A Wetland Inventory and Connectivity Assessment for Harpers Ferry National Historical Park

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Wetlands are a valuable natural resource in national parks, providing, among other services, valuable foraging habitat for species threatened by regional habitat loss. Most wetlands are considered in isolation without consideration of the broader landscape connections. We hypothesized that the network configuration of wetlands within park landscapes may be important for the conservation of mobile species that depend on wetland resources during at least part of their life cycle. We inventoried wetland habitat within and adjacent to Harpers Ferry National Historical Park. Our initial wetland inventory used a combination of aerial photography with ancillary GIS data and field surveys to delineate wetlands within park boundaries. We supplemented this information with data from the National Wetlands Inventory (NWI) and compared the abundance of wetlands within Harpers Ferry to the abundance in the landscape adjacent to the park, and in four neighboring parks. We used this information in a graph theoretic framework to construct network models of potential landscape connectivity for common bat species of the Mid-Atlantic. Harpers Ferry has some of the highest density of wetlands in the region. Consideration of how this network may best be managed to promote connectivity would benefit bats and other water-loving species in this mixed-use setting.

Introduction

Wetlands are considered transitional areas between terrestrial and aquatic ecosystems that support unique plant life adapted to inundated and anaerobic conditions for at least part of the growing season. Wetlands provide important ecosystem services such as excess nutrient removal, flood regulation, primary production and carbon storage, and are thus a primary conservation target (Keddy 2000). Despite the recognized need to manage wetlands effectively (e.g., Zedler and Kercher 2005), many protected areas lack even a basic map of the distribution and composition of wetlands within their boundaries. Further, most wetlands are considered in isolation, without consideration of the broader landscape connections (wetland–wetland, land–water) that many mobile species depend on to complete their life cycle (Roshier et al. 2001).

Effective landscape and habitat conservation planning depends critically on the spatial arrangement and connections among habitats. Graph networks have been increasingly and successfully used to describe habitat networks for conservation and restoration (Rothley and Rae 2005; Lookingbill et al. 2008) and to assess connectivity among landscape elements for individual species (Bunn, Urban, and Keitt 2000; Neel 2008). For example, Roshier and colleagues (2001) used graph-theory based network analysis to demonstrate how the configuration of wetland habitats can explain the extraordinary numbers of waterbirds present on the arid Australian continent. Rhodes et al. (2006) used graph theory to demonstrate the high connectivity of bat roosting sites in Brisbane, Australia.

The primary purpose of our wetland inventory was to document, characterize, and delineate wetlands of Harpers Ferry National Historical Park. By extending the analysis to lands adjacent to the park and to four neighboring parks, and by considering the individual wetlands within larger wetland networks, we provide context to the inventory that should be important to both wetland and species-based park management.

Study area

Harpers Ferry National Historical Park was designated a National Monument in 1944, and a National Historical Park in 1963. The park is located at the confluence of the Potomac and Shenandoah Rivers across the West Virginia, Virginia, and Maryland State boundaries, approximately fifty miles northwest of Washington, D.C. (Figure 1). Located in the foothills of the Blue Ridge Mountains, in the water gap between Maryland and Loudoun Heights, the terrain is very steep, and dominated by well-drained, shaly silt loams. Wetland habitats within the Blue Ridge and neighboring physiographic provinces are limited in extent, and are known to harbor numerous rare, threatened, and endangered species not found elsewhere. The park requires an accurate and detailed inventory of these sites to ensure proper management and protection of wetland resources, and to comply with existing federal laws that regulate activities in or near these habitats (e.g., National Environmental Policy Act, Clean Water Act, and the Rivers and Harbors Act).

For context, we considered the distribution of wetlands within Harpers Ferry relative to the wetland distributions within four nearby parks of the National Capital Region (Figure 1) that are similar in size, support significant wetland habitats, and cover a gradient of decreasing urbanization of surrounding land cover. The four additional parks, in decreasing proximity from Washington, D.C., are Rock Creek Park, Monocacy National Battlefield, Antietam National Battlefield, and Catoctin Mountain Park. All five parks are located in either or both of the Piedmont and Blue Ridge physiographic provinces of the eastern United States.

Parks do not exist in isolation, and effects of surrounding lands on nature reserves have been well documented (Hansen and DeFries 2007). For our network analyses, we therefore extended each park landscape to fifty times the foraging range size used to build the graph networks (see below) to avoid missing important wetlands at the edges of parks (greater park landscape = 5-km-radius circle). This circle, centered on the centroid of each park, was large enough to contain each park, except for some small outlying parcels of Rock Creek Park and Harpers Ferry. The circles standardized area so that landscapes could be compared across parks.

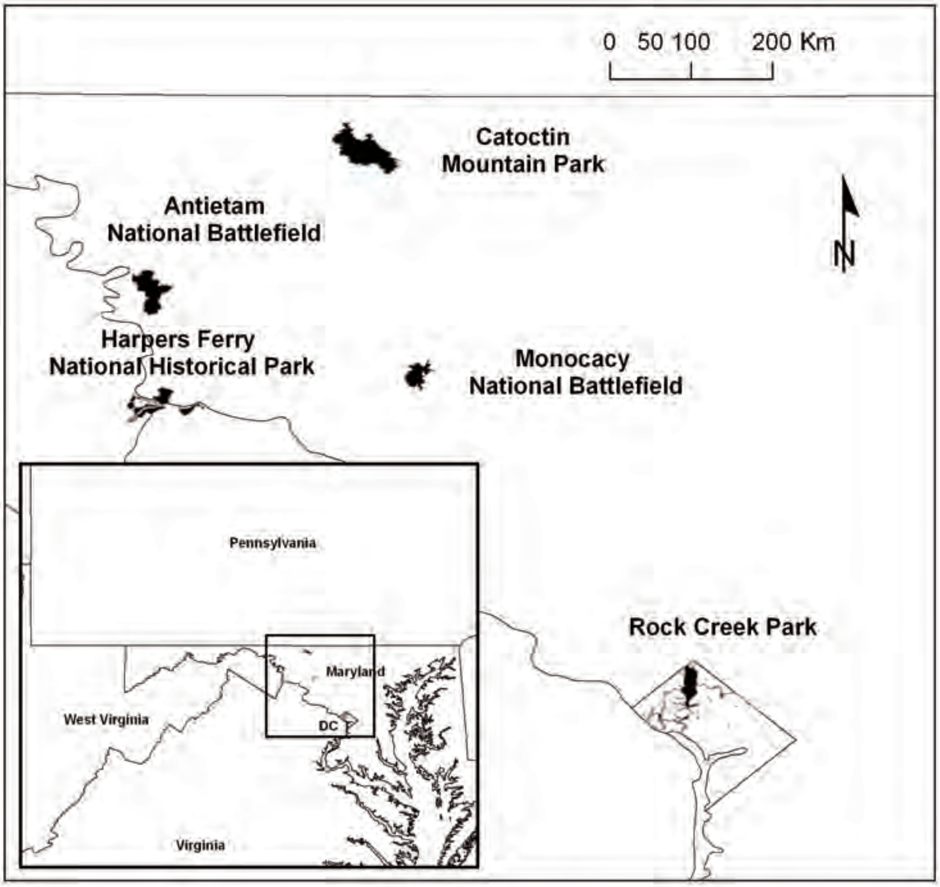


Figure 1. Study sites. An enhanced wetland inventory was conducted at Harpers Ferry National Historical Park and the results compared to wetland networks for other national parks in the region.

Methods

Possible wetlands were identified within Harpers Ferry based on aerial photography, GIS layers of park boundaries and water bodies, and prior knowledge of NPS natural resource personnel. All sites listed by the U.S. Fish and Wildlife Service's NWI were also considered as part of an initial assessment of wetland area. Following this geospatial assessment, groundtruthing and field mapping of wetland habitats were conducted using methods outlined by the Army Corps of Engineers Wetland Delineation Manual (USACE 1987). Wetlands encountered in the field were classified according to Cowardin's Classification of Wetlands as forested, emergent, aquatic bed, unconsolidated bottom, scrub-shrub, or rock bottom (Cowardin et al. 1987).

Mapping of wetlands from aerial photographs was done by searching for wetland features at a scale of 1:1200, and then digitizing them at a scale of 1:700. Digitizing was accomplished using ArcMap 9.2 software from Environmental Systems Research Institute, Inc. (ESRI), Redlands, California. GPS data collected in the field were used to guide the delineations, using a Trimble ProXR-1 GPS unit, since the GPS provides better accuracy in terms of seeing below the canopy when the photo is obscured. We used the following datasets for wetland identification:

- Six-inch resolution TIF format images acquired by the park from April 13, 2001.
- SPOT imagery from November 20, 2005.
- Digital orthophoto quarter quads (DOQQs) from March 24, 2004.
- USFWS NWI data.
- USGS NHD hydrography and drainage features.

During late spring and early summer of 2007, we visited all sites in Harpers Ferry, and searched for evidence of wetland hydrology. We recorded all dominant plant species at each possible wetland, and documented whether hydrophytic vegetation was present. For sites with more than 50% cover of hydrophytic plant species, we also checked for indicators of hydric soils by digging soil pits 12-inches deep and looking for evidence of reducing conditions. Thus, wetlands within Harpers Ferry were mapped and described using a combination of digital information and extensive ground truthing based on three criteria: hydrophytic vegetation, wetland hydrology, and hydric soils (USACE 1987). For other parks and for lands outside park boundaries, we relied solely on digital information to create wetland maps.

Landscape graphs are built from a combination of landscape structural information (here, the wetland maps) and information on organism traits (i.e., dispersal distances). We used bats to define connections for wetland networks. In addition to being a group of species of conservation concern globally and locally (Johnson, Gates, and Ford 2008), we selected bats as our model organism as they are potentially affected by not just the total area of wetlands but also the spatial distribution of wetlands (e.g., Ford et al. 2006). We assume that bat activity should be higher for more connected wetlands than for unconnected wetlands, as has been shown for waterbirds and other water-dependent species (Roshier et al. 2001). Based on the high levels of bat activity observed within 100 m of wetlands in the region (Lookingbill et al., forthcoming), we drew lines connecting all wetlands separated by less than 100 m.

A large number of well-developed indices are available for quantifying landscape attributes, based on properties of the landscape network (e.g., see Minor and Urban 2008). We chose two of these indices that emphasize different aspects of the graph: (1) graph diameter (G_{diam}), a measure of length of the largest component in the wetland network, where a component is defined as a collection of connected wetlands; (2) area of the largest component (A_{LC}), a measure of the amount of connected habitat. Ferrari, Lookingbill, and Neel (2007) provide a detailed description of the two metrics.

Results

Eleven wetlands were field characterized and delineated within Harpers Ferry, with an additional 10 potential sites identified by the desktop geospatial analysis as having some level of wetland characteristics (Figure 2, and see Tessel et al. 2007). In addition, considerable stream and river resources are included in the park, and are identified in Figure 2. Four of

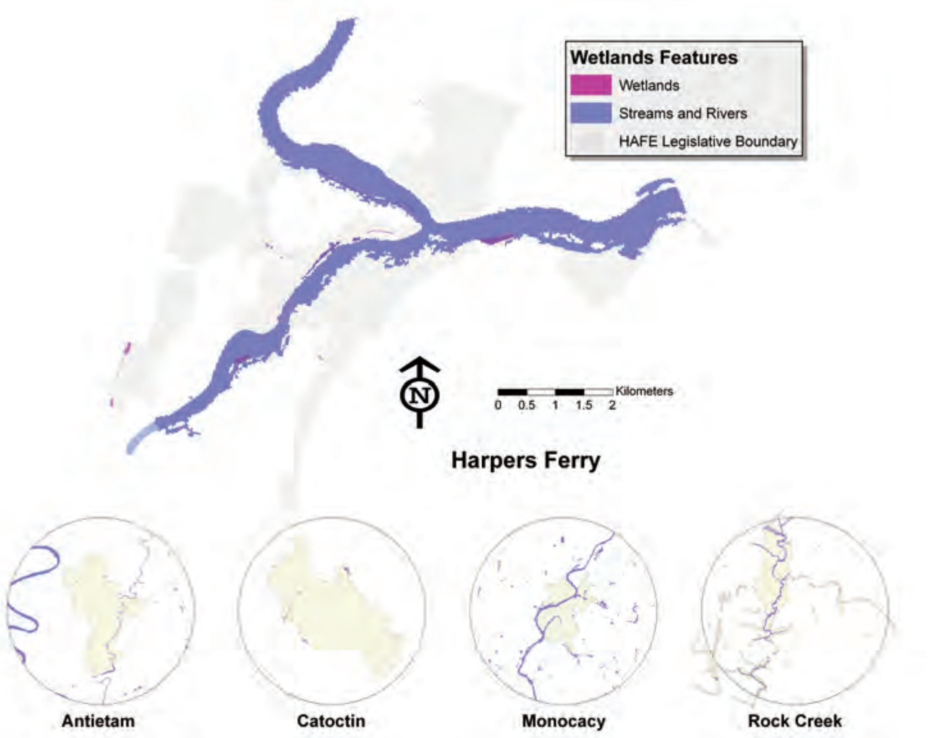


Figure 2. Wetland maps. The enhanced wetland map for Harpers Ferry combines information from digital geospatial data and field surveys. Also shown are wetland maps for 4 other parks in the region using a 5-km radius circle to define greater park landscapes.

the wetlands were characterized as forested, one was emergent, one was aquatic bed, two were palustrine, forested, and emergent at different parts, one was emergent and scrub-shrub at different parts, and two were emergent and aquatic bed at different parts. These wetlands were delineated at a broad scale to capture gradation in class type, and to be robust to inter-annual fluctuation in wetland location on floodplains. Three areas were floodplains or low areas, with many moist depressions dominated by the obligate wetland species, *Saururus cernuus* (lizard's tail). Hydric soils were generally found only within these depressions, but wetlands were delineated at a broader scale to avoid delineating around one species, and because every flood may change topography of the area, and the specific locations of each depression. Many of the wetlands had human-altered hydrology resulting from dams or wetland construction.

Two additional pond sites were recognized by the NWI as wetlands, and were readily delineated using aerial photos. The ponds were not visited owing to accessibility issues, and the certainty of the wetland designation and delineation. Several islands patches in the Shenandoah and the Potomac Rivers also could not be field characterized, but were recognized as wetlands. Three potential wetland sites identified by the NWI were not included in our final inventory due to the lack of hydric soils and wetland hydrology.

In total, 16% of the park area was mapped as wetland habitat. This is nearly double the amount of wetlands in the 5-km greater park landscape (Table 1). It is also substantially more than in any of the other park landscapes in the region (Figure 2, Table 1). By considering connectivity in addition to amount of wetland, the network metrics provided an independent measure of habitat quality. Graph diameter (G_{diam}), in particular, was strongly affected by the presence or absence of small stepping stone wetlands, and was uncorrelated to wetland amount ($R^2 = 0.24$, $p = 0.40$), though Harpers Ferry was exceptionally high in both amount and connectivity of wetlands (Figure 3). Over 90% of the wetland area at Harpers Ferry was connected, as indicated by the area of the largest component (A_{LC}) graph measure (Table 1). Rock Creek and Antietam also had relatively high proportions of their total wetlands contained within a single connected graph component; however, the lengths of the networks for these two parks as measured by G_{diam} were the shortest observed (Table 1).

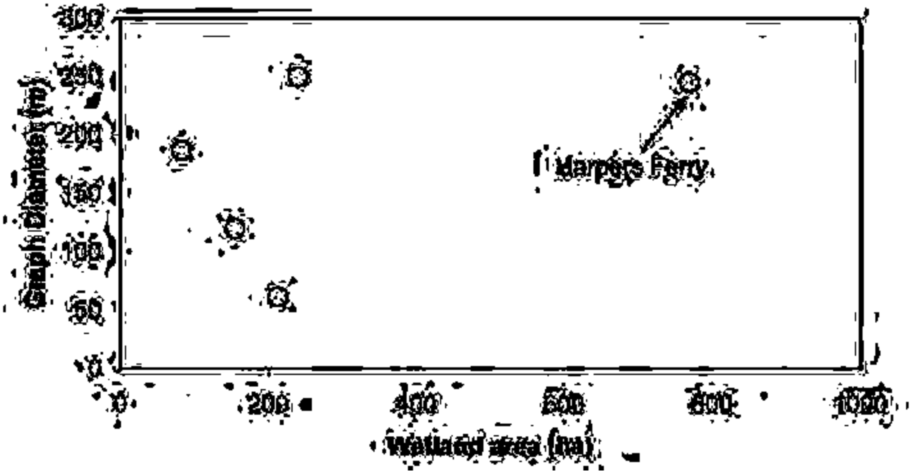
Discussion

By all measures, Harpers Ferry National Historical Park contains extraordinary wetland resources for the region. In addition to two major rivers, the park supports a diverse group

Table 1. Wetland area and graph metrics for 5 park landscapes (each landscape = 7854 ha). Graph networks built using a connectivity threshold distance of 100m as defined in Lookingbill et al. (in prep) for bats in the region.

Park	Wetland area - (ha)	Graph diameter - G_{diam} (m)	Area of the largest component - A_{LC} (ha)
Harpers Ferry	769	245	710
Antietam	213	62	172
Catoctin	83	187	20
Monocacy	240	250	158
Rock Creek	155	120	136

Figure 3. Wetland area vs. connectivity for 5 parks. Connectivity is defined using graph diameter, a measure of the length of the wetland network.



of wetlands on shallow slopes, mainly found on the floodplains of the Shenandoah and Potomac Rivers, and along streams and seeps throughout the park. The total amount and connectivity of these resources are exceptionally high relative to other parks in the National Capital Region. None of the other four parks or greater park landscapes contained as much as half the wetland area as found in Harpers Ferry—Monocacy was the park with the next greatest wetland cover as a percent of total park area (7.3%, compared to 16.4% for Harpers Ferry). The two other parks that had most of their wetland area connected via large streams (Antietam and Rock Creek) did not have networks that extended much beyond these stream corridors, as represented by their relatively low graph diameters. Thus, in addition to their important roles in water purification, shoreline stabilization, and flood mitigation, the wetland habitats within Harpers Ferry likely provide valuable foraging networks for the region's bats and other species with a proclivity for feeding over water.

Wetland management and restoration goals that do not consider the broader landscape may fall short of their target and waste limited funds. We have shown here how park wetlands can be considered not just individually, but within the context of neighboring wetlands within the greater park landscape. We argue that both the overall amount and configuration of critical resources such as wetlands are important in assessing whether a landscape is suitable for highly mobile species such as bats. Graph theory-based network analysis provides a valuable tool for quantifying landscape connectivity on a species-specific basis.

The importance of regional management efforts is increasingly recognized by the National Park Service, but the implementation of effective habitat conservation at this scale is often limited by the lack of coherent, cross-boundary management strategies. Landscape-level analyses of wetland networks provide the type of spatial information needed to work with neighbors and other local conservation agencies to inform regional management plans.

Acknowledgments

We thank Dale Nisbet for help with initial field reconnaissance. Funding was provided by cooperative agreements between UMCES, Harpers Ferry Historical Park, and the NPS I&M Program through the Chesapeake Watershed Cooperative Ecosystem Study Unit, Task Agreements J3992-07-0100 and J3992-07-0104.

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