \times 100$).
- Fidelity – the degree to which a species is restricted to a group, expressed as the proportion of total frequency that frequency in a given group constitutes ($= \text{Frequency} / \text{Total Frequency} \times 100$). An accidental or nonnative species can have maximal (100) fidelity to a plant community if it occurs in only one plot in the entire data set. As a result, fidelity alone can perform poorly as a criterion for identifying characteristic species and distinguishing among plant communities.
- Diagnostic Value (DV) ($= \text{Constancy} \times \text{Fidelity} / 100$). A synthetic value indicating species that are both frequent within and relatively restricted to a group of plots.
- Diagnostic Value Adjusted by Cover, Scaled (Adj DV [scaled]) ($= \text{Diagnostic Value} \times \text{Mean Cover} / 9$). By dividing DV by 9, the maximum possible cover value, this statistic synthesizes information about frequency, diagnostic value, and mean abundance. A species entirely restricted to a particular plant community, occurring in every plot of that community, and attaining maximum mean cover will have a Scaled Adjusted DV of 100 for that community. Empirically, taxa most characteristic of a plant community will have a much lower Adjusted

DV, although the exact range of values in any given community or data set may vary considerably.

- Diagnostic Value Adjusted by Cover, Unscaled (Adj DV [unscaled]) (= Diagnostic Value X 2relative cover). An alternative, unscaled synthetic measure of adjusted DV, using relative cover as the modifier of DV. Since cover classes form a logarithmic, rather than linear scale of values, Unscaled Adjusted DV is a statistically more legitimate means of incorporating information on cover and has the advantage of not favoring only dominant species and better identifying species that are considerably more abundant within a given plant community than in the data set as a whole. This statistic is sensitive, however, to plant communities containing few plots and to species with overall low frequency.

Additionally, the following statistics were generated for each group:

- Mean Species Richness – the average number of species present per plot (S); only species rooted inside plot boundaries were included in this calculation.
- Homoteneity – the average constancy of the S most constant species, expressed as a fraction. This value (sensu Curtis 1959) can be considered the constancy of the average species in a plant community; higher values for homoteneity indicate greater uniformity in species composition among plots. Homoteneity is not independent of group size and often increases as the number of group members decreases. However, it can be used to evaluate whether plant communities have been defined at an appropriate level. Ordinarily, we would consider approximately 0.600 or higher to be a desirable homoteneity value for moderate-sized association-level or plant community groups in a state-level regional dataset where data were collected consistently by one or a few people. Because of multiple data collectors, variations in data collection protocols, the natural diversity of some plant communities, and the size of groups represented in the NCR dataset, we set 0.500 as the lowest acceptable homoteneity for associations in this project (we had to accept slightly less for three naturally heterogeneous plant communities).

These procedures were executed in Access and Excel using macros written in Visual Basic (Coulling 2006). These macros greatly reduced the time required for calculations and made it possible to efficiently evaluate a large number of groups in the competing dendrograms generated by two different cluster algorithms using different similarity or dissimilarity matrices. Problematic plots that shifted among multiple groups, depending on the clustering protocol used were ultimately assigned to one group after we compared the analysis of each affected group with and without the questionable plot(s), and by examining the position of the plot on the axes of non-metric multidimensional scaling ordinations (see below).

Head-to-head statistical comparisons of similar groups were also conducted by calculating total frequency and total mean cover and generating summary statistics solely for the groups in question. This kind of analysis was used to compare problematic or questionable potential plant communities with related vegetation by identifying within-group distinguishing or separating and diagnostic species. In combination with ordination analyses, these posthoc comparison analyses were especially

helpful to determine whether certain groups should be treated as separate plant communities or as variants of other plant communities.

Ordination

The multivariate ordination method non-metric multidimensional scaling (NMDS; Kruskal 1964) was used to examine the pair-wise dissimilarity among the potential plant communities. This allows the detection of compositional variation and trends that are obscured in the previous cluster analyses. Often this results in identifying environmental gradients along which plant communities are distributed.

Ordination analyses were conducted posthoc for each major compositional group identified in cluster analysis, as well as for selected smaller groups of closely related plant communities. The Bray-Curtis coefficient was used to calculate dissimilarity and VARIMAX rotation was employed to optimize axis placement in all ordination runs. Each ordination was computed using 50 to 100 random starting configurations, and configurations with the best fit (i.e., the lowest stress levels) were used for interpretation.

We used the best fit in the fewest dimensions. Most ordinations were extracted in three dimensions (some were in two dimensions). Pearson correlations between environmental variables and plot coordinates on each axis were calculated, and significant correlations were displayed through joint plot overlays. Environmental variables used in ordination analyses were ordinal variables for slope and topographic relative moisture index (TRMI); and continuous variables for arcsine-transformed surface substrate values, Beers-transformed aspect, and raw and natural log-transformed soil chemistry values. Some of the supplementary plot data did not include quantitative environmental measurements, e.g., Potomac Gorge plots (Lea 2000) and Maryland Natural Heritage Program supplementary data. The ordinations involving substantial groups of those plots were run without environmental correlations. In cases where smaller numbers of plots in a given dataset had missing data, those plots were deleted before running the ordinations.

Environmental Summary Statistics

Mean values for continuous and ordinal environmental variables were calculated for each group of plots forming a potential USNVC association to further aid in describing them and for identifying the differences between them. These calculations were performed with raw (untransformed) values, which were averaged across all plots representing a potential USNVC association. Mean aspect was calculated as the average position along an arc defined by the range of aspect values.

Assignment of NCR Proposed Plant Communities to the USNVC

Once the classification was finalized, the classified plant communities were subjectively compared to existing associations of the USNVC. Many of the supplementary regional plots used in the analysis had been previously assigned to or formed the basis of published USNVC associations. All classified plant communities were either assigned to a conceptually similar USNVC association or used as the basis for a new USNVC association. In selecting nominals for new USNVC associations, high-constancy species (especially those with relatively high mean cover and high diagnostic value, if available) were favored to facilitate identification of the association in the field. A "constant" species

was generally considered to be a species occurring in > 67% of plot samples. In a few cases, species that were less constant in a plant community but had high mean cover and diagnostic value were selected as parenthetical nominals. The global USNVC descriptions for existing associations were edited, and global descriptions for new associations were drafted.

In addition to the USNVC associations derived from quantitative analysis, qualitative observation data collected throughout the parks were used to describe and map vegetation types not targeted for quantitative plot data, e.g., already well described late successional plant communities, early successional vegetation and heavily disturbed areas. Some of these observation data were subjectively cross walked to the USNVC association level, while others (i.e., cultural or disturbed vegetation) were not appropriate for inclusion in the USNVC, and were described as nonstandard, park-specific vegetation.

Assignment of NCR USNVC Associations to ITESC Ecological Systems

The ITESC provides an alternative way to group USNVC associations into landscape level assemblages that provide a coarser scale view of the vegetation of a region. Refinements to the ITESC have continued since it was first published for the U.S. in 2003 (Comer et al.). When we began the NCR vegetation classification and mapping project, some NCR associations had already been matched to an ecological system, but others, especially newly described associations had not. A review team consisting of NatureServe and Natural Heritage Program ecologists from VA, MD, and WV reviewed and matched the NCR USNVC associations to ITESC ecological systems. This review introduced 2 new ecological systems Northern Atlantic Coastal Plain Calcareous Ravine (CES203.069) and Northern Atlantic Coastal Plain Stream and River (CES203.070). Ultimately, a total of 24 ecological systems were described for NCR.

Results

During the vegetation classification phase of the project, 87 natural and seminatural plant communities were identified, consisting of 86 USNVC associations and one park special plant community (Table 6). Twenty successional/ruderal USNVC associations, and four USNVC cultural subtypes were identified (Table 7). In Tables 6 and 7, USNVC associations have a code that begins with C EGL; USNVC cultural subtypes have a code that begins with C EST, and park special plant communities have a code that begins with C EPS.

Table 6. NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Upland	Basic Mesic and Rich Cove Forests	CEGL008412	<i>Acer (nigrum, saccharum)</i> - <i>Tilia americana</i> / <i>Asimina triloba</i> / <i>Jeffersonia diphylla</i> - <i>Caulophyllum thalictroides</i> Forest	G4G5	–	–	x	x	x	–	–	–	–	–	–
	Basic Mesic and Rich Cove Forests	CEGL006055	<i>Fagus grandifolia</i> - <i>Liriodendron tulipifera</i> - <i>Carya cordiformis</i> / <i>Lindera benzoin</i> / <i>Podophyllum peltatum</i> Forest	G4?	–	–	x	x	–	–	x	x	–	x	–
	Basic Mesic and Rich Cove Forests	CEGL006186	<i>Liriodendron tulipifera</i> - <i>Quercus rubra</i> - <i>Fraxinus americana</i> / <i>Asimina triloba</i> / <i>Actaea racemosa</i> - <i>Uvularia perfoliata</i> Forest	G4?	–	–	–	–	–	–	–	–	x	–	–
	Basic Mesic and Rich Cove Forests	CEGL007710	<i>Liriodendron tulipifera</i> - - <i>Fraxinus americana</i> - (<i>Tilia americana</i> , <i>Aesculus flava</i>) / <i>Actaea racemosa</i> - <i>Laportea canadensis</i> Forest	G4	–	–	x	–	x	–	–	–	–	–	–
	Basic Mesic and Rich Cove Forests	CEGL006125	<i>Quercus rubra</i> - <i>Acer saccharum</i> - <i>Liriodendron tulipifera</i> Forest	G4?	–	x	–	–	–	–	–	–	–	–	–
	Acidic Mesic Forests	CEGL006075	<i>Fagus grandifolia</i> - <i>Quercus (alba, rubra)</i> - <i>Liriodendron tulipifera</i> / (<i>Ilex opaca</i> var. <i>opaca</i>) / <i>Polystichum acrostichoides</i> Forest	G5	–	–	x	x	–	–	–	x	x	x	x
	Acidic Mesic Forests	CEGL006919	<i>Fagus grandifolia</i> - <i>Quercus (alba, velutina, prinus)</i> / <i>Kalmia latifolia</i> Forest	G4	–	–	x	–	–	–	–	x	x	x	–
	Acidic Mesic Forests	CEGL006474	<i>Tsuga canadensis</i> - <i>Fagus grandifolia</i> - <i>Quercus (prinus, alba)</i> Forest	G2G3	–	–	–	–	x	x	–	–	x	–	–
	Acidic Mesic Forests	CEGL006923	<i>Tsuga canadensis</i> - <i>Quercus prinus</i> - <i>Betula lenta</i> Forest	G3	–	x	x	–	–	–	x	–	–	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Upland (continued)	Acidic Mesic Forests	CEGL006639 [mapped as CEGL006109]	<i>Tsuga canadensis</i> - <i>Acer saccharum</i> - <i>Fagus grandifolia</i> / <i>Dryopteris intermedia</i> Forest [Old name: <i>Tsuga canadensis</i> - <i>Betula alleghaniensis</i> - <i>Acer saccharum</i> / <i>Dryopteris intermedia</i> Forest]	G4?	–	x	–	–	–	–	–	–	–	–	–
	Dry and Dry-Mesic Calcareous Forests	CEGL006017	<i>Acer saccharum</i> - <i>Quercus muehlenbergii</i> / <i>Cercis canadensis</i> Forest	G4?	–	–	x	–	–	–	–	–	–	–	–
	Dry and Dry-Mesic Calcareous Forests	CEGL004793	<i>Quercus muehlenbergii</i> - <i>Quercus (alba, rubra)</i> - <i>Carya cordiformis</i> / <i>Viburnum prunifolium</i> Forest	G3G4	x	–	x	–	x	x	–	–	–	–	–
	Dry and Dry-Mesic Calcareous Forests	CEGL007748	<i>Quercus muehlenbergii</i> / <i>Cercis canadensis</i> / <i>Dichanthelium boscii</i> - <i>Bromus pubescens</i> - <i>Erigeron pulchellus</i> var. <i>pulchellus</i> - <i>Aquilegia canadensis</i> Forest	G1	–	–	–	–	–	–	–	x	–	–	–
	Dry and Dry-Mesic Calcareous Forests	CEGL008517	<i>Quercus rubra</i> - <i>Acer saccharum</i> / <i>Ostrya virginiana</i> / <i>Cardamine concatenata</i> Forest	G4	x	–	x	x	–	–	–	–	–	–	–
	Dry-Mesic Oak and Oak-Hickory Forests	CEGL008475	<i>Quercus alba</i> - <i>Quercus rubra</i> - <i>Carya alba</i> / <i>Cornus florida</i> / <i>Vaccinium stamineum</i> / <i>Desmodium nudiflorum</i> Piedmont Forest	G4G5	–	–	x	x	–	x	x	–	x	–	–
	Dry-Mesic Oak and Oak-Hickory Forests	CEGL008515	<i>Quercus alba</i> - <i>Quercus prinus</i> - <i>Carya glabra</i> / <i>Cornus florida</i> / <i>Vaccinium pallidum</i> Forest	G4	–	–	x	–	x	–	–	–	–	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Upland (continued)	Dry-Mesic Oak and Oak-Hickory Forests	CEGL008514	<i>Quercus rubra</i> - <i>Quercus prinus</i> - <i>Carya ovalis</i> / (<i>Cercis canadensis</i>) / <i>Solidago caesia</i> Forest	G3G4	–	x	x	–	x	–	x	–	–	–	–
	Dry-Mesic Oak and Oak-Hickory Forests	CEGL006057	<i>Quercus prinus</i> - <i>Quercus rubra</i> / <i>Hamamelis virginiana</i> Forest	G5	–	x	x	x	x	–	x	–	–	–	–
	Piedmont Hardpan Forests	CEGL006209	<i>Carya glabra</i> - <i>Quercus</i> (<i>rubra</i> , <i>pinus</i>) - <i>Fraxinus americana</i> / <i>Viburnum rafinesquianum</i> / <i>Piptochaetium avenaceum</i> Forest	G1G2	–	–	–	x	–	–	–	–	–	–	–
	Piedmont Hardpan Forests	CEGL006216	<i>Quercus alba</i> - <i>Carya glabra</i> - <i>Fraxinus americana</i> / <i>Cercis canadensis</i> / <i>Muhlenbergia sobolifera</i> - <i>Elymus hystrix</i> Forest	G3	–	x	x	–	–	x	–	–	–	–	–
	Oak/Heath and Pine-Oak/Heath Forests and Woodlands	CEGL008521	<i>Quercus alba</i> - <i>Quercus</i> (<i>coccinea</i> , <i>velutina</i> , <i>pinus</i>) / <i>Gaylussacia baccata</i> Forest	G5	–	–	x	x	–	–	–	x	x	x	x
	Oak/Heath and Pine-Oak/Heath Forests and Woodlands	CEGL006299	<i>Quercus prinus</i> - (<i>Quercus coccinea</i> , <i>Quercus rubra</i>) / <i>Kalmia latifolia</i> / <i>Vaccinium pallidum</i> Forest	G5	–	x	x	x	x	–	–	x	–	x	x
	Oak/Heath and Pine-Oak/Heath Forests and Woodlands	CEGL006490	<i>Quercus prinus</i> / <i>Deschampsia flexuosa</i> - <i>Solidago bicolor</i> Forest	GNR	–	–	–	–	–	–	–	x	–	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Upland (continued)	Oak/Heath and Pine-Oak/Heath Forests and Woodlands	CEGL008523	<i>Quercus prinus</i> - <i>Quercus rubra</i> / <i>Vaccinium pallidum</i> - (<i>Rhododendron periclymenoides</i>) Forest	G3G4	–	x	x	–	x	–	–	–	–	–	–
	Oak/Heath and Pine-Oak/Heath Forests and Woodlands	CEGL008539	<i>Pinus strobus</i> - <i>Quercus alba</i> - <i>Quercus prinus</i> / <i>Vaccinium stamineum</i> Forest	G4	–	–	x	–	–	x	–	–	–	–	–
	Oak/Heath and Pine-Oak/Heath Forests and Woodlands	CEGL006329	<i>Pinus rigida</i> - <i>Quercus coccinea</i> - <i>Quercus falcata</i> / (<i>Quercus marilandica</i>) / <i>Gaylussacia frondosa</i> Woodland	G2G3	–	–	–	–	–	–	–	x	–	–	–
	Oak/Heath and Pine-Oak/Heath Forests and Woodlands	CEGL004996	<i>Pinus (pungens, rigida)</i> - <i>Quercus prinus</i> / (<i>Quercus ilicifolia</i>) / <i>Gaylussacia baccata</i> Woodland	G4	–	x	x	–	–	–	–	–	–	–	–
	Boulderfield / Talus / Scree Forests	CEGL006471	<i>Acer saccharum</i> - <i>Tilia americana</i> / <i>Staphylea trifolia</i> / <i>Dryopteris marginalis</i> - (<i>Impatiens pallida</i>) Forest	G3G4	–	–	x	x	x	–	–	–	–	–	–
	Boulderfield / Talus / Scree Forests	CEGL006565	<i>Betula lenta</i> - <i>Quercus prinus</i> / <i>Parthenocissus quinquefolia</i> Woodland	G4	–	x	–	–	x	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL008449	<i>Pinus virginiana</i> - <i>Juniperus virginiana</i> var. <i>virginiana</i> - <i>Quercus stellata</i> / <i>Amelanchier stolonifera</i> / <i>Danthonia spicata</i> / <i>Leucobryum glaucum</i> Woodland	G1	–	–	x	x	–	–	–	–	–	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Upland (continued)	Rock Outcrop Woodlands and Barrens	CEGL008540	<i>Quercus prinus</i> - <i>Pinus virginiana</i> - (<i>Pinus pungens</i>) / <i>Schizachyrium scoparium</i> - <i>Dichanthelium depauperatum</i> Woodland	G3?	–	x	x	–	x	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL008526	<i>Quercus prinus</i> / <i>Quercus ilicifolia</i> / <i>Danthonia spicata</i> Woodland	G3?	–	–	x	–	–	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL003683	<i>Fraxinus americana</i> - <i>Carya glabra</i> / <i>Muhlenbergia sobolifera</i> - <i>Helianthus divaricatus</i> - <i>Solidago ulmifolia</i> Woodland	G2	–	x	x	–	x	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL002596	<i>Thuja occidentalis</i> / <i>Carex eburnea</i> - <i>Pellaea atropurpurea</i> Woodland	G2G3	–	–	x	–	–	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL006047	<i>Juniperus virginiana</i> / <i>Bouteloua curtipendula</i> - <i>Carex eburnea</i> Wooded Herbaceous Vegetation	G1G2	–	–	–	–	x	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL004391	<i>Asplenium montanum</i> Central Appalachian Sandstone Sparse Vegetation	GNR	–	–	x	–	–	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL004476	<i>Asplenium ruta-muraria</i> - <i>Pellaea atropurpurea</i> Sparse Vegetation	G3G4	–	–	x	–	–	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL006479	<i>Hydrangea arborescens</i> / <i>Sedum ternatum</i> - <i>Polypodium virginianum</i> Shrubland	GNR	–	–	x	–	x	–	–	–	–	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Upland (continued)	Rock Outcrop Woodlands and Barrens	CEGL006491	(<i>Hypericum prolificum</i> , <i>Leucothoe racemosa</i>) / <i>Schizachyrium scoparium</i> - <i>Solidago simplex</i> var. <i>racemosa</i> - <i>Ionactis linariifolius</i> Sparse Vegetation	G2	–	–	x	x	–	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL006037	<i>Juniperus virginiana</i> - <i>Fraxinus americana</i> / <i>Carex pensylvanica</i> - <i>Cheilanthes lanosa</i> Wooded Herbaceous Vegetation	G2	–	–	x	–	–	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL006288	<i>Pinus virginiana</i> - <i>Juniperus virginiana</i> - <i>Quercus rubra</i> / <i>Solidago arguta</i> var. <i>harrisii</i> - <i>Opuntia humifusa</i> Woodland	G3	–	–	x	–	–	–	–	–	–	–	–
	Rock Outcrop Woodlands and Barrens	CEGL008525	<i>Pinus virginiana</i> - <i>Quercus prinus</i> / <i>Quercus ilicifolia</i> / (<i>Hieracium greenii</i> , <i>Viola pedata</i>) Woodland	G3	–	–	x	–	–	–	–	–	–	–	–
Alluvial and Riparian	Large-Stream / River Floodplain Forests	CEGL006217	<i>Acer saccharinum</i> - <i>Acer negundo</i> / <i>Ageratina altissima</i> - <i>Laportea canadensis</i> - (<i>Elymus virginicus</i>) Forest	G4	–	–	x	x	x	–	x	x	–	–	–
	Large-Stream / River Floodplain Forests	CEGL004073	<i>Platanus occidentalis</i> - <i>Acer negundo</i> - <i>Juglans nigra</i> / <i>Asimina triloba</i> / <i>Mertensia virginica</i> Forest	G4	x	–	x	x	x	x	x	–	–	–	–
	Large-Stream / River Floodplain Forests	CEGL006459	<i>Acer saccharum</i> - <i>Fraxinus americana</i> / <i>Carpinus caroliniana</i> / <i>Podophyllum peltatum</i> Forest	G3?	–	–	x	x	x	–	x	–	–	–	–
	Large-Stream / River Floodplain Forests	CEGL006475	<i>Platanus occidentalis</i> - <i>Fraxinus pennsylvanica</i> - <i>Acer negundo</i> / <i>Sanicula odorata</i> - <i>Elymus virginicus</i> Forest [Provisional]	GNR	–	–	–	x	–	–	–	–	–	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Alluvial and Riparian (continued)	Large-Stream / River Floodplain Forests	CEGL006494	<i>Quercus phellos</i> - <i>Liquidambar styraciflua</i> / <i>Claytonia virginica</i> Forest [Provisional]	GNR	–	–	–	x	–	–	–	–	–	–	–
	Large-Stream / River Floodplain Forests	CEGL006495	<i>Quercus rubra</i> - <i>Quercus shumardii</i> / <i>Cercis canadensis</i> Temporarily Flooded Forest [Provisional]	GNR	–	–	–	x	–	–	–	–	–	–	–
	Small-Stream Floodplain Forests	CEGL004418	<i>Liquidambar styraciflua</i> - <i>Liriodendron tulipifera</i> / <i>Lindera benzoin</i> / <i>Arisaema triphyllum</i> Forest	G4	–	–	–	–	–	–	–	x	x	–	–
	Small-Stream Floodplain Forests	CEGL006492	<i>Liriodendron tulipifera</i> - <i>Acer (rubrum, negundo)</i> - (<i>Platanus occidentalis</i>) / <i>Carpinus caroliniana</i> / <i>Polygonum virginianum</i> Forest	G4	–	–	x	x	–	x	–	–	–	x	x
	Small-Stream Floodplain Forests	CEGL006603	<i>Platanus occidentalis</i> - (<i>Liquidambar styraciflua</i> , <i>Liriodendron tulipifera</i>) / <i>Asimina triloba</i> Forest	G3G4	–	–	–	–	–	–	–	x	–	–	–
	Small-Stream Floodplain Forests	CEGL006255	<i>Liriodendron tulipifera</i> - <i>Platanus occidentalis</i> - <i>Betula lenta</i> / <i>Lindera benzoin</i> / <i>Circaea lutetiana</i> ssp. <i>canadensis</i> Forest	G3?	–	x	–	–	–	–	–	–	–	–	–
	Small-Stream Floodplain Forests	CEGL007312 [mapped as 2086]	<i>Betula nigra</i> - <i>Platanus occidentalis</i> / <i>Alnus serrulata</i> / <i>Boehmeria cylindrica</i> Forest [Old name: <i>Betula nigra</i> - <i>Platanus occidentalis</i> Forest]	G4G5	–	–	–	–	–	–	–	–	x	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Alluvial and Riparian (continued)	Alluvial Swamp Forests	CEGL006606	<i>Acer rubrum</i> - <i>Fraxinus pennsylvanica</i> / <i>Saururus cernuus</i> Forest	G3G4	–	–	–	–	–	–	–	x	–	–	–
	Alluvial Swamp Forests	CEGL006548	<i>Acer (rubrum, saccharinum)</i> - <i>Fraxinus pennsylvanica</i> - <i>Ulmus americana</i> / <i>Boehmeria cylindrica</i> Forest	G4	–	–	x	x	x	x	–	x	–	–	–
	Alluvial Swamp Forests	CEGL006605	<i>Quercus (phellos, palustris, michauxii)</i> - <i>Liquidambar styraciflua</i> / <i>Cinna arundinacea</i> Forest	G3G4	–	–	–	–	–	–	–	x	–	–	–
	Alluvial Swamp Forests	CEGL006497	<i>Quercus palustris</i> - <i>Quercus bicolor</i> / <i>Carex tribuloides</i> - <i>Carex radiata</i> - (<i>Carex squarrosa</i>) Forest	G3G4	–	–	x	–	–	x	–	–	x	–	–
	Depositional Bar and Shore Vegetation	CEGL003896	<i>Platanus occidentalis</i> - <i>Betula nigra</i> - <i>Salix (caroliniana, nigra)</i> Woodland	G4G5	x	–	x	x	x	x	x	–	–	–	–
	Depositional Bar and Shore Vegetation	CEGL006476	<i>Platanus occidentalis</i> - <i>Acer saccharinum</i> - <i>Betula nigra</i> - <i>Fraxinus pennsylvanica</i> / <i>Boehmeria cylindrica</i> - <i>Carex emoryi</i> Woodland	G2?	–	–	x	x	x	–	–	–	–	–	–
	Depositional Bar and Shore Vegetation	CEGL006218	<i>Quercus bicolor</i> - <i>Fraxinus pennsylvanica</i> - (<i>Platanus occidentalis</i>) / <i>Chasmanthium latifolium</i> - <i>Dichanthelium clandestinum</i> - <i>Zizia aurea</i> Woodland	G1G2	–	–	x	x	–	–	–	–	–	–	–
	Depositional Bar and Shore Vegetation	CEGL006484	<i>Carpinus caroliniana</i> - <i>Ilex decidua</i> Shrubland	G1?	–	–	x	x	–	–	–	–	–	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Alluvial and Riparian (continued)	Depositional Bar and Shore Vegetation	CEGL004103	<i>Carex torta</i> Herbaceous Vegetation	G3G4	–	x	x	–	–	–	–	–	x	–	–
	Depositional Bar and Shore Vegetation	CEGL006480	<i>Verbesina alternifolia</i> - <i>Elymus riparius</i> - <i>Solidago gigantea</i> - (<i>Teucrium canadense</i>) Herbaceous Vegetation	GNR	x	–	x	–	x	–	–	–	–	–	–
	Depositional Bar and Shore Vegetation	CEGL006481	<i>Eupatorium serotinum</i> - <i>Polygonum (lapathifolium, punctatum, pensylvanicum)</i> Herbaceous Vegetation	GNR	–	–	x	x	x	–	–	–	–	–	–
	Depositional Bar and Shore Vegetation	CEGL006483	<i>Eragrostis hypnoides</i> - <i>Ludwigia palustris</i> - <i>Lindernia dubia</i> - <i>Cyperus squarrosus</i> Herbaceous Vegetation	G3	–	–	x	x	x	–	x	–	–	–	–
	Depositional Bar and Shore Vegetation	CEPS006675	<i>Impatiens capensis</i> Herbaceous Vegetation	GNR	–	–	x	–	x	–	–	–	–	–	–
	Depositional Bar and Shore Vegetation	CEGL004286	<i>Justicia americana</i> Herbaceous Vegetation	G4G5	–	–	x	x	x	x	–	–	–	–	–
	Riverside Prairies	CEGL006283	<i>Andropogon gerardii</i> - <i>Panicum virgatum</i> - <i>Baptisia australis</i> Herbaceous Vegetation	G3	–	–	x	x	x	–	–	–	–	–	–
	Riverside Prairies	CEGL006478	<i>Fraxinus americana</i> / <i>Andropogon gerardii</i> - <i>Sorghastrum nutans</i> - <i>Schizachyrium scoparium</i> - <i>Pycnanthemum tenuifolium</i> Herbaceous Vegetation	G1	–	–	x	x	–	–	–	–	–	–	–
	Riverside Prairies	CEGL006477	<i>Panicum virgatum</i> - <i>Andropogon gerardii</i> Gravel Wash Herbaceous Vegetation	G2G3	–	–	x	–	–	–	–	–	–	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Non-Alluvial Wetlands	Non-Riverine Saturated Forests and Depression Swamps	CEGL006390	<i>Quercus falcata</i> - <i>Quercus phellos</i> / <i>Ilex opaca</i> Forest	GNR	–	–	–	–	–	–	–	x	–	x	–
	Non-Riverine Saturated Forests and Depression Swamps	CEGL006110	<i>Liquidambar styraciflua</i> - <i>Acer rubrum</i> - <i>Quercus phellos</i> / <i>Leucothoe racemosa</i> Forest	G3	–	–	–	–	–	–	–	x	–	–	–
	Non-Riverine Saturated Forests and Depression Swamps	CEGL006240	<i>Quercus palustris</i> - (<i>Quercus bicolor</i>) - <i>Acer rubrum</i> / <i>Vaccinium corymbosum</i> / <i>Osmunda cinnamomea</i> Forest	GNR	–	–	x	x	–	–	–	–	x	–	–
	Non-Riverine Saturated Forests and Depression Swamps	CEGL007403	<i>Quercus phellos</i> / <i>Carex (albolutescens, intumescens, jorii)</i> / <i>Climacium americanum</i> Forest	G2G3	–	–	–	x	–	–	–	–	x	–	–
	Non-Riverine Saturated Forests and Depression Swamps	CEGL004643	<i>Quercus palustris</i> - <i>Quercus bicolor</i> / <i>Viburnum prunifolium</i> / <i>Leersia virginica</i> - <i>Impatiens capensis</i> Forest	G2	–	–	x	–	–	x	–	–	–	–	–
	Seepage Wetlands	CEGL006238	<i>Acer rubrum</i> - <i>Nyssa sylvatica</i> - <i>Magnolia virginiana</i> / <i>Viburnum nudum</i> var. <i>nudum</i> / <i>Osmunda cinnamomea</i> - <i>Woodwardia areolata</i> Forest	G3?	–	–	–	–	–	–	–	x	x	–	–
	Seepage Wetlands	CEGL006406	<i>Acer rubrum</i> - <i>Fraxinus (pennsylvanica, americana)</i> / <i>Lindera benzoin</i> / <i>Symplocarpus foetidus</i> Forest	G4G5	–	–	x	x	–	–	–	–	x	x	x

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. CEGL is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Non-Alluvial Wetlands (continued)	Seepage Wetlands	CEGL008416	<i>Acer rubrum</i> - <i>Fraxinus americana</i> - <i>Fraxinus nigra</i> - <i>Betula alleghaniensis</i> / <i>Veratrum viride</i> - <i>Carex bromoides</i> Forest	G3	–	x	–	–	–	–	–	–	–	–	–
	Seepage Wetlands	CEGL006219	<i>Nyssa sylvatica</i> - <i>Magnolia virginiana</i> - (<i>Pinus rigida</i>) / <i>Rhododendron viscosum</i> - <i>Toxicodendron vernix</i> / <i>Smilax pseudochina</i> Woodland	G1	–	–	–	–	–	–	–	x	–	–	–
	Seepage Wetlands	CEGL006926	<i>Pinus rigida</i> - <i>Nyssa sylvatica</i> / <i>Clethra alnifolia</i> - <i>Leucothoe racemosa</i> Forest	G2G3	–	–	–	–	–	–	–	x	–	–	–
Tidal Wetlands	Freshwater Tidal Wetlands	CEGL006325	<i>Impatiens capensis</i> - <i>Peltandra virginica</i> - <i>Polygonum arifolium</i> - <i>Schoenoplectus fluviatilis</i> - <i>Typha angustifolia</i> Tidal Herbaceous Vegetation	GNR	–	–	–	x	–	–	–	x	–	–	–
	Freshwater Tidal Wetlands	CEGL004706	<i>Peltandra virginica</i> - <i>Pontederia cordata</i> Tidal Herbaceous Vegetation	G3G4	–	–	–	x	–	–	–	x	–	–	–
	Freshwater Tidal Wetlands	CEGL004472	<i>Nuphar advena</i> Tidal Herbaceous Vegetation	G4G5	–	–	–	x	–	–	–	x	–	–	–
	Freshwater Tidal Wetlands	CEGL002386	<i>Nuphar advena</i> - <i>Nymphaea odorata</i> Herbaceous Vegetation	G4G5	–	–	x	x	–	–	–	–	–	–	–
	Freshwater Tidal Wetlands	CEGL004188	<i>Schoenoplectus pungens</i> Tidal Herbaceous Vegetation	GNR	–	–	–	x	–	–	–	x	–	–	–
	Freshwater Tidal Wetlands	CEGL006287	<i>Fraxinus profunda</i> - <i>Nyssa biflora</i> - (<i>Fraxinus pennsylvanica</i>) / <i>Ilex verticillata</i> / <i>Polygonum arifolium</i> Forest	G3	–	–	–	x	–	–	–	x	–	–	–

Table 6 (continued). NCR natural/seminatural USNVC associations (n=86) and park special (n=1). An “x” indicates presence. Cegl is Community Element Code—Global and is a published unique identifier for USNVC. CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. All classified natural/seminatural associations were not used as mapping units, some of these are associations that typically occur below the minimum mapping unit, and others were included as part of a composite map class, (see Tables 8, 9, 11, and 12 for these map classes). In addition, three USNVC associations were added during mapping: *Schoenoplectus tabernaemontani* - *Typha spp.* - (*Sparganium spp.*, *Juncus spp.*) Herbaceous Vegetation (CEGL002026), *Wisteria sinensis* Vine-Shrubland (CEGL008568), and *Alnus serrulata* Swamp Shrubland (CEGL005082). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022b).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Nonvascular	Lichen Vegetation	CEGL004142	<i>Lasallia (papulosa, pensylvanica)</i> - <i>Dimelaena oreina</i> - (<i>Melanelia culbersonii</i>) Nonvascular Vegetation	G5	–	x	–	–	–	–	–	–	–	–	–
TOTALS	–	–	–	–	5	16	55	37	27	12	9	24	14	8	4

Table 7. NCR successional and ruderal USNVC associations (n=20) and cultural subtypes (n=4). An “x” indicates presence. CEGL is the code used for USNVC associations; CEST is the code used for USNVC cultural subtypes; and CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Upland Successional	Planted Deciduous Forest	CEST007452	<i>Taxodium distichum</i> Planted Forest	GNA	–	–	–	–	–	–	–	x	–	–	–
	Planted Evergreen Forest	CEST007167	<i>Picea abies</i> Planted Forest	GNA	–	–	x	x	–	–	–	–	–	–	–
	Planted Evergreen Forest	CEST007178	<i>Pinus strobus</i> Planted Forest	GNA	x	x	x	–	–	–	x	–	–	–	–
	Planted Evergreen Forest	CEST007179	<i>Pinus taeda</i> Planted Forest	GNA	–	–	x	–	–	x	–	x	–	–	–
	Successional Evergreen Forest	CEGL002591	<i>Pinus virginiana</i> Successional Forest	GNA	–	–	x	x	–	x	–	x	x	x	x
	Successional Evergreen Forest	CEGL006024	<i>Juniperus virginiana</i> Forest	GNA	x	–	x	–	x	x	–	x	–	–	–
	Successional Mixed Deciduous Forest	CEGL006599	<i>Prunus serotina</i> - <i>Liriodendron tulipifera</i> - <i>Acer rubrum</i> - <i>Fraxinus americana</i> - (<i>Robinia pseudoacacia</i>) Forest	GNA	–	x	x	x	x	x	x	x	x	–	x
	Successional Mixed Deciduous Forest	CEGL007191	<i>Ailanthus altissima</i> Forest	GNA	x	–	x	–	–	–	–	–	–	–	–
	Successional Mixed Deciduous Forest	CEGL007216	<i>Liquidambar styraciflua</i> Forest	GNA	–	–	–	–	–	–	–	x	–	–	–
	Successional Mixed Deciduous Forest	CEGL007220	<i>Liriodendron tulipifera</i> / (<i>Cercis canadensis</i>) / (<i>Lindera benzoin</i>) Forest	GNA	x	x	x	x	x	–	x	x	–	x	x
	Successional Mixed Deciduous Forest	CEGL007221	<i>Liriodendron tulipifera</i> - <i>Quercus</i> spp. Forest	GNA	–	x	x	x	–	–	–	x	x	x	x

Table 7 (continued). NCR successional and ruderal USNVC associations (n=20) and cultural subtypes (n=4). An “x” indicates presence. CEGL is the code used for USNVC associations; CEST is the code used for USNVC cultural subtypes; and CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Upland Successional (continued)	Successional Mixed Deciduous Forest	CEGL007279	<i>Robinia pseudoacacia</i> Forest	GNA	x	x	x	–	–	–	–	x	–	–	–
	Successional Mixed Deciduous Forest	CEGL007281	<i>Robinia pseudoacacia</i> - <i>Celtis occidentalis</i> - (<i>Fraxinus americana</i> , <i>Liriodendron tulipifera</i>) Forest	GNA	x	–	x	–	–	–	–	–	–	–	–
	Successional Mixed Deciduous Forest	CEGL007879	<i>Juglans nigra</i> / <i>Verbesina alternifolia</i> Forest	GNA	x	–	x	x	x	x	–	–	–	–	–
	Successional Vine-Shrubland	CEGL003882	<i>Pueraria montana</i> var. <i>lobata</i> Vine-Shrubland	GNA	–	–	x	–	–	–	–	–	–	–	–
Wetland Successional	Successional Floodplain Forest	CEGL005033	<i>Acer negundo</i> Forest	GNA	x	–	x	x	x	x	x	x	–	–	–
	Successional Floodplain Forest	CEGL006976	<i>Betula nigra</i> - <i>Acer rubrum</i> - (<i>Liquidambar styraciflua</i> , <i>Platanus occidentalis</i>) Successional Forest	GNA	–	–	–	–	–	–	–	x	–	–	x
	Successional Floodplain Forest	CEGL007330	<i>Liquidambar styraciflua</i> - (<i>Liriodendron tulipifera</i>) Temporarily Flooded Forest	GNA	–	–	–	x	–	–	–	x	–	–	–
	Successional Herbaceous Wetland	CEGL004141	<i>Phragmites australis</i> Eastern North America Temperate Semi-natural Herbaceous Vegetation	GNA	–	–	–	–	–	–	–	–	–	–	–
	Successional Herbaceous Wetland	CEGL006044	<i>Phalaris arundinacea</i> Eastern Herbaceous Vegetation	GNA	–	x	x	–	x	–	–	–	–	–	–
	Successional Herbaceous Wetland	CEGL006153	<i>Typha (angustifolia, latifolia)</i> - (<i>Schoenoplectus</i> spp.) Eastern Herbaceous Vegetation	G5	–	–	x	–	x	x	–	x	–	–	–

Table 7. NCR successional and ruderal USNVC associations (n=20) and cultural subtypes (n=4). An “x” indicates presence. CEGL is the code used for USNVC associations; CEST is the code used for USNVC cultural subtypes; and CEPS is the code used for park special plant communities with insufficient data to be recognized as a plant community in the USNVC. Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Landscape Position	Ecological Group	CEGL	Vegetation Community	G-rank	ANTI	CATO	CHOH	GWMP	HAFE	MANA	MONO	NACE	PRWI	ROCR	WOTR
Wetland Successional (continued)	Successional Herbaceous Wetland	CEGL006349	<i>Scirpus cyperinus</i> Seasonally Flooded Herbaceous Vegetation	GNR	–	–	x	–	–	x	–	x	x	–	–
	Successional Woody Wetland	CEGL006069	<i>Cephalanthus occidentalis</i> - <i>Decodon verticillatus</i> Shrubland	G4G5	–	–	–	–	–	–	–	x	–	–	–
	Successional Tidal Wetland	CEGL004187	<i>Phragmites australis</i> Tidal Herbaceous Vegetation	GNA	–	–	–	x	–	–	–	–	–	–	–
Totals	–	–	–	–	8	6	18	9	7	8	4	15	4	3	5

Altogether, a total of 3,005 plots of vegetation and environmental data were compiled and analyzed as part of the regional NCR analysis. This number represents 510 of the 578 plots collected specifically for the project from within and in the vicinity of NCR parks; 395 plots of supplemental plot data from the Potomac Gorge and surrounding area; and 2,100 additional plots collected throughout Virginia and Maryland and compiled by the Virginia Natural Heritage Program and the Maryland Natural Heritage Program (Figure 1). Ultimately, 1,972 of the initial 3,005 plots were used to define the USNVC associations for the NCR region. Plots were eliminated from the final dataset if they occurred as strong outliers, were heterogeneous in composition, dominated by weedy exotics, or if they grouped into plant communities unrelated to the vegetation of the NCR region. In addition to quantitative plots, 519 qualitative observation points were collected or obtained from other project throughout the NCR parks to better characterize natural communities, early successional vegetation, and recently disturbed habitats.

The classification analysis for the NCR eastern subregion resulted in 40 association-level plant communities: 15 represented upland vegetation and 25 represented wetland vegetation. Thirty-three of these were assigned to existing USNVC associations, and seven formed the basis of proposed new USNVC associations. Twelve plant communities reported for the NCR eastern region by Lea (2004) and others were not confirmed in analysis, nor were considered variants of existing or new USNVC associations. Six associations overlapped between the NCR eastern subregion and the NCR western subregion.

The classification analysis for the NCR western subregion resulted in 53 association-level plant communities: 29 represented upland vegetation and 24 represented alluvial or riparian vegetation. The relatively large proportion of alluvial/riparian units was due to approximately one-third of the plots from NCR parks in this dataset representing diverse depositional bar or related vegetation. Eighteen plant communities reported for the NCR western subregion (Lea 2004) were not confirmed in analysis or were considered variants of existing or new USNVC associations. Thirty-seven plant communities identified in this classification were assigned to existing USNVC associations. Thirteen plant communities (mostly depositional bars) formed the basis of proposed new USNVC associations.

The analytical protocols used to generate the NCR vegetation classification give the most weight to the *full floristic composition* of stands and the application of consistent criteria for classification to vegetation occurring at a wide variety of scales and sampled at variable intensities. These analytical biases tend to allow more variation in dominance patterns and physiognomy within some plant communities (especially widespread forests) than protocols favoring the more abundant species. On the other hand, plant communities with very distinctive species composition (especially those that are rare) tend to emerge strongly in analysis. As a result, in the NCR classification, the larger-patch, naturally variable forest communities were defined quite broadly while small-patch, environmentally restricted plant communities were defined more narrowly. In addition, plant communities are not immutable organisms but abstract concepts that grade into each other over geographic clines, or more locally as environmental conditions change on a given landscape. Thus, as in any analysis, there were a number of transitional plots that could have been assigned to different plant communities without

changing the basic circumscriptions of those communities, thus providing some flexibility in mapping.

The results of the vegetation classification were used by the vegetation mapping team as a starting point for the map classification. The classified plant communities do not correspond exactly with the map classes since some were mapped as part of a composite map class. No attempt was made to classify or identify all early successional, disturbed or planted vegetation present in NCR.

Descriptions and dichotomous field keys representing the USNVC associations, map classes, and ITESC ecological systems included in the NCR classification and maps are provided in separate documents (NatureServe 2020, Teague et al. 2022b). Updates and changes to the published nomenclature of USNVC park plant communities are provided in a separate document (Teague et al. 2022a).

Vegetation Mapping

Introduction

In conjunction with the NCR classification effort, VANHP conducted the photo-interpretation and created the vegetation maps for ten NCR parks. Rock Creek Park (ROCR) was completed as a prototype early in the USGS/NPS mapping program in 1998. During this project NatureServe remapped the vegetation at ROCR to ensure this park had a robust vegetation classification similar to the other NCR parks. The mapping work for the remaining ten NCR parks began by VANHP in June 2006. The project goal was to map vegetation to the association level of the USNVC using a vector (polygon) spatial model, at a scale of 1:6,000.

Methods

Map Data Sources

A primary requirement of any vegetation mapping project is an aerial photograph or other set of remotely-sensed imagery covering the area to be mapped. In addition, spatially referenced field observations are needed to calibrate the interpretation of photo signatures. In some cases, these two items in conjunction may be sufficient to develop a reasonable map. However, for the purpose of this project, which was to map vegetation to the association level of the USNVC, a variety of additional spatial data sources was essential to help distinguish between vegetation communities that could not be distinguished by photo signature alone. An overview of all the data sources ultimately used to develop the vegetation maps is presented here.

Imagery

We acquired and utilized several different sets of imagery to serve as the backdrop for photo interpretation and digitizing. All imagery used in this project was acquired in digital form, so that photo interpretation and digitizing could be conducted directly on-screen.

NCR Imagery

At the outset of the project, NPS-NCR provided a set of color-infrared (CIR) images to cover the entire NCR region. This set of images was produced by VARGIS (now Infotech Enterprises America, Inc.) and QA/QC by USGS Remote Sensing Division, specifically to serve as the base imagery for the vegetation mapping project. It included over 3,000 overlapping image tiles, enabling stereoscopic viewing (with specialized hardware and software). In addition, to facilitate more rapid viewing without the stereo effect, the individual images were compiled into 20 flat mosaics – one each for most parks, with multiple mosaics for the more extensive parks (CHOH, GWMP, and NACE).

The scale of the NCR imagery is 1:1,200, with 1-ft pixel resolution. Aerial photography for each park were captured in late March or early April 2003 and in 2004. Because of regional differences in leaf phenology as well as timing of photography, there was much variation in image characteristics. In some areas (e.g., CATO), imagery appeared mostly leaf-off, whereas in others (e.g., NACE), canopy crowns had fully expanded leaves. Quality of the imagery also varied among areas, presenting some challenges for photo interpretation.

Supplemental Imagery

In addition to the CIR imagery, NPS staff provided several park-specific imagery mosaics. These were true-color, leaf-off images covering MANA (1998 and 2000 imagery), PRWI (2002), GWMP (2002), WOTR (2002), MONO (2000), and HAFE (date unknown). To supplement the imagery provided by NPS, we also acquired imagery from state, county, and city sources. These images were obtained as individual tiles rather than mosaics. Using ArcCatalog, they were managed using raster catalogs for efficient storage and on-screen display. The sets of supplementary imagery included the following:

- Virginia Base Mapping Program (VBMP) Digital Orthophotography (2006–2007): True-color, leaf-off imagery covering GWMP, MANA, PRWI, WOTR, and parts of CHOH and HAFE
- Digital Ortho Quarter-Quads (Virginia, 1999): Color-infrared, leaf-off imagery covering GWMP, MANA, PRWI, WOTR, and parts of CHOH and HAFE
- Maryland SHA Contract Imagery (2007–2008): True-color, leaf-on/leaf-off (depending on area) imagery covering ANTI, CATO, MONO, and parts of NACE, CHOH, GWMP, and HAFE
- West Virginia Orthophotography (2006): True-color, leaf-off imagery covering part of HAFE
- Montgomery County, MD Digital Orthophotography (2006): True-color, partial leaf-off imagery covering parts of GWMP and CHOH
- USGS High Resolution Orthoimagery for the Washington D.C. Urban Area (2008): Natural color (4-band), leaf-on/leaf-off (depending on area) imagery covering parts of NACE

In addition to aerial photography, digital raster graphic (DRG) topographic maps produced by the USGS were used as background images. A total of 55 7.5-minute topographic map quadrangles were needed to cover the NCR region (<https://www.usgs.gov/core-science-systems/national-geospatial-program/topographic-maps>).

Field Observations

We relied on several field datasets to determine the regional distribution, landscape settings, and photo signatures associated with various vegetation communities. The datasets, including rapid assessment points, quantitative vegetation plots, and qualitative observation points, are briefly described below. Rapid assessment points and vegetation plots were collected prior to commencement of mapping activities. The observation points were collected both prior to and during the mapping process. All field datasets included both spatial locations determined by GPS and tabular attributes recorded by ecologists and photointerpreters.

Spatial locations for field data points were compiled into a geodatabase, with separate feature classes representing vegetation plots, rapid assessment points, and observation points. Any detected spatial inaccuracies (e.g., due to datum shift) were corrected. As new observation data were collected over the course of the mapping project, features were appended to the observation points feature class. Detailed attribute data were imported or entered manually, and maintained in a separate, non-spatial database linked to the spatial data via a unique point identification field. A draft dichotomous key was developed for each park to assist in field identification of plant communities and map classes. Customized data forms were developed in the non-spatial database to facilitate the reference and

review of existing field data, entry of new data and comments about classification, mapping considerations, field key issues, quality control notes, and any other relevant information.

Rapid Assessment Points

Extensive rapid assessment observation point data were collected by Chris Lea in 2002, (on Detail to NCR from Assateague Island National Seashore (ASIS) and then the NPS VMI 2003–2004). These data were collected for initial reconnaissance as part of the NCR vegetation classification and mapping project, and many, but not all points, had detailed species lists associated with them. Relative abundance of species was not recorded, preventing the data from being used in the vegetation classification analyses. Narrative descriptions of the landscape context and representativeness were also lacking, so it was not possible to determine whether the vegetation community identified by a data point was representative of a large or small area. Chris Lea assigned each point to a plant community in 2004, then revised some assignments in 2006 after classification work had been completed.

Quantitative Vegetation Plots

Many of the quantitative plot data used in the NCR vegetation classification were located within NCR parks and were directly used to inform the mapping of park vegetation. This dataset was analyzed to formally classify the natural vegetation of NCR, and this classification forms the basis of the vegetation maps. Data collected at each quantitative plot included comprehensive species lists as well as estimates of cover by species and by strata. Narrative descriptions of the landscape context and representativeness were often, but not always, included.

Plot locations were subjectively selected to capture the most pristine available examples of natural communities. The plots do not represent more disturbed, successional vegetation communities that are also widespread throughout NCR parks. Vegetation communities were assigned to points based on how they clustered or grouped in the classification analyses. Some points were outliers in the analyses. The outlier communities were assigned more subjectively with low confidence.

Qualitative Observation Points

Observation points were non-quantitative data collected to supplement the rapid assessment points and quantitative vegetation plots and assist with and inform and validate the mapping process. Species lists and/or a brief narrative description or assessment of the area were usually included, although in some cases the point was simply assigned to a map class or described as the transition between map classes. Species lists were not nearly as comprehensive as for vegetation plots, but, where included, an attempt was made to record the most important community components along with evaluations of relative abundance.

Like the more formal vegetation plots, observation points were collected by several different ecologists. Prior to the initiation of mapping, 519 qualitative observation points were collected by Virginia Natural Heritage and other project ecologists between 2003 and 2006. After the mapping effort began in June 2006, an additional 996 observation points were collected during reconnaissance and map validation over the course of numerous trips taken through 2009. For the earliest trips, in 2006, the lead mapper was accompanied by ecologists familiar with the parks and the vegetation.

These trips served as both training and sampling opportunities. Later observation points, collected primarily by the photo interpreters/mappers, were a part of ground truthing and to verify map class assignments of attributed polygons, to determine the map classes of unassigned polygons and polygons likely to need subdivision, to cover areas that were underrepresented in previous vegetation samples, and to clarify any outstanding mapping issues.

Initial map class assignments for observation points were typically made in the field, often but not always with the help of draft field keys. Field keys were not available for the earliest observation points but were more heavily used later in the project. Map class assignments for ambiguous points were checked and evaluated back in the office in consultation with experienced vegetation ecologists.

Ancillary Spatial Data

The areas to be included in the vegetation maps for each park were defined by the parks' boundaries. Digital spatial layers representing the boundaries were delivered to us by NCR Regional GIS Coordinator in 2006. As reference layers, we also obtained spatial data representing roads, trails, rail, and buildings (if applicable) from NPS staff, individual park managers, and or the NPS GIS Data Store (which later became the Integrated Resource Management Applications (IRMA) Data Store¹).

We acquired multiple ancillary spatial datasets to assist with the process of photointerpretation. In general, the scale of these spatial data sources was either unspecified (unknown), or coarser than the specified scale of the vegetation maps, which is 1:6,000. Datasets included, for all parks:

- Hypsography: We downloaded USGS Digital Line Graph (DLG) elevation contours from the NPS GIS portal² in 2006 (that is now a part of the IRMA Data Store). There were separate datasets for each park. The scale of the vector datasets (lines) is 1:24,000.
- Hydrography: We used the USGS DLG representation of rivers, streams, and other water bodies. The 1:24,000 scale datasets consisted of both lines and polygons, depending on the size of the water body. Datasets covering each of the NCR parks were downloaded from the NPS GIS portal in 2006 (that is now part of the IRMA Data Store).
- Wetlands: We downloaded the National Wetlands Inventory (NWI) data for the entire NCR region from the U.S. Fish and Wildlife Service website³ in 2006. The map scale of this polygon dataset is unknown.
- Geology
 - ANTI, CATO, GWMP, MANA, MONO, NACE, PRWI, and WOTR were covered by The Geologic Map of the National Parks in the National Capital Region (Southworth and Denenny 2005), which was downloaded from the USGS online source⁴. It included

¹ <https://irma.nps.gov/DataStore/>

² <http://nrdata.nps.gov/>

³ <https://www.fws.gov/wetlands/>

⁴ <https://pubs.usgs.gov/of/2005/1331/>

- separate park-specific datasets for surficial and bedrock geology (polygon representation). The map scale was not specified.
- HAFE and CHOH were covered as a unit in The Geology of the Chesapeake and Ohio Canal National Historical Park and Potomac River Corridor, District of Columbia, Maryland, West Virginia, and Virginia (Southworth et al., 2001), which was obtained from NPS on CD in 2006. The disk included separate datasets for surficial and bedrock geology (polygon representation). The map scale was 1:24,000.
 - We combined the park-specific geologic map data (both surficial and bedrock layers) into a single data layer. Map units were assigned to a much smaller set of aggregate geologic map classes: alluvium, colluvium/debris/landslide, coastal plain coarse sediments, coastal plain fine sediments, acidic sedimentary, carbonate, granitic, mafic, phyllite/metasiltstone/shale, and artificial. This facilitated a regional overview of how geologic patterns relate to the distribution of vegetation communities across NCR.
 - Soils
 - We downloaded Soil Survey Geographic (SSURGO) Database shapefiles for all NCR counties from the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) web site (NRCS Soil Data Mart that is now part of the NRCS Web Soil Survey⁵) in 2009. The map scale of the polygon datasets varied depending on soil survey area. The detailed tabular data associated with the soils shapefiles were imported into the template Access database provided by NRCS.
 - We used the Soil Data Viewer extension for ArcMap⁶ to derive new data layers depicting various soil characteristics (e.g., pH, hydric rating, and surface texture) from the primary dataset. We developed a separate geodatabase to store the derived soil layers.
 - Digital elevation model (DEM)
 - We downloaded National Elevation Dataset (NED) data covering the entire NCR region from the USGS national elevation data website (now part of USGS 3D Elevation Program⁷) in 2007. Due to the large volume of data, this was accomplished in sections, using the individual imagery mosaics to specify the spatial extent to be extracted in each download. The resolution of the raster datasets was 1/3 arc-second (approximately 10 m). The native datasets were unprojected; we projected the data into UTM coordinates (zone 18, NAD83) with 10-m resolution so that we could use the elevation data to derive additional data layers (see below).

⁵ <https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>

⁶ The Soil Data Viewer is available at https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/survey/geo/?cid=nrcs142p2_053620.

⁷ <https://www.usgs.gov/core-science-systems/ngp/3dep>

- The TauDEM⁸ extension for ArcMap was used to derive slope and aspect, to model hydrologic flow, and to generate a raster representing an index of soil moisture based on topography (= Topographic Moisture Model). Calculations of soil moisture account for slope steepness and curvature, and flow accumulation from all upstream sources. Soil types were not used.
- The Spatial Analyst/Solar Radiation toolkit in ArcMap was used to generate rasters representing indices of solar exposure (= Solar Radiation Model). The solar analysis tools account for sun angle, elevation, orientation (slope and aspect), and shading from topographic features in the calculations of solar radiation.

In addition to the above data available for all parks, we acquired some park-specific datasets. These included:

- ANTI and MONO vegetation maps: Stephanie Perles (ecologist, Pennsylvania Natural Heritage Program) provided hard-copy imagery on which she had delineated draft plant community polygons by hand⁹. Only natural/semi-natural communities were delineated; large portions of these parks are cultural. Accompanying spreadsheets linked polygon identification numbers with different plant communities. These were cross walked to NCR map classes.
- ANTI agricultural lease: ANTI park staff provided a vector dataset (polygons) representing open fields under agricultural lease, which were designated as pasture/hay, crop fields, or managed reforestation areas.
- MANA vegetation map: The map was in the form of a vector dataset (polygons) representing forested communities only. It was an earlier map developed by Gary Fleming and Joseph Weber, Virginia Natural Heritage Program. The map is accompanied by a technical report which was completed in 2003.
- MANA warm-season grasslands: MANA park staff provided two vector datasets (polygons) representing formerly forested areas that were converted to native warm-season grasslands. They also provided a vector dataset representing open fields that were formerly dominated by cold-season grasses, but now managed as native warm-season grasslands.
- GWMP and CHOH vegetation map (Gold Mine Tract): As part of the review process in 2009, Chris Lea, an ecologist with the National Park Service, provided us with a map of the vegetation in the “Gold Mine Tract”, an area within both CHOH and GWMP boundaries at Great Falls in Maryland. The hand-drawn map, which was digitally scanned but not georeferenced, was developed by John Hack in 1985. The generalized map classes were cross-walked to the most probable standard USNVC associations by Lea.

⁸ The TauDEM (Terrain Analysis Using Digital Elevation Models) software and documentation are available at <https://hydrology.usu.edu/taudem/taudem5/index.html>.

⁹ These sources were mistakenly omitted from the metadata.

- HAFE vegetation map: Jim Vanderhorst, an ecologist with the West Virginia Natural Heritage Program, provided a vegetation map from 2000 in digital form (ESRI shapefile). Both natural/semi-natural and cultural map classes were delineated for seamless coverage across the park. However, some sections of the park were not covered due to expansion of park boundaries that occurred after his map was completed. The plant communities were cross-walked to our standard map classes for NCR.

Vegetation Map Development

Software and Hardware

ESRI ArcGIS software (version 9.2) was used to develop the vegetation maps. All digitizing and polygon attribution work was conducted on two Windows XP desktop workstations that were networked for file sharing. The Leica StereoAnalyst extension (version 9.1) for ArcMap was loaded on one workstation (Dell Precision Workstation 690) to enable stereoscopic viewing and editing. Specialized hardware included a stereo-enabled video card (nVidia Quadro FX 4500), a Stereographics Monitor Zscreen mounted on a 21" CRT monitor (NEC AccuSync 120), and polarized glasses supplied with the Zscreen. Properly oriented, overlapping image tiles could be viewed in stereo when used in combination with Leica Photogrammetry Suite Block files (*.blk) providing the necessary parameters; these were supplied by NPS.

Data Structure

For each park, a working file geodatabase was created to store and edit vegetation polygons. A polygon feature class was created within a feature dataset that included map topology. The cluster tolerance was set to 0.5 m (approximately one tenth of the desired positional accuracy). Topology rules were established such that polygons would neither overlap nor have gaps between them. Topology was repeatedly validated as digitizing proceeded to ensure geometric integrity.

Draft products were delivered as shapefiles that were exported from the working geodatabases. Final products were delivered as feature classes within personal geodatabases (Microsoft Access database format) for each park, which also included supplemental data layers for convenience.

Mapping Standards

Photo interpretation was conducted using imagery with a reported scale of 1:1,200. Polygons were digitized to meet U.S. National Map Accuracy Standards for a scale of 1:6,000, meaning that 90% of all well-defined points should fall within 5 m of true position. Note, however, that boundaries between vegetation communities are rarely well-defined due to ecotonal gradation from one to another. The 5 m positional accuracy standard only applies to well-defined boundaries, such as between a road and a forest. It usually does not apply to the delineated boundaries between different forest communities or other natural/semi-natural communities unless there is a sharp transition, such as between a natural deciduous forest and a dense conifer plantation.

Preliminary linework was drafted at a scale of 1:6,000, but we found that fine-tuning the linework at a scale of 1:2,000 was necessary to meet the positional accuracy standard for well-defined points. In some areas, misalignment of imagery made spatial accuracy uncertain. In these areas, we chose to follow the imagery that appeared to be more accurate (based on comparisons with other spatial

layers). We also followed the more recent imagery in areas where image discrepancies were obviously due to actual changes on the ground (e.g., development of previously forested areas).

NCR standards specified a minimum mapping unit (MMU) of 0.5 ha. All vegetation and land cover types above MMU that could be distinguished by photo interpretation, in conjunction with ancillary layers, were mapped. Vegetation and cultural features under this size were generally not mapped unless (1) the feature represents a community that is rare and/or of special interest, (2) the feature occurs at the junction of two or more polygons and could not be reasonably considered an inclusion of either one, or (3) inclusion of the feature as a separate polygon is likely to improve map accuracy and/or visual appeal. For linear features such as roads and streams, we established a minimum mapping width of 5 m. Narrower linear features were not generally mapped, even if the total size of the feature would have exceeded MMU.

Each map was developed to completely cover the area enclosed within the park boundary delivered to us by NPS-NCR at the beginning of the project. Polygons mapped at park edges were extended across the boundaries to their natural extent, or, for linear features, to the extent of adjacent polygons. Because of the boundary overlap between CHOH and GWMP, and between CHOH and HAFE, the overlap areas were digitized only as part of the GWMP and HAFE feature classes, respectively. This was necessary to avoid duplicating efforts in the same areas of CHOH. The relevant areas were spliced into the CHOH feature class prior to delivery to provide full coverage of the park.

Map Classes

A key component of the photo interpretation process is the establishment of a list of permissible map classes. We compiled a working list based on field data that had been collected prior to mapping, and consultation with field ecologists. We developed a database to house and provide ready access to information about each map class, including USNVC names, global descriptions, notes about environmental settings, distribution among and within parks, etc. The map class list was refined, and the database updated as needed while field work and mapping continued. Defining the relationship between USNVC associations and ITESC Ecological Systems afforded an opportunity to develop park vegetation map classes and maps at two thematic scales. Photo interpretation and mapping focused on the USNVC association map class scale which were then rolled up to an ITESC ecological systems map class scale by cross-walking associations to ecological systems for NCR.

Polygon Delineation and Photo Interpretation

Preliminary map development began with the delineation of polygons representing broad, easily distinguishable categories (e.g., forests, fields, developed areas, open water). Heads-up digitizing was conducted at a scale of 1:6,000, with the CIR imagery supplied by NPS-NCR as the base layer. At this early stage, polygons were attributed only with National Landcover Database (NLCD) categories. After the initial linework was completed, vegetation maps were iteratively edited and updated, and polygons were attributed with a map code representing one of the permissible map classes. In this phase, all imagery used as base layers, and linework was refined at a scale of 1:2,000 to ensure 5-m accuracy for well-defined boundaries.

Differences in color, texture, density, and pattern were useful for distinguishing some plant communities based on photo-signature, but many were indistinguishable by photo signature alone. In addition, a single community could have several different photo signature variants. Having access to more than one set of imagery was helpful, as communities that were indistinguishable in one set of imagery could sometimes be separated using a different set. It is noteworthy that significant edits were made and much detail was added after we acquired Maryland and Washington, D.C. imagery later in the project timeline. Stereoscopic view using the StereoAnalyst extension helped delineate floodplains and wetlands, and to distinguish communities by topographic position, slope, vegetation stature and/or subtle signature variations not apparent in flat image mosaics.

The importance of additional non-imagery data sources cannot be overstated. Polygon boundaries were edited, and map classes were assigned based on a holistic combination of photo signatures, field data, ancillary data layers, regional and local context, consultation with ecologists familiar with the vegetation patterns in particular areas and reviews of draft maps by NPS staff and others. Decision rules for polygon attribution were developed and refined iteratively as new data were acquired and our understanding of vegetation patterns across NCR solidified over time. These decision rules are codified in the photo interpretation keys provided for each park (Teague et al. 2022c). In general, the decision rules were qualitative rather than quantitative, which still leaves room for interpretation as to where exact polygon boundaries should be drawn. This is consistent with the fact that vegetation communities on the ground are not sharply delineated, but intergrade with each other.

After delivery of second draft maps, but prior to delivery of final map products, we completed an extensive, internal quality control review. This phase included substantial editing in Maryland and Washington, D.C. parks because more recently acquired imagery revealed patterns that had not been apparent in the NPS-supplied imagery. Quality control protocols are described in a later section.

Polygon Attribution

During the polygon delineation and photo interpretation process, the map code was the primary attribute being modified. However, the tabular data of the final vegetation datasets included numerous additional attributes, including USNVC names, International Terrestrial Ecological Systems Classification (ITESC) equivalents, NLCD equivalents, physical characteristics of the vegetation, and other information.

All attributes included in the final vegetation map datasets are itemized and defined in a data dictionary delivered to the NPS. These attributes generally were, added and updated prior to delivery rather than during the mapping process. Several attribute fields were automatically updated by the software. Some were assigned values based on spatial location. Many others were updated based on crosswalk tables we developed tying the map code to specific attribute values.

Metadata Development

We used the NPS Metadata Tools extension for ArcGIS to prepare embedded metadata, stored within the vegetation geodatabase. To prepare the entity/attribute portions of the metadata, we used the NPS Database Metadata Extractor MS Access Add-In, version 1.1. We exported metadata in various formats (*.xml, *.html, *.txt) so that metadata files could be read without requiring ArcGIS software.

Development of Visual Map Products

Working closely with NPS, we developed a standardized map format and layout for all NCR parks. The symbology for map classes was the same for all NCR maps. The symbology set was carefully chosen to ensure that each map class could be readily recognized and distinguished from others across the range.

Map dimensions and scale varied among parks, and some parks (GWMP, CHOH, and NACE) required a series of maps to cover the full extent. Although the map scale for digital products was 1:6,000, the scale of printed maps varied to best accommodate the extent of each map plotted on 36 or 42 inch plotter rolls. Most maps were printed at a coarser scale than the underlying data. The exception was WOTR, which was printed at a scale of 1:3,000 due to the requirement of a minimum map size of 24 inches x 36 inches.

Quality Control Measures

External Review

Several opportunities for external map review were built into the project timeline. We first delivered, in digital format only, preliminary linework without attribution. The next deliverables were first and second draft maps with attribution. These drafts included hard copy print maps as well as digital spatial data representing vegetation communities in shapefile format. All polygons were attributed with USNVC or other standard map code. Full USNVC or map class names were included in some of the delivered first drafts, but no other attributes were included at that time. Second drafts included full USNVC common, global, and translated names if applicable, as well as embedded draft metadata. Second draft maps for later parks delivered in 2009 were also accompanied by map layout files and any ancillary spatial data included in the print maps. Third draft maps were not a formal deliverable, but we delivered digital map data and associated files to ensure that all requirements were met prior to creating final data disks. The vegetation datasets included the full suite of tabular attributes (see Section 5.6) as well as finalized embedded metadata.

At each stage of the process, any review comments received from reviewers were carefully considered, and were incorporated into later drafts where appropriate. We received and incorporated comments relating to the distribution of vegetation communities, attribute accuracy of polygons, detail of the linework, digital data integrity, and content of the metadata. Visual presentation was also evaluated, and we iteratively amended our map layouts and symbology.

Internal Review

Before each delivery, whether of draft or final products, we performed a topology validation and made any necessary corrections to remove gaps or overlaps between polygons. We checked for and repaired any geometry errors, then performed a final topology validation.

Because the development of the vegetation maps relied heavily on the field data points, we also thoroughly reviewed these point data in conjunction with the review of mapped polygons. To facilitate the review, we created a fishnet layer of 1-km x 1-km blocks (“QC blocks”). The block size was chosen so that at the specified map scale of 1:6,000, the entire block could be viewed at once on-screen. We methodically checked the point data, linework, and polygon attribution within each block.

As needed, we edited linework and/or changed tabular attributes of polygons and points. After all points and linework within a QC block were evaluated (and edited, if needed), the block's tabular record was updated with a date stamp to indicate that it had been reviewed.

Review of Field Data Points

For the final review, we consolidated the spatial layers for vegetation plots, rapid assessment points, and observation points into a single data layer. Two attribute fields (SAREV and AAREV) were used to document a qualitative evaluation of spatial accuracy (= positional accuracy) and attribute accuracy. During the review, accuracy was designated as “use with caution, accuracy questionable” (coded as 0), “presumed reasonably accurate” (coded as 1), or “presumed reasonably accurate, but too small to pull out as a separate polygon” (coded as 2). The latter refers to situations where this designation was made based on the spatial context of mapped polygons and other data points in the vicinity of the point in question.

Because boundaries between vegetation types are usually not well-defined on the ground, positional accuracy of point locations collected by GPS was generally assumed to be sufficient for mapping purposes unless there were notes to the contrary in the data record. Positional accuracy was designated “questionable” when GPS data were recorded as 2-D, when field notes indicated that satellite reception was poor, or when estimated precision recorded in the field was >10 m. Point accuracy was also designated “questionable” if there was conflict with other layers (e.g., a point attributed as a floodplain community positioned in uplands), or if any other issue became apparent during field work, mapping, or review.

“Attribute accuracy” refers to whether or not the map code assigned to a field data point is correct. Map classes are often ambiguous due to the natural intergradation of vegetation communities, influence of human disturbance, quality of field keys, and variable experience and biases of field data collectors. Attribute accuracy of vegetation plots was assessed based primarily on the results of the classification analysis. In some cases, a vegetation plot was designated “questionable” due to the data collector's narrative comments or other issues that arose during mapping and review, despite clustering with a particular vegetation type.

Attribute accuracy of rapid assessment points and observation points was evaluated by comparing the species data to vegetation plot data summaries. For most natural vegetation types, plot data were used to derive a measure of “constancy” for each plant species. Constancy values range from near zero (for species rarely recorded in plots assigned to that type) to 100 (for species recorded in all plots assigned to that plant association). Within a Microsoft Access database, a data table was compiled containing the constancy values for each species--plant association combination. A series of interacting queries was designed based on the constancy table; these resulted in a ranking of the relative correspondence of each plant association to the species data recorded for a particular rapid assessment point or observation. Species that were present in a plant association's summary table and also present at the rapid assessment point or observation in question contributed positively to that association's ranking, with the weighting influenced by the constancy value, the relative abundance at the point, and the typical species richness of the plant association. Species that were highly constant in the plant association (present in > 67% of plots), but absent at the point in question,

reduced the plant association's ranking. If the highest-ranked association matched the association that had been assigned to the point, it was considered accurate. If there was not a match, or if a match was not possible because there were no plot data for the originally assigned association, the point data were carefully inspected and the reviewer made the final call whether to designate the point "accurate" or "questionable." In some cases, the map code of the point was changed based on this review. Where species data were lacking or deemed insufficiently detailed to make an informed assessment, attribute accuracy was designated "questionable."

Review of Mapped Polygons

We reviewed mapped polygons for quality of the linework as well as attribute accuracy. The polygon layer was examined at a scale of 1:6,000, using transparent symbology, to ensure that linework was smooth, visually pleasing, and matched the imagery well. If necessary, we zoomed in to a scale of 1:2,000 to edit the linework. Map symbology depicting map classes was then used to ensure that map classes occurred in reasonable locations and appropriate landscape settings, and that no polygons needed to be split or merged. Finally, we checked for any discrepancies in the map code attribute between each polygon and any field data points contained within it. A final choice of map code for the polygon was then made, informed by the point accuracy assessment described above.

After polygon review and editing was complete, we conducted a final topology validation and geometry check/repair operation. All attributes were updated based on the final map codes as described in earlier sections of this report.

Results

NCR parks have interesting relationships among the plant communities or associations. For instance, NCR parks have 8 critically imperiled (G1) USNVC associations. CHOH and GWMP share 5 of these critically imperiled associations. Two G1 associations cover the smallest areas. Limestone Red-Cedar Glad (CEGL 006047) occurs only in HAFE and covers 0.41 ha (1.01 acre), and Magnolia Bog (CEGL006219) in NACE covers 0.5 ha (1.24 acres). There are 11 imperiled (G2) USNVC associations and 25 vulnerable (G3) USNVC associations.

Some USNVC associations occur in only 1 park: NACE has 8 unique associations, CHOH has 8, CATO has 5, PRWI has 2, and HAFE has 1.

Seven USNVC associations are found across 6 parks; and five USNVC associations are shared by 5 parks. Two USNVC associations are each present in 9 parks: Black Cherry - Tuliptree - Red Maple - White Ash - (Black Locust) Ruderal Forest (CEGL 006599) and Successional Tuliptree Forest (Rich Type) (CEGL 007220).

Mesic Mixed Hardwood Forest (CEGL 006075) covers the largest area in parks (3,576 ha [8,837 acres]), and Successional Virginia Pine Forest (CEGL 002591) covers 2,152 ha [2,152 acres]. A third association, Successional Tuliptree Forest (Rich Type) (CEGL 007220), covers 1,606 ha [3,969 acres].

In the finest scale final maps (i.e., USNVC association level), we used a total of 110 map classes to characterize the vegetation and other land cover across the NCR region. The majority of these map classes were 80 USNVC associations (Table 8).

Table 8. NCR vegetation map: USNVC association map classes (n=80). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	USNVC Association Map Class	USNVC Global Name	Where Mapped
CEGL7312 [mapped as CEGL002086]	River Birch - Sycamore Small River Floodplain Forest	<i>Betula nigra</i> - <i>Platanus occidentalis</i> / <i>Alnus serrulata</i> / <i>Boehmeria cylindrica</i> Forest [Old name: <i>Betula nigra</i> - <i>Platanus occidentalis</i> Forest]	PRWI
CEGL002386	Water-lily Aquatic Wetland	<i>Nuphar advena</i> - <i>Nymphaea odorata</i> Herbaceous Vegetation	CHOH, GWMP
CEGL002591	Successional Virginia Pine Forest	<i>Pinus virginiana</i> Successional Forest	CHOH, GWMP, MANA, NACE, PRWI, ROCR, WOTR
CEGL002596	Cliff White-cedar Woodland	<i>Thuja occidentalis</i> / <i>Carex eburnea</i> - <i>Pellaea atropurpurea</i> Woodland	CHOH
CEGL003683	Basic Woodland	<i>Fraxinus americana</i> - <i>Carya glabra</i> / <i>Muhlenbergia sobolifera</i> - <i>Helianthus divaricatus</i> - <i>Solidago ulmifolia</i> Woodland	CATO, CHOH, HAFE
CEGL004073	Rich Floodplain Forest	<i>Platanus occidentalis</i> - <i>Acer negundo</i> - <i>Juglans nigra</i> / <i>Asimina triloba</i> / <i>Mertensia virginica</i> Forest	ANTI, CHOH, GWMP, HAFE, MANA, MONO, NACE
CEGL004142	Acidic Boulderfield	<i>Lasallia (papulosa, pensylvanica)</i> - <i>Dimelaena oreina</i> - (<i>Melanelia culbersonii</i>) Nonvascular Vegetation	CATO, HAFE
CEGL004187	Reed-grass Tidal Marsh	<i>Phragmites australis</i> Tidal Herbaceous Vegetation	GWMP, NACE
CEGL004188	Brackish Tidal Marsh	<i>Schoenoplectus pungens</i> Tidal Herbaceous Vegetation	GWMP
CEGL004391	Spleenwort Acidic Cliff	<i>Asplenium montanum</i> Central Appalachian Sandstone Sparse Vegetation	CHOH, MONO
CEGL004418	Small Stream Sweetgum - Tuliptree Forest	<i>Liquidambar styraciflua</i> - <i>Liriodendron tulipifera</i> / <i>Lindera benzoin</i> / <i>Arisaema triphyllum</i> Forest	NACE, PRWI
CEGL004472	Pond-lily Tidal Marsh	<i>Nuphar advena</i> Tidal Herbaceous Vegetation	GWMP, NACE
CEGL004476	Montane Cliff (Calcareous Type)	<i>Asplenium ruta-muraria</i> - <i>Pellaea atropurpurea</i> Sparse Vegetation	CHOH
CEGL004643	Pin Oak - Swamp White Oak Seasonal Pond	<i>Quercus palustris</i> - <i>Quercus bicolor</i> / <i>Viburnum prunifolium</i> / <i>Leersia virginica</i> - <i>Impatiens capensis</i> Forest	CHOH, MANA

Table 8 (continued). NCR vegetation map: USNVC association map classes (n=80). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	USNVC Association Map Class	USNVC Global Name	Where Mapped
CEGL004706	Pickereelweed Tidal Marsh	<i>Peltandra virginica</i> - <i>Pontederia cordata</i> Tidal Herbaceous Vegetation	GWMP, NACE
CEGL004793	Limestone Oak - Hickory Forest	<i>Quercus muehlenbergii</i> - <i>Quercus (alba, rubra)</i> - <i>Carya cordiformis</i> / <i>Viburnum prunifolium</i> Forest	ANTI, CHOH, HAFE, MANA, MONO
CEGL004996	Pine - Oak / Heath Woodland	<i>Pinus (pungens, rigida)</i> - <i>Quercus prinus</i> / (<i>Quercus ilicifolia</i>) / <i>Gaylussacia baccata</i> Woodland	CATO, CHOH
CEGL005033	Successional Box-elder Floodplain Forest	<i>Acer negundo</i> Forest	ANTI, CHOH, GWMP, HAFE, MANA, MONO, NACE
CEGL006017	Sugar Maple - Chinquapin Oak Limestone Forest	<i>Acer saccharum</i> - <i>Quercus muehlenbergii</i> / <i>Cercis canadensis</i> Forest	CHOH
CEGL006024	Successional Old-field Eastern Red-cedar Forest	<i>Juniperus virginiana</i> Forest	ANTI, CHOH, HAFE, MANA
CEGL006047	Limestone Red-cedar Glade	<i>Juniperus virginiana</i> / <i>Bouteloua curtipendula</i> - <i>Carex eburnea</i> Wooded Herbaceous Vegetation	HAFE
CEGL006055	Basic Mesic Hardwood Forest (Coastal Plain / Piedmont Type)	<i>Fagus grandifolia</i> - <i>Liriodendron tulipifera</i> - <i>Carya cordiformis</i> / <i>Lindera benzoin</i> / <i>Podophyllum peltatum</i> Forest	CHOH, GWMP, MONO, NACE, ROCR
CEGL006057	Dry-Mesic Chestnut Oak - Northern Red Oak Forest	<i>Quercus prinus</i> - <i>Quercus rubra</i> / <i>Hamamelis virginiana</i> Forest	CATO, CHOH, GWMP, HAFE, MONO
CEGL006075	Mesic Mixed Hardwood Forest	<i>Fagus grandifolia</i> - <i>Quercus (alba, rubra)</i> - <i>Liriodendron tulipifera</i> / (<i>Ilex opaca</i> var. <i>opaca</i>) / <i>Polystichum acrostichoides</i> Forest	CHOH, GWMP, MONO, NACE, PRWI, ROCR, WOTR
CEGL006639 [mapped as CEGL006109]	Hemlock - Northern Hardwood Forest	<i>Tsuga canadensis</i> - <i>Acer saccharum</i> - <i>Fagus grandifolia</i> / <i>Dryopteris intermedia</i> Forest [Old name: <i>Tsuga canadensis</i> - <i>Betula alleghaniensis</i> - <i>Acer saccharum</i> / <i>Dryopteris intermedia</i> Forest]	CATO
CEGL006110	Red Maple - Sweetgum Swamp	<i>Liquidambar styraciflua</i> - <i>Acer rubrum</i> - <i>Quercus phellos</i> / <i>Leucothoe racemosa</i> Forest	NACE
CEGL006125	Rich Red Oak - Sugar Maple Forest	<i>Quercus rubra</i> - <i>Acer saccharum</i> - <i>Liriodendron tulipifera</i> Forest	CATO
CEGL006186	Basic Mesic Hardwood Forest (Upper Piedmont / Blue Ridge Type)	<i>Liriodendron tulipifera</i> - <i>Quercus rubra</i> - <i>Fraxinus americana</i> / <i>Asimina triloba</i> / <i>Actaea racemosa</i> - <i>Uvularia perfoliata</i> Forest	PRWI

Table 8 (continued). NCR vegetation map: USNVC association map classes (n=80). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	USNVC Association Map Class	USNVC Global Name	Where Mapped
CEGL006209	Bedrock Terrace Oak - Hickory Forest	<i>Carya glabra</i> - <i>Quercus (rubra, prinus)</i> - <i>Fraxinus americana</i> / <i>Viburnum rafinesquianum</i> / <i>Piptochaetium avenaceum</i> Forest	CHOH, GWMP
CEGL006216	Hardpan Basic Oak - Hickory Forest	<i>Quercus alba</i> - <i>Carya glabra</i> - <i>Fraxinus americana</i> / <i>Cercis canadensis</i> / <i>Muhlenbergia sobolifera</i> - <i>Elymus hystrix</i> Forest	CHOH, MANA
CEGL006217	Silver Maple Floodplain Forest	<i>Acer saccharinum</i> - <i>Acer negundo</i> / <i>Ageratina altissima</i> - <i>Laportea canadensis</i> - (<i>Elymus virginicus</i>) Forest	CHOH, GWMP, HAFE, MONO, NACE
CEGL006219	Magnolia Bog	<i>Nyssa sylvatica</i> - <i>Magnolia virginiana</i> - (<i>Pinus rigida</i>) / <i>Rhododendron viscosum</i> - <i>Toxicodendron vernix</i> / <i>Smilax pseudochina</i> Woodland	NACE
CEGL006238	Red Maple - Blackgum Seepage Swamp	<i>Acer rubrum</i> - <i>Nyssa sylvatica</i> - <i>Magnolia virginiana</i> / <i>Viburnum nudum</i> var. <i>nudum</i> / <i>Osmunda cinnamomea</i> - <i>Woodwardia areolata</i> Forest	NACE, PRWI
CEGL006240	Pin Oak - Swamp White Oak Forest	<i>Quercus palustris</i> - (<i>Quercus bicolor</i>) - <i>Acer rubrum</i> / <i>Vaccinium corymbosum</i> / <i>Osmunda cinnamomea</i> Forest	CHOH, GWMP, PRWI
CEGL006255	Montane Alluvial Forest	<i>Liriodendron tulipifera</i> - <i>Platanus occidentalis</i> - <i>Betula lenta</i> / <i>Lindera benzoin</i> / <i>Circaea lutetiana</i> ssp. <i>canadensis</i> Forest	CATO
CEGL006287	Freshwater Tidal Swamp	<i>Fraxinus profunda</i> - <i>Nyssa biflora</i> - (<i>Fraxinus pennsylvanica</i>) / <i>Ilex verticillata</i> / <i>Polygonum arifolium</i> Forest	GWMP, NACE
CEGL006299	Chestnut Oak / Mountain Laurel Forest	<i>Quercus prinus</i> - (<i>Quercus coccinea</i> , <i>Quercus rubra</i>) / <i>Kalmia latifolia</i> / <i>Vaccinium pallidum</i> Forest	CATO, CHOH, GWMP, HAFE, NACE, ROCR, WOTR
CEGL006325	Freshwater Tidal Mixed High Marsh	<i>Impatiens capensis</i> - <i>Peltandra virginica</i> - <i>Polygonum arifolium</i> - <i>Schoenoplectus fluviatilis</i> - <i>Typha angustifolia</i> Tidal Herbaceous Vegetation	GWMP, NACE
CEGL006329	Pine - Oak Woodland	<i>Pinus rigida</i> - <i>Quercus coccinea</i> - <i>Quercus falcata</i> / (<i>Quercus marilandica</i>) / <i>Gaylussacia frondosa</i> Woodland	NACE
CEGL006390	Coastal Plain Oak Forest	<i>Quercus falcata</i> - <i>Quercus phellos</i> / <i>Ilex opaca</i> Forest	NACE, ROCR
CEGL006406	Red Maple Seepage Swamp	<i>Acer rubrum</i> - <i>Fraxinus (pennsylvanica, americana)</i> / <i>Lindera benzoin</i> / <i>Symplocarpus foetidus</i> Forest	CHOH, GWMP, PRWI, ROCR, WOTR

Table 8 (continued). NCR vegetation map: USNVC association map classes (n=80). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	USNVC Association Map Class	USNVC Global Name	Where Mapped
CEGL006459	Terrace Hardwood Floodplain Forest	<i>Acer saccharum</i> - <i>Fraxinus americana</i> / <i>Carpinus caroliniana</i> / <i>Podophyllum peltatum</i> Forest	CHOH, GWMP, MONO
CEGL006471	Rich Boulderfield Forest	<i>Acer saccharum</i> - <i>Tilia americana</i> / <i>Staphylea trifolia</i> / <i>Dryopteris marginalis</i> - (<i>Impatiens pallida</i>) Forest	CHOH, GWMP, HAFE
CEGL006474	Eastern Hemlock - Hardwood Forest	<i>Tsuga canadensis</i> - <i>Fagus grandifolia</i> - <i>Quercus</i> (<i>prinus</i> , <i>alba</i>) Forest	HAFE, MANA, PRWI
CEGL006475	Ice-Scour Floodplain Forest	<i>Platanus occidentalis</i> - <i>Fraxinus pennsylvanica</i> - <i>Acer negundo</i> / <i>Sanicula odorata</i> - <i>Elymus virginicus</i> Forest [Provisional]	CHOH, GWMP
CEGL006479	Basic Cliff	<i>Hydrangea arborescens</i> / <i>Sedum ternatum</i> - <i>Polypodium virginianum</i> Shrubland	CHOH, HAFE
CEGL006490	River-Bluff Chestnut Oak Forest	<i>Quercus prinus</i> / <i>Deschampsia flexuosa</i> - <i>Solidago bicolor</i> Forest	NACE
CEGL006492	Tuliptree Small-Stream Floodplain Forest	<i>Liriodendron tulipifera</i> - <i>Acer</i> (<i>rubrum</i> , <i>negundo</i>) - (<i>Platanus occidentalis</i>) / <i>Carpinus caroliniana</i> / <i>Polygonum virginianum</i> Forest	CHOH, GWMP, MANA, ROCR, WOTR
CEGL006494	Potomac Gorge Willow Oak Floodplain Forest	<i>Quercus phellos</i> - <i>Liquidambar styraciflua</i> / <i>Claytonia virginica</i> Forest [Provisional]	CHOH
CEGL006495	Potomac Gorge Bedrock Floodplain Oak Forest	<i>Quercus rubra</i> - <i>Quercus shumardii</i> / <i>Cercis canadensis</i> Temporarily Flooded Forest [Provisional]	CHOH, GWMP
CEGL006497	Pin Oak Floodplain Swamp	<i>Quercus palustris</i> - <i>Quercus bicolor</i> / <i>Carex tribuloides</i> - <i>Carex radiata</i> - (<i>Carex squarrosa</i>) Forest	CHOH, MANA, PRWI
CEGL006548	Maple-Ash Swamp Forest	<i>Acer</i> (<i>rubrum</i> , <i>saccharinum</i>) - <i>Fraxinus pennsylvanica</i> - <i>Ulmus americana</i> / <i>Boehmeria cylindrica</i> Forest	CHOH, GWMP, HAFE, MANA, NACE
CEGL006565	Sweet Birch - Chestnut Oak Talus Woodland	<i>Betula lenta</i> - <i>Quercus prinus</i> / <i>Parthenocissus quinquefolia</i> Woodland	CATO, CHOH, HAFE
CEGL006603	Coastal Plain Streamside Forest	<i>Platanus occidentalis</i> - (<i>Liquidambar styraciflua</i> , <i>Liriodendron tulipifera</i>) / <i>Asimina triloba</i> Forest	NACE
CEGL006605	Oak Floodplain Swamp	<i>Quercus</i> (<i>phellos</i> , <i>palustris</i> , <i>michauxii</i>) - <i>Liquidambar styraciflua</i> / <i>Cinna arundinacea</i> Forest	GWMP, NACE, PRWI
CEGL006606	Red Maple / Lizard's-tail Swamp	<i>Acer rubrum</i> - <i>Fraxinus pennsylvanica</i> / <i>Saururus cernuus</i> Forest	NACE
CEGL006919	Oak - Beech / Heath Forest	<i>Fagus grandifolia</i> - <i>Quercus</i> (<i>alba</i> , <i>velutina</i> , <i>prinus</i>) / <i>Kalmia latifolia</i> Forest	CHOH, NACE, PRWI, ROCR

Table 8 (continued). NCR vegetation map: USNVC association map classes (n=80). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	USNVC Association Map Class	USNVC Global Name	Where Mapped
CEGL006923	Hemlock - Chestnut Oak Forest	<i>Tsuga canadensis</i> - <i>Quercus prinus</i> - <i>Betula lenta</i> Forest	CATO, CHOH, MONO
CEGL006926	Pine Barrens Lowland Forest	<i>Pinus rigida</i> - <i>Nyssa sylvatica</i> / <i>Clethra alnifolia</i> - <i>Leucothoe racemosa</i> Forest	NACE
CEGL006976	Successional Red Maple Small River Floodplain Forest	<i>Betula nigra</i> - <i>Acer rubrum</i> - (<i>Liquidambar styraciflua</i> , <i>Platanus occidentalis</i>) Successional Forest	NACE, PRWI, WOTR
CEGL007191 ¹⁰	Successional Tree-of-Heaven Forest	<i>Ailanthus altissima</i> Forest	CHOH
CEGL007216	Successional Sweetgum Upland Forest	<i>Liquidambar styraciflua</i> Forest	NACE
CEGL007220	Successional Tuliptree Forest (Rich Type)	<i>Liriodendron tulipifera</i> / (<i>Cercis canadensis</i>) / (<i>Lindera benzoin</i>) Forest	ANTI, CATO, CHOH, GWMP, HAFE, MONO, NACE, ROCR, WOTR
CEGL007221	Successional Tuliptree Forest (Typic Type)	<i>Liriodendron tulipifera</i> - <i>Quercus</i> spp. Forest	CATO, CHOH, GWMP, NACE, PRWI, ROCR, WOTR
CEGL007330	Successional Sweetgum Floodplain Forest	<i>Liquidambar styraciflua</i> - (<i>Liriodendron tulipifera</i>) Temporarily Flooded Forest	GWMP, NACE
CEGL007403	Upland Depression Willow Oak Swamp Forest	<i>Quercus phellos</i> / <i>Carex (albolutescens, intumescens, jorii)</i> / <i>Climacium americanum</i> Forest	CHOH, GWMP, PRWI
CEGL007710	Cove Forest (Typic Montane Type)	<i>Liriodendron tulipifera</i> - <i>Fraxinus americana</i> - (<i>Tilia americana</i> , <i>Aesculus flava</i>) / <i>Actaea racemosa</i> - <i>Laportea canadensis</i> Forest	CHOH, HAFE
CEGL007748	Dry Calcareous Forest	<i>Quercus muehlenbergii</i> / <i>Cercis canadensis</i> / <i>Dichanthelium boscii</i> - <i>Bromus pubescens</i> - <i>Erigeron pulchellus</i> var. <i>pulchellus</i> - <i>Aquilegia canadensis</i> Forest	NACE
CEGL007879	Successional Black Walnut Forest	<i>Juglans nigra</i> / <i>Verbesina alternifolia</i> Forest	ANTI, CHOH, HAFE, MANA, MONO

¹⁰ Stands dominated by *Ailanthus altissima* were generally subsumed under the composite map class COMP_SMDF (successional mixed deciduous forest). The exception was in an area of steep rocky slopes and rock outcrops in CHOH. In this situation, stands dominated by *Ailanthus altissima* were thought to be successional to CEGL003683, and were mapped as CEGL007191 rather than as part of the composite map class.

Table 8 (continued). NCR vegetation map: USNVC association map classes (n=80). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	USNVC Association Map Class	USNVC Global Name	Where Mapped
CEGL008412	Rich Cove / Mesic Slope Forest (Twinleaf - Blue Cohosh Type)	<i>Acer (nigrum, saccharum)</i> - <i>Tilia americana</i> / <i>Asimina triloba</i> / <i>Jeffersonia diphylla</i> - <i>Caulophyllum thalictroides</i> Forest	CHOH, GWMP, HAFE
CEGL008416	Basic Seepage Swamp	<i>Acer rubrum</i> - <i>Fraxinus americana</i> - <i>Fraxinus nigra</i> - <i>Betula alleghaniensis</i> / <i>Veratrum viride</i> - <i>Carex bromoides</i> Forest	CATO
CEGL008449	Riverside Outcrop Woodland	<i>Pinus virginiana</i> - <i>Juniperus virginiana</i> var. <i>virginiana</i> - <i>Quercus stellata</i> / <i>Amelanchier stolonifera</i> / <i>Danthonia spicata</i> / <i>Leucobryum glaucum</i> Woodland	CHOH, GWMP
CEGL008475	Dry-Mesic Acidic Oak - Hickory Forest	<i>Quercus alba</i> - <i>Quercus rubra</i> - <i>Carya alba</i> / <i>Cornus florida</i> / <i>Vaccinium stamineum</i> / <i>Desmodium nudiflorum</i> Piedmont Forest	CHOH, GWMP, MANA, MONO, PRWI
CEGL008514	Basic Oak - Hickory Forest	<i>Quercus rubra</i> - <i>Quercus prinus</i> - <i>Carya ovalis</i> / (<i>Cercis canadensis</i>) / <i>Solidago caesia</i> Forest	CATO, CHOH, HAFE, MONO
CEGL008515	Acidic Oak - Hickory Forest	<i>Quercus alba</i> - <i>Quercus prinus</i> - <i>Carya glabra</i> / <i>Cornus florida</i> / <i>Vaccinium pallidum</i> Forest	CHOH, HAFE
CEGL008517	Dry-Mesic Rich Red Oak - Sugar Maple Forest	<i>Quercus rubra</i> - <i>Acer saccharum</i> / <i>Ostrya virginiana</i> / <i>Cardamine concatenata</i> Forest	ANTI, CHOH, GWMP
CEGL008521	Low-Elevation Mixed Oak / Heath Forest	<i>Quercus alba</i> - <i>Quercus (coccinea, velutina, prinus)</i> / <i>Gaylussacia baccata</i> Forest	CHOH, GWMP, NACE, PRWI, ROCR, WOTR
CEGL008523	Dry Chestnut Oak - Northern Red Oak / Heath Forest	<i>Quercus prinus</i> - <i>Quercus rubra</i> / <i>Vaccinium pallidum</i> - (<i>Rhododendron periclymenoides</i>) Forest	CATO, CHOH, HAFE
CEGL008539	White Pine - Xeric Oak Forest	<i>Pinus strobus</i> - <i>Quercus alba</i> - <i>Quercus prinus</i> / <i>Vaccinium stamineum</i> Forest	CHOH, MANA
CEGL008540	Xeric Chestnut Oak - Virginia Pine Woodland	<i>Quercus prinus</i> - <i>Pinus virginiana</i> - (<i>Pinus pungens</i>) / <i>Schizachyrium scoparium</i> - <i>Dichanthelium depauperatum</i> Woodland	CATO, CHOH, HAFE

In the coarsest scale final maps (i.e., ITESC ecological system level), we used 28 map classes to characterize the vegetation and other land cover categories across the NCR region. The majority of these map classes were 23 ITESC ecological systems.

Keys to plant communities and map classes defined for NCR parks were developed and iteratively refined throughout the vegetation classification and mapping effort. Final versions of keys for each park are in Teague et al. (2022b).

Summaries of acreages by park for ecological systems and USNVC associations and other map classes are provided in Teague et al. (2022d).

USNVC Associations Used for Association-scale Mapping

During the classification phase of the project, 106 associations were identified for the 11 NCR parks (Tables 6–7). Three new associations (CEGL002026 - *Schoenoplectus tabernaemontani* - *Typha* spp. - (*Sparganium* spp., *Juncus* spp.) Herbaceous Vegetation, CEGL008568 - *Wisteria sinensis* Vine-Shrubland, CEGL005082 - *Alnus serrulata* Swamp Shrubland) were added to this list of associations during the mapping phase of the project, bringing the total number of associations to 109 for the 11 NCR parks. Of these 109 associations, 80 were mapped individually (Table 8, above) and the remaining were grouped into composite map classes (Table 9).

Table 9. NCR vegetation map: composite map classes (n=11). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	Composite Map Class and Definition	Where Mapped
COMP_HDEP	Herbaceous Depositional Bar. Various predominantly herbaceous (and often ephemeral) communities subject to frequent high-energy floods, occurring on scoured shorelines or on sand, gravel, and cobble bars within the channels of rivers and streams. USNVC associations documented in NCR: • CEGL004103 - <i>Carex torta</i> Herbaceous Vegetation • CEGL004286 - <i>Justicia americana</i> Herbaceous Vegetation • CEGL006477 - <i>Panicum virgatum</i> - <i>Andropogon gerardii</i> Gravel Wash Herbaceous Vegetation • CEGL006480 - <i>Verbesina alternifolia</i> - <i>Elymus riparius</i> - <i>Solidago gigantea</i> - (<i>Teucrium canadense</i>) Herbaceous Vegetation • CEGL006481 - <i>Eupatorium serotinum</i> - <i>Polygonum (lapathifolium, punctatum, pennsylvanicum)</i> Herbaceous Vegetation • CEGL006483 - <i>Eragrostis hypnoides</i> - <i>Ludwigia palustris</i> - <i>Lindernia dubia</i> - <i>Cyperus squarrosus</i> Herbaceous Vegetation • CEPS006675 - <i>Impatiens capensis</i> Herbaceous Vegetation	CATO, CHOH, GWMP, HAFE, MANA, MONO, PRWI
COMP_HEWE	Successional Herbaceous Wetland. Successional herbaceous vegetation of non-tidal stream-and riverside habitats (not depositional bars) periodically inundated by overbank flooding and/or influenced by groundwater seepage, as well as impounded wetlands disturbed or created by human or beaver activity. USNVC associations documented in NCR: • CEGL002026 - <i>Schoenoplectus tabernaemontani</i> - <i>Typha</i> spp. - (<i>Sparganium</i> spp., <i>Juncus</i> spp.) Herbaceous Vegetation • CEGL004141 - <i>Phragmites australis</i> Eastern North America Temperate Semi-natural Herbaceous Vegetation • CEGL006044 - <i>Phalaris arundinacea</i> Eastern Herbaceous Vegetation • CEGL006153 - <i>Typha (angustifolia, latifolia)</i> - (<i>Schoenoplectus</i> spp.) Eastern Herbaceous Vegetation • CEGL006349 - <i>Scirpus cyperinus</i> Seasonally Flooded Herbaceous Vegetation	ANTI, CATO, CHOH, GWMP, HAFE, MANA, NACE, PRWI, WOTR

Table 9 (continued). NCR vegetation map: composite map classes (n=11). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	Composite Map Class and Definition	Where Mapped
COMP_PLDE	Planted Deciduous Forest. Any planted deciduous forest, not including fruit orchards. Plantation may be monocultural or mixed species. Can also include decadent plantations that are no longer actively maintained. USNVC associations documented in NCR: • CEST007452 - <i>Taxodium distichum</i> Planted Forest	CHOH, MONO, NACE
COMP_PLEV	Planted Evergreen Forest. Any planted evergreen forest, typically occurring as an even-aged monoculture or nearly so. Can also include decadent plantations that are no longer actively maintained. USNVC associations documented in NCR: • CEST007167 - <i>Picea abies</i> Planted Forest • CEST007178 - <i>Pinus strobus</i> Planted Forest • CEST007179 - <i>Pinus taeda</i> Planted Forest	ANTI, CATO, CHOH, MANA, MONO, NACE, ROCR
COMP_RROP	Riverside Rock Outcrop and Prairie. Any combination of shrublands, prairies, and barrens occurring on riverside rock outcrops and eroded bedrock terraces in association with high-gradient stretches of major rivers. All communities in this map class are influenced and shaped by major flood scouring events, although flood return intervals vary widely. Communities typically occur in a mosaic of patches too small to map separately. In NCR, this map class is restricted primarily to the Potomac Gorge with a few outliers at Harpers Ferry. USNVC associations documented in NCR: • CEGL006283 - <i>Andropogon gerardii</i> - <i>Panicum virgatum</i> - <i>Baptisia australis</i> Herbaceous Vegetation • CEGL006478 - <i>Fraxinus americana</i> / <i>Andropogon gerardii</i> - <i>Sorghastrum nutans</i> - <i>Schizachyrium scoparium</i> - <i>Pycnanthemum tenuifolium</i> Herbaceous Vegetation • CEGL006484 - <i>Carpinus caroliniana</i> - <i>Ilex decidua</i> Shrubland • CEGL006491 - (<i>Hypericum prolificum</i>, <i>Leucothoe racemosa</i>) / <i>Schizachyrium scoparium</i> - <i>Solidago simplex</i> var. <i>racemosa</i> - <i>Ionactis linariifolius</i> Sparse Vegetation	CHOH, GWMP, HAFE
COMP_RSWO	River-scour Woodland. Various wooded communities (where shrubs and/or stunted trees comprise at least 25% of cover) subject to frequent high-energy floods, occurring on scoured shorelines or on sand, gravel, and cobble bars within the channels of rivers and streams. USNVC associations documented in NCR: • CEGL003896 - <i>Platanus occidentalis</i> - <i>Betula nigra</i> - <i>Salix (caroliniana, nigra)</i> Woodland • CEGL006218 - <i>Quercus bicolor</i> - <i>Fraxinus pennsylvanica</i> - (<i>Platanus occidentalis</i>) / <i>Chasmanthium latifolium</i> - <i>Dichanthelium clandestinum</i> - <i>Zizia aurea</i> Woodland • CEGL006476 - <i>Platanus occidentalis</i> - <i>Acer saccharinum</i> - <i>Betula nigra</i> - <i>Fraxinus pennsylvanica</i> / <i>Boehmeria cylindrica</i> - <i>Carex emoryi</i> Woodland	CHOH, GWMP, HAFE, MANA, MONO, PRWI

Table 9 (continued). NCR vegetation map: composite map classes (n=11). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	Composite Map Class and Definition	Where Mapped
COMP_SBWO	Shale Barren Woodland. Stunted, very open woodlands occurring on steep, unstable, exposed slopes with conspicuously abundant shale channery as the primary substrate. In NCR, limited to areas of western CHOH. USNVC associations documented in NCR: • C EGL006037 - <i>Juniperus virginiana</i> - <i>Fraxinus americana</i> / <i>Carex pensylvanica</i> - <i>Cheilanthes lanosa</i> Wooded Herbaceous Vegetation • C EGL006288 - <i>Pinus virginiana</i> - <i>Juniperus virginiana</i> - <i>Quercus rubra</i> / <i>Solidago arguta</i> var. <i>harrisii</i> - <i>Opuntia humifusa</i> Woodland • C EGL008525 - <i>Pinus virginiana</i> - <i>Quercus prinus</i> / <i>Quercus ilicifolia</i> / (<i>Hieracium greenii</i>, <i>Viola pedata</i>) Woodland • C EGL008526 - <i>Quercus prinus</i> / <i>Quercus ilicifolia</i> / <i>Danthonia spicata</i> Woodland	CHOH
COMP_SMDF	Successional Mixed Deciduous Forest. A diverse map class representing upland successional deciduous forests of highly variable composition. The following is a list of USNVC associations classified as successional or ruderal forests that documented in NCR parks mapped as part of this map class. However, since the NCR vegetation classification process did not attempt to address all successional forests and woodlands present in the parks, this map class may include additional successional or ruderal forest and woodland vegetation not listed here. USNVC associations documented in NCR: • C EGL006599 - <i>Prunus serotina</i> - <i>Liriodendron tulipifera</i> - <i>Acer rubrum</i> - <i>Fraxinus americana</i> - (<i>Robinia pseudoacacia</i>) Forest • C EGL007191 - <i>Ailanthus altissima</i> Forest¹¹ • C EGL007279 - <i>Robinia pseudoacacia</i> Forest • C EGL007281 - <i>Robinia pseudoacacia</i> - <i>Celtis occidentalis</i> - (<i>Fraxinus americana</i>, <i>Liriodendron tulipifera</i>) Forest	ANTI, CATO, CHOH, GWMP, HAFE, MANA, MONO, NACE, ROCR, WOTR
COMP_SUME	Successional Meadow / Grassland. Successional upland herbaceous communities typically occurring on abandoned agricultural fields or in powerline rights-of-way where the invasion of woody species is curtailed by occasional mowing or other management practices. Successional meadows often include some invasion by woody shrubs and vines, but these comprise < 20% of total cover. This map class does not include grasslands actively maintained for agricultural or scenic/cultural purposes, nor does it include herbaceous or wooded herbaceous communities naturally occurring on rock outcrops. No specific USNVC associations were identified for this map class.	ANTI, CATO, CHOH, GWMP, HAFE, MANA, MONO, NACE, PRWI

¹¹ Stands dominated by *Ailanthus altissima* were generally subsumed under the composite map class COMP_SMDF (successional mixed deciduous forest). The exception was in an area of steep rocky slopes and rock outcrops in CHOH. In this situation, stands dominated by *Ailanthus altissima* were thought to be successional to C EGL003683, and were mapped as C EGL007191 rather than as part of the composite map class.

Table 9 (continued). NCR vegetation map: composite map classes (n=11). Updates to the nomenclature in USNVC since mapping are included in Teague et al. (2022a).

Map Code	Composite Map Class and Definition	Where Mapped
COMP_VISH	Successional Vine-Shrubland. Successional upland communities dominated by shrubs and/or vines, typically occurring on abandoned agricultural fields, powerline rights-of-way, or canopy gaps resulting from windthrow and other disturbance. USNVC associations documented in NCR: • CEGL003882 - <i>Pueraria montana</i> var. <i>lobata</i> Vine-Shrubland • CEGL008568 - <i>Wisteria sinensis</i> Vine-Shrubland	ANTI, CATO, CHOH, GWMP, HAFE, MANA, MONO, NACE, PRWI, ROCR
COMP_WOWE	Successional Woody Wetland. Successional shrublands, woodlands, and forests of disturbed floodplains, seepage wetlands, and artificial impoundments (including impoundments due to beaver activity). Typically dominated by <i>Salix nigra</i>, <i>Populus deltoides</i>, <i>Alnus serrulata</i>, and/or <i>Cephalanthus occidentalis</i>. Standing snags of dead or dying trees are often present. USNVC associations documented in NCR: • CEGL005082 - <i>Alnus serrulata</i> Swamp Shrubland • CEGL006069 - <i>Cephalanthus occidentalis</i> - <i>Decodon verticillatus</i> Shrubland	CATO, CHOH, GWMP, HAFE, MANA, NACE, PRWI

Composite Map Classes

We also used composite map classes (code prefix = “COMP_”; Table 9). These usually included several possible USNVC associations that either could not be reliably mapped separately, or that were mapped as a group for convenience and consistency across the region. Composite Map Classes at NCR are known to include 29 UNSVC associations (code begins with CEGL), 4 USNVC cultural subtypes (code begins with CEST), and one park special plant community (code begins with CEPS).

Ecological Systems used for Ecological System-Scale Mapping

Map classes of the fine scale association-level map were cross-walked to 28 map classes for the coarse scale ecological system-level map (Table 10). The coarser ecological systems scale map included 23 ITESC ecological systems and 5 broad classes representing successional upland vegetation, successional wetland vegetation, cultivated vegetation, developed areas, and open water.

Table 10. NCR Ecological System map classes (n=23) and landcover/early successional vegetation map classes (n=5).

Map Code	Ecological System Map Class Name	Where Mapped
CES202.268	Piedmont Hardpan Woodland and Forest	CHOH, GWMP, MANA
CES202.336	Piedmont Upland Depression Swamp	CHOH, GWMP, MANA, PRWI
CES202.348	Southern and Central Appalachian Mafic Glade and Barrens	CATO, CHOH, HAFE
CES202.373	Southern and Central Appalachian Cove Forest	CHOH, GWMP, HAFE
CES202.591	Central Appalachian Dry Oak-Pine Forest	CATO, CHOH, GWMP, HAFE, MANA, MONO, NACE, PRWI, ROCR, WOTR
CES202.592	Northeastern Interior Dry-Mesic Oak Forest	ANTI, CATO, CHOH, GWMP, HAFE, MANA, MONO, PRWI
CES202.593	Appalachian (Hemlock)-Northern Hardwood Forest	CATO, HAFE, MANA, PRWI
CES202.598	Appalachian Shale Barrens	CHOH
CES202.600	Central Appalachian Pine-Oak Rocky Woodland	CATO, CHOH, GWMP, HAFE
CES202.601	North-Central Appalachian Acidic Cliff and Talus	CATO, CHOH, HAFE, MONO
CES202.602	Central Appalachian Alkaline Glade and Woodland	CHOH, HAFE
CES202.603	North-Central Appalachian Circumneutral Cliff and Talus	CHOH, GWMP, HAFE
CES202.608	Central Appalachian River Floodplain	ANTI, CHOH, GWMP, HAFE, MANA, MONO, NACE
CES202.609	Central Appalachian Stream and Riparian	CATO, CHOH, GWMP, MANA, ROCR, WOTR
CES203.069	Northern Atlantic Coastal Plain Calcareous Ravine	NACE
CES203.070	Northern Atlantic Coastal Plain Stream and River	GWMP, NACE, PRWI
CES203.242	Southern Atlantic Coastal Plain Mesic Hardwood Forest	CHOH, GWMP, MONO, NACE, PRWI, ROCR, WOTR
CES203.269	Northern Atlantic Coastal Plain Pitch Pine Barrens	NACE
CES203.282	Northern Atlantic Coastal Plain Tidal Swamp	GWMP, NACE

Table 10 (continued). NCR Ecological System map classes (n=23) and landcover/early successional vegetation map classes (n=5).

Map Code	Ecological System Map Class Name	Where Mapped
CES203.374	Northern Atlantic Coastal Plain Pitch Pine Lowland	NACE
CES203.475	Northern Atlantic Coastal Plain Hardwood Forest	CHOH, NACE, PRWI, ROCR
CES203.516	Northern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh	GWMP, NACE
CES203.520	Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest	CHOH, GWMP, NACE, PRWI
NS_CDEV	No system assigned; developed areas	all parks
NS_CVEG	No system assigned; cultivated vegetation	all parks
NS_SUPL	No system assigned; successional upland	all parks
NS_SWET	No system assigned; successional wetland or floodplain	all parks except ROCR
NS_WATER	No system assigned; open water	all parks

A 24th ecological system, CES202.339 was added to the NCR Ecological Systems Classification after the vegetation maps were completed. It would be mapped everywhere the Dry-Mesic Acidic Oak - Hickory Forest Association (CEGL008475) is mapped in five parks: CHOH, GWMP, MANA, MONO, and PRWI. This association was previously considered part of the Northeastern Interior Dry-Mesic Oak Forest (CES202.592).

Special Feature and National Land Cover Database Map Classes

A third map class category includes special feature map classes (prefix = “SF_”; Table 11, below) for natural, successional, or planted vegetation or other features that were not readily mappable to the association level but for which National Landcover Database (NLCD) categories were deemed insufficiently informative. NLCD, forming the fourth and final map class category (code prefix – “NLCD”), included developed and barren areas, orchards and agricultural fields, lawns, and open water (Table 12).

Table 11. NCR vegetation map: special feature map classes (n=9).

Map Code	Special Feature Map Class and Definition	Where Mapped
SF_AQUA	Aquatic Garden. Kenilworth Park and Aquatic Garden, a unique feature occurring only as a single polygon.	NACE
SF_FORS	Forested Open Space. Residential or recreational open space with substantial tree canopy; similar to NLCD21 (developed, open space; see Table 12), but trees rather than planted nonnative lawns are considered the dominant vegetation. Lawn grasses may or may not be dominant below the canopy. This map class represents forested or heavily wooded recreational areas such as campgrounds and picnic sites and large-lot residential areas. In these areas, classification as successional or natural forest is inappropriate, but the definition for NLCD21 does not fit either due to the heavy tree cover.	CATO, CHOH, GWMP, HAFE, MANA, NACE, PRWI, WOTR
SF_QUAR	Historic Quarry. Areas mined but with forest cover now.	ROCR
SF_MANMEAD	Managed Meadow. Open meadows managed for wildlife habitat.	ROCR
SF_NWSG	Native Warm-season Grassland. Open fields similar to NLCD81 (pasture/hay; see Table 12), but with native warm-season grasses rather than nonnative, cool-season grasses as the dominant vegetation. These were mapped separately from NLCD81 at MANA at the request of park staff, using the park's own data layers. SF_NWSG	MANA
SF_REFO	Managed Reforestation Area. Former agricultural fields actively being reforested or designated for reforestation in the future. Differs from COMP_PLDE (planted deciduous forest) in that the intent is to restore a "natural" forest rather than to produce timber for harvest. Only a few reforestation sites were mapped at ANTI at the request of park staff and using the park's own data layers.	ANTI
SF_SHOAL	Rocky Shoals. Rocky shoals on the Potomac River that are often submersed.	ROCR
SF_TOWP	C & O Canal Towpath. Right-of-way associated with the Chesapeake & Ohio Canal National Historical Park towpath, including the towpath itself (whether gravel, dirt, or paved) and narrow embankments or strips of vegetation (whether herbaceous or wooded) on either side that cannot reasonably be pulled out as separate map classes.	CHOH, GWMP, HAFE
SF_TWRE	Tidal Wetland Restoration and Experimental Area. Areas of freshwater tidal mudflats where marshes are being or have been actively restored, and/or where experimental plots have been established to monitor restoration success under different conditions. This special feature is limited to a few polygons in NACE.	NACE

Table 12. NCR vegetation map: National Landcover Database (NLCD) map classes (n=10). Definitions correspond to the NLCD 2001 Level II scheme unless otherwise indicated. Each NLCD map class could theoretically be present in any park.

Map Code	NLCD Map Class and Definition	Where Mapped
NLCD11	Open Water. All areas of open water (e.g., rivers, ponds, and lakes), generally with less than 25% cover of vegetation or soil. Note: Within this map class there are often small inclusions (< minimum mapping unit) of depositional bars (COMP_HDEP, COMP_RSWO), unconsolidated shores (NLCD32), or successional wetlands (COMP_HEWE, COMP_WOWE).	ANTI, CATO, CHOH, GWMP, HAFE, MANA, MONO, NACE, PRWI, ROCR, WOTR
NLCD21	Developed, Open Space. Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of planted nonnative lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	ANTI, CATO, CHOH, GWMP, HAFE, MANA, MONO, NACE, PRWI, ROCR, WOTR
NLCD22	Developed, Low Intensity. Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20–49 percent of total cover. These areas most commonly include single-family housing units.	ANTI, CATO, CHOH, GWMP, HAFE, MANA, MONO, NACE, PRWI, ROCR, WOTR
NLCD23	Developed, Medium Intensity. Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50–79 percent of the total cover. These areas most commonly include single-family housing units.	CATO, CHOH, GWMP, MANA, NACE, PRWI, ROCR, WOTR
NLCD24	Developed, High Intensity. Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover. Note: This map class was also used to represent transportation corridors and parking lots in less developed areas.	ANTI, CATO, CHOH, GWMP, HAFE, MANA, MONO, NACE, PRWI, ROCR, WOTR
NLCD31	Barren Land. Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.	CHOH, GWMP, HAFE, NACE, PRWI
NLCD32	Unconsolidated Shore. Unconsolidated material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms representing this class.	NACE

Table 12 (continued). NCR vegetation map: National Landcover Database (NLCD) map classes (n=10). Definitions correspond to the NLCD 2001 Level II scheme unless otherwise indicated. Each NLCD map class could theoretically be present in any park.

Map Code	NLCD Map Class and Definition	Where Mapped
NLCD61	Orchards and Vineyards. Orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals. Note: This code/map class was standard in the NLCD 1992 scheme but was absorbed into code NLCD82 (cultivated crops) in the 2001 scheme. For NCR, we continued to use this as a separate map class to separate orchards from herbaceous row crops.	CHOH, NACE
NLCD81	Pasture/Hay. Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.	ANTI, CATO, CHOH, HAFE, MANA, MONO, NACE, PRWI
NLCD82	Cultivated Crops. Areas used for the production of annual crops such as corn, soybeans, vegetables, and cotton. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled. Note: "Perennial woody crops such as orchards and vineyards" are included in this map class under the NLCD 2001 scheme; however, we did not include woody vegetation in this map class for NCR (see NLCD61, above).	ANIT, CATO, CHOH, MONO, NACE

Accuracy Assessment

Introduction

A map Accuracy Assessment (AA) provides the probability that a given place on the ground or on the map is mapped correctly. Two general types of map accuracy can be assessed: thematic accuracy and positional accuracy. Positional accuracy was based on the base map data used for the vegetation mapping and not directly assessed. We assessed thematic accuracy, or accuracy of map classes used to label the map polygons. Thematic mapping errors are evaluated by comparing map data to data collected in the field during the accuracy assessment. Two types of mapping error can be evaluated: producer's accuracy and user's accuracy. Producer's accuracy is the probability that a given place on the ground is mapped correctly. In other words, producer's accuracy is a measure of the reliability of the aerial photo interpretation to distinguish different plant communities (i.e., how well the map maker was able to represent the ground features). Errors in Producer's Accuracy are sometimes referred to as errors of omission (meaning that the mapper failed to capture all of a map class and under-represented it). User's accuracy is the probability that a given place on the map is mapped correctly. In other words, user's accuracy is a measure of the reliability of the map to predict what is found on the ground (i.e., how likely the map user is to encounter correct information while using the map). Errors in User's Accuracy are sometimes referred to as errors of commission (meaning that the mapper misrepresented the ground features). We calculated both user's and producer's accuracies for the overall map and for each map class individually.

Vegetation Map Classes

Vegetation maps were produced for NCR at two scales: the association level of the USNVC, and the ecological system scale as classified in the International Terrestrial Ecological Systems Classification (ITESC) (Jennings et al. 2009, Comer et al. 2003, <http://usnvc.org>). At the finest scale, the final NCR vegetation map included a total of 110 map classes used to characterize 109 USNVC associations and other land cover across the 11 parks (Tables 8, 9, 11, and 12). These 110 map classes can be separated into four categories: individual USNVC associations (n=80), composite map classes primarily comprised of another 29 USNVC associations (n=11), "special feature" map classes (n=9), and NLCD map classes (n=10). At the finest level, there were a total of 91 natural and semi-natural map classes and 19 non-natural or non-vegetated map classes.

The coarser ecological systems scale map included 28 map classes including 23 ITESC ecological systems (Table 10) and 5 broad classes representing successional upland vegetation, successional wetland vegetation, cultivated vegetation, developed areas, and open water.

All map classes were considered for including in the accuracy assessment, but due to factors explained below, the accuracy assessment included 86 out of the 110 fine-scale map classes (association level maps) and 27 out of the 28 coarse-scale map classes (ecological system level maps).

Methods

Sampling Design

Natural and semi-natural map classes represented by the USNVC were targets for the map accuracy assessment. These included all map classes in Table 8 and all in Table 9 except Successional Meadow/Grassland, which did not include any USNVC associations. We used a stratified random sampling design on a region-wide scale with target map classes as the strata. Our goals were to:

1. Follow a point-based approach using a formula proposed by Lea and Curtis (2010) of approximately 1 point per 1.67 hectares (ha) with a minimum of 5 and maximum of 30 points per map class. This resulted in a goal of 2,133 points, where points serve as the anchor for the observation area. Multiple observation areas were allowed within an individual polygon as long as they did not overlap.
2. Use a 0.5 ha observation area around each point to match the minimum mapping unit (MMU) for the vegetation maps. The default shape for an observation area was circular with a radius of 40 meters; however, for linear or oddly shaped polygons, alternative shapes were allowed provided the sample size was equivalent to 0.5 hectare (Lea and Curtis 2010).
3. Buffer each observation area from the polygon boundary to reduce the probability of an observation area including more than one map class. Buffer distance = $\sqrt{R^2 + F^2 + M^2}$ where R is the radius distance of the observation area, F is the expected field positioning (GPS) error distance, and M is the expected positional error distance in the map. Using R = 40 m, F = 19 m, and M = 5 m, we obtained a target buffer distance of 45 m.
4. Use a minimum distance of 82 m between observation areas to minimize overlap in the observation areas to reduce observer bias. Using a formula similar to that used for calculating polygon buffers, this distance takes into account the size and shape of the default observation area and an estimate of GPS error. We restricted overlap of observation areas to no more than 10 percent, following Lea and Curtis (2010).

Adhering to these goals, we used Geospatial Modeling Environment (www.SpatialEcology.com) to randomly select AA points from within map class polygons. However, we found that the combined effects of the small polygon sizes, enforcement of polygon buffers, and use of a minimum distance between observation areas, greatly reduced the available inference area and the number of possible observations. Discussions with NPS resulted in a modified process.

Observation Area Size and Shape

Although the NCR park maps had a default minimum mapping unit (MMU) of 0.5 ha, distinct vegetation areas were mapped at sizes below this. In addition, many map classes had a large number of polygons that were below 1 ha in size (Figure 2). Polygons less than 1 hectare in area were less likely to be able to support an observation area after polygon buffering. The high number of small polygons reduced the number of accuracy assessment observation areas that could fit within some map classes.

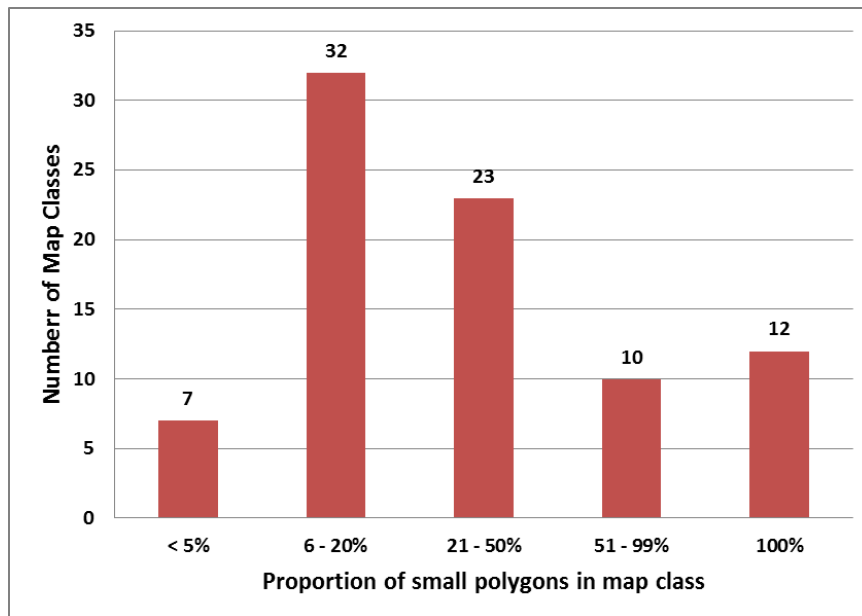


Figure 2. Abundance and proportion of small polygons (<1 ha in size).

Polygon Buffers (Accuracy Assessment Point Placement)

Applying an internal buffer to polygons considers the size of the observation area, acceptable map error based on map scale, and GPS error to ensure that observation areas fall completely within polygon boundaries. However, buffering polygons by this distance (45 m) eliminated smaller polygons from the inference area, completely removing some map classes from the sampling, and reducing the available inference area in other map classes. For some parks, almost half of the area available for placement of observation areas had been buffered away even with a 45 m internal polygon buffer (e.g., Figure 3). Adhering to a 45 m internal buffer for each polygon would have eliminated a total of 27 map classes across the region. In other cases, when there were areas remaining within map classes, they were so small that they were unable to accommodate the recommended number of AA points. The figure below illustrates the number of map classes in categories reflecting the proportional prevalence of small polygons.

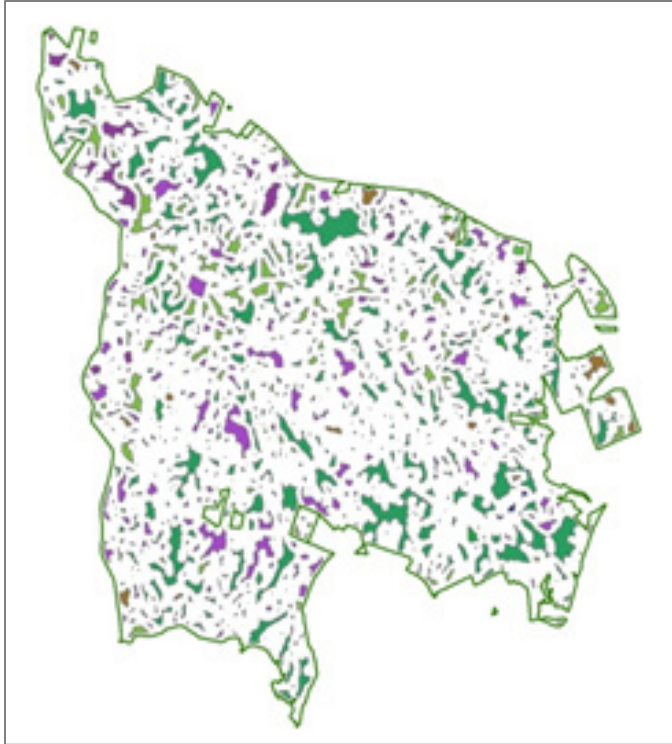


Figure 3. Illustration of sample area loss caused by a 45 m polygon buffer. As an example, a 45 m buffer (represented as white space) eliminated half of the sample area (colored portions) at Prince William Forest Park. Colors represent map class areas remaining after the application of a 45 m buffer on the inside of each polygon.

Minimum Distance between Observation Areas:

Using a formula similar to that used for calculating polygon buffers, the minimum distance between observation areas takes into account the size and shape of the default circular observation area and an estimate of GPS error. The goal was to restrict overlap of observation areas to no more than 10 percent (Lea and Curtis 2010). However, enforcing the minimum distance between AA points (82m) further reduced the number of potential points.

Amendments to NCR AA Methodology

Facing the fact that the sample design goals listed above would greatly reduce the inference area and number of AA observations, we consulted with NPS and other team members about the best way to modify our goals. After many iterations that considered the impacts of reducing the internal polygon buffer and the separation distance between AA points, we made the following changes to the original sampling goals.

The internal polygon buffer was reduced from 45 m (Figure 3) to 12 m (Figure 4). This still incorporated a distance for GPS error but did not incorporate observation area distance nor map error distance. Through this modification, we greatly increased the available inference area (e.g., see PRWI example in Figure 4, below), and maintained the 0.5 ha observation area and 82 m AA point separation.



Figure 4. Illustration of sample area loss caused by a 12 m polygon buffer. Applying 12 m internal buffer to map class polygons at Prince William Forest Park resulted in remaining sample areas in most map classes. Compare with Figure 3. Colors represent map class areas remaining after the application of a 12 m buffer.

Using Geospatial Modeling Environment we generated a list of 1,638 randomly selected target AA points and grouped them geographically for assignment to field teams.

Even though we reduced the internal polygon buffer to 12 m, 24 map classes were not able to accommodate the desired minimum number of AA points. Of these, 16 map classes with an average polygon size of 0.9 ha, had fewer than five (5) AA points, and 8 map classes with an average polygon size of 0.2 ha had zero AA points. Map classes with no points totaled 17.58 ha (less than 1% of the mapped area).

In addition to the original target AA points, additional AA points were generated, called oversamples. If target AA points were inaccessible, field crews could easily be assigned one of the oversample points as a replacement. At the initiation of the project, there were approximately 172 oversample points available with, at most, 5 oversamples in each map class that could accommodate the points (the largest classes). Therefore, a random number generator was used to randomly assign the oversamples within each map class across different parks.

Field Data Collection

A standard protocol for field methods to collect the accuracy assessment data was jointly developed by NatureServe and NPS scientists (Appendix B). A training session was hosted by NatureServe in early spring of 2011 and nine participants in the data collection process were carefully walked through field procedures to ensure uniform methodology. Draft field forms were reviewed, and

questions and feedback were used to finalize the field methods and form. Field work was conducted throughout the 2011 and 2012 growing seasons.

To promote expert field assessment and assignment of vegetation map classes, AA observations were performed by teams of two ecologists from a group of 9 trained ecologists. The basic process involved using handheld GPS units (primarily the Garmin GPS map 76C series) and hardcopy maps to navigate to the randomly selected AA points generated by the sampling design. A new GPS point was recorded in the field, and the AA observation area was established around it. The AA teams were unaware of the identity of the mapped plant community. Once a sample point was located, the first step of the process involved determining whether the vegetation around the point was homogenous, i.e., represented one map class. If the vegetation was homogenous, normal sampling would proceed with the establishment of a 0.5 ha observation area or plot. If the vegetation was heterogeneous, the GIS sample point could be shifted a minimum of 40 m to establish a 0.5 ha observation area in homogenous vegetation. Information regarding the decision to move the observation area was recorded. The default observation area was a 0.5 ha circle (radius of 40 m), but alternative 0.5 ha shapes were allowed in plant communities where a 0.5 ha circle would not fit. The shape and dimensions of the observation area were recorded on the field form. Once the field team determined that they had an area of homogenous vegetation that could accommodate a 0.5-ha observation area, a new GPS waypoint was collected to document the location of the observation area. To improve accuracy of the GPS waypoint, the GPS unit was allowed to average a minimum of 100 readings of the position before recording latitude and longitude (in decimal degree format, NAD 83 datum) of the waypoint.

Once the observation area or plot was established, environmental and floristic data were recorded. A map of the plot was drawn showing the shape of the sample and any notable field features such as rock outcrops, old forest roads, streams, and trails. At least one plot photo and the location of the photograph were recorded on the field form (Appendix B, Figure 11). Standard ecological environment data was collected for each observation area including slope, aspect, moisture regime (flooding interval for alluvial forests), amount of exposed rock, and notes regarding evidence of human or natural disturbance. The structure of the vegetation was also evaluated with an estimate of canopy cover, size of tree stems, canopy height for various layers, the leaf phenology, and physiognomic class (forest, woodland, shrubland, herbaceous, nonvascular, and sparsely vegetated).

Floristic data recorded included the documentation of all dominant and diagnostic species present within the plot, assigning a total cover class (classes 1–9) for each species, and noting the major stratum of dominant and diagnostic species. Once all the floristic data were recorded, keys specifically developed for each of the NCR parks were used to determine the most appropriate map class for the observation area or plot. This step was conducted by both ecologists in the team, and if the vegetation was ambiguous and there was no agreement of the plant community or map class, the floristic and environmental information was reviewed and discussed on site to see if an agreement on the best call could be made. If, after this step, no agreement could be determined, the two differing field calls were recorded along with an explanation of decisions that led to differing interpretations of the plant community. A final call for these situations was made by a third ecologist after the field

season was completed and a thorough review of field data was available. The field form used in the NCR vegetation map accuracy assessment is presented in Appendix B, Figure 11.

Updates to Field Keys

Keys to vegetation and map classes present at NCR parks were refined throughout the vegetation classification and mapping effort. Final edits to clarify confusions encountered during the AA and to incorporate lessons learned were completed during the office review of AA field assignments and AA plot review. Final versions of keys are included in Teague et al. (2022b).

Data Preparation and Analysis

Out of the 1,637 target AA points, 10 were abandoned in the field because a homogenous 0.5 ha observation area was not present, or the observation area around the point was inaccessible either because of environmental conditions (e.g., steep slope), or because it fell outside of NPS property.

Minus the abandoned observations, field data for 1,627 AA observation areas were collected. Final assignment of a map class to the AA observation area was made during a review of the field and GPS data. An ArcGIS feature class was developed from the AA GPS data collected in the field. Then, ArcGIS was used to join the AA field point location to the map class attribute of the vegetation polygons in which the points were located.

AA field data was reviewed to determine a final map class for observation areas where the two ecologists disagreed on the map class assignment, for observation areas where the map class assigned in the field did not match that of the mapped polygon, and for a subset of AA field points where the map class assigned in the field did match that of the mapped polygon. In addition, office review of mismatches also included reviewing the observation locations in the AA field form notes and diagrams against the GPS locations using ArcGIS.

We determined that some mismatches were due to errors that could not be reconciled, e.g., GPS error due to poor satellite coverage, observation areas smaller than the 0.5 ha MMU, and shifting of AA field points causing the observation area to include more than one map polygon and heterogeneous vegetation that was not identified in the field. A total of 66 observation areas were dropped from the analysis because of these unreconcilable errors. Unfortunately, the reduction in the distance of the internal polygon buffer described above contributed to these issues. While it allowed us to include more AA target points in our sample, the resulting location of many AA field points near polygon boundaries caused problems in data interpretation, preparation, and analysis.

Data for a total of 1,561 AA field points were recorded in a new ArcGIS feature class and were entered into the NPS PLOTS 2.0 database; this software was developed and published by NatureServe (2005). We prepared for and conducted the AA analysis in a Microsoft Excel workbook (Teague et al. 2022e). AA data were summarized in a series of contingency tables to analyze the map classes observed in the field against those on the map. For each field point a series of attributes or labels were cross-walked to the mapped map class and the field map class. These attributes included the upper levels of the USNVC hierarchy (alliance, group, and macrogroup), the ITESC ecological system, and a series of analysis classes developed during the analysis (see Results section). User's

and producer's accuracy for each map and analysis class and overall accuracy of the map including the kappa statistic were calculated. The Kappa statistic is a measure of an accuracy that would be expected by chance.

An example of a contingency matrix is presented below (Table 13). Sample data (i.e., mapped values) are listed in rows and reference data (i.e., field value) in columns. Cell values represent the number of AA field points belonging to that map class. The numbers along the diagonal represent correctly mapped AA field points, and all other cells represent incorrectly mapped field points (or misclassifications). Row totals in the contingency table are the number of AA field points collected for each map class as mapped (on the map). Column totals are the number of AA field points belonging to each map class on the ground. In this example, four of the five AA field points mapped as belonging to Class B were mapped correctly, while the fifth point was found to belong to Class D in the field. In addition, the field crew identified two field points that were mapped as Class C but were shown to belong in Class B in the field. They also identified three evaluation points that were mapped in class D but were shown to belong in class C in the field. Examining the contingency table in this manner allows the users to discern patterns in mapping error between classes.

Table 13. Sample contingency matrix table.

Mapped Value	Field Value				Row Totals
	A	B	C	D	
A	5	0	0	0	5
B	0	4	0	1	5
C	0	2	8	0	10
D	0	0	3	2	5
Column Totals	5	6	11	3	25

Results and Discussion

NCR AA contingency matrix results are presented as a separate Microsoft Excel workbook product (Teague et al. 2022e). Worksheets in this workbook are referenced in the following discussion. The analysis included 1,561 AA field points representing 86 map classes as mapped, 84 of which were encountered in the field. All but one of the map classes encountered in the field represented natural and semi-natural vegetation targets. The one map class encountered in the field that was not a target map class was open water.

Analysis goals were to assess the accuracy of the two scales of vegetation maps produced for NPS NCR: the USNVC association scale map and the ITESC ecological system scale map.

Overall Map Accuracy

USNVC Association

An initial contingency matrix created for the finest resolution map data, the USNVC association (see CEGP_Pivot_Copy and CEGP_Kappa worksheets), had eighty-six (86) map classes, and an overall accuracy of seventy-two percent (72%) (Teague et al. 2022e). This matrix was reviewed to determine

patterns of confusion between map classes. Decisions were made on whether to group map classes that were most often confused with each other into “analysis classes” to increase accuracy. To maintain an analysis that corresponded most closely with the association-level map classes, we proceeded with an iterative approach to developing analysis groups for new matrices.

In the first analysis group matrix, two new analysis classes were created. One combined all 7 fresh water tidal vegetation and open water map classes (CEGL004187, CEGL004472, CEGL004706, CEGL006287, CEGL006325, NLCD11) into one analysis class (FWTV_NLCD11), and the other expanded the COMP_WOWE map class to include other semi-natural forested wetlands (CEGL005033, CEGL006976, and CEGL007330). A new contingency matrix was built with these new analysis classes, FWTV_NLCD and the redefined COMP_WOWE. Overall accuracy of this second matrix with a total of seventy-nine (79) map classes (see AnalysisGroup1_Pivot_Copy and AnalysisGroup1_Kappa worksheets) was 74% (Teague et al. 2022e).

After review of the first analysis group contingency matrix, another analysis class (DOP_DMO) was created to combine all 11 dry oak-pine and dry mesic oak forest associations (CEGL004793, CEGL006057, CEGL006299, CEGL006923, CEGL008475, CEGL008514, CEGL008515, CEGL008517, CEGL008521, CEGL008523, and CEGL008539). The overall accuracy for this second analysis class matrix with a total of sixty-nine (69) map classes (see AnalysisGroup2_Pivot_Copy and AnalysisGroup2_Kappa worksheets) was 78% (Teague et al. 2022e).

To achieve 80% overall map accuracy, another analysis class (LRFPF) was created to combine 4 natural and semi-natural large river floodplain forest map classes (CEGL004073, CEGL006217, CEGL006459, and COMP_WOWE) exclusive of those restricted to the Potomac Gorge (CEGL006494, CEGL006495, and CEGL006475). Overall accuracy for this matrix with sixty-six (66) map classes (see AnalysisGroup3_Pivot_Copy and AnalysisGroup3_Kappa worksheets) was 81% (Teague et al. 2022e).

Ecological Systems and other classifications

The contingency matrix created for the ecological system map (see System_Pivot_Copy and System_Kappa worksheets) had 27 map classes and an overall accuracy of 82% (Teague et al. 2022e). Other contingency matrices were created for other levels of the USNVC hierarchy - alliance, group and macrogroup (see Alliance_Pivot_Copy, Alliance_Kappa, Group_Pivot_Copy, Group_Kappa, Macrogroup_Pivot_Copy, Macrogroup_Kappa worksheets) (Teague et al. 2022e).

The overall accuracy including the Kappa statistic of each contingency matrix developed during the AA analysis are provided in Table 14.

Table 14. Overall accuracy and Kappa statistic with 90% confidence intervals for all NPS NCR accuracy assessment contingency matrices (Teague et al. 2022e).

Matrix	# Classes	Overall Accuracy	Kappa	90%CI -	90%CI +
Preliminary USNVC Association Matrix (CEGL_Kappa worksheet)	86	0.7194	0.7147	0.6956	0.7339
Preliminary USNVC Association Analysis Class Matrix 1 (AnalysisGroup1_Kappa worksheet)	79	0.7380	0.7324	0.7137	0.7512
Preliminary USNVC Association Analysis Class Matrix 2 (AnalysisGroup2_Kappa worksheet)	69	0.7803	0.7675	0.7496	0.7854
Final USNVC Association Analysis Class Matrix 3 (AnalysisGroup3_Kappa worksheet)	66	0.8059	0.7923	0.7750	0.8095
Ecological System Matrix (System_Kappa worksheet)	27	0.8219	0.8051	0.7883	0.8220
USNVC Alliance Matrix (Alliance_Kappa worksheet)	60	0.7431	0.7345	0.7158	0.7532
USNVC Group Matrix (Group_Kappa worksheet)	37	0.7687	0.7526	0.7343	0.7708
USNVC Macrogroup Matrix (Macrogroup_Kappa worksheet)	26	0.8065	0.7741	0.7564	0.7918

Individual Map Class Accuracy

Calculations for user's and producer's accuracy (and 90% confidence intervals) for individual map classes are provided in the contingency matrix worksheets (Teague et al. 2022e). Large confidence intervals (CI) can indicate insufficient data for assessing map class accuracy, i.e., insufficient sample size.

USNVC Association Analysis

For the finest resolution map data, 22 out of the 86 original map classes had fewer than 5 plots for either user's or producer's accuracies (see CEGL_Pivot_Copy worksheet): therefore, the accuracy for these 22 map classes could not be reliably assessed. After some map classes were combined into analysis groups for the USNVC Association Analysis Class Matrix 3 analysis, 19 out of 66 map classes had fewer than 5 plots for either user's or producer's accuracies (see Table 15 and AnalysisGroup3_Pivot_Copy worksheet) (Teague et al. 2022e). Map classes with fewer than 5 plots were often unable to support more samples because they are uncommon plant communities in NCR and of limited extent. Of the 47 map classes/analysis groups that had 5 or more plots for both producer's and user's accuracy, 38 had an accuracy of 80% or above in the 90% CI for both producers and user's accuracy, and 5 had between 70% and 80 % in the 90% confidence interval (see Tables 16 and 17, and AnalysisGroup3_Pivot_Copy worksheet) (Teague et al. 2022e).

Table 15. Map classes with fewer than five observations. These map classes represent uncommon plant communities in NCR that are of limited extent (PO – Producer’s Observations, UO – User’s Observations, PA – Producer’s Accuracy, UA – User’s Accuracy).

Map Class / Analysis Group Code	Map Class / Analysis Group Name	PO	UO	PA	UA
CEGL004391	<i>Asplenium montanum</i> Central Appalachian Sandstone Cliff Sparse Vegetation	0	1	na	0%
CEGL006479	<i>Hydrangea arborescens</i> / <i>Sedum ternatum</i> - <i>Polypodium virginianum</i> Cliff Shrubland	0	1	na	0%
CEGL006926	<i>Pinus rigida</i> - <i>Nyssa sylvatica</i> / <i>Clethra alnifolia</i> - <i>Leucothoe racemosa</i> Forest	1	1	100%	100%
CEGL007403	<i>Quercus phellos</i> / <i>Carex (albolutescens, intumescens, jorii)</i> / <i>Climacium americanum</i> Wet Forest	1	1	100%	100%
CEGL007191	<i>Ailanthus altissima</i> Ruderal Forest	1	4	100%	25%
CEGL002596	<i>Thuja occidentalis</i> / <i>Carex eburnea</i> - <i>Pellaea atropurpurea</i> Cliff Woodland	1	6	100%	17%
CEGL006329	<i>Pinus rigida</i> - <i>Quercus coccinea</i> - <i>Quercus falcata</i> / (<i>Quercus marilandica</i>) / <i>Gaylussacia frondosa</i> Woodland	2	2	100%	100%
CEGL007748	<i>Quercus muehlenbergii</i> / <i>Cercis canadensis</i> / <i>Bromus pubescens</i> - <i>Erigeron pulchellus</i> var. <i>pulchellus</i> - <i>Aquilegia canadensis</i> Forest	2	2	100%	100%
COMP_PLDE	Planted Deciduous Forest	2	2	50%	50%
CEGL006186	<i>Liriodendron tulipifera</i> - <i>Quercus rubra</i> - <i>Fraxinus americana</i> / <i>Asimina triloba</i> / <i>Actaea racemosa</i> Forest	2	3	100%	67%
CEGL006494	<i>Quercus phellos</i> - <i>Liquidambar styraciflua</i> / <i>Claytonia virginica</i> Floodplain Forest	3	3	100%	100%
CEGL007312 [Mapped as: CEGL002086]	<i>Betula nigra</i> - <i>Platanus occidentalis</i> / <i>Alnus serrulata</i> / <i>Boehmeria cylindrica</i> Forest [Old name: <i>Betula nigra</i> - <i>Platanus occidentalis</i> Floodplain Forest]	3	4	100%	75%
CEGL006474	<i>Tsuga canadensis</i> - <i>Fagus grandifolia</i> - <i>Quercus (prinus, alba)</i> Forest	3	4	100%	75%
CEGL008540	<i>Quercus prinus</i> - <i>Pinus virginiana</i> - (<i>Pinus pungens</i>) / <i>Schizachyrium scoparium</i> - <i>Dichanthelium depauperatum</i> Woodland	3	4	67%	50%
CEGL006606	<i>Acer rubrum</i> - <i>Fraxinus pennsylvanica</i> / <i>Saururus cernuus</i> Swamp Forest	3	7	100%	43%
CEGL006639 [mapped as CEGL006109]	<i>Tsuga canadensis</i> - <i>Acer saccharum</i> - <i>Fagus grandifolia</i> / <i>Dryopteris intermedia</i> Forest [Old name: <i>Tsuga canadensis</i> - <i>Betula alleghaniensis</i> - <i>Acer saccharum</i> / <i>Dryopteris intermedia</i> Forest]	4	4	100%	100%
CEGL006406	<i>Acer rubrum</i> - <i>Fraxinus (pennsylvanica, americana)</i> / <i>Lindera benzoin</i> / <i>Symplocarpus foetidus</i> Swamp Forest	4	4	100%	100%

Table 15 (continued). Map classes with fewer than five observations. These map classes represent uncommon plant communities in NCR that are of limited extent (PO – Producer’s Observations, UO – User’s Observations, PA – Producer’s Accuracy, UA – User’s Accuracy).

Map Class / Analysis Group Code	Map Class / Analysis Group Name	PO	UO	PA	UA
CEGL006495	<i>Quercus rubra</i> - <i>Quercus shumardii</i> / <i>Cercis canadensis</i> Floodplain Forest	6	4	67%	100%
COMP_SUME	Successional Meadow / Grassland	7	1	14%	100%

Table 16. Map classes with more than five observations and > 80% accuracy in 90% CI for both producer’s and user’s accuracy.

Map Class / Analysis Group Code	Map Class / Analysis Group Name	PO	PA	PA 90% CI -	PA 90% CI +	UO	UA	UA 90% CI -	UA 90% CI +
CEGL002591	<i>Pinus virginiana</i> Ruderal Forest	33	85%	73%	97%	32	88%	76%	99%
CEGL004418	<i>Liquidambar styraciflua</i> - <i>Liriodendron tulipifera</i> / <i>Lindera benzoin</i> / <i>Arisaema triphyllum</i> Floodplain Forest	28	86%	73%	98%	27	89%	77%	101%
CEGL004996	<i>Pinus (pungens, rigida)</i> - <i>Quercus prinus</i> / (<i>Quercus ilicifolia</i>) / <i>Gaylussacia baccata</i> Woodland	10	100%	95%	105%	13	77%	54%	100%
CEGL006017	<i>Acer saccharum</i> - <i>Quercus muehlenbergii</i> / <i>Cercis canadensis</i> Forest	13	54%	27%	80%	9	78%	49%	106%
CEGL006024	<i>Juniperus virginiana</i> Ruderal Forest	25	92%	81%	103%	26	88%	76%	101%
CEGL006055	<i>Fagus grandifolia</i> - <i>Liriodendron tulipifera</i> - <i>Carya cordiformis</i> / <i>Lindera benzoin</i> / <i>Podophyllum peltatum</i> Forest	24	100%	98%	102%	29	83%	69%	96%
CEGL006110	<i>Liquidambar styraciflua</i> - <i>Acer rubrum</i> - <i>Quercus phellos</i> / <i>Leucothoe racemosa</i> Swamp Forest	12	67%	40%	93%	9	89%	66%	112%
CEGL006125	<i>Quercus rubra</i> - <i>Acer saccharum</i> - <i>Liriodendron tulipifera</i> Forest	27	89%	77%	101%	33	73%	58%	87%
CEGL006209	<i>Carya glabra</i> - <i>Quercus (rubra, prinus)</i> - <i>Fraxinus americana</i> / <i>Viburnum rafinesquianum</i> Forest	25	96%	88%	104%	26	92%	82%	103%
CEGL006216	<i>Quercus alba</i> - <i>Carya glabra</i> - <i>Fraxinus americana</i> / <i>Muhlenbergia sobolifera</i> - <i>Elymus hystrix</i> Forest	23	100%	98%	102%	30	77%	62%	91%

Table 16 (continued). Map classes with more than five observations and > 80% accuracy in 90% CI for both producer's and user's accuracy.

Map Class / Analysis Group Code	Map Class / Analysis Group Name	PO	PA	PA 90% CI -	PA 90% CI +	UO	UA	UA 90% CI -	UA 90% CI +
CEGL006238	<i>Acer rubrum</i> - <i>Nyssa sylvatica</i> - <i>Magnolia virginiana</i> / <i>Viburnum nudum</i> var. <i>nudum</i> / <i>Osmunda cinnamomea</i> Swamp Forest	8	63%	28%	97%	5	100%	90%	110%
CEGL006255	<i>Liriodendron tulipifera</i> - <i>Platanus occidentalis</i> - <i>Betula lenta</i> / <i>Lindera benzoin</i> / <i>Circaea lutetiana</i> ssp. <i>canadensis</i> Floodplain Forest	14	100%	96%	104%	18	78%	59%	97%
CEGL006287	<i>Fraxinus profunda</i> - <i>Nyssa biflora</i> - (<i>Fraxinus pennsylvanica</i>) / <i>Ilex verticillata</i> / <i>Polygonum arifolium</i> Tidal Forest	32	88%	76%	99%	28	100%	98%	102%
CEGL006390	<i>Quercus falcata</i> - <i>Quercus michauxii</i> / <i>Ilex opaca</i> Forest	19	95%	84%	106%	28	64%	48%	81%
CEGL006471	<i>Acer saccharum</i> - <i>Tilia americana</i> / <i>Staphylea trifolia</i> / <i>Dryopteris marginalis</i> - (<i>Impatiens pallida</i>) Forest	12	83%	61%	105%	12	83%	61%	105%
CEGL006475	<i>Platanus occidentalis</i> - <i>Fraxinus pennsylvanica</i> - <i>Acer negundo</i> / <i>Sanicula odorata</i> - <i>Elymus virginicus</i> Floodplain Forest	20	100%	98%	103%	22	91%	79%	103%
CEGL006490	<i>Quercus prinus</i> / <i>Deschampsia flexuosa</i> - <i>Solidago bicolor</i> Forest	5	100%	90%	110%	5	100%	90%	110%
CEGL006492	<i>Liriodendron tulipifera</i> - <i>Acer negundo</i> - (<i>Platanus occidentalis</i>) / <i>Carpinus caroliniana</i> / <i>Polygonum virginianum</i> Floodplain Forest	26	100%	98%	102%	31	84%	71%	96%
CEGL006497	<i>Quercus palustris</i> - <i>Quercus bicolor</i> / <i>Carex tribuloides</i> - <i>Carex radiata</i> - (<i>Carex squarrosa</i>) Wet Forest	12	100%	96%	104%	14	86%	67%	105%
CEGL006565	<i>Betula lenta</i> - <i>Quercus prinus</i> / <i>Parthenocissus quinquefolia</i> Woodland	13	85%	64%	105%	15	73%	51%	95%
CEGL006603	<i>Platanus occidentalis</i> - (<i>Liquidambar styraciflua</i> , <i>Liriodendron tulipifera</i>) / <i>Asimina triloba</i> Floodplain Forest	25	76%	60%	92%	27	70%	54%	87%
CEGL006605	<i>Quercus (phellos, palustris, michauxii)</i> - <i>Liquidambar styraciflua</i> / <i>Cinna arundinacea</i> Floodplain Forest	29	86%	74%	98%	31	81%	67%	94%
CEGL006919	<i>Fagus grandifolia</i> - <i>Quercus (alba, velutina, prinus)</i> / <i>Kalmia latifolia</i> Forest	21	90%	78%	103%	28	68%	52%	84%
CEGL007220	<i>Liriodendron tulipifera</i> / (<i>Cercis canadensis</i>) / (<i>Lindera benzoin</i>) Ruderal Forest	43	70%	57%	82%	31	97%	90%	104%

Table 16 (continued). Map classes with more than five observations and > 80% accuracy in 90% CI for both producer's and user's accuracy.

Map Class / Analysis Group Code	Map Class / Analysis Group Name	PO	PA	PA 90% CI -	PA 90% CI +	UO	UA	UA 90% CI -	UA 90% CI +
CEGL007710	<i>Liriodendron tulipifera</i> - <i>Fraxinus americana</i> - (<i>Tilia americana</i> - <i>Aesculus flava</i>) / <i>Actaea racemosa</i> - <i>Laportea canadensis</i> Forest	19	100%	97%	103%	30	63%	47%	80%
CEGL008412	<i>Acer saccharum</i> - <i>Tilia americana</i> / <i>Asimina triloba</i> / <i>Jeffersonia diphylla</i> - <i>Caulophyllum thalictroides</i> Forest	21	67%	47%	86%	20	70%	51%	89%
CEGL008416	<i>Acer rubrum</i> - <i>Fraxinus nigra</i> - <i>Betula alleghaniensis</i> / <i>Veratrum viride</i> - <i>Carex bromoides</i> Seep Forest	8	100%	94%	106%	8	100%	94%	106%
CEGL008449	<i>Pinus virginiana</i> - <i>Quercus stellata</i> / <i>Amelanchier stolonifera</i> / <i>Danthonia spicata</i> / <i>Leucobryum glaucum</i> Woodland	7	100%	93%	107%	7	100%	93%	107%
COMP_HDEP	Herbaceous Depositional Bar	13	100%	96%	104%	16	81%	62%	100%
COMP_HEWE	Successional Herbaceous Wetland	30	87%	75%	99%	28	93%	83%	103%
COMP_PLEV	Planted Evergreen Forest	17	88%	72%	104%	18	83%	66%	101%
COMP_RROP	Riverside Rock Outcrop and Prairie	18	100%	97%	103%	19	95%	84%	106%
COMP_RSWO	River-scour Woodland	25	88%	75%	101%	28	79%	64%	93%
COMP_SBWO	Shale Barren Woodland	23	87%	73%	101%	23	87%	73%	101%
DOP_DMO	Dry Oak - Pine and Dry Mesic Oak Forest	305	83%	79%	86%	303	83%	79%	87%
FWTV_NLCD11	Fresh Water Tidal Vegetation and Open Water	54	98%	94%	102%	54	98%	94%	102%
LRFPF	Large River Floodplain Forests Exclusive of Potomac Gorge	214	78%	73%	83%	190	88%	84%	92%
NLCD61	Orchards and Vineyards	10	100%	95%	105%	11	91%	72%	110%

Table 17. Map classes with more than five observations < 80% accuracy in 90% CI for either producer's or user's accuracy.

Map Class / Analysis Group Code	Map Class / Analysis Group Name	PO	PA	PA 90% CI -	PA 90% CI +	UO	UA	UA 90% CI -	UA 90% CI +
CEGL003683	<i>Fraxinus americana</i> - <i>Carya glabra</i> / <i>Muhlenbergia sobolifera</i> - <i>Helianthus divaricatus</i> - <i>Solidago ulmifolia</i> Woodland	22	55%	35%	74%	15	80%	60%	100%
CEGL004643	<i>Quercus palustris</i> - <i>Quercus bicolor</i> / <i>Viburnum prunifolium</i> / <i>Leersia virginica</i> - <i>Impatiens capensis</i> Wet Forest	12	42%	14%	69%	5	100%	90%	110%
CEGL006075	<i>Fagus grandifolia</i> - <i>Quercus (alba, rubra)</i> - <i>Liriodendron tulipifera</i> / (<i>Ilex opaca</i> var. <i>opaca</i>) Forest	60	45%	34%	56%	36	75%	62%	88%
CEGL006548	<i>Acer (rubrum, saccharinum)</i> - <i>Fraxinus pennsylvanica</i> - <i>Ulmus</i> <i>americana</i> / <i>Boehmeria cylindrica</i> Floodplain Forest	19	84%	68%	101%	27	59%	42%	77%
CEGL007216	<i>Liquidambar styraciflua</i> Ruderal Forest	20	90%	76%	104%	30	60%	44%	76%
CEGL007221	<i>Liriodendron tulipifera</i> - <i>Quercus</i> spp. Ruderal Forest	30	63%	47%	80%	31	61%	45%	77%
CEGL007879	<i>Juglans nigra</i> / <i>Verbesina alternifolia</i> Ruderal Forest	8	75%	44%	106%	20	30%	11%	49%
COMP_S MDF	Successional Mixed Deciduous Forest	63	33%	23%	44%	28	75%	60%	90%
COMP_VISH	Successional Vine-Shrubland	16	94%	81%	107%	27	56%	38%	73%

From a map user's perspective, of the map classes with less than 80% user's accuracy in 90% CI, one was a floodplain forest and the rest represented ruderal or early successional vegetation. From a map producer's perspective, of the map classes with less than 80% user's accuracy in the 90% CI, two were upland forests, one wetland forest, and two ruderal forests and shrublands (Table 17).

Ecological Systems Analysis

Of the 27 individual map classes for the ecological system map, 4 had fewer than 5 plots for either user's or producer's accuracies (see Table 18 and System_Pivot_Copy worksheet) (Teague et al. 2022e). Of the 24 map classes that had 5 or more plots for both producer's and user's accuracy, 17 had an accuracy of 80% or above in the 90% CI for both producers and user's accuracy (see Table 19 and System_Pivot_Copy worksheet) (Teague 2022d). Six (6) had producer's or user's accuracies below 80% but all were above 70% in the 90% confidence interval (see Table 20 and System_Pivot_Copy worksheet) (Teague et al. 2022e).

Table 18. Ecological System map classes with fewer than five observations. (PO – Producer’s Observations, UO – User’s Observations, PA – Producer’s Accuracy, UA – User’s Accuracy).

Ecological System Map Class Code	Ecological System Map Class Name	PO	PA	PA 90% CI -	PA 90% CI +	UO	UA	UA 90% CI -	UA 90% CI +
CES203.069	Northern Atlantic Coastal Plain Calcareous Ravine	2	100%	75%	125%	2	100%	75%	125%
CES203.269	Northern Atlantic Coastal Plain Pitch Pine Barrens	2	100%	75%	125%	2	100%	75%	125%
CES203.374	Northern Atlantic Coastal Plain Pitch Pine Lowland	1	100%	50%	150%	1	100%	50%	150%
NS_WATER	Water	11	9%	10%	28%	1	100%	50%	150%

Table 19. Ecological System map classes with more than five observations and > 80% accuracy in 90% CI for both producer’s and user’s accuracy. (PO – Producer’s Observations, UO – User’s Observations, PA – Producer’s Accuracy, UA – User’s Accuracy).

Ecological System Map Class Code	Ecological System Map Class Name	PO	PA	PA 90% CI -	PA 90% CI +	UO	UA	UA 90% CI -	UA 90% CI +
CES202.268	Piedmont Hardpan Woodland and Forest	48	98%	93%	102%	56	84%	75%	93%
CES202.373	Southern and Central Appalachian Cove Forest	40	100%	99%	101%	50	80%	70%	90%
CES202.593	Appalachian (Hemlock)-Northern Hardwood Forest	34	91%	82%	101%	41	76%	63%	88%
CES202.598	Appalachian Shale Barrens	23	87%	73%	101%	23	87%	73%	101%
CES202.600	Central Appalachian Pine-Oak Rocky Woodland	20	100%	98%	103%	24	83%	69%	98%
CES202.601	North-Central Appalachian Acidic Cliff and Talus	13	85%	64%	105%	16	69%	47%	91%
CES202.602	Central Appalachian Alkaline Glade and Woodland	12	58%	31%	86%	9	78%	49%	106%
CES202.608	Central Appalachian River Floodplain	234	92%	89%	95%	242	89%	86%	93%
CES202.609	Central Appalachian Stream and Riparian	53	100%	99%	101%	62	85%	77%	94%
CES203.070	Northern Atlantic Coastal Plain Stream and River	141	98%	96%	100%	156	88%	84%	93%
CES203.242	Southern Atlantic Coastal Plain Mesic Hardwood Forest	105	72%	65%	80%	96	79%	72%	87%
CES203.282	Northern Atlantic Coastal Plain Tidal Swamp	32	88%	76%	99%	28	100%	98%	102%
CES203.475	Northern Atlantic Coastal Plain Hardwood Forest	26	92%	82%	103%	33	73%	58%	87%

Table 19 (continued). Ecological System map classes with more than five observations and > 80% accuracy in 90% CI for both producer's and user's accuracy. (PO – Producer's Observations, UO – User's Observations, PA – Producer's Accuracy, UA – User's Accuracy).

Ecological System Map Class Code	Ecological System Map Class Name	PO	PA	PA 90% CI -	PA 90% CI +	UO	UA	UA 90% CI -	UA 90% CI +
CES203.516	Northern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh	43	100%	99%	101%	53	81%	71%	91%
CES203.520	Northern Atlantic Coastal Plain Basin Swamp and Wet Hardwood Forest	12	67%	40%	93%	9	89%	66%	112%
NS_CVEG	Cultivated Vegetation	29	93%	84%	103%	31	87%	76%	99%
NS_SUPL	Successional Upland	241	78%	73%	83%	219	86%	82%	90%

Table 20. Ecological System map classes with more than five observations and < 80% accuracy in 90% CI for both producer's and user's accuracy. (PO – Producer's Observations, UO – User's Observations, PA – Producer's Accuracy, UA – User's Accuracy).

Ecological System Map Class Code	Ecological System Map Class Name	PO	PA	PA 90% CI -	PA 90% CI +	UO	UA	UA 90% CI -	UA 90% CI +
CES202.336	Piedmont Upland Depression Swamp	13	46%	20%	73%	6	100%	92%	108%
CES202.348	Southern and Central Appalachian Mafic Glade and Barrens	22	55%	35%	74%	15	80%	60%	100%
CES202.591	Central Appalachian Dry Oak-Pine Forest	161	73%	67%	79%	153	77%	71%	83%
CES202.592	Northeastern Interior Dry-Mesic Oak Forest	144	69%	62%	75%	150	66%	59%	73%
CES202.603	North-Central Appalachian Circumneutral Cliff and Talus	13	85%	64%	105%	19	58%	37%	79%
NS_SWET	Successional Wetland or Floodplain	86	63%	54%	72%	64	84%	76%	93%

Discussion

Mismatches between a map and field assessment data generally fall within one of three types of errors:

1. Incomplete vegetation classification
2. Field key errors (the field keys led the field crews to pick the wrong plant community or map class)
3. Mapping model errors

The errors encountered during the NCR AA fell into categories 2 and 3. We did not encounter any new plant communities during the field assessment that were not covered in the map classes.

Although we tried to provide the best expert field assessment of the vegetation, in some cases we cannot be certain that a reported error was an error in the map and not the field assessment. Office review of field forms helped to guard against errors in assignment of a field observation to a map class.

The following are observations about the mismatches in the contingency matrices:

- Difficulties in differentiating the boundary between wetland and upland forests during mapping and differentiating wetland versus upland hydrology in the field. Some areas mapped as wetland forests were determined to be uplands in the field.
- Difficulty in photo interpreting disturbed and successional (ruderal) vegetation from natural vegetation classes.
- Difficulties in remotely distinguishing different deciduous tree species during mapping.
- Vegetation change between the dates for the imagery used in mapping (2003–2004) and the accuracy assessment field work (2011–2012). Plant communities that are expected to be relatively unstable can be expected to have a high rate of “error” because of changes that occurred between mapping imagery and assessment. This includes natural vegetation changes (e.g., successional vegetation, freshwater tidal vegetation, and areas associated with shorelines of rivers and lakes) and vegetation that is being actively managed/cultivated (e.g., to remove invasive species or to maintain meadows and grasslands). In the case of freshwater tidal vegetation, combining all 7 freshwater tidal vegetation map classes with the open water map class produced a producer’s and user’s accuracy of 98% for the combined map class. Creating COMP or combinations of USNVC associations was the best option to reduce error.
- One of the biggest challenges in the USNVC association-level map was working with disturbed vegetation: “old-growth” successional (e.g., CEG007221), early successional, and all levels of vegetation impacted by invasive species. Sometimes, it was difficult to distinguish natural vegetation from a late successional disturbance vegetation, and it was hard to distinguish one disturbance (successional) plant community from another both in the field and during mapping. This was exacerbated by areas that had been previously farmed or otherwise heavily impacted by soil and substrate disturbance. For example, at NACE upland areas with topsoil loss, resembled wetlands and had a mixture of wetland and upland

vegetation. In another example, an open grassland area in 2003 was growing up in early successional woody vegetation during the AA.

- Different wetland vegetation map classes were confused with each other in mapping and in the field. Including all successional woody wetland vegetation (CEGL005033, CEGL006976, and CEGL007330) in the COMP_WOWE map class increased the producer's accuracy from 35% to 75% and user's accuracy from 72% to 78%. When successional woody wetland map classes (COMP-WOWE) were combined with natural and seminatural woody wetland vegetation (CEGL004073, CEGL006217, and CEGL006459) the producer's and user's accuracy of these three large river floodplain forests improved (78% and 88% respectively).
- Accuracy assessment results for the USNVC association-level map indicate that mesic hardwood forests (CEGL006075) and successional forests (COMP_SMDF) may have both been under mapped. They were most often confused in mapping with different dry oak-pine and dry-mesic oak forest plant communities.
- Plant communities that often occurred together on the landscape, especially those associated with a similar geologic formation had lower accuracies, e.g., Ecological System: Piedmont Upland Depression Swamp (CES202.336 - *Quercus palustris* - *Quercus bicolor* / *Viburnum prunifolium* / *Leersia virginica* - *Impatiens capensis* Wet Forest (CEGL004643)) and Ecological System: Piedmont Hardpan Woodland and Forest (CES202.268 - *Quercus alba* - *Carya glabra* - *Fraxinus americana* / *Muhlenbergia sobolifera* - *Elymus hystrix* Forest (CEGL006216)).
- Three of the larger ecological system map classes with between 70% and 80% map accuracy were CES202.591 (Central Appalachian Dry Oak-Pine Forest), CES202.592 (Northeastern Interior Dry-Mesic Oak Forest), and NS_SWET (Successional Wetland or Floodplain). Accuracy assessment results indicate that Central Appalachian Dry Oak-Pine Forest may have been under mapped, being most often confused in mapping with dry-mesic to mesic upland forests. Northeastern Interior Dry-Mesic Oak Forest may have been over mapped, being most often confused in mapping with successional upland forests and Dry Oak-Pine forests. Successional Wetland or Floodplain may have been under mapped, being most often confused in mapping with natural (later successional) floodplain vegetation.

We hope that these observations along with review of the AA matrices (Teague et al. 2022e) will assist in using the vegetation maps in the field (see producer's accuracy) and in reviewing the map (see user's accuracy).

Vegetation Classification and Map Products

This project delivers many products, some of which are included as part of this report and others delivered separately:

- Discussion of methods and results for vegetation classification, vegetation mapping, and map AA.
- Lists of USNVC associations documented at NCR parks (Tables 8 and 9).
- Detailed vegetation descriptions for USNVC associations, map classes, and ITECS ecological systems in Part 2 (NatureServe 2020).
- Nomenclature Changes of USNVC Associations and ITECS Ecological Systems for NCR in Part 3 (Teague et al. 2022a).
- Dichotomous keys to USNVC associations, map classes, and ITECS ecological systems in each park in Part 4 (Teague et al. 2022b).
- Photo Interpretation Key - dichotomous key to remote sensing signature (including representative images) for each map class in Part 5 (Teague et al. 2022c).
- Map classes (Tables 8–12).
- Summary of acreages for USNVC association-level and ITECS ecological system-level map classes in Part 6 (Teague et al. 2022d).
- Accuracy Assessment workbook with contingency tables showing AA results in Part 7 (Teague et al. 2022e).
- Ground photos of quantitative vegetation plots and AA observation areas.
- Plots Database with data for quantitative vegetation plots and AA observation areas.
- Quantitative vegetation plot and qualitative observation data forms (Appendix A).
- Accuracy Assessment field form and field protocols (Appendix B).
- Aerial photography images used in photo interpretation.

Geodatabases with vegetation and ecological systems map polygons, fieldwork locations (classification plot and AA observation sites), aerial photographic indexes, a project boundary, and metadata (NCR GIS server). Since the NCR crosses two UTM zones (17 and 18), the AA geodata is in USA_Contiguous_Albers_Equal_Area_Conic_USGS_version. Individual park geodata are in projections specified by the individual parks.

Limitations and Conclusions

There are many benefits to classifying and mapping vegetation. Not only does this provide baseline information about the natural resources at a park, it also facilitates other biological inventories by defining relationships between species and different vegetation communities. Using a standardized national vegetation classification (the USNVC) extends these benefits to regional and national scales, allowing scientists to define and map vegetation communities across their entire range and to communicate about the vegetation communities' condition and extent.

We expect that the NCR vegetation maps give a reasonable representation of the vegetation communities occurring in each park and the general locations that they occur. From these maps, the user should be able to easily determine which vegetation communities are common and widespread, and which are more restricted in size and distribution. Although new plant communities were not encountered during the AA, it is always possible that a plant community not included in a park's classification and map does occur in the park. The AA also indicates which polygons may not be correctly attributed, and some USNVC associations are likely to be over or underrepresented.

We recommend that each vegetation map be used in combination with field locations for classification plot and AA observation locations, along with the AA results, which can serve as a relative indicator of map accuracy in specific areas and for specific map classes. Areas with little or no field data will be much less reliable than those with ample data supporting the mapped area. The minimum mapping unit (MMU) is 0.5 ha. Many patches smaller than MMU were mapped because they were readily visible on the imagery and/or had available field data. The user should have no expectation that this level of detail is consistent throughout all areas, hence, the descriptions of the percentages of error. It is likely that a mapped polygon of a widespread matrix or large-patch plant community will have small inclusions of other plant communities that are not mapped.

The vegetation map data are not intended to be used at scales greater than 1:6,000. Even at a scale of 1:6,000, there will be some discrepancies between what is on the ground and what is presented in the maps due to various possible sources of mapping error: positional error of GPS readings, attribute error of field data, misalignment of imagery sources, errors, and/or lack of detail in ancillary data sources (many had a much coarser scale than the vegetation maps), and errors of photo interpretation. In addition, it is important to note that delineations between adjacent vegetation polygons are typically not well-defined on the ground. Because vegetation is distributed along a continuum, discrete polygons can only approximate the wider ecotones that often occur between vegetation communities.

The vegetation maps are based on the USNVC, which is a dynamic system of cataloguing natural communities. Thus, future classification analyses may cause some map classes to be split or merged as the understanding of the data change, rendering the map inconsistent with the most current classification. In addition, the natural communities themselves are dynamic, with changes occurring over time due to succession, fire exclusion, exotic species invasions, climate change, urban development, reforestation, conversion of agricultural fields to other uses, etc. For example, during the timeframe of this project, NCR has lost some diagnostic trees such as hemlock (*Tsuga* spp.) and several species of ash (*Fraxinus* spp.) due to invasive nonnative pests. The maps should be treated as a baseline model of the state of best available knowledge and understanding of the classification and distribution of vegetation communities across the NCR region during the time of this study (Table 3). The classifications and maps will change over time and will need to be updated. These baseline results are the starting point for evaluating changes that are always part of dynamic natural and managed ecosystems.

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Appendix A. Classification Data Forms

Figures 5 through 7 are screenshots of the three pages that make up the Vegetation Inventory Form. Figures 8 through 9 are screenshots of the two pages that make up the Observation Plot Sampling Form.

NATIONAL CAPITAL REGION - VEGETATION INVENTORY FORM		rev. 2005 April 01 JT	P.1
GENERAL INFORMATION		PLOT LOCATION	
PLOT: Project: <u>NCR Vegetation mapping</u> Date: _____ Surveyors: _____		RA Point Managed Area (Park): Survey Site: _____ Quad: _____ County: _____ State: _____	
Plot dimensions: ____ by ____ m Sample area _____ sq. m		Type of GPS unit: _____ UTM zone: _____ Datum: _____ GPS pointname or file: _____ est accuracy: _____ mft # of sats fixed: _____ Reciever status: 2D / 3D / 3D WAAS / NDGPS / Post-processed Corrected PDOP _____ HDOP _____	
PLOT DOCUMENTATION Source Code: _____ Film Roll: _____ Frames: _____ Description of pic(s): _____			
Relative Stand Size A - extensive (> 100x plot size) B - large (10-100x plot size) C - small (3-10x plot size) D - very small (1-3x plot size) U - Unknown		Field UTM X _____ E Y _____ N Corrected UTM X _____ E Y _____ N LAT _____ LAT corrected _____ LONG _____ LONG corrected _____ Marked est. location on toposheet yes	
SITE CHARACTERISTICS		compass: magnetic corrected	
Elevation _____ mft via GPS _____ map _____ altimeter _____			
Slope (o) _____ single measure. _____ avg of _____ or: A - 0-3% (level or nearly so) B - 3-8% (gentle/undulating) C - 8-16% (sloping/rolling) D - 16-30% (moderate/hilly) E - 30-65% (steep) F - 65-75% (very steep) G - 75+% (extremely steep)	Slope Shape (V w/ slope) VERTICALLY HORIZONTALLY C - concave C - concave X - convex X - convex S - straight S - straight H - hummock (____ % of plot) and hollow (____ %) microtopography I - irregular craggy/bouldery microtopography	Aspect (N = 0o): single measure. _____ avg of _____ F (flat) N 338-22 ° NE 23-67 ° V (variable) E 68-112 ° SE 113-157 ° S 158-202 ° SW 203-247 ° W 248-292 ° NW 293-337 °	
Topographic Position A - crest B - upper slope C - middle slope D - lower slope E - toe slope F - plain/level/bottom G - basin/depression	Landform IF - interfluvium P - flat plain G - gap/saddle TF - tidal flat SS - side slope R - ravine SB - slope bench S - seep/swale FP - fan piedmont A - alluvial plain C - cove L - levee E - escarpment/face CS - channel shelf O - bedrock outcrop BS - backswamp DS - debris slope B - basin/sag pond U - rolling upland OTHER:	Surface Substrate bedrock boulders and stones gravel and cobbles litter / organic matter decaying wood water mineral soil / sand other (bryophytes and lichens) TOTAL 100%	
Geologic Map Unit and Code			
Rock Types Present			
Soil Drainage Class A - very poorly drained B - poorly drained C - somewhat poorly drained D - moderately well drained E - well drained F - rapidly drained	Soil Moisture Regime A - very xeric (moist for neglig. time after ppt) B - xeric (moist for brief time) C - somewhat xeric (moist for short time) D - submesic (moist for moderately short time) E - mesic (moist for significant time) F - subhyvric (wet for significant part of growing season; mottles <20cm) G - hyvric (wet for most of growing season; permanent seepage/mottling) H - subhydric (water table at or near surface for most of the year) I - hydric (water table at or above surface year round) - ephemeral seepage/subsurface water present locally in plot	Hydrologic Regime _____ Terrestrial (i.e. not a wetland) Tidal A - Irregularly exposed B - Regularly flooded C - Irregularly flooded D - Wind tidally flooded Non-Tidal A - Permanently flooded B - Semipermanently flooded C - Seasonally flooded D - Intermittently flooded E - Temporarily flooded F - Saturated Salinity/Halinity A - Saltwater Refractometer Measurement; B - Brackish C - Oligohaline D - Freshwater	
Cowardin System Upland Riverine Lacustrine Estuarine Palustrine			
Soil Sample Single Sample _____ Composite Sample _____ Mean of _____			
Soil Profile Description Horizon/ Depth(cm) Description (texture, structure, consistency)			
0-			

Figure 5. First page of the Vegetation Inventory Form.

PLOT CONFIGURATION, MAP SKETCH, AND DIRECTIONS FOR RELOCATING PLOT			P.2						
Sketch plot configuration , indicate the plot architecture, points where GPS positions were collected, locations of permanent stakes (if any), locations and bearings of photopoints, and directions and distances to landmarks (include species and dbh of witness trees). Use the symbols in the key below for GPS points, photos, and permanent markers. Also provide complete directions for relocating permanently marked plots, accompanied if possible by a sketch showing plot orientation and depicting roads, trails, etc., as well as distinctive features of the vegetation. Attach copy of USGS topographic quad map indicating location of plot.									
			<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center; width: 40px;"></td> <td>GPS position</td> </tr> <tr> <td style="text-align: center;"></td> <td>Photo # and direction</td> </tr> <tr> <td style="text-align: center;"></td> <td>Permanent Marker</td> </tr> </table>		GPS position		Photo # and direction		Permanent Marker
	GPS position								
	Photo # and direction								
	Permanent Marker								
Evidence of Disturbance logging ____ fire ____ exotic plants ____ erosion ____ trails/roads ____ clearing ____ grazing/browsing ____ wind/ice damage ____ ditching/hydrologic alteration ____ chestnut blight ____ pine bark beetle ____ dogwood anthracnose ____ oak decline ____ hemlock adelgid ____ gypsy moth ____ spruce decline ____ Other: _____ Disturbance Comments: _____									
Provisional Community name (floristic description of sample): _____									
QUALITATIVE ASSESSMENT AND NOTES Write a brief word picture of community. Describe the representativeness of the plot to the vegetation type being sampled and any variation within the occurrence in terms of veg structure and environment. Note vertical stratification or horizontal zonation patterns. Describe dominant and characteristic species and inclusion communities (if present). If community occurs as a mosaic describe spatial distribution and associated community types. Include landscape context information (adjacent communities). Describe any special or unusual features of the vegetation. If possible, note the origin and (for moderately even-aged forests) approximate age of the stand. Record the presence at the site of species not sampled in the plot. Note, where appropriate, the approximate distance and direction to proximate water sources, such as river channels, perennial streams, intermittent streams, and seepage or runoff areas. For riparian sites note the height of primary and secondary water marks and the presence of fluvial features.									
PHYSIOGNOMY (entire stand) Forest Woodland Shrubland Herbaceous with sparse tree layer Herbaceous with sparse shrub layer Herbaceous Nonvascular Bryophyte Lichen Sparsely Vegetated		DOMINANT LEAF PHENOLOGY(entire stand) Deciduous (< 25% evergreen) Mixed deciduous (25-49% evergreen) Mixed evergreen (25-49% deciduous) Evergreen (< 25% deciduous) Perennial graminoid Perennial forb Perennial mixed Annual herbaceous Not applicable							
		Leaf Type (Dominant Stratum) Broadleaf Needleleaf Mixed Ericad Broadleaf Herbaceous Graminoid Pteridophyte Bryophyte Lichen							

Figure 6. Second page of the Vegetation Inventory Form.

Figure 7. Third page of the Vegetation Inventory Form.

IDENTIFIERS/LOCATORS

Date: ____ - ____ - 2004		Surveyor(s): _____	
NCR Park: ☐ ANTI ☐ CATO ☐ CHOH ☐ GWMP ☐ HAFE ☐ MANA ☐ MONO ☐ NACE ☐ PRWI ☐ ROCR ☐ WOTR			
Provisional Community Name _____		By: _____	
General Location _____			
Polygon ID # _____	Area Observed _____	Quad. _____	
GPS Unit ID _____ Datum _____ (Record DD in WGS84) UTM zone _____ Other _____			
Plot ID _____ Long (UTM X / E) _____ Lat (UTM Y / N) _____ est accuracy m / ft _____ PDOP _____ # sats _____ Fixed Status			
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Write the Plot ID numbers, separated by commas, in the space provided next to the categories below (ex: 1,4,7).

Leaf type (dominant stratum) Broadleaf _____ Needleleaf _____ Mixed _____ Ericad _____ Graminoid _____ Broadleaf Herbaceous _____ Pteridophyte _____ Bryophyte _____ Lichen _____	Leaf phenology (dominant stratum) Deciduous (< 25% evergreen) _____ Mixed Deciduous (25-49% evergreen) _____ Mixed Evergreen (25-49% deciduous) _____ Evergreen (< 25% deciduous) _____ Perennial Graminoid _____ Perennial Forb _____ Perennial Mixed _____ Annual Herbaceous _____	Physlognomic class Forest _____ Woodland _____ Shrubland _____ Dwarf-shrubland _____ Herbaceous Vegetation _____ Nonvascular Veg _____ Sparse Vegetation _____
---	---	--

Figure 8. First page of the Observation Plot Sampling Form.

Appendix B. Accuracy Assessment Field Protocols

Protocols

Trip Planning

Park specific research permits will be provided by NatureServe to each researcher. Prior to beginning work at a park, each team will notify the park staff identified on the NPS research permit of the upcoming visit. This notification must take place during the time period specified on the permit. All requirements as outlined in the individual permit must be followed. In addition to the named research permit contact at each park, we also have a designated vegetation mapping contact at each park. When these individuals are not the same person, it is suggested that the field ecology team contact both individuals. Field teams may need to interact with park staff to obtain gate keys, discuss access issues, get clearance to work past normal park hours, or ask for access to boats that may help them get their work done. Always first contact the vegetation mapping contact and the staff person on the permit for that park, and then contact other staff at the park only after the research coordinator or vegetation mapping contact has made it clear that this is permissible. Remember that park staff, especially law enforcement, generally have much more work than they can actually get done in a day, so try to be sensitive to this if possible and let them offer to help us rather than demanding assistance.

Prior to beginning field work at a park, the field ecologists should review the ecological classification, field key, and list of relevant diagnostic and characteristic species for the park and be prepared to identify diagnostic species and relevant natural communities. Also, review field map and target accuracy assessment (AA) point locations to prepare an efficient route for data collection. If alternative transportation may make the plot data collection quicker (boats, bicycles, etc.) then try to arrange for rental before arriving at the park. Teams should plan to assess an average of 40 assessment areas per week (except for the training week).

The materials you should have before you begin each week of field work are 1) scientific research permit for the park; 2) names and contact information for park contacts; 3) paper maps of the target assessment points overlaid on aerial photos with topographic lines, trails, roads, streams, and park boundaries, without information about polygon attributes (except for lines that are within 40 meters of the AA point); 4) pre-selected target AA point coordinates loaded into your Global Positioning System (GPS) unit; 5) the park specific AA code to be used for new AA point codes; 6) the field key to vegetation types; 7) vegetation type descriptions; 8) a list of all vascular plant species confirmed for the parks with seven letter codes; and 9) the point inventory checklist where you will record points assessed and any comments about the target AA points. You may also want to carry a compass and clinometer.

Navigating to Target Accuracy Assessment Points

Prior to the start of field work, NatureServe will provide teams with a random set of assessment points. Each map class has a pre-determined number of assessment points based on the area and distribution of that class within the region. Each field team will be assigned a number of points to

visit each week by the project leads. Point locations should be loaded into a WAAS-enabled GPS unit, Trimble Juno, or other more accurate GPS unit which will be used to navigate to each point.

Navigation to target AA points may also be facilitated by paper maps with point locations that will be provided to each team. Paper maps will show the target assessment point locations, topographic contour lines, roads, trails, water features, and partial vegetation polygon linework where needed. Partial vegetation polygon linework will only be provided when a polygon line falls within 40 meters of a target AA point. Paper maps including the mapped vegetation polygons are generally not supplied as part of the accuracy assessment to minimize observer bias.

Once a field team navigates to the target AA point, the team will proceed through a series of decision rules to determine how to establish the accuracy assessment observation area (see Establishing Accuracy Assessment Area).

If a field team is unable to navigate to a target AA point, the team will need to determine if an assessment area can still be sampled or if that target point will be abandoned by following the guidance outlined below and in the NCR AA Plot Layout Decision Tree.

Abandoning Target AA Points due to Navigation Error or Safety Concerns

If the field team cannot navigate with confidence to the target AA point because of loss of GPS signals and an inability to locate the target position with confidence on the paper map, the target AA point should be abandoned. If satellite reception is poor and the estimated error is greater than 10 meters, but the field team is close to the target AA point and the vegetation appears homogeneous in all directions for 40 meters plus the estimated GPS error, the assessment area should be established and data collected.

For assessment points that are near polygon boundaries, the field team should consider the location of the point with regard to the polygon boundaries and not assess points if the GPS error is greater than the distance of the point to the polygon boundary as drawn on the map. Again, when the AA target point falls within 40 meters of a polygon line, this line will be shown on the paper map. Field teams can examine the linework in relationship to other landmarks and if they cannot be sure that they are assessing the target polygon, the AA point should be abandoned.

If the field team cannot navigate to the target AA point because of accessibility/safety concerns, the team can determine if the vegetation of the target AA area can be adequately assessed from a safe distance. If it can, the team can proceed to record data as usual except they will mark on the field form that a new GPS point was not taken and the area assessed corresponds to the target AA point code.

If the team cannot safely navigate to the target AA point and determines that they cannot adequately assess the vegetation from a safe distance, the team will abandon the point.

If a target AA point is abandoned, that decision will be noted on field map and the Point Inventory Checklist, and the team will proceed to the next target AA point.

Note: See NCR AA Plot Layout Decision Tree diagram below.

Establishing the Accuracy Assessment Observation Area

All assessment areas will equal 0.5 hectares. The first decision that a field team will make once arriving at a target AA point is whether or not the vegetation present within a 0.5 hectare circular area surrounding the target point is homogenous (i.e., represents a single vegetation type).

Assessments will not be taken if there is more than one vegetation type present within the 0.5 hectare assessment area. In these cases, the assessment area must be reshaped, moved, or abandoned.

If the vegetation surrounding the target point is determined to be homogenous, the team will proceed to record data about the AA area using the NCR AA field form. If the circular 0.5 hectare area surrounding the target AA point is determined to not be homogenous, the team must then decide if the target AA point falls within a linear vegetation type that can accommodate a linear or irregularly shaped 0.5 hectare assessment area. For this type of ecosystem, a 40 meter circular observation area radius will not be suitable. Instead, the observation area should be reshaped to incorporate the linear features of the ecosystem but maintain the same observation area size. This way the area will remain the same, but the shape of the area will differ. An examination of the paper maps can help in determining if the vegetation type present at the target AA point is linear because the maps will show short segments of all polygon lines within 40 meters of target AA points. Field teams can examine the linework in relationship to other landmarks and vegetation features to ensure that they are assessing a linear vegetation type.

If the circular 0.5 hectare AA area surrounding the target AA point is not homogenous and the target AA point does not fall within a linear vegetation type, the AA point may be moved to capture an area of homogenous vegetation. This new assessment point must be no farther than 40 meters from the target assessment point location. If possible, the new assessment area should be centered around the new assessment point. The location of the assessment point relative to the entire assessment area must be recorded on the field form.

If the vegetation surrounding a target AA point is not homogenous and the AA area cannot be reshaped or moved to a homogenous vegetation type, the target AA point can be abandoned.

It is important to not assess vegetation patches smaller than 0.5 hectares because these areas are below the minimum mapping unit for the map and therefore could have been intentionally not mapped. In circumstances where the vegetation is variable and at relatively small scales (close to that of the minimum mapping unit of 0.5 hectares), it is very important that the field team ensure that they either have a high degree of accuracy in their GPS reading (to within at least 10 meters) or if the GPS accuracy is lower, have enough confidence that the vegetation is very homogeneous in the area surrounding them. As long as the field team is close (within 10 meters) to the target AA point and the vegetation appears homogeneous for 50 meters in all directions, it is more important that the field team collect data efficiently rather than spend more time attempting to obtain a very precise location.

A determination about vegetation homogeneity can be informed by a considering the homogeneity of the hydrology, topography, and substrate of the 0.5 hectare assessment area.

Figure 10 shows the Plot Layout Decision Tree and summarizes the discussion of establishing or abandoning an accuracy assessment area.

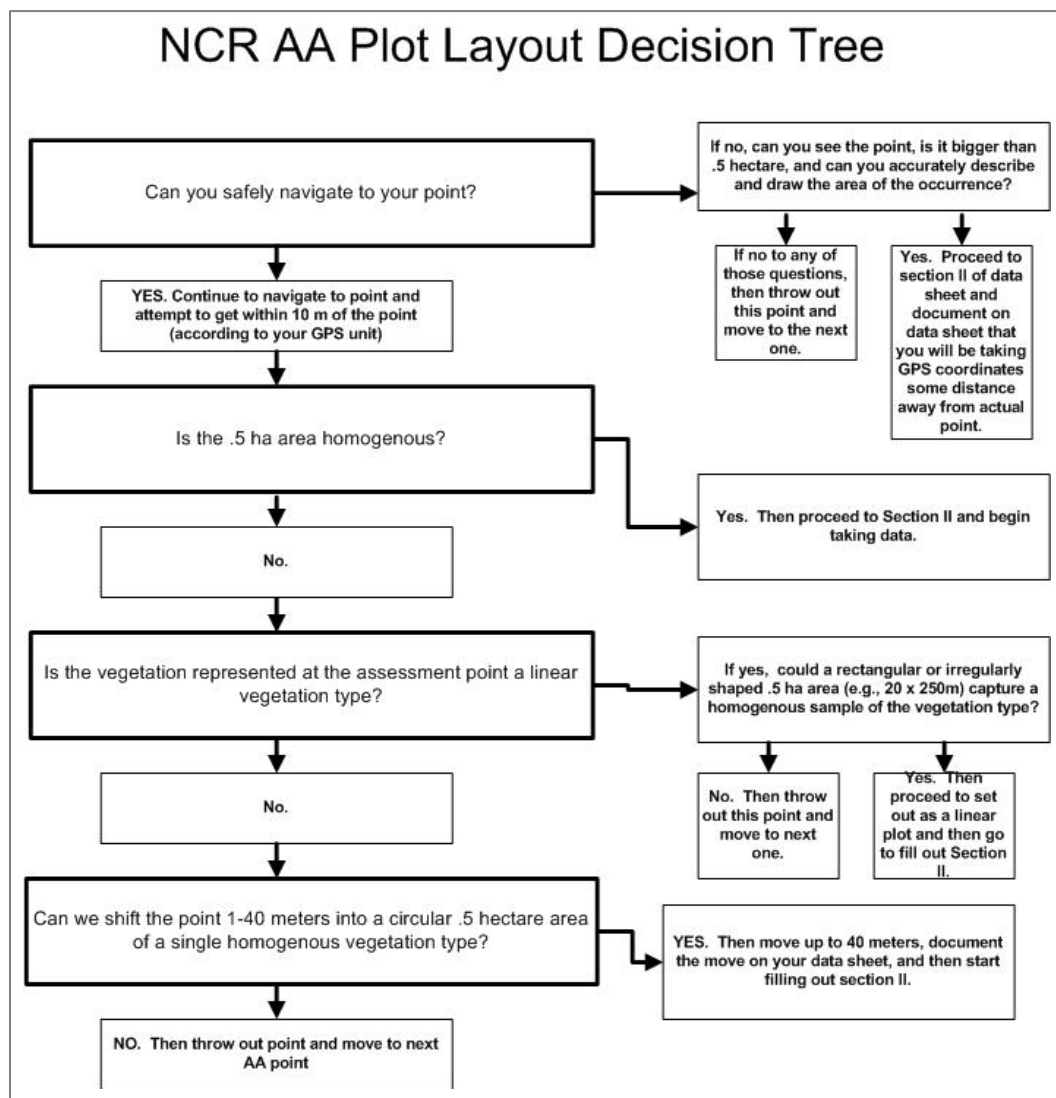


Figure 10. Accuracy Assessment Plot Layout Decision Tree.

Recording a New Assessment Point

Once an assessment area has been identified, the team will record a new assessment point and a new point ID with their GPS unit. Before recording a new assessment point, the team should wait until the estimated error (or EPE) reported by their GPS unit is less than 10 meters. Then the team should record the new assessment point location in Lat/Long decimal degrees in the NAD83 datum. Teams must also record the number of satellites fixed, the number of points averaged, the estimated error (or EPE), and the type of GPS equipment used. Be sure and record the new coordinates with the maximum number of significant digits.

When GPS reception is favorable, we recommend that the point location be recorded based on averaging at least 100 measurements. In some extreme cases, it is possible that the lack of accessibility in the National Capital Region will prevent collection of point location data via the GPS (i.e., point on the edge of a cliff that is visible for assessment but not readily accessible to record a GPS point). If this situation is encountered, but the field team is confident in their location using the topographic map, they should assess the point but make a note that no GPS data was collected for that point and they should document the point location clearly on a paper map. A point can be thrown out if it cannot be safely accessed or if there is no way to take an accurate GPS reading.

If satellite reception is poor and the estimated error is greater than 10 meters, but the field team is close to the target AA point and the vegetation appears homogeneous in all directions for 40 meters plus the estimated GPS error, it is more important that the field team collect data efficiently than spend more time attempting to obtain a very precise location (lower estimated error). Always be sure to record the estimated GPS error on the field form.

New AA point codes must be recorded in the GPS and on the field form using the following three letter codes for each park plus the 3 digit number used for the target AA point code.

ANF: Antietam National Battlefield (ANTI)

CAF: Catoctin Mountain Park (CATO)

CHF: Chesapeake and Ohio Canal National Historical Park (CHOH)

GWF: George Washington Memorial Parkway (GWMP)

HAF: Harpers Ferry National Historical Park (HAFE)

MAF: Manassas National Battlefield Park (MANA)

MOF: Monocacy National Battlefield (MONO)

NAF: National Capital Parks–East (NACE)

PRF: Prince William Forest Park (PRWI)

ROF: Rock Creek Park (ROCR)

WOF: Wolf Trap National Park for the Performing Arts (WOTR)

Table 21 illustrates the relationship between the target AA point code and the new AA point code.

Table 21. Accuracy Assessment Target Point Code and Corresponding New Point Code.

Target Point Code	New Point Code
ANTI023, ANTI123	ANF023, ANF123
CATO023, CATO123	CAF023, CAF123
CHOH023, CHOH123	CHF023, CHF123
GWMP023, GWMP123	GWF023, GWF123
HAFE023, HAFE123	HAF023, HAF123
MANA023, MANA123	MAF023, MAF123
MONO023, MONO123	MOF023, MOF123
NACE023, NACE123	NAF023, NAF123
PRWI023, PRWI123	PRF023, PRWI123
ROCR023, ROCR123	ROF023, ROF123
WOTR023, WOTR123	WOF023, WOF123

Field Form

Figures 11 through 14 show examples of the pages that make up an accuracy assessment field form.

NCR NATIONAL PARK VEGETATION MAPPING PROJECT ACCURACY ASSESSMENT FIELD FORM			
I. ASSESSMENT AREA PLACEMENT			
Observers (First and last names): _____			
Is the 0.5 hectare assessment area safely accessible? If yes, continue below. If no and you can reasonably accurately locate the assessment area on a map, do so and continue below. If no and you cannot reasonably locate the assessment area on the map, abandon the point.			
Is the 0.5 hectare assessment area homogenous (if yes, skip to section II)? Y N			
If not, does the vegetation represented at the assessment point more easily accommodate a rectangular or irregularly shaped 0.5 ha assessment area? Y N			
If yes, could a rectangular or irregularly shaped 0.5 hectare area (e.g., 20 x 250 m) capture a homogenous sample of the vegetation type? Y N			
If not, can we shift the point <40 meters (avoiding nearby assessment areas) into a circular 0.5 hectare area of a single homogenous vegetation type? Y N Bearing Shifted: _____ Distance shifted: _____			
AA sample size (circle): 0.5 ha circular area / other shape 0.5 ha			
Notes on decisions to reshape or move assessment area: _____			
II. IDENTIFIERS AND LOCATION DATA			
1. Time (EDT) _____ AM / PM		2. GPS unit (circle): Garmin MAP76 or other _____	
3. Lat _____ Long _____ (decimal degrees - report maximum number of significant digits)			
5. Datum: NAD83 (note all data must be recorded in NAD 83 Lat/Long) 6. Target AA Point Code (already in GPS): _____			
7. Estimated accuracy (EPE) _____ m		8. # of satellites fixed _____ 9. # points averaged _____	
10. Receiver status (circle): 2D / 3D / 2D WAAS / 3D WAAS / NO SIGNAL (estimated location marked on map)			
III. ENVIRONMENTAL DESCRIPTION			
1. Unvegetated Surface Substrate <i>(estimate percentage of applicable covers; should total 100%):</i> _____ bedrock _____ loose boulders and stones _____ leaf litter / organic matter _____ decaying wood _____ water _____ mineral soil / sand _____ other (specify) _____	2. Slope _____ A – 0-3% (0-2°) (level or nearly level) B – 3-9% (2-5°) (gentle) C – 9-16% (5-9°) (sloping/rolling) D – 16-31% (9-17°) (moderate/hilly) E – 31-65% (17-33°) (steep) F – 65-75% (33-37°) (very steep) G – 75%+ (>37°) (extremely steep)	3. Aspect _____ F (flat) V (variable) N 338-22° NE 23-67° E 68-112° SE 113-157° S 158-202° SW 203-247° W 248-292° NW 293-337°	
4. Environmental Comments (Note environmental characteristics that affect vegetation –e.g., if site is a wetland, indicate type of hydrology, e.g., seepage wetland, temporarily flooded stream bottom, seasonally flooded pond, etc.)			

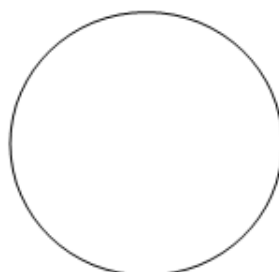
Figure 11. The first page of the Accuracy Assessment Field Form.

IV. SKETCH OF OBSERVATION AREA (aerial view or transect view or both): indicate north arrow, where GPS positions were collected, locations and bearings of **photopoints**, plot orientation, roads, trails, as well as distinctive features of the vegetation, or landscape, etc. Use the symbols in the key below for GPS points and photos.

	GPS position
	Photo # and direction

***Note: If camera tracks numbers reliably, enter number of photo in box to the left. If not, just take a picture of the first page of the plot sheet, then take your plot photo to ensure that we can track which photo goes with which plot. (Note: label photo files with plot code once

they are downloaded, e.g., CHFO_023)



V. VEGETATION DESCRIPTION (check one item in each box) (Forest = >60%, Woodland = 25-60%)

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class
<u>Trees (canopy only) and Shrubs</u>	☐ Broad-leaved	☐ Forest (canopy + subcanopy)
☐ Evergreen (> ~75%)	☐ Needle-leaved	☐ Woodland (canopy + subcanopy)
☐ Cold-deciduous (> ~75%)	☐ Mixed broad-leaved/needle-leaved	☐ Shrubland
☐ Mixed evergreen - cold-deciduous (~ 25-75%)	☐ Graminoid	☐ Herbaceous
<u>Herbs</u>	☐ Forb	☐ Nonvascular
☐ Annual ☐ Perennial		☐ Sparsely Vegetated

Notes on vegetation phenology, physiognomy, etc: _____

Is the assessment area obviously human influenced / disturbed? Y N (put comments under section X below.)

VI. VEGETATION STRUCTURE (record maximum absolute cover class in each stratum):

Stratum	Strata max. height (select one from right)	Cover values by strata (upper value of range = 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100%)	Strata Heights (max. defaults)
Canopy			20 m, 35 m, or > 35 m
Subcanopy			10 m, 20m
Shrub			2 m, or 5 m
Herbaceous/Field			0.5 m, 1 m, or 2 m
Aquatic			
Nonvascular			

VII. VEGETATION STRUCTURAL STAGE: Estimate the % aerial relative cover of **all tree stems supporting the top canopy layer**. Record values for each structural stage to nearest 10%. **Evaluate only the top canopy layer (i.e., view canopy from above, but canopy might be composed of saplings).** Total should add to 100% (relative cover) (dbh ranges – eastern N.A. temperate)

☐ % Very Large: stems >50 cm (20") dbh ☐ % Sapling: stems < 10 cm (< 4") dbh
☐ % Large: stems 30-50 cm (12-20") dbh ☐ % woody stages absent or **sdlngs** (i.e. stems < 2m)
☐ % Pole: stems 10-30 cm (4-12") dbh

Figure 12. The second page of the Accuracy Assessment Field Form.

OBSERVER: _____
Both team members must fill out this section individually

IX. COMMENTS ON VEGETATION KEY (NOTE: THIS AREA MUST BE FILLED OUT IF YOU MARKED MEDIUM OR LOW FIT OR CONFIDENCE IN SECTION XI BELOW.)

1. Notes on major splits in the field key supporting your decision on vegetation type:

2. Notes on any issues in field key: (use this space to provide additional comments about problems or ease in applying the vegetation key at this site, rationale for choice of association if there was doubt, etc)

3. Representativeness: Is the vegetation within the 0.5 ha sample site representative of vegetation in the surrounding area? Y or N
Please note relationship of observation area to surrounding area, e.g., small inclusion, part of matrix, etc. If community occurs as a mosaic, describe spatial distribution and associated community types. Include landscape context information (adjacent communities). Describe any special or unusual features of the vegetation.

4. Prevalent vegetation type within 0.5 ha sample site, based on field key and vegetation composition data:

X. ADDITIONAL COMMENTS (use this space to provide additional comments about vegetation physiognomy, structure or composition, and evidence of either natural and anthropogenic disturbance including land-use history – especially recent)

XI. FIELD CLASSIFICATION

Do both team members agree with the vegetation type assignment? Y N
If yes, only fill this section out once. If no, each team member needs to fill out this section

Fit (does stand key easily to an association?): H M L Your confidence in determination: H M L

Provisional Name _____ Elcode: _____

Name of interpreter(s): _____

XII. OFFICE CLASSIFICATION (OFFICE USE ONLY)

Final Veg Assoc Name : _____

If final veg association differs from original, give reason why here: _____

Date of final vegetation association determination (Y/M/D): ____/____/____

Name of interpreter for final call in office: _____

Figure 14. The fourth page of the Accuracy Assessment Field Form.

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