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Natural Resource Stewardship and Science

Hopewell Furnace National Historic Site Natural Resource Condition Assessment

Natural Resource Report NPS/HOFU/NRR-2016/1153

ON THE COVER
Photograph of Hopewell Furnace National Historical Site.
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Executive Summary

Hopewell Furnace National Historic Site (HOFU) lies 50 miles northwest of Philadelphia and straddles the Berks-Chester County border in southeastern Pennsylvania (PA). HOFU is an example of a rural iron plantation from the late 18th to the late 19th centuries in America. It is a small cultural (343.2 ha) park with historical buildings, iron making structures, agricultural lands, pastures, woodlands, and streams. The local landscape was altered by the early tenants of the iron plantation and human land use disturbances are part of the site's historical relevance. Raw ore was mined locally, fuel for the cold blast furnace was logged from the surrounding hardwood forests, and water from streams and ponds were diverted to power the furnace's water wheel. Thus, the managed landscape is an important cultural backdrop to the interpretation of Hopewell Furnace's history.

HOFU is managed by the National Park Service (NPS) under the administration of Valley Forge National Historical Park (VAFO) and is part of the Mid-Atlantic Network (MIDN). Much of the lands surrounding HOFU are protected areas. French Creek State Park and State Game Lands #43 surround the park and Hopewell Big Woods encircles both HOFU and French Creek State Park. Hopewell Big Woods is the largest contiguous forest in southeastern PA. HOFU is dominated by a disturbed mixed secondary deciduous forest (76% of the park) and agricultural areas that are maintained as pastures, hay fields, crops, and orchards (~16% of the park). Developed or historic property comprises 8% of the park. The major streams in the park are French Creek and Baptism Creek. Small wetland areas are also present in the park.

Natural resources presented in this Natural Resource Condition Assessment (NRCA) were divided into four general areas: physical resources, water-related resources, ecosystem integrity, and focal animal communities. Within each of these general areas specific natural resources were assessed (Table E-1).

Table E-1. Natural resources assessed in this NRCA report.

Physical Resources	Water-Related Resources	Ecosystem Integrity	Focal Animal Communities
Air Quality- ozone	Stream water quality	Forest communities	Avian community
Air quality- wet deposition	Streambed habitat and morphology	Agricultural fields	Mammal community
Air quality - visibility	Aquatic macroinvertebrates	Wetlands	Herpetofauna community
Night sky resources	Fish Community	Invasive plants	
Acoustic resources			

The approach of the NRCA was to use existing data to evaluate the condition of natural resources at HOFU. Thresholds for condition (good, moderate concern, and significant concern) were obtained from a variety of resources such as federal and state regulations (e.g., water quality criteria), peer-reviewed literature, study reports, and in some cases when threshold values were not available, best professional judgment. If possible, trends in the condition (improving, declining, or stable) were also noted. And finally, an estimate of the confidence in the assessment based on the quality and quantity of available information (high, medium, low confidence) was also provided. The assessment of condition used standardized symbology provided by NRCA guidelines as presented in Table E-2.

Table E-2. Symbol key legend used to report natural resource condition, trend, and confidence in data used for the assessment.

Condition Status		Trend in Condition		Confidence in Assessment	
	Good Condition		Condition is Improving		High
	Moderate Concern		Condition is Unchanging		Medium
	Significant Concern		Condition is Deteriorating		Low
	Condition Status Unknown; Consequently, Trend is also Unknown and Confidence is Low				

Physical Resources Summary

The National Park Service Air Resources Division (NPS ARD) oversees the national air resource management program for the NPS and assesses the condition of air quality metrics for all NPS units. The NPS ARD uses data from local, state, and federal monitoring programs and interpolates and interprets these data over a five-year period to estimate trends in air quality. The NPS ARD used three metrics to assess ozone conditions: the 4th-highest daily maximum 8-hour average ozone concentration, which is the human health standard, and W126 and SUM06 metrics (both ecological standards) that measure exposure to ozone sensitive vegetation. All three of these ozone metrics were rated as significant concern for HOFU. While trends in these metrics were not specifically evaluated for HOFU, NPS ARD regional interpolated trend maps showed an improving trend in the general area of the park. The confidence in the assessment was medium since the condition was based on interpolated data from stations that were distant from the park (Table E-3).

Wet deposition was estimated by the NPS ARD as total nitrogen (N) wet deposition, total sulfur (S) wet deposition, and trends in mercury deposition based on interpolated data. Both total N and total S wet deposition were rated as significant concern for HOFU. Trends in wet deposition were not estimated by the NPS ARD. Threshold standards for air quality related to mercury deposition have not yet been established; however, the trend in mercury deposition was evaluated as unchanging. The confidence in the assessment was medium since the condition was based on interpolated data from stations that were distant from the park (Table E-3).

The NPS ARD estimated visibility as a Haze Index that was based on haze levels on the clearest and haziest days to characterize visibility conditions at NPS units. The visibility at HOFU was evaluated as significant concern. Although the NPS ARD did not estimate trends in visibility for HOFU, NPS

ARD regional haze maps indicated no change on the 20% clearest days and a possible improving trend in visibility on the 20% haziest days. The confidence in the assessment was medium since the condition was based on interpolated data from stations that were distant from the park (Table E-3).

Table E-3. Summary condition table for natural resources at Hopewell Furnace National Historic Site.

	HOFU Condition/Trend		
Metric	**Symbol**	**Description**	**Recommendation**
Air Quality			
Ozone (human health standard)		*significant concern with improving trend*	Continued monitoring by local, state , and federal agencies (data interpolated by the NPS ARD)
Ozone, SUM06 (ecological standard)		*significant concern with improving trend*	
Ozone, W126 (ecological standard)		*significant concern with improving trend*	
Wet N deposition		*significant concern, no trend estimated*	
Wet S deposition		*significant concern, no trend estimated*	
Mercury wet deposition		*Condition threshold not established but trend was stable*	
Visibility		*significant concern, no trend estimated*	
Night sky resources		*significant concern, no trend estimated*	Continued monitoring of night sky resources based on NSNSD guidance
Acoustic environment		*significant concern, no trend estimated*	Based on modeled data, field data from HOFU would be beneficial
Water Resources			
Water quality- trace metal		*good condition, trend unknown*	Continue with MIDN water quality monitoring

Table E-3 (continued). Summary condition table for natural resources at Hopewell Furnace National Historic Site.

Metric	HOFU Condition/Trend		Recommendation
	Symbol	Description	
Water Resources (continued)			
Water quality- temperature		*moderate concern, stable trend*	Continue with MIDN water quality monitoring
Water quality- dissolved oxygen		*good condition, stable trend*	
Water quality- pH		*good condition, stable trend*	
Water quality- specific conductance		*good condition, stable trend*	
Stream habitat-trace metals in sediment		*good condition, trend unknown*	
Stream habitat-morphology		*French Creek: good concern, stable trend*	Continue monitoring the aquatic macroinvertebrate community using the MIDN protocol.
		Baptism Creek: *moderate condition, stable trend*	
Aquatic macroinvertebrates		*French Creek: moderate concern, stable trend*	
		Baptism Creek: *good condition, stable trend*	
Fish community		*good condition, trend unknown*	
Terrestrial Resources			
Forest structural stage		*good condition, trend unknown*	Continue with MIDN forest monitoring. Data are currently being analyzed by the MIDN with respect to trends.

Table E-3 (continued). Summary condition table for natural resources at Hopewell Furnace National Historic Site.

Metric	HOFU Condition/Trend		Recommendation
	Symbol	Description	
Terrestrial Resources (continued)			
Forest canopy tree cover		*moderate condition, trend unknown*	Continue with MIDN forest monitoring. Data are currently being analyzed by the MIDN with respect to trends.
Forest snags		*significant concern, trend unknown*	
Forest course woody debris		*significant concern, trend unknown*	
Forest regeneration (stocking index)		*moderate concern, trend unknown*	
Forest soil chemistry (acidification)		*moderate concern, trend unknown*	
Forest soil chemistry		*moderate concern, trend unknown*	
Agricultural fields		*condition and trend were unknown*	Review management goals and set criteria for either cultural or natural resource management.
Wetlands		*condition and trend were unknown*	Wetlands were surveyed in 2014-2015; data are not yet available.
Invasive plants		*significant concern, trend unknown*	Pursue efforts for funding to monitor and eradicate invasive vegetation.
Focal Communities			
Avian community		*good condition, trend unknown*	Conduct avian monitoring.
Mammal community		*moderate concern, trend unknown*	Conduct mammal monitoring and a focal deer density study.

Table E-3 (continued). Summary condition table for natural resources at Hopewell Furnace National Historic Site.

Metric	HOFU Condition/Trend		Recommendation
	Symbol	Description	
Focal Communities (continued)			
Amphibian community	Yellow circle	*moderate concern, trend unknown*	Conduct herpetofauna monitoring.
Reptile community	Yellow circle	*moderate concern, trend unknown*	

NPS Natural Sounds and Night Skies Division (NSNSD) monitors night sky resources and natural lightscape for park units. The NSNSD surveyed night sky resources at HOFU in August 2014. The Anthropogenic Light Ratios or ALR (measures of sky brightness related to anthropogenic sources) were found to be of moderate concern for HOFU (both ground based and modeled). Other parameters measured, Bortle Dark Sky Scale and Sky Quality Meter readings, were found to be in the significant concern range. At these light levels, the Milky Way may be visible overhead but has typically lost most of its detail and is not visible along the horizon. Zodiacal light was rarely seen (moderate concern). Anthropogenic light likely dominates natural celestial features and shadows from distant lights may be seen. Overall the condition of the night sky at HOFU scored as significant concern. The data were of good quality and were recent; however, since monitoring night sky resources has just recently been done the confidence in the assessment was medium (Table E-3).

In the National Park setting the acoustic environment can be made up of natural, cultural, and historic sounds depending on the purpose and values of the park. The NPS Natural Sounds Team collects sound data and provides management objectives based on the needs of the park. The acoustic environment has not yet been monitored but it has been modeled for HOFU. The modeled noise impacts for HOFU were estimated as significant concern with an unknown trend, and the confidence in the assessment was medium since the estimate was based on modeled data as opposed to field data (Table E-3).

Water and Water-Related Resources

The primary water resources at HOFU are streams: French Creek, Baptism Creek, Spout Run, and a few smaller unnamed streams. The headwaters of French Creek originate from the outfall of Hopewell Lake which is within French Creek State Park, and therefore the water quality of French Creek is influenced by Hopewell Lake. All streams within HOFU were designated as Exceptional Value streams and protected for Migratory Fishes (MF); outside of the park, the downstream reach of French Creek was designated as a Trout Stocked Fishery (TSF). Water quality and trace metal contaminants in surface water have been monitored periodically in the past (1992, 2002, and 2009), and the MIDN has recently established continuous water quality monitoring at HOFU (2010 to present). All trace metal concentrations in surface water were within acceptable limits set by the US

Environmental Protection Agency criteria for protection of aquatic organisms. The MIDN data have not yet been formally analyzed; however, most parameters (dissolved oxygen, pH, and specific conductance) were within acceptable ranges for MF/TSF streams. Water temperature exceeded the maximum limit for TSF streams 23-45% of the time (depending on location) indicating that water temperature was of moderate concern. The trend for these parameters was assessed as stable best on best professional judgment. The confidence in the evaluation of trace metals in surface waters was high, while the confidence in the assessment of the other parameters measured by the MIDN was medium due to the ongoing analyses of the data by the Network (Table E-3).

Stream sediment trace metal concentration, streambed habitat, and stream morphology pertinent to habitat quality were evaluated as part of the trace metal study conducted in 2009. The trace metal study sampled five sites (one reference site on Baptism Creek, one above the ironworks at the outfall of Hopewell Lake, and three sites downstream of the ironworks on French Creek). The MIDN continued streambed habitat monitoring as part of their aquatic macroinvertebrate sampling that was initiated in 2009 and continues to present. The MIDN samples one site on French Creek and another reference site at Baptism Creek. Both the trace metal study and the MIDN measured a variety of streambed habitat parameters such as quality of substrate, channel morphology, bank structure, and quality of riparian areas. The trace metal study in 2009, observed that only copper was found to exceed the probable effect concentration (the concentration at which harmful effects on aquatic communities were likely to be observed) in streambed sediments. Streambed habitat quality condition was based on the MIDN sampling from 2009-2012 (more recent data have yet to be interpreted) from one site on French Creek and a reference site on Baptism Creek. In MIDN assessment, the Baptism Creek site had suboptimal ratings for epifaunal substrate cover, embeddedness, velocity and depth, sediment deposition, channel flow, riffle frequency, and bank stability and was evaluated as moderate concern. The French Creek site had suboptimal ratings for epifaunal substrate cover, embeddedness, sediment deposition, riffle frequency, and bank stability, but overall scored in better condition (good condition) than the Baptism Creek reference site. Based on the MIDN sampling, the condition of French Creek was evaluated as good condition with a stable trend; while the condition of Baptism Creek was assessed as moderate concern with a stable trend. The confidence in the assessment was high since the data were recent (Table E-3).

The aquatic macroinvertebrate community was surveyed in 2008 at five sites (four on French Creek, and one reference site on Baptism Creek) as part of the trace metal study. The MIDN adopted aquatic macroinvertebrate communities as a vital sign metric and they have been monitored at HOFU at two sites (one on French Creek, and a reference site on Baptism Creek) from 2009 to present (although only data from 2009-2012 have been interpreted). Both the 2008 study and the MIDN used similar metrics (although some were different) to assess the condition of the aquatic macroinvertebrate community. These metrics included: total taxa richness, Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa richness, percent of Diptera and non-insects, percent abundance of the dominant two taxa, percent abundance of scrapers, modified Beck's index, percent abundance of intolerant taxa with a pollution tolerance value of ≤ 2, percent abundance of clingers, Shannon diversity index, percent abundance of Plecoptera and Trichoptera-Hydropsychidae, and Hilsenhoff Biotic Index (HBI). Based on the data from both the 2008 sampling and the MIDN aquatic macroinvertebrate monitoring, the condition of the community for French Creek was evaluated as moderate concern, while Baptism Creek was evaluated as good. The trend for both sites was estimated as stable since it the condition has been relatively stable for past 4-5 sampling years. The confidence in the assessment was high since the data were recent and the MIDN plans to continue aquatic macroinvertebrate sampling at HOFU (Table E-3).

The fish community at HOFU has been surveyed twice, with the most recent survey occurring in 2002. An IBI developed for New Jersey streams and based on the Environmental Protection Agency's Rapid Bioassessment Method was used to evaluate the fish community at HOFU. Metrics used in the IBI included species richness, trophic composition, and abundance. The condition of the fish community was evaluated as good condition for both survey periods. Trends could not be estimated because it was unclear if the two survey efforts used similar sampling protocols. The confidence in the condition for the individual survey efforts was rated as high (Table E-3).

Ecosystem Integrity

The majority of the landscape at HOFU is forested woodlands and the MIDN monitors forest health at HOFU as part Vital Signs Monitoring Program. Metrics used by the MIDN to evaluate forest health include forest community structure, density and composition of tree seedlings, monitoring selected herbaceous species as indicators of deer browsing, detection of forest pests and diseases, detection of invasive plants, status of coarse woody debris and snags, and measures of soil chemistry. The most recent monitoring by the MIDN in 2011 indicated that overall the condition of forest health at HOFU was of moderate concern. Two metrics (snags and coarse woody debris were evaluated as significant concern. Canopy tree condition was rated as moderate concern and only forest structural stage was rated as good condition. Soil chemistry was only sampled in 2012 and was of moderate concern, but sampling in earlier years (2007 to 2010) indicated that both soil chemistry parameters were of significant concern. The MIDN has not yet analyzed the forest health data for trends, but with continued sampling trends will be estimated. The confidence in the assessment was high (Table E-3).

The fields at HOFU are agriculturally managed areas that are maintained as hay fields, pastures for livestock, and crops. They are small parcels of land totaling 55 ha over 12 fields. The fields have never been surveyed for vegetation communities and have only been mentioned in passing in surveys of other focal communities (e.g., birds and mammals). Their small size makes them unlikely to support grassland bird communities. Thus, there were no data on the condition of the agricultural fields and the condition was rated as unknown. Since the condition was unknown trends could not be estimated and the confidence in the assessment was low (Table E-3).

The wetlands at HOFU are currently being mapped (2014-2015) and since the data are still being interpreted. Therefore, the condition of the wetlands was evaluated as unknown. Since the condition was unknown trends could not be estimated and the confidence in the assessment was low (Table E-3).

Invasive plants are prevalent at HOFU and have been recorded at various times over the past several decades. Twenty percent of the plant species recorded in the park were Pennsylvania listed invasive species or non-native. In 2006, when the invasive vegetation was mapped, approximately two-thirds of park had heavy infestation (greater than 6.3% of the park area). Based on that assessment the invasive plants were rated as significant concern. There is a strategic plan to monitor and control invasive vegetation in the park; however, current NPS base funding provides minimal support for invasive plant management. The confidence in the assessment was medium since the last survey effort was done in 2006 and the density of invasive plants could be higher due to a lack of funding to support invasive plant control (Table E-3).

Focal Animal Communities

The avian community at HOFU has been surveyed twice over the past two decades with the most recent survey in 2001. The condition of the avian community was evaluated using a guild based Bird Community Index (BCI) developed for the Mid-Atlantic Piedmont and Coastal Plain region The BCI incorporates the percent of species in nine bird guilds in three biotic elements (structural, functional, and compositional, three guilds per biotic element) to rank the avian community during the breeding season. Using this system both survey efforts were assessed as good condition for the breeding bird community. Long term data were not available to evaluate trends and confidence in the assessment was medium due to the age of the data. The grassland bird community was not assessed because the agricultural fields at HOFU are likely too small to support grassland bird communities (Table E-3).

The mammal community, excluding bats, was surveyed at HOFU once in the mid-1990s and a focal study on bats was completed in 2005. A bat study was also conducted in 2014; however, the data have not yet been interpreted. The metric used to assess the mammal community was the percent of observed species in comparison to the percent of species recorded in the park. Fifty percent (21 species) of the expected mammal species have been documented in the park, and the condition was evaluated as moderate concern. Trends were not evaluated due a lack of long term data and the confidence in the assessment was low (Table E-3).

Amphibian and reptile communities have been surveyed twice over the past three decades, with the most recent survey in 2000 to 2001. The metric used to evaluate the condition of the herpteofaunal community was the percent of observed species as compared to the percent of species observed in Berks and Chester Counties by the Pennsylvania Amphibian and Reptile Survey and likely to be present at HOFU based on suitable habitat. Based on the most recent data and best professional judgment this community was assessed as moderate concern. The trend was unknown as the two survey efforts used different methods. The confidence in the assessment was medium due to the age of the data used to assess this community (Table E-3).

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Acronyms

BCI: Bird Community Index

DBH: Diameter at Breast Height

EPT: Ephemeroptera, Plecoptera, Trichoptera Species Richness

GETT: Gettysburg National Military Park

GIS: Geographic Information System

GRI: Geologic Resources Inventory

HBI: Hilsenhoff Biotic Index

HOFU: Hopewell Furnace National Historic Site

IBI: Index of Biological Integrity

IDA: International Dark-Sky Association

MIDN: Mid-Atlantic Network

NCBN: Northeast Coastal and Barrier Network

NER: NPS Northeast Region

NETN: Northeast Temperate Network

NHS: National Historic Site

NPS: National Park Service

NPS ARD: National Park Service Air Resources Division

NPS NRI: National Park Service Nationwide Rivers Inventory

NPS WRD: National Park Service Water Resources Division

NSNSD: Natural Sounds and Night Skies Division

NVC: National Vegetation Classification

PIF: Partners in Flight

PA DCNR: Pennsylvania Department of Conservation and Natural Resources

PA DEP: Pennsylvania Department of Environmental Protection

PARS: The Pennsylvania Amphibian and Reptile Survey

PEC: Probable Effect Concentration

PNHP: Pennsylvania Natural Heritage Program

PVT: Pollution Tolerance Value

USACE: US Army Corps of Engineers

USDA: U.S. Department of Agriculture

US EPA: U.S. Environmental Protection Agency

VAFO: Valley Forge National Historical Park

WNS: White-nose Syndrome

1. NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement—not replace—traditional issue-and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

NRCAs Strive to Provide…

Credible condition reporting for a subset of important park natural resources and indicators

Useful condition summaries by broader resource categories or topics, and by park areas

- Are multi-disciplinary in scope;[1]
- Employ hierarchical indicator frameworks;[2]
- Identify or develop reference conditions/values for comparison against current conditions;[3]
- Emphasize spatial evaluation of conditions and GIS (map) products; [4]
- Summarize key findings by park areas; and [5]
- Follow national NRCA guidelines and standards for study design and reporting products.

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for

[1] The breadth of natural resources and number/type of indicators evaluated will vary by park.

[2] Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas

[3] NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-up response (e.g., ecological thresholds or management "triggers").

[4] As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.

[5] In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators; recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but, in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Important NRCA Success Factors

Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline

Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)

Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What an NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

NRCA Reporting Products…
Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations
(near-term operational planning and management)
Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values
(longer-term strategic planning)

Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public
("resource condition status" reporting)

Over the next several years, the NPS plans to fund an NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.

[6] An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

[7] While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

[8] The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

2. Introduction and Resource Setting

2.1. Introduction

2.1.1. History and Enabling Legislation

Hopewell Furnace National Historic Site (HOFU) showcases an example of rural iron production from the late 18th to the late 19th centuries in America, including iron making processes and technologies, forest management practices for industrial production, and the related economic, social, agricultural and transportation, and is significant primarily for its cultural resources (NPS 2007). The park's 343.2 hectares (848.06 acres) encompass more than 81 historical structures, including the original masonry blast furnace, ironmaster's house, tenant buildings, smaller outbuildings, farm houses, a school house, church ruins, as well as restorations of buildings used for casting, fuel storage and fuel loading. The pastoral nature of the park provides a view of early industrial Americana within a long standing conservation relationship between nature and industry (NPS 2013).

The cold blast charcoal iron furnace at Hopewell operated for 113 years from 1771 to 1883. The site is representative of the hundreds of iron plantations that flourished in the 18th and early 19th centuries and laid the foundation for American Industrialization (NPS 2013). Outcrops of locally iron-rich rock provided ore that was refined in HOFU's furnace and the surrounding hardwood forests provided charcoal to fuel the blast furnace. Most of the ore used at HOFU came from three local mines (Hopewell, Jones, and Warwick Mines), all of which were outside of the park boundaries. The ore deposits contained abundant magnetite and accessory sulfide minerals enriched in arsenic, cobalt, copper, and other metals (Sloto and Reif 2011). Water was diverted from streams and ponds to power the furnace's waterwheel (Neff and Sharpe 1993, Comiskey and Callahan 2008). The opening of Hopewell Furnace coincided with the beginning of the Revolutionary War, and Hopewell's founder, Mark Bird, produced cannon shells and other supplies for the war including the casting of 115 cannons for the Colonial Navy (Sloto and Reif 2011). The park is rich in African American culture as Bird was the largest slave owner in Berks and Chester Counties, Pennsylvania (PA), and future owners were sympathetic to run-away slaves (Shean-Hammond 2011). Hopewell Furnace's most profitable period was under the ownership of Clement Brooke in 1820s when the furnace was operating in excess of 300 days per year. Hopewell Furnace produced as many as 23 types and sizes of cooking and heating stoves and many other household cast iron products which found a ready market in Philadelphia. The most profitable product was the popular Hopewell Stove (Sloto and Reif 2011).

The park is located 80.5 km (50 mi) northwest of Philadelphia and straddles the Berks-Chester County border in southeastern PA. The ironworks village and furnace were discovered during the construction of the French Creek Demonstration Recreation Area by the Works Progress Administration and the Civilian Conservation Corps (WPA/CCC) Depression programs. HOFU was established as the second National Historic Site in the National Park Service for its nationally significant historic values (NPS 2007). Originally it was part of French Creek National Recreation Demonstration Area (1935) designed primarily for the use of people from the Philadelphia urban region. The park's enabling legislation was "to preserve the iron making community as a significant way of life and work in the late 18th and 19th centuries" (Comiskey and Callahan 2008). The focus for resource protection emanating from the park’s enabling legislation therefore centers on its cultural and historical values.

HOFU is managed by the NPS under shared administration with Valley Forge National Historical Park (VAFO) and is part of the Mid-Atlantic Inventory and Monitoring Network (MIDN). Hopewell Furnace National Historic Site (NHS) lies at the center of Hopewell Big Woods, the largest contiguous forest in southeastern PA (over 73,000 acres) and one of the most important natural areas in the region. French Creek State Park, State Game Lands #43, Crow's Nest Preserve, and the privately owned Windsome Farm border the park (Figure 2). The Hopewell Big Woods Partnership is headed by the Natural Lands Trust, a group of over 40 agencies, private non-profits, and municipal entities (Hopewell Big Woods 2013)

2.1.2. Geographic Setting

Hopewell Furnace NHS lies within the Piedmont Upland and Conestoga Valley sections of the Piedmont Province (Tiebout 2003, Yahner et al. 2001). Elevations within the park range from 140 m (460 ft) in the eastern section of the park to a high of 280 m (920 ft) in the northern section of the park. The southern two-thirds of HOFU are dominated by relatively moderately topography with little relief, with the exception of one forested elevation near the southern border of the park (Yahner 1998). Geologically, the area is characterized by Precambrian crystalline rocks, Lower Paleozoic metamorphosed sedimentary and sedimentary rocks that give the park its irregular topography (Thornberry-Ehrlich 2010). The geology influences soil patterns at HOFU. Soils within the park vary from well-drained on the gabbro, to deep and poorly drained along the major creeks, to very stony on much of the northern conglomerate (Soil Survey Division Staff 1993).

The park has a much protected rural setting. Two thirds of the park is forested and the forest is an important cultural resource as well as a natural resource. Hopewell Furnace NHS is surrounded by the forestlands of French Creek State Park, and to the south, HOFU is bounded by small-scale agriculture, low-density residential development, and state game lands (Figure 2). The majority of the visitor’s experience at Hopewell is buffered from modern development limiting the intrusion of noise, motion, and non-agricultural views. This broader landscape seamlessly connects with Hopewell Furnace NHS and the adjoining state and land trust lands in a mosaic of fields and forests, reflecting the region’s agricultural heritage (NPS 2007). The state-owned park surrounding HOFU allows much of the French Creek watershed to remain forested, with some 15,000 acres of land surrounding the park under some level of conservation and protection, in contrast to lands outside the park that have been developed for agricultural, residential, and commercial uses (Keener and Sharpe 2004).

At Hopewell Furnace, past human land use disturbances are part of the site’s historical relevance. Furnace operators sculpted the landscape, logged the surrounding forests, impounded and diverted local streams, and imported ore and flux from surrounding mines and quarries (Thornberry-Ehrlich 2010). The park is dominated by a disturbed mixed secondary deciduous forest (257 ha, 76% of the park), with principle over story trees of oak, tulip popular, red maple, sycamore, red cedar, ash, elm and black walnut. Agricultural areas consist of 13 fields totaling 55 ha (~16% of the park) that are maintained as pastures, hay fields, crops, and orchards. Developed or historic property is found on 27 ha (8%) of the park (Comiskey and Callahan 2008). Drainage of the area is dominated by French Creek (which originates from Hopewell Lake in French Creek State Park). Baptism Creek drains the east central portion of the park and empties into French Creek (Figure 3). Other small, undefined intermittent tributaries empty into French Creek in many portions of HOFU but remain unnamed. The area is well drained, except along French Creek where floodplain shrublands and forest occur (Yahner 1998).

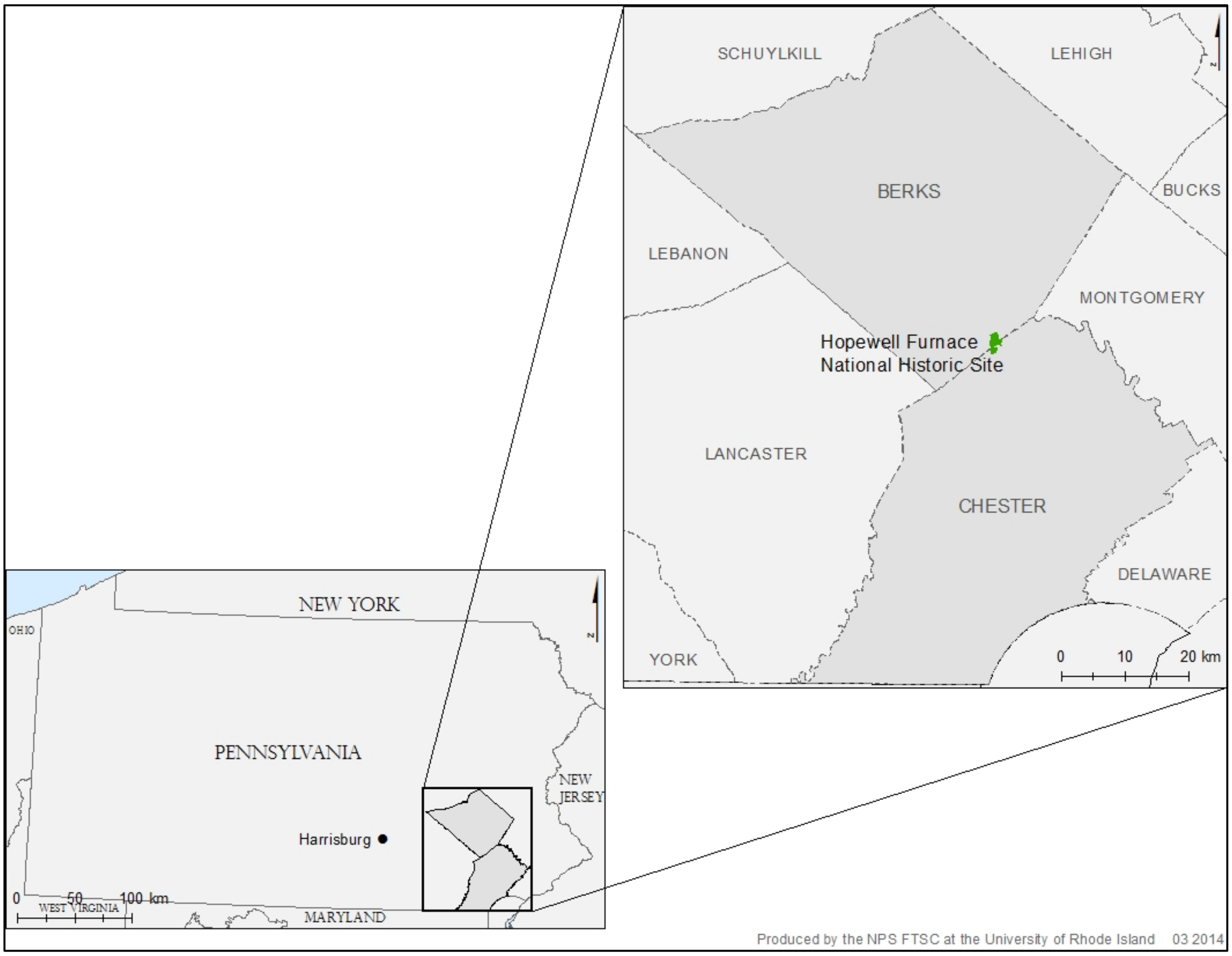

Figure 1. Location of Hopewell Furnace National Historic Site.

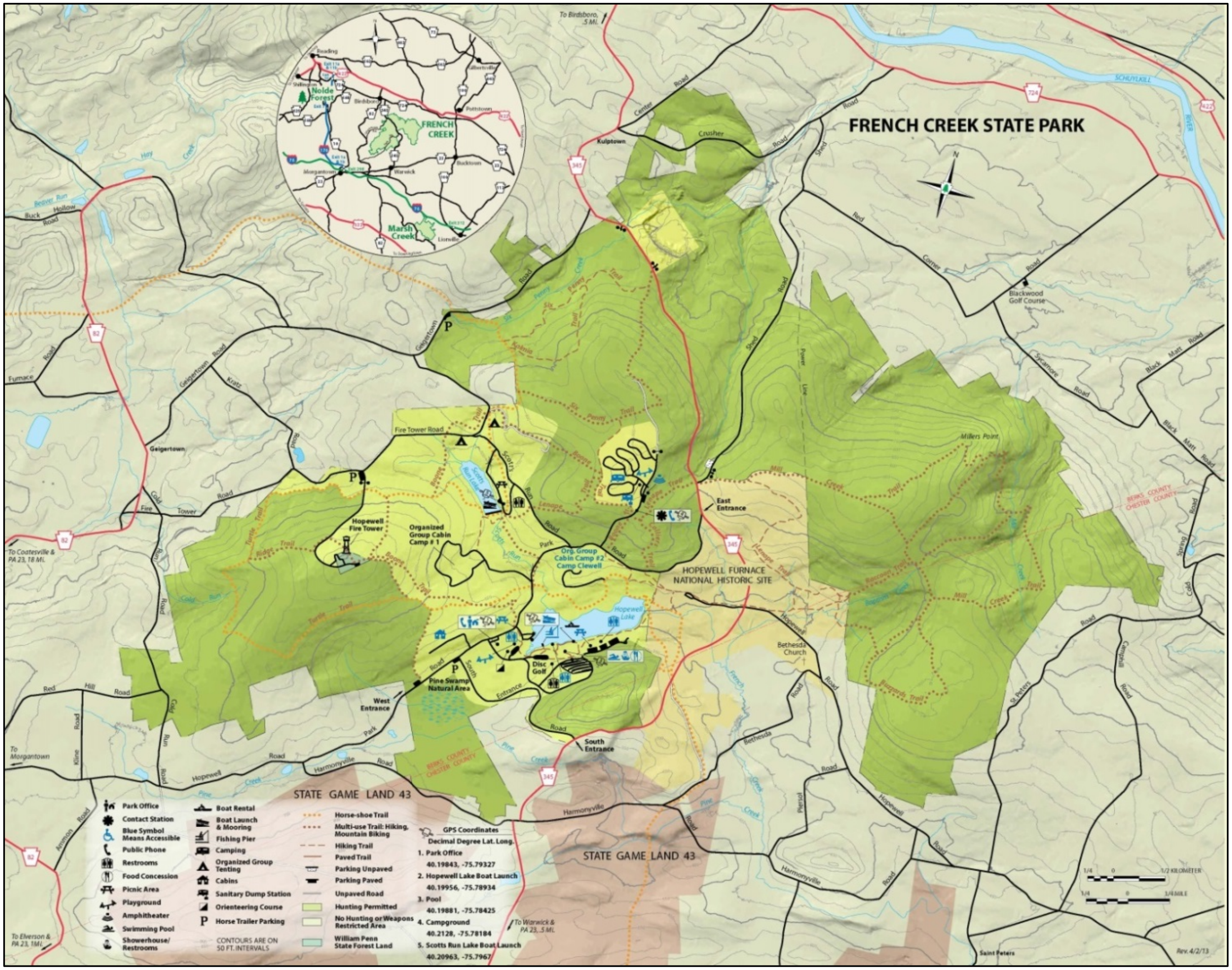

Figure 2. Map of HOFU, French Creek State Park, and State Game Lands #43 (map courtesy of Pennsylvania Department of Conservation and Natural Resources 2014).

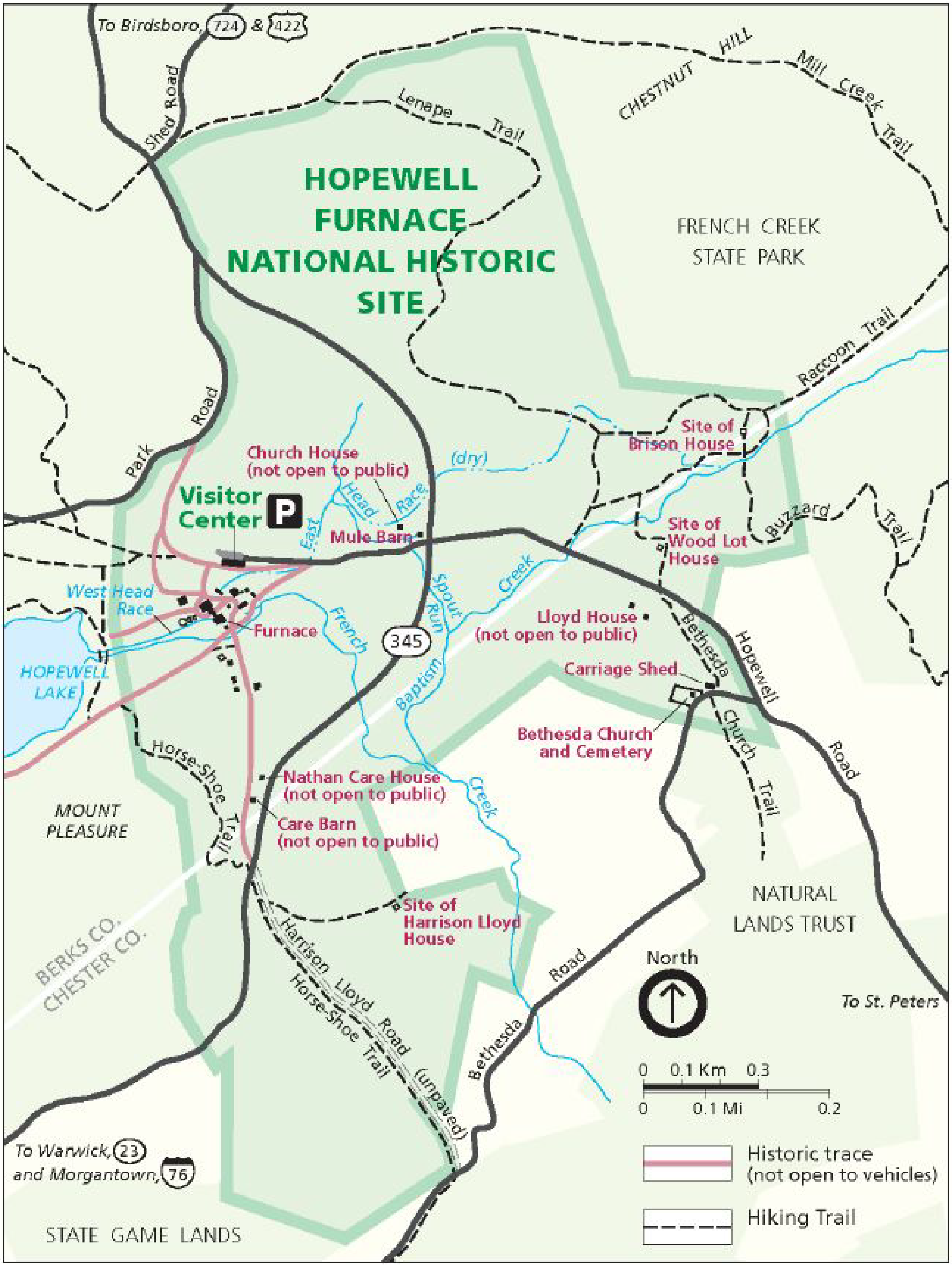

Figure 3. Map of Hopewell Furnace National Historic Site, National Park Service map.

2.1.3. Watershed

Hopewell Furnace NHS lies within the 181 km^2 (70 mi^2) French Creek Watershed. The watershed originates in French Creek State Park and flows 35 km (22 mi) to its confluence with the Schuylkill River (Figure 4). Land in the basin is mostly rural, consisting of forested areas, crop farmland, horse farms, large estates, scattered villages, and smaller residential tracts (Anonymous 2003). Only 16% of the land is developed, with agriculture comprising 36% of the area and the remaining 46% being wooded uses. French Creek and its six major tributaries (68.8 km) are designated as a PA Scenic Rivers. Rock Run, French Creek, Pine Creek, South Branch French Creek, and Birch Run are designated as Exceptional Value (EV) waters (French Creek Watershed Action Plan 2002). The French Creek Watershed has numerous outstanding natural and cultural resources. Upper French Creek, South Branch French Creek, and Middle French Creek are designated as EV waters and have a good biodiversity of aquatic organisms (French Creek Watershed Action Plan 2002). The watershed is also one of the few watersheds in the region without any waters listed on the 303(d) list of impaired waters (as of the 1998 watershed assessment) (French Creek Watershed Action Plan 2002).

The estimated population of the French Creek Watershed was 25,246 in 1998 with a projected population of 31,348 in 2020, an increase of 24%. The percent of impervious cover (e.g., pavement, concrete, rooftops) of the French Creek Watershed was estimated to be 6.5% in 1998, and was projected to increase to 7.5% by 2020 (French Creek Watershed Action Plan 2002). Generally, when impervious surfaces cover less than 10% of the land area, a watershed functions well and supports sensitive resources. When impervious surface area increases above 10%, impacts to water quality occur; and watersheds with more than 20% impervious cover often show flow patterns and water quality of indicative of a degraded or impaired watershed (French Creek Watershed Action Plan 2002). The projected population growth raises concerns about additional stormwater and pollutant runoff problems and increased flooding (French Creek Watershed Action Plan 2002).

2.1.4. Geologic Setting

At HOFU the regional geologic resources are an integral part of the parks cultural and historic fabric. Outcrops of locally iron-rich rock provided ore that was smelted in the Hopewell furnace. Most of the ore used at HOFU came from three local mines (Hopewell, Jones, and Warwick Mines), all of which were outside of park boundaries (Inners and Fergusson 1996, Thornberry-Erhlich 2010). The ore deposits contained abundant magnetite and accessory sulfide minerals enriched in arsenic, cobalt, copper, and other metals (Sloto and Reif 2011). Thus, the site’s geologic resources and their role in history are an integral part of interpretation for park visitors.

The park straddles the boundary between the two geologic divisions of the Piedmont. Southeast of Hopewell Lake, metamorphic rocks of the Crystalline Uplands form Mount Pleasure and nearby hills; these rocks range in age from about 580 million to 1 billion years old. The rest of the area is underlain by 185- to 200-million-year-old sedimentary and igneous rocks of the Mesozoic Lowlands (Inners and Fergusson 1996) (Figure 5, Figure 6). The boundaries between these two geologic divisions are unconformities, or erosional surfaces, that separate rocks of very different geologic ages and are responsible for the topography of the park’s landscape. Another significant geologic feature of the area is the contact between the diabase, the youngest rock in the park area, and all of the older rocks. This is normally an intrusive contact formed by the forceful injection of a molten magma (melted rock which later crystallized as diabase) into previously existing rocks (Inners and Fergusson 1996). French Creek Falls, a unique geologic feature of the park, is formed from a series of diabase boulders (NPS Nationwide Rivers Inventory [NRI] 2014).

The Triassic Stockton Formation (refer to Figure 6) outcrops within the park and regionally contain plant fossils, invertebrate body and trace fossils, mollusk fossils, fish and amphibian remains, and reptilian and dinosaurian body fossils and footprints. The highly erosion-resistant quartzite of the Cambrian-age Chickies Formation contains the trace fossil Skolithos (worm-like burrows). Dinosaur footprints have been observed locally in sedimentary rocks of the Gettysburg-Newark Basin and approximately 200-million year-old fossil dinosaur tracks are within rocks of the same age at the Limerick Nuclear Power Station, located approximately 16 km (10 mi) to the east of Hopewell Furnace (Inners and Fergusson 1996, Thornberry-Ehrlich 2010). No formal, field-based paleontological resource inventories have been completed in HOFU and the park has no collections of paleontological material; however, the NPS conducted a paleontological inventory from literature of known and potential fossil occurrences in the area, and none were known to exist in the park (Kenworthy et al. 2006).

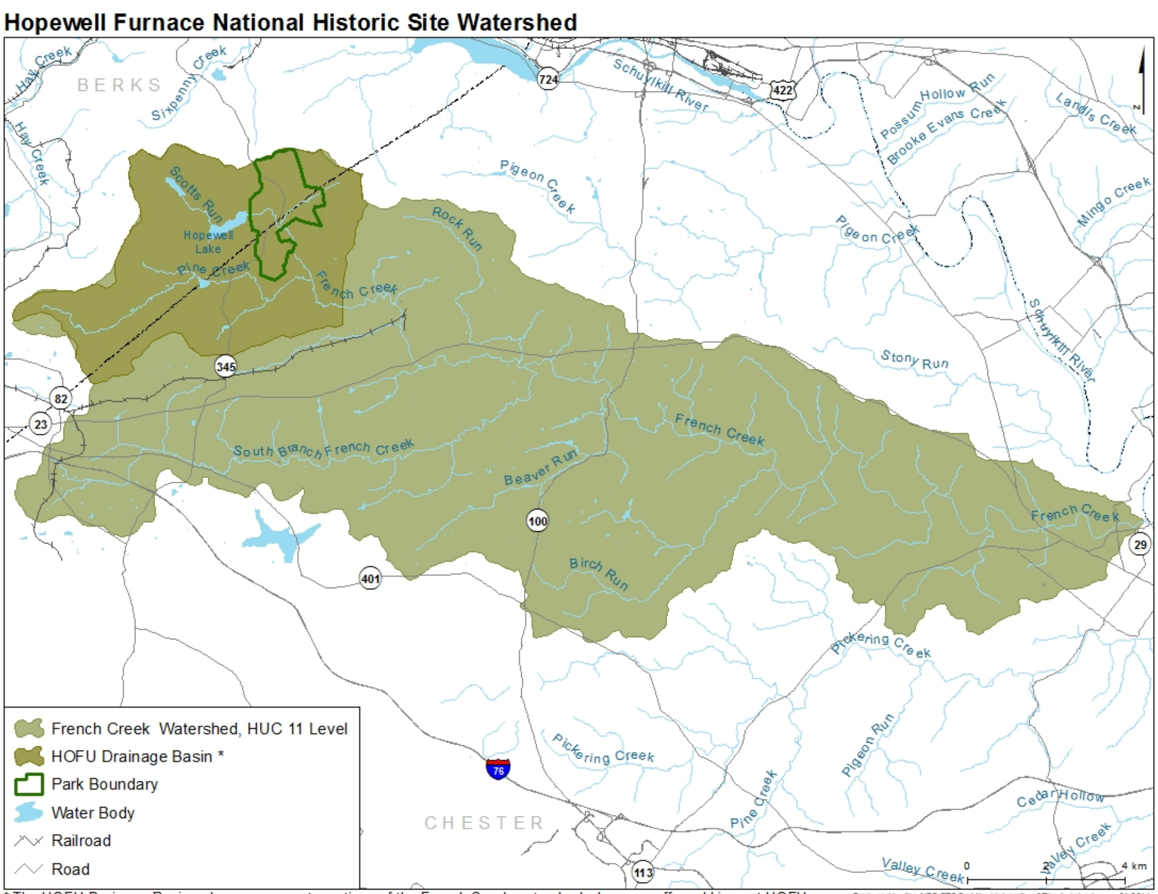

Figure 4. HOFU Drainage basin.

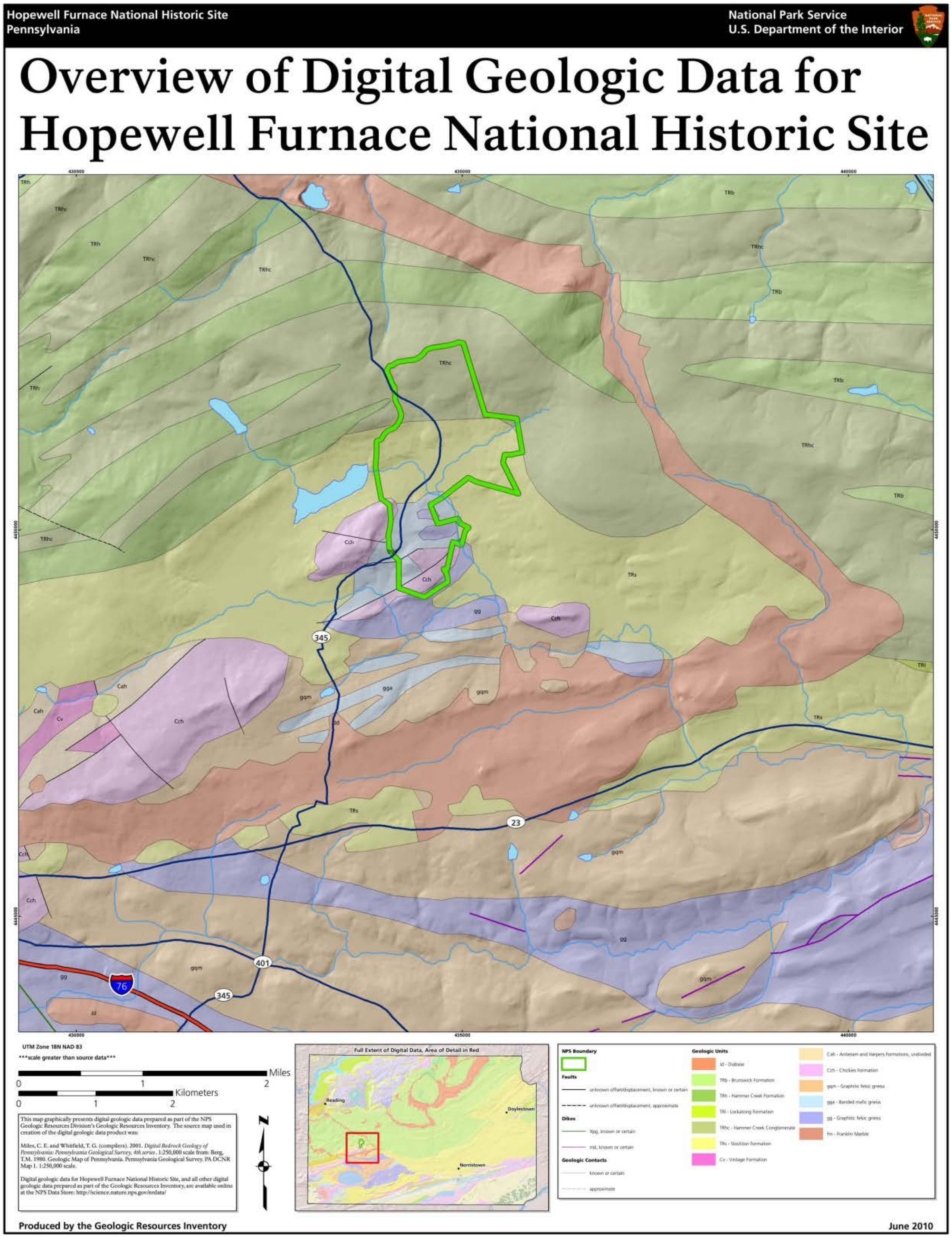

Figure 5. Geologic map of HOFU (figure excerpted from Thornberry-Ehrlich 2010).

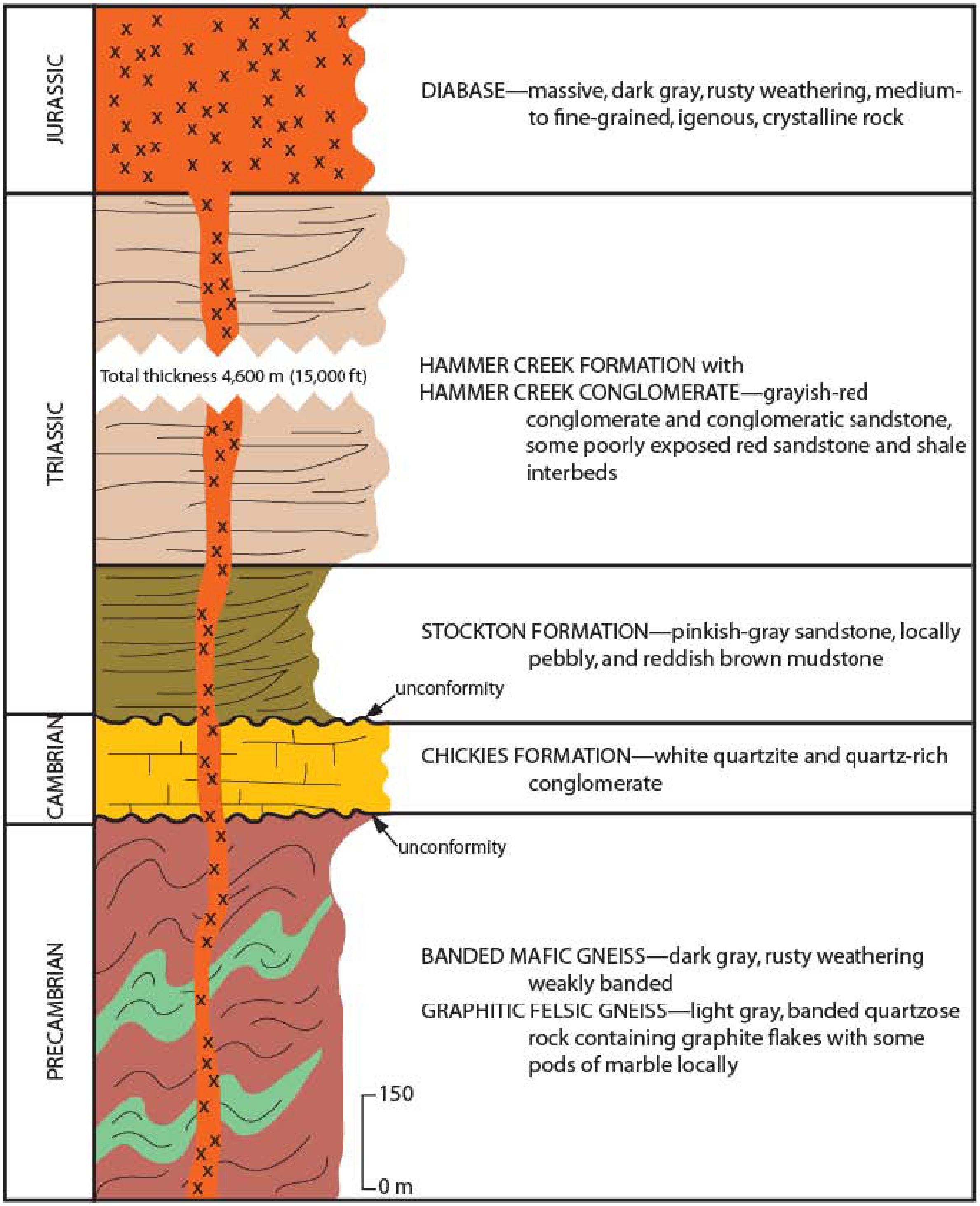

Figure 6. Geologic column of rocks exposed within HOFU (figure excerpted from Thornberry-Ehrlich 2010 that was modified from Inners and Fergusson 1996).

2.1.5. Climate

Hopewell Furnace NHS is located in Southeastern Piedmont region of Pennsylvania. This region is generally considered to have a humid, continental type of climate, but the rolling hills and valleys have an effect on the weather and climate of the various parts of the region (Knight et al. 2011). Prevailing westerly winds carry most of the weather disturbances from the interior of the continent, with the Atlantic Ocean having only an occasional influence on the climate of the area (Davey et al. 2006, Gawtry and Stenger 2007). Coastal storms do, at times, affect the day-to-day weather, especially in the winter. Also, storms of tropical origin can have the greatest effect within this portion of Pennsylvania, causing severe floods in some instances (Gelber 2002).

Precipitation is fairly evenly distributed throughout the year. Annual amounts generally range between 965–1,219 mm (38–48 in). Precipitation is greatest in the late spring and summer months, while February is the driest month, having about 51 mm (2 in) less than the wettest months. In the cold season, surface winds are from the west and northwest, and during the warm half of the year they are from southwest. Thunderstorms follow a frequency that matches the solar cycle, occurring between the equinoxes and reaching a peak near the solstice (Knight et al. 2011). Hail is relatively infrequent, but flash floods and damaging thunderstorm winds affect parts of the region each summer. On average, tornadoes pass through the area about once every three years. The direct effects of an Atlantic hurricane are uncommon, though remnant rains from tropical storms have contributed to the region’s worst floods (Knight et al. 2011). Ice storms, which can cause significant disruption, occur at irregular intervals, but are primarily confined to the months between December and March (Kocin and Uccellini 2004). The last freeze for the parks typically occurs in early May and the first frosts appear in October.

HOFU has experienced flooding and localized erosion problems since its inception in the late 1700s (US Army Corps of Engineers [USACE] 2011). Flooding originates from French Creek (from storm overflow events at the Hopewell Lake spillway) and from local runoff from park gravel roads and the parking lot. Flooding has damaged historic structures (e.g., the Cast House) in the past. In an effort to identify the source and reduce the frequency of flooding and erosion to HOFU facilities, the park sought the assistance of the USACE. Recommendations from the USACE study were to remove the existing footbridge and abutments, install a new longer span footbridge over French Creek, possible channelization within French Creek, and modification to the existing storm management system within HOFU park grounds (USACE 2011).

2.1.6. Visitation Statistics

Over the past 5 years, approximately 50,000 people visit HOFU annually. The highest visitation occurred during the United States Bicentennial in 1976 (NPS Stats 2013b) (Figure 7). It is likely that visitation is higher as visitors recreating in surrounding Hopewell Big Woods and French Creek State Park can enter park property through a variety of hiking trails and would not be counted using the current inductive loop vehicular traffic counter at Mark Bird Lane (E. Shean-Hammond, personal communication, 22 October 2013).

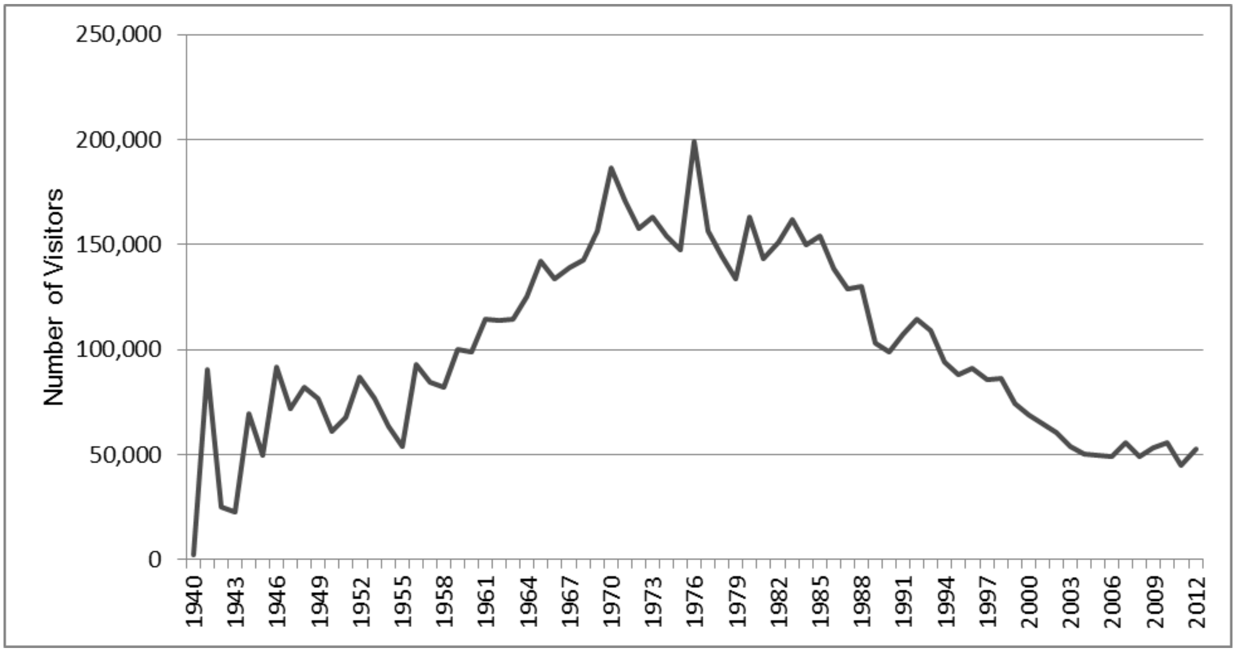

Figure 7. Annual visitation for HOFU.

2.2. Natural Resources Descriptions and Ecological Units

2.2.1. Physical Resources

Air quality metrics monitored by the National Park Service Air Resources Division (NPS ARD) for HOFU are: ozone (both human health and ecological standards), total nitrogen (N) and total sulfur (S) wet deposition, and visibility. The NPS ARD uses data from a variety of federal, state, tribal and local resources to assess air quality at all NPS units nationwide.

Other physical resources at HOFU include nightsky resources and the acoustic environment (NPS 2012a, 2014b). Night sky resources are easily altered and, in many places, are becoming lost in the glow of artificial lights, and can negatively impact the ability to experience dark night skies. Recently the NPS Natural Sounds and Night Skies Division (NSNSD) has recognized the importance of protecting and conserving the night sky as cultural, natural, and scientific natural resource and has developed methodologies for assessing the condition of the nightsky resources in urban and non-urban parks (NSNSD 2013). The NSNSD also collects sound data and provides management objectives based on the needs of the park (NSNSD 2013). The NSNSD (2013) has modeled the acoustic environment at HOFU but has not yet monitored it at HOFU. In the National Park setting, both natural, cultural, historic sounds may be desirable and appropriate depending on the purpose and values of the park. The acoustic environment, like water, scenery, or wildlife, is a valuable resource that can easily be degraded by inappropriate sounds or sound levels and as a result, the acoustic environment requires careful management just as any other park resource.

2.2.2. Water Resources

The primary water resources of the park are streams and small wetlands. French Creek, a tributary of the Schuylkill River, flows through the center of the park and is part of the greater Schuylkill River watershed of southeastern Pennsylvania. French Creek flows from Hopewell Lake that lies within

French Creek State Park. The main tributaries of French Creek are Spout Run and Baptism Creek (Figure 3). The Commonwealth of Pennsylvania designated French Creek as a State Wild and Scenic River in 1982 because of its outstanding natural and scenic values. It also bears the Commonwealth's designations of an Exceptional Value (EV) stream and for Migratory Fishes (MF). French Creek is listed in the National Park Service Nationwide Rivers Inventory (NPS NRI). The NPS NRI is a listing of free-flowing river segments in the United States that possess one or more "outstandingly remarkable" natural or cultural values judged to be of more than local or regional significance (NPS NRI 2014). The Outstandingly Remarkable Values listed by the NPS for French Creek include (1) hydrologic: northernmost, least developed, free-flowing river within the Piedmont Province, (2) historic: river-related National Historic Register sites and an Historic District within the corridor, and (3) geologic: area includes the unique Falls of French Creek, a series of diabase boulders (NPS NRI 2014). The diabase boulders are dikes and sills of impermeable igneous rock that act as groundwater flow boundaries. Such boundaries impede groundwater flow, increasing residence time and concurrent mineralization (Sharpe and Neff 1993).

During the operation of the Hopewell Furnace the water resources were manipulated to provide additional water to the furnace's waterwheel and to provide water for livestock and domestic needs. The existing man-made hydrological structures at HOFU include the waterwheel, the East Headrace, and the tailrace. The East Headrace diverted water from Baptism Creek and Spout Run, but no longer feeds the water wheel. The West Headrace diverted water to the waterwheel from Baptism Creek and Spout Run and was redesigned/modernized in the 1960s; while the tailrace drained from the waterwheel into French Creek. Currently the waterwheel is fed through an intake pipe that takes water from the bottom of Hopewell Lake. (Sharpe and Neff 1993, Keener and Sharpe 2004). Other water resources within HOFU include wetlands, numerous springs, floodplains, riparian zones, and an extensive groundwater system (Comiskey and Callahan 2008).

Water quality and streambed habitat quality can affect aquatic communities. The headwaters of French Creek are within French Creek State Park, which abuts park land. French Creek State Park contains nearly all of the French Creek Basin upstream of the park, and therefore it is the source of much of the stream water found in French Creek within the park's boundaries. French Creek drains from Hopewell Lake, which is located within the state park, and thus activities and water quality of the lake greatly influence the water quality of French Creek (Keener and Sharpe 2004). Overflow events from the Hopewell Lake spillway and local storm runoff from the park's gravel roads and parking lot also impact the water quality of French Creek (USACE 2011). Streambed habitat can also affect aquatic organisms, and while concentrations of trace metals, except for copper, met the guidelines for the protection of aquatic organisms, streambed habitat at some sites on French Creek were degraded, possibly related to lack of stable substrate, erosion, and deposition (Sloto and Reif 2011). Historical land use and current management practices (e.g., iron smelting, agriculture, mowing fields, livestock grazing, stream restriction caused by the footbridge) within and adjacent to HOFU may also impact water quality and the aquatic communities of French Creek (e.g., aquatic macroinvertebrate and fish communities).

2.2.3. Ecosystem Integrity and Focal Communities

Hopewell Furnace National Historic Site includes 343.2 ha of rolling countryside. About 75% of the park land is forested with secondary and other disturbed forests. Historical and recent changes of the regional forested landscape have occurred since European colonization including repeated logging, fires, and the of loss dominant tree species to disease (e.g., Dutch elm disease: American elm, Ulmus americana; Chestnut blight: American chestnut, Castanea dentata) (Russell 1987). The forest ecosystem was and is an integral part of the Hopewell Furnace cultural landscape, providing charcoal to fuel the furnace and cleared lands use for agricultural and livestock grazing. Abandonment of the furnace operations and farmlands in late 19th century has resulted in a secondary successional landscape that exists to the present time (Russell 1987).

The National Vegetation Classification (NVC) mapping effort in 2003 identified the most common vegetation type as Dry Oak–Heath and Dry Oak–Mixed Hardwood Forest which covered 203 ha (approximately 56% of the park). The least common natural vegetation types included Birch Rocky Slope Woodland and other uncommon vegetation types included shrub wetlands (Buttonbush Wetland and Highbush Blueberry–Meadowsweet Wetland). The single occurrence of the Buttonbush Wetland was within an active pasture and was described by Podniesinski et al. (2005) as very degraded. Disturbed vegetation types, especially the modified successional forest, had no NVC equivalent and were noted as park-specific types. Agricultural grasslands (anthropogenic vegetation) were classified within the Orchard Grass–Sheep-Sorrel Herbaceous Alliance. None of the vegetation types described at Hopewell Furnace NHS were classified as rare in PA (Podniesinski et al. 2005).

Approximately 700 species of vascular plants have been observed in the park (refer to Appendix Table 48), including five PA listed plant species. Invasive vegetation is a major threat to natural vegetation at HOFU with 20% of the plant species being either PA state-listed invasive (27 species, Table 1) or non-native (85 species) (refer to Appendix Table 48).

A variety of wildlife has been recorded at HOFU. Species identified as existing or potentially present in the park include 18 fish species, various aquatic macroinvertebrates including two species of crayfish, 190 species of birds, 42 mammals, 20 amphibians, and 20 reptiles. These include five federal and/or state special status vertebrate species and seven species of state conservation concern.

Table 1. Pennsylvania state listed invasive species observed at HOFU (PA DCNR 2014b).

Scientific Name	Common Name
PA DCNR listed Invasive Plants	
Acer platanoides	Norway maple
Ailanthus altissima	Tree of heaven
Alliaria petiolata	Garlic mustard
Berberis thunbergii	Japanese barberry
Carduus nutans	Nodding plumeless thistle
Celastrus orbiculatus	Asian Bittersweet
Cirsium arvense	Canada thistle
Cirsium vulgare	Bull thistle
Elaeagnus umbellata	Autumn-olive
Euonymus alata	Winged euonymus
Hedera helix	English ivy
Lespedeza cuneata	Chinese lespedeza
Ligustrum obtusifolium	Border privet
Lonicera japonica	Japanese Honeysuckle
Lonicera morrowii	Marrow's honeysuckle
Lonicera tatarica	Tartarian honeysuckle
Microstegium vimineum	Japanese stilitgrass
Ornithogalum umbellatum	Star of Bethlehem
Persicaria perfoliata	Mile-a-minute
Perilla frutescens	Beefsteakplant
Potamogeton crispus	Curly pondweed
Rosa multiflora	Multiflora rose
Rubus phoenicolasius	Wine raspberry
PA DCNR Watch Listed Invasive Plants	
Broussonetia papyrifera	Paper mulberry
Hemerocallis fulva	Orange daylily
Holcus lanatus	Common velvetgrass
Morus alba	White mulberry
Poa trivialis	Rough bluegrass
Phyllostachys aurea	Golden bamboo
Schedonorus arundinaceus	Tall fescue
Vinca minor	Common periwinkle
Wisteria sinensis	Chinese wisteria
USGS Native transplants[1]	
Lepomis cyanellus	Green sunfish (fish)
Trachemys scripta elegans	Red-eared slider (turtle)

[1] A native transplant is a species that is indigenous to the US, but is found outside of its native range.

2.2.4. Resources Issues Overview

The most serious threats to natural resources within HOFU are likely those pertaining to the water quality and quantity of French Creek (and associated wetlands) and invasive plants. The water quality of French Creek is likely largely determined by events related to the drainage from Hopewell Lake (e.g., drawdown events, flooding) that lies upstream outside of the park boundaries. Invasive vegetation is becoming more of an issue, primarily along the edges of the fields. Invasive, exotic vegetation is prevalent within the park with a continuous gradient that is lightest in the northern section of the park and heaviest in the southern portion of the park (Ambrose and Åkerson 2006). Typically infested areas included road sides, field edges, along rock walls, and stream banks. Deer browsing may also pose a problem for forest integrity as deer browsing allows invasive plants to propagate (Comiskey and Wakayima 2011). The Mid-Atlantic Exotic Plant Management Team, park staff/volunteers, and Student Conservation Association interns cut and uproot invasive plants (at least 3 days per year) that infringe upon trails and the Historic Village. Management of invasive species is being undertaken through support by VAFO natural resource staff and volunteers.

The water resources at HOFU have been disturbed and/or threatened by a variety of resources such as upstream development, turbidity during high flows, and contamination by septic systems (Keener and Sharpe 2004). French Creek was impounded upstream to form Hopewell Lake and water quality of Hopewell Lake can influence the water quality of this stream. Additionally there are concerns about the stability of the earthen dam at the outlet of Hopewell Lake (Thornberry-Ehrlich 2010). Water quality in the park could also be impacted from heavy metals as a result of leaching from the slag piles. Leachate experiments on slag samples found that four metals (Al, Cu, Fe, and Mn) had potential environmentally problematic concentrations, exceeding thresholds for both drinking water and aquatic life criteria (Piatak and Seal 2012). Erosion and flooding occur along park waterways during seasonal storms and could threaten park infrastructure (Thornberry-Ehrlich 2010, USACE). In an effort to identify the source and reduce the frequency of flooding and erosion to HOFU facilities, the park sought the assistance of the USACE. Recommendations from the USACE study were to remove the existing footbridge and abutments, install a new longer span footbridge over French Creek, possible channelization within French Creek, and modification to the existing storm management system within HOFU park grounds (USACE 2011).

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

The 1993 Statement for Management for Hopewell Furnace National Historic Site directs the National Park Service to preserve and interpret the site to represent an iron making community and a significant way of life and work in the late eighteenth and nineteenth centuries (NPS 1994). Specifically, the purpose of the park is to (NPS 2007):

- provide for the public enjoyment of Hopewell Furnace NHS through a range of learning and recreational opportunities;
- preserve and protect the old Furnace, Mansion House, and other resources that define the natural and cultural landscape known as Hopewell; and

- interpret and share the history of Hopewell and its people.

The parkland is divided into four zones which are differentiated by their designated uses: Eastern deciduous forest (257 ha) designated as conservation of woodlands, recreation, and scientific study; 12 agricultural fields (55 ha); and historic and developed areas (32 ha) set aside for reconstruction and preservation of historic structures and scenery and park operations, maintenance, and visitor service (Sharpe and Keener 2003). Special use permits have been granted to farmers to hay ten fields. The permit fee is paid for in hay or by mowing other fields. The number and location of fields has varied over the past decade from as few as seven fields to as many as 12 (NPS 2007).

Currently, Hopewell Furnace's General Management Plan (GMP) is in planning stages and the park has begun a multi-year planning effort to develop a blueprint for the park’s future (NPS 2015). This is the park's first General Management Plan and will guide the park's management actions for the next several decades.

2.3.2. Status of Supporting Science

The MIDN monitors, or will monitor in the future, several natural resource vital signs and several inventories have been conducted at HOFU (Table 2). Several of these monitoring activities (e.g., forest health monitoring, avian inventory, herpetofauna inventory) have been collaborative efforts among the MIDN, Northeast Coastal and Barrier Network (NCBN), Northeast Temperate Inventory and Monitoring Network (NETN, and Hopewell Big Woods. Much of the GIS data for the park has been housed at the Natural Lands Trust. Data and reports are accessible through the MIDN website and The NPS Integrated Resource Management Applications (IRMA) website.

Table 2. Status of natural resource supporting science at HOFU as of 2013.

Natural Resource	Period of available data	Data type	Source
Air Quality – Ozone, wet deposition, visibility	1995 to present	Inventory and Monitoring	Kohut 2007, NPS Air Resources Division, Sullivan et al. 2011
Aquatic Macroinvertebrate Community	2007, 2009-2014 (no final report as of this NRCA)	Inventory and Monitoring	Lieb et al. 2007, MIDN 2011, Sloto and Reif 2011, MIDN (no final report for 2009-2014 as of this NRCA)
Avian Community	1994, 1999-2001	Inventory	Yahner et al. 1998, 2001
Forest Community	1987, 2002-2003, 2007 to present	Inventory and Monitoring	Ambrose and Åkerson 2006, Comiskey 2013, Comiskey and Wakamiya 2011, 2012, Podniesinski et al. 2005, Russell 1987, Vanderwerff 1994
Fish Community	1990-1992, 2002	Inventory	Gutowski 1996, Sharpe & Keener 2003
Herpetofauna	1994-1996, 2000-2001	Inventory	Yahner et al. 1999, Tiebout 2003
Invasive Plants	1987, 2006, 2007 to present	Inventory. Management activities by the Exotic Plant Management Team. Additional data recorded in the context of other monitoring.	Ambrose and Åkerson 2006, Comiskey 2013, Comiskey and Wakamiya 2011, Russell 1987, Vanderwerff 1994
Mammal Community	1994-1995, 2005 (bats only)	Inventory	Yahner et al. 1997, Hart 2006
Agricultural Fields	No data	No data	No data
Night Sky Resources	2011	Monitoring	NPS Natural Sounds and Night Skies Division 2014
Acoustic environment	No data	No data	No data
Streambed Sediments and Stream habitat	2002, 2009	Monitoring	Sharpe and Keener 2003, Sloto and Reif 2011
Water Quality	1993, 2004, 2010 to present	Baseline and Inventory and Monitoring	MIDN water quality monitoring, Keener and Sharpe 2004, Sharpe and Neff 1993, Sloto and Reif 2011
Wetlands	2002-2003 (mapping data only)	No data, mapping conducted in 2014-2015	Podniesinski et al. 2005, P. Sharpe mapped wetlands in 2014-2015

Sources of Expertise

E. Shean-Hammond, former Superintendent, Hopewell Furnace National Historic Site. 2 Mark Bird Lane, Elverson, PA. 19520

P. Sharpe, Northeast Regional Hydrologist, National Park Service, 200 Chestnut Street, Philadelphia, PA 19106.

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3. Study Scoping and Design

3.1. Preliminary Scoping

3.1.1. Park Involvement

An initial kick-off meeting for the NRCA was conducted on 22 October 2013 at HOFU. Meeting attendees included: Charles Roman, NPS North Atlantic Coast Cooperative Ecosystem Studies Unit Research Coordinator; Peter Sharpe, NPS Natural Resource Condition Assessment Coordinator; Mark Johnson, NPS Mid-Atlantic Network Data Manager; Kate Jensen, NPS-VAFO/HOFU; Deirdre Gibson, NPS-VAFO; Kate Hammond, NPS-VAFO/HOFU; Amy Ruhe, NPS-VAFO/HOFU, James Thorne, former Senior Director of Science Natural Lands Trust; Edie Shean-Hammond, former Superintendent HOFU; Stan Stubbe, Pennsylvania Outdoor Lighting Council; Lauren Ritchey, NPS-VAFO; Mary-Jane James-Pirri, University of Rhode Island. At this meeting, the general approach and framework for the Natural Resource Condition Assessment was presented and attendees toured the park. Park and MIDN staff kindly supplied the author with digital copies of GIS data and other documents. Throughout the compilation of this document the author communicated with HOFU-VAFO park staff (Kate Jensen), Mid-Atlantic Network staff (Mark Johnson), and Regional staff (Peter Sharpe, Charles Roman, William Gawley) for additional information and data for park resources.

3.2. Study Design

3.2.1. Assessment Framework and General Approach and Methods

This Natural Resource Condition Assessment report was organized by Natural Resource Ecosystems. Within each ecosystem, the reporting areas such as specific habitats and/or communities were summarized. Each of the reporting areas was subdivided into the sections listed below:

- *Relevance and Context*: A brief overview of the importance of the natural resource to the park.
- *Data and Methods*: Description of available information (e.g., research studies, surveys, inventory and monitoring) for the resource and the methodology used to obtain data, including the period of data collection.
- *Reference Condition:* Metrics and benchmarks that were used to compare the current condition of the resource, including the justification for the metric and benchmark. Depending on the available data, there may be one or several metrics for the resource. Whenever possible established NPS metrics and benchmarks (e.g., NPS vital sign parameters, MIDN forest condition, NPS air quality assessment) or metrics from established monitoring programs (e.g., US EPA water quality monitoring) were used to estimate the condition of the park’s natural resources. In cases where metrics and/or benchmarks were not available, condition was based on the most recent, quantitative, and reliable data for the park or on best professional judgment.
- *Status of the Resource, Condition and Trends*: A summary of the status of the resource based on historic, recent research, and/or monitoring efforts and a statement of current condition

status and trend. In some chapters this may be combined with *Reference Condition* in tabular format, if appropriate.

- *Confidence in Assessment*: A statement of the confidence and/or data used to evaluate the condition (refer to
- and **Error! Reference source not found.**) for each metric previously described in the *Reference Condition* section. A brief justification for the statement of condition is presented if appropriate.
- *Data Gaps*: A description of data gaps, if any, in the assessment of resource condition.
- *Threats*: A brief synopsis of known threats to the resource.
- *Sources of Expertise*: A list of people that provided unpublished data or personal anecdotes regarding the resource.
- *Literature Cited*: A list of information sources cited in the text.

Table 3. Symbol key legend used to report natural resource condition, trend, and confidence in data used for the assessment.

Condition Status		Trend in Condition		Confidence in Assessment	
	Good Condition		Condition is Improving		High
	Moderate Concern		Condition is Unchanging		Medium
	Significant Concern		Condition is Deteriorating		Low
	Condition Status Unknown; Consequently, Trend is also Unknown and Confidence is Low				

Table 4. Example of interpretation of condition symbols.

Symbol	Interpretation of condition or trend
	Resource is in good condition, its condition is improving, high confidence in the assessment.
	Condition of resource warrants moderate concern; condition is unchanging; medium confidence in the assessment.
	Condition of resource warrants significant concern; trend in condition is unknown or not applicable; low confidence in the assessment.

Since natural resource conditions are typically evaluated for each indicator or metric, the NPS has recently developed guidelines for combining the conditions for different metrics for resources that were represented by one or more metrics. (NPS-NRCA 2013). To determine the combined condition, each red symbol (significant concern) was assigned 0 points, each yellow symbol (moderate concern) is assigned 50 points, and each green symbol (good condition) 100 points. The average condition was calculated and the scale in Table 5 was used to determine the resulting condition (NPS-NRCA 2013). To determine the overall trend the total number of down arrows was subtracted from the total number of up arrows. If the result was -3 or lower, the overall trend was down. If the result is between 2 and -2, the overall trend was unchanging (NPS-NRCA 2013).

Table 5. Range of values from NRCA guidelines when averaging multiple metrics to estimate condition.

Condition	Point value	Average for multiple metrics
Good	100	67 to 100 points (good)
Moderate Concern	50	34 to 66 points (moderate concern)
Significant Concern	0	Score 0 to 33 points (significant concern)

3.2.2. Reporting Areas

The MIDN selected a suite of physical, chemical, and biological elements and processes as key Vital Signs to monitor within their Network's parks. These 15 Vital Signs collectively represent the overall health or condition of the park (Comiskey and Callahan 2008). The Vital Signs were grouped into four general categories: air and climate, geology and soils, water, and biological integrity (Table 6). This NRCA follows these same general groupings.

Table 6. MIDN Vital Signs categories and vital signs selected for monitoring at HOFU.

Level 1 Category	Level 2 Category	MIDN Vital Sign	Vital Sign Selected for Monitoring
Air and Climate	Air Quality	Ozone	+
		Wet and dry deposition	+
		Visibility	+
		Air contaminants (mercury)	+
	Weather and Climate	Weather and climate	+
Geology and Soils	Geomorphology	Stream/river channel characteristics	●
	Soil Quality	Soil structure and composition	●
Water	Hydrology	Stream/river water dynamics	●
		Wetland water dynamics	◊
	Water Quality	Water chemistry	●
		Aquatic macroinvertebrates	●
Biological Integrity	Invasive Species	Invasive exotic plants	●
	Infestations and Disease	Native forest pests	●
		Exotic diseases/pathogens – plants	●
	Focal Species or Communities	Riparian wetland communities	◊
		Forest plant communities	●
		Fish communities	
		Amphibian communities	◊
		Breeding birds	◊
		Mammals	
		White tailed deer (herbivory)	●
		Vegetation communities	
		T & E species and communities	
Human Use	Visitor usage		
Ecosystem Pattern and Processes	Fire	Fire and Fuel Dynamics	
	Landscape	Landcover and landuse change	◊

● Inventory and monitoring funded vital signs that are being monitored or for which protocols will be developed.

+ Vital signs monitored by the park or an outside partner, where network does not have the lead.

◊ High priority vital sign with no current or planned monitoring due to limitations in staff time or funding.

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4. Natural Resource Conditions

4.1. Physical Resources

4.1.1. Air Quality - Ozone

Relevance and Context

The National Park Service Air Resources Division (NPS ARD) oversees the national air resource management program for the NPS. To assess ozone air quality condition, the NPS ARD uses all available monitoring data (e.g., NPS, EPA, state, tribal, and local monitors) over a five-year period to generate interpolations for all NPS units within the continental US, including those without on-site monitoring.

Ozone is not directly emitted into the air but, is produced at ground level by a chemical reaction with certain air pollutants (e.g., nitrogen oxides and volatile organic compounds from industrial and automobile emissions) in the presence of intense, high-energy sunlight during hot summer months (US EPA 2014). Ground-level ozone is a health and environmental hazard. It is a respiratory irritant, can reduce lung function, cause asthma attacks, and reduce resistance to infection (US EPA 2014). Ozone can also cause damage to ozone sensitive vegetation (Kohut 2005). Foliar damage can lead to reduced growth and increased susceptibility to disease and insect damage (Kohut 2005, Porter 2003). While foliar ozone injury has not been assessed at HOFU, it has been documented in other national parks (Kohut 2005).

Data and Methods

The US EPA has established National Ambient Air Quality Standards (NAAQS) for human health standards for ozone levels that are intended to protect public health and welfare. The NPS ARD (2013a) has developed park-specific estimates based on five-year (2008-2012) interpolations for ozone. The interpolations were used by the NPS ARD to determine an index for ozone-related air quality, and each index was assigned one of three condition categories: *Good Condition, Moderate Condition*, or *Significant Concern* (NPS ARD 2013a). At HOFU, ambient concentrations of ozone were not monitored on-site, but were estimated by kriging, a statistical interpolation process (**Error! Reference source not found.**). The nearest ozone monitoring stations to the park were located in Reading, PA (20 km from the park) (NPS-ARD 2014). The estimated hourly concentrations of ozone were then used to generate annual exposure values for the HOFU (Kohut 2007).

For natural resources, the NPS ARD conducted a risk assessment for ozone sensitive vegetation using the W126 and SUM06 metrics. W126 measures cumulative ozone exposure during daylight hours over the growing season and is expressed in parts per million-hours (ppm-hrs). The SUM06 metric sums hourly daylight ozone concentrations $\geq$ 0.060 ppm over the growing season, and is expressed in ppm-hrs. Both metrics are better predictors of plant response to ozone condition than the 8-hour US EPA human health standard metric (NPS ARD 2013a). The NPS ARD rated parks at low, moderate, or high risk for ozone injury to vegetation, based on presence of sensitive plant species, ozone exposures, and environmental conditions (e.g., soil moisture). For ozone condition assessment, parks that were evaluated at high risk were moved into the next condition category (e.g., a park with an average ozone concentration of 72 ppb, but judged to be at high risk for vegetation injury, would move from the *Moderate* to *Significant Concern* for ozone) (NPS ARD 2013a). The NPS ARD uses the W126 and SUM06 metrics, in addition to the human health standard, as ecological benchmarks for ozone. The HOFU ozone exposure values for the SUM06 and W126 indices were also calculated by kriging (Kohut 2007).

In 2004 and 2008, the NPS ARD completed a risk assessment for ozone related vegetation injury using an ecologically based rating system that focused on ozone plant sensitivity and the presence of ozone sensitive vegetation within park units (MIDN 2004, Kohut 2005, NPS ARD 2013b). There are 30 species of ozone sensitive plants are present at HOFU (Kohut 2007) (Table 7).

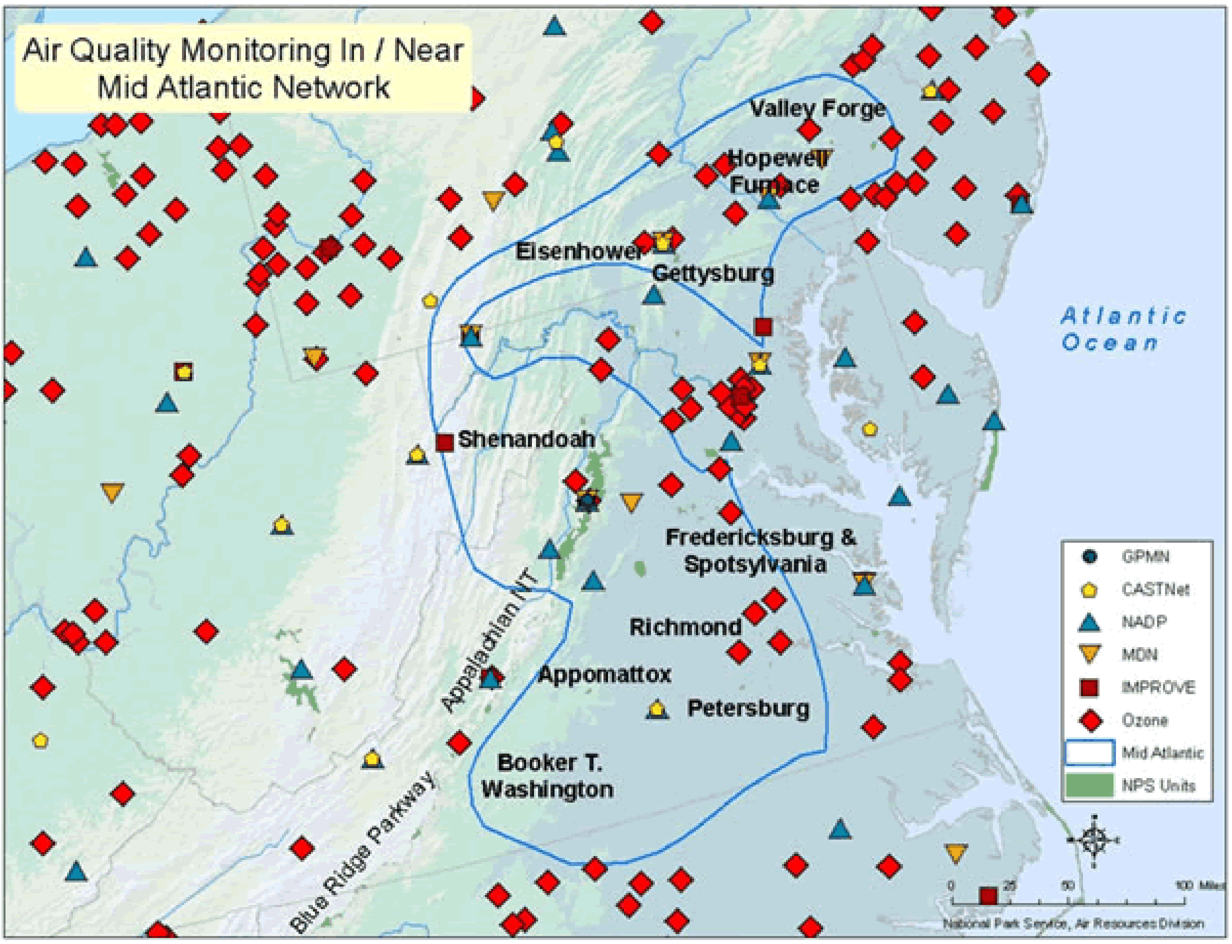

Figure 8. Air quality monitoring sites in the vicinity of HOFU (NPS-ARD 2014b).

Table 7. Plant species present at HOFU that are sensitive to ozone damage. Scientific names are presented as given in MIDN 2004, NPS-ARD 2006, and Kohut 2007, and accepted scientific synonyms are given in parentheses as listed in Integrated Taxonomic Information System (http://www.itis.gov/)

Scientific Name	Common Name
Ailanthus altissima	Tree of heaven
*Alnus rugosa (Alnus rugosa var. americana)**	Speckled alder
*Apios americana**	Groundnut
*Apocynum androsaemifolium**	Spreading dogbane
*Apocynum cannabinum**	Indian hemp
*Asclepias exaltata**	Poke milkweed
*Asclepias syriaca**	Common milkweed
*Aster macrophyllus (Eurybia macrophyll)***	Bigleaf aster
*Cercis canadensis**	Eastern redbud
Clematis virginiana	Devil's darning needles
*Corylus americana**	American hazelnut
Eupatorium rugosum (Ageratina altissima var. altissima)	White snakeroot
Fraxinus americana	White ash
Fraxinus pennsylvanica	Green ash
Gaylussacia baccata	Black Huckleberry
Liriodendron tulipifera	Tulip poplar
Lyonia ligustrina	Maleberry
Parthenocissus quinquefolia	Virginia creeper
*Pinus rigida**	Pitch pine
Platanus occidentalis	American sycamore
Prunus serotina	Black Cherry
*Prunus virginiana**	Chokecherry
*Rhus copallina (Rhus copallinum)**	Winged sumac
Robinia pseudoacacia	Black locust
Rubus allegheniensis	Allegheny blackberry
*Rudbeckia laciniata**	Cutleaf coneflower
*Sambucus canadensis (Sambucus nigra ssp. canadensis)**	American black elderberry
Sassafras albidum	Sassafras
*Solidago altissima**	Canada goldenrod
Vitis labrusca	Fox grape

* indicates species was listed in Kohut 2007 and NPS-ARD 2006, but was not listed in NPSpecies database for HOFU.

Reference Condition and Status of the Resource (current condition and trends)

The ozone injury risk assessment indicated the risk of injury was moderate to high in MIDN parks (NPS 2014). In 2004, a risk assessment of foliar ozone injury to plants at HOFU was determined to be high (MIDN 2004). Subsequent analyses of ozone metrics in 2008-2012 also indicated that HOFU exceeded the significant concern threshold for all metrics (NPS-ARD 2015) (Table 8, Figure 10, Figure 11, Figure 12).

Although trends for ozone concentration, SUM06, and W126 metrics were not specifically estimated for HOFU, trend maps from the NPS-ARD (2013a) show significant and possible improving trends in the general area of HOFU (Figure 13, Figure 14).

Table 8. Reference thresholds and condition estimate for ozone at HOFU.

Metric	Good Condition	Moderate Concern	Significant Concern	HOFU Condition and Trend[1]
Ozone concentration (ppb) (human health standard)	**≤60 ppb**	**61-75 ppb**	**≥76 ppb**	**(1995-1999, 95.7 ppb)[2]** **(2008-2012, 77.0 ppb)[3]**
SUM06, Ozone ecological standard (ppm-hrs)	**< 8 ppm-hrs**	**8-15 ppm-hrs**	**> 15 ppm-hrs**	**(1995-1999, 34.4 ppm-hrs)[2]** **(2008-2012, 17.0 ppm-hrs)[3]**
W126, Ozone ecological standard (ppm-hrs)	**<7 ppm-hrs**	**7-13 ppm-hrs**	**> 13 ppm-hrs**	**(1995-1999, >28 for all years)[4]** **(2008-2012, 13.2 ppm-hrs)[3]**

[1] Trends for ozone metrics were not estimated for HOFU by the NPS-ARD (2013a); NPS-ARD trend maps show significant and possible improving trends in the general area of HOFU.

[2] Data source NPS-ARD 2014b

[3] Data source NPS-ARD 2015.

[4] Data source MIDN 2004.

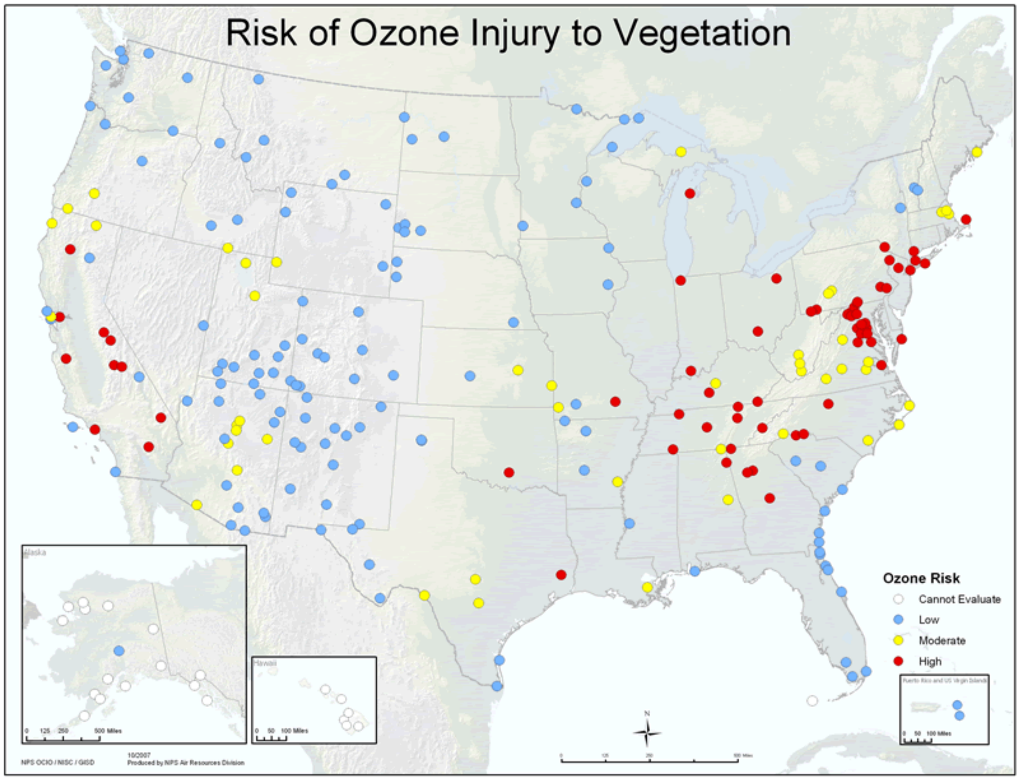

Figure 9. Ozone risk assessment for sensitive vegetation (NPS ARD 2013b).

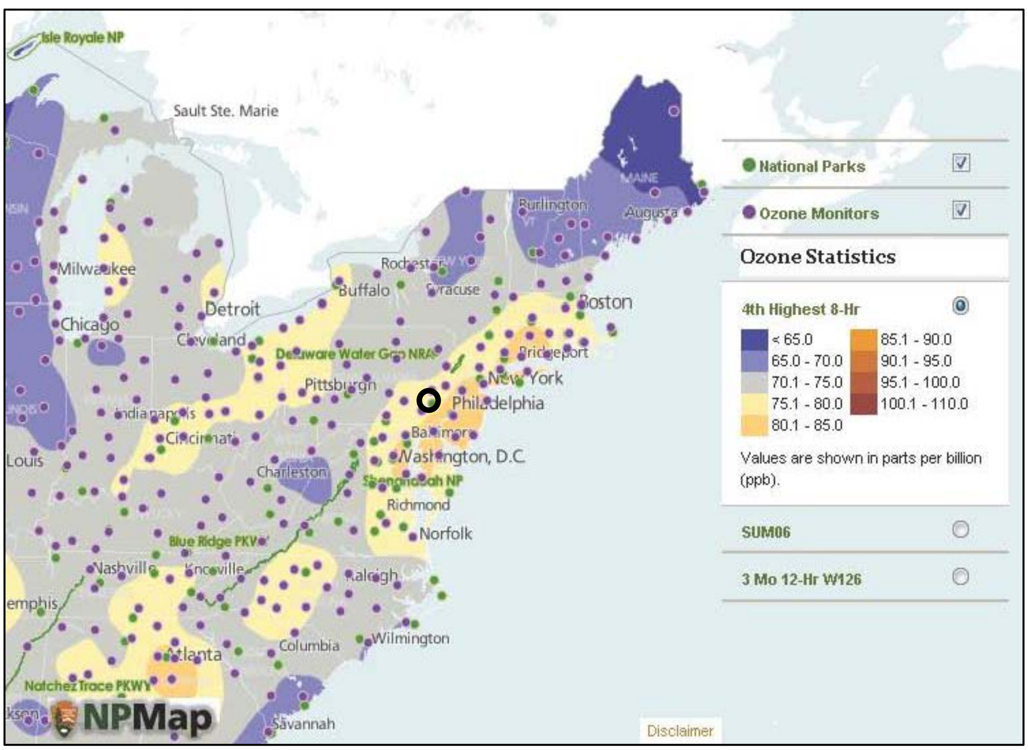

Figure 10. Ozone concentration statistics (annual 4th highest daily maximum average ozone concentration (ppb yr-1), for 2006-2010. HOFU is indicated by black circle (NPS ARD 2014a).

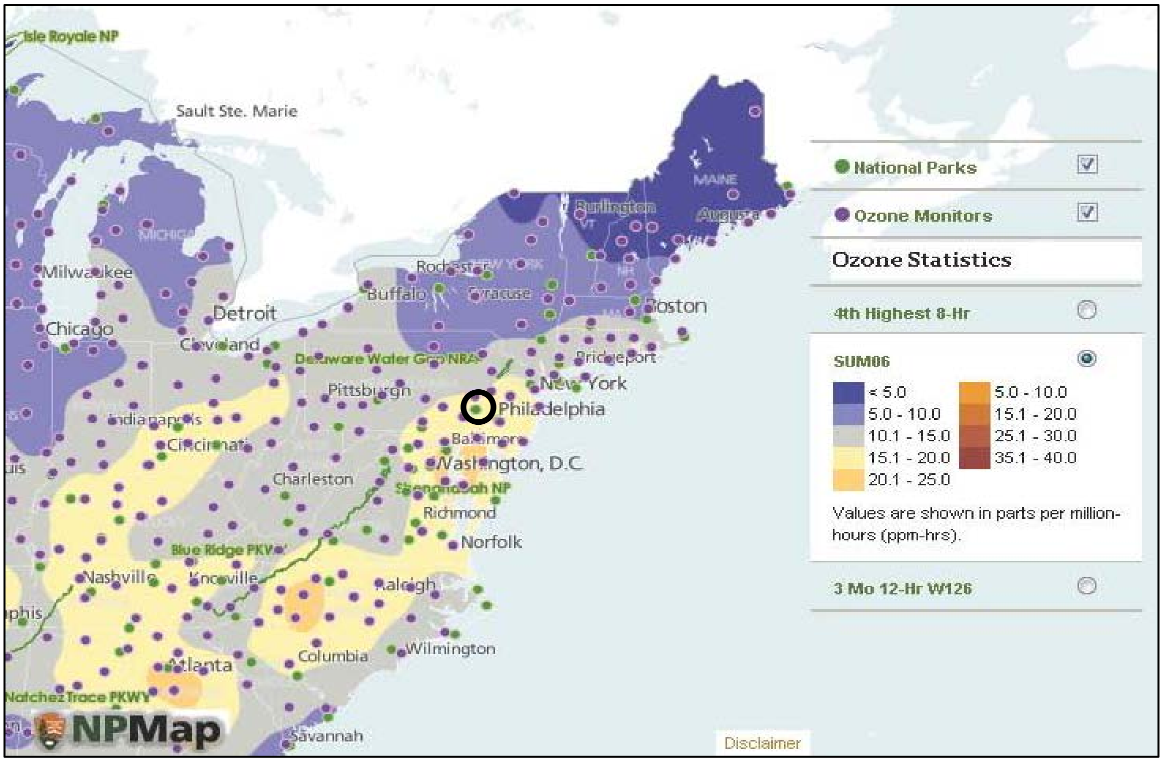

Figure 11. SUM06 ozone concentration statistics for 2006-2010. HOFU is indicated by black circle (NPS ARD 2014a).

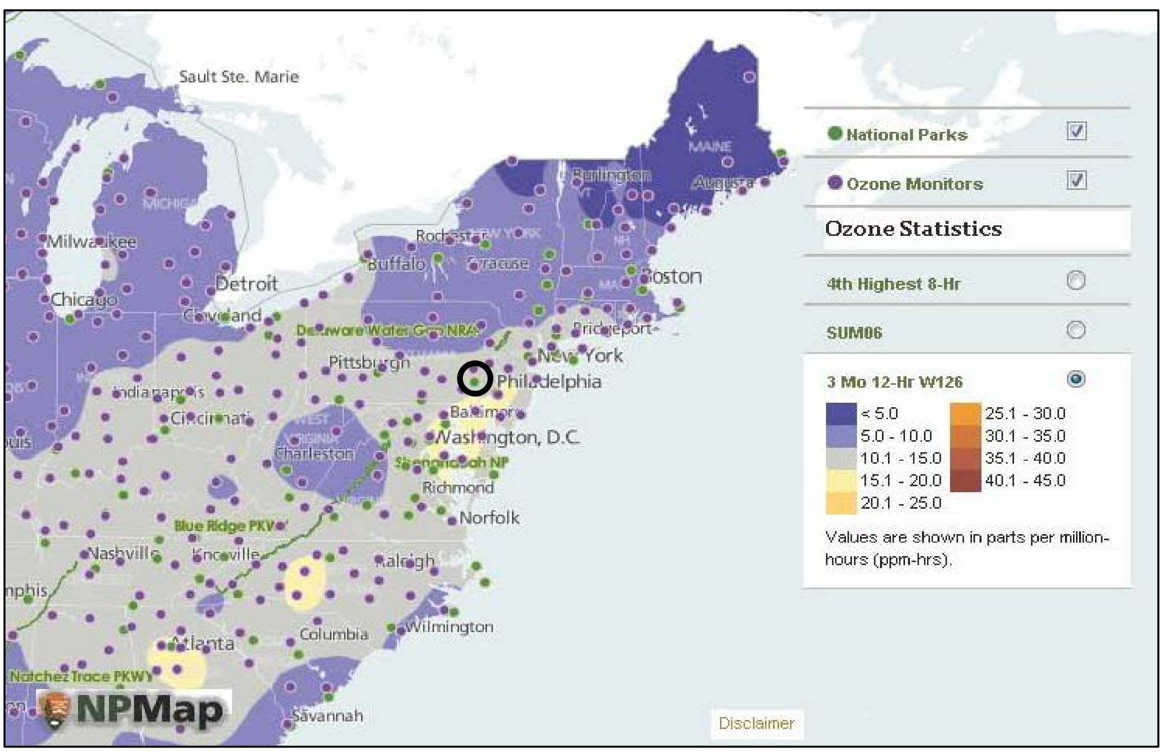

Figure 12. W126 ozone concentration statistics for 2006-2010. HOFU is indicated by black circle (NPS ARD 2014a).

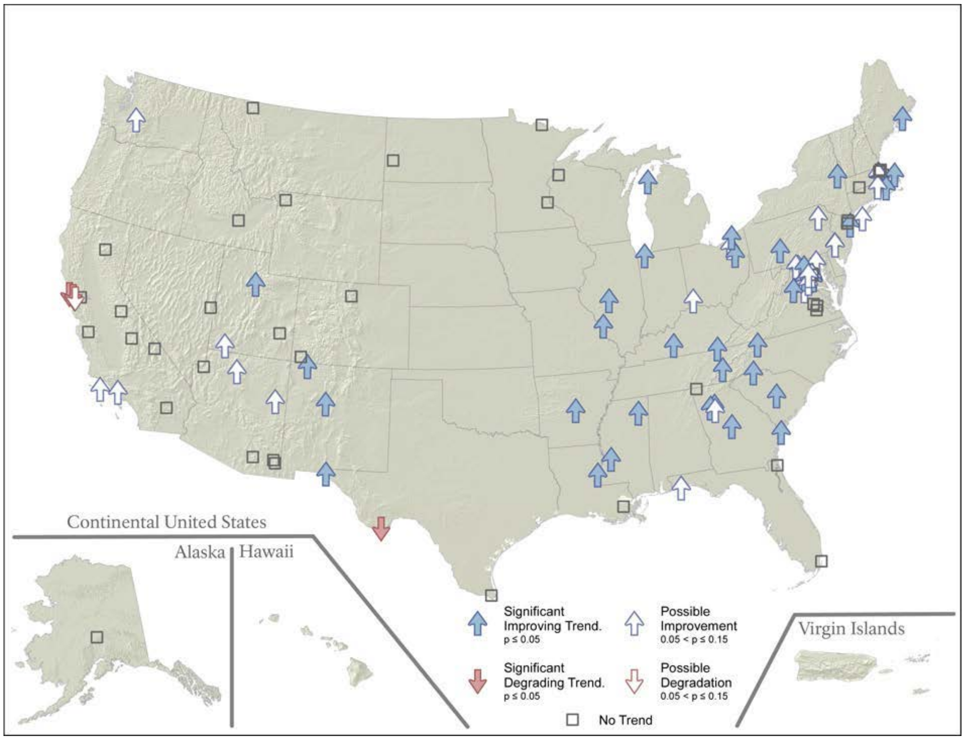

Figure 13. Map of trends in annual 4th highest daily maximum average ozone concentration (ppb yr-1), 2000-2009. Map excerpted from NPS-ARD 2013a.

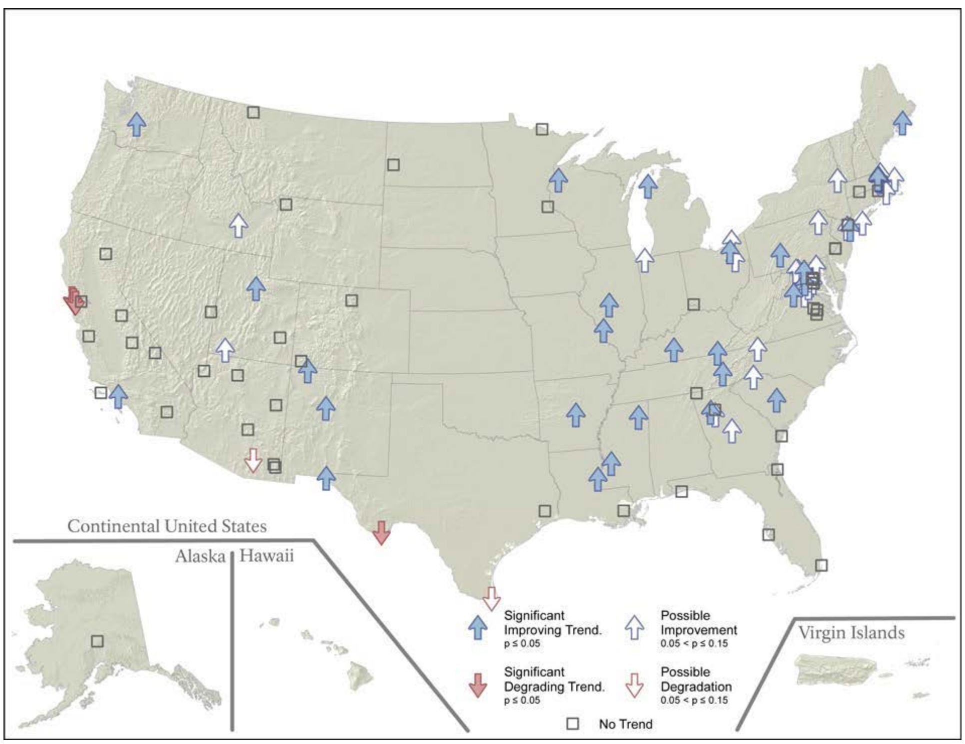

Figure 14. Map of trends in W126 metric (ppm-hrs yr-1), 2000-2009. Map excerpted from NPS-ARD 2013a.

Confidence in Assessment

The data used to assess ozone were recent and of good quality. The confidence in the current condition and trend was assessed as medium since the data were interpolated for HOFU.

Data Gaps

There were no data gaps for ozone as air quality is regularly monitored and interpreted by both federal and state agencies (NPS, EPA).

Threats

While HOFU contains very little emission sources that contribute to air pollution, air quality at the park is highly influenced by local and regional air pollution transport as it is influenced by both local (adjacent urban areas such as Philadelphia and Reading, PA) and regional (Northeast) emissions from automobile traffic and industry.

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4.1.2. Air Quality - Wet Deposition

Relevance and Context

Deposition of nitrogen and sulfur compounds can acidify sensitive resources such as streams, lakes, soils, disrupt soil nutrient cycling, and affect biodiversity. Ammonium, nitrate, and sulfate ions in precipitation (rain and snow) are used as indicators of atmospheric deposition because they can be directly linked to these ecological effects. The NPS ARD used the amount of total N wet deposition and total S wet deposition (dry deposition data are not available for most areas) as a measure of condition for atmospheric deposition (NPS ARD 2013).

The National Atmospheric Deposition Network/National Trends Program (NADP/NTN) is a nationwide network of precipitation monitoring sites. NADP/NTN collects data on the chemistry of precipitation to monitor geographical and temporal long-term changes. The NADP/NTN has expanded its sampling to include the Mercury Deposition Network (MDN), which currently has over 35 sites. The MDN was formed in 1995 to collect weekly samples of precipitation, which are analyzed for total mercury. The NPS ARD used data from a variety of sources including the NADP/NTN to assess air quality in national park units. Air quality conditions were evaluated by the

NPS ARD as total nitrogen (N) wet deposition, total sulfur (S) wet deposition, and trends in mercury deposition (NPS ARD 2013). The NPS ARD used data from five-year periods to generate interpolations for all NPS units within the continental US, including those without on-site monitoring. The data used to estimate wet deposition at HOFU were from monitors outside of the park as there were no air quality or weather/climate stations located at HOFU. The nearest air quality monitoring station to HOFU is located at Valley Forge National Historical Park (25 km, NADP/NTN and Mercury Deposition Network [MDN] stations) (NPS-ARD 2014a) (**Error! Reference source not found.**).

Data and Methods

The NPS ARD (2013) has developed park-specific estimates based on five-year interpolations for wet deposition. The interpolations were used by the NPS ARD to determine an index for wet deposition-related air quality, and each index was assigned one of three condition categories: good condition, moderate condition, or significant concern (NPS ARD 2013). The NPS ARD estimated wet deposition for park units within the continental US by multiplying N or S concentrations in precipitation by a normalized precipitation amount. Several factors were considered in rating deposition condition, including natural background deposition estimates and deposition effects on ecosystems. Estimates of natural background deposition for total N or S deposition were approximately 0.50 kg ha^{-1} yr^{-1} in the East, which was roughly equivalent to a wet deposition only rate of 0.25 kg ha^{-1} yr^{-1}. Certain sensitive ecosystems respond to levels of deposition on the order of 1.5 kg ha^{-1} yr^{-1} wet deposition and evidence is not currently available that indicates that wet deposition amounts less than 1 kg ha^{-1} yr^{-1} cause ecosystem harm (NPS 2014b). For parks with ecosystems potentially sensitive to N or S, interpolated values were adjusted up one category (e.g., a park with a moderate N deposition of 1-3 kg ha^{-1} yr^{-1} that contains N-sensitive ecosystems would be assigned the deposition condition of significant concern).

Sullivan et al. (2011) evaluated the sensitivity of all Inventory and Monitoring National Park units to potential acidification effects caused by atmospheric deposition. The assessment considered three factors that influenced acidification risk to park resources: pollutant exposure, inherent ecosystem sensitivity, and park protection mandates (Sullivan et al. 2011). Pollutant exposure was evaluated using N and S atmospheric deposition rates. Ecosystem sensitivity was evaluated by the make-up of terrestrial plant, aquatic algae, and higher life form communities. Acidification can cause sensitive species to decline and therefore the mix of species present and biodiversity in the ecosystem can be indicative acidification stress. Sullivan et al. (2011) ranked each park according to these factors and calculated a summary risk ranking for each park based on the averages of the three theme rankings.

Mercury is primarily emitted by the burning of coal in power plants and most often deposited in the inorganic form; it is converted to an organic form, methylmercury, in the environment. Methylmercury is a toxic form of mercury that enters the food chain and accumulates in organisms. Animals and people who eat fish contaminated with mercury are at greatest risk for mercury exposure (NPS ARD 2013). Thresholds for mercury deposition have not yet been established; however, a trend in mercury deposition (2000 to 2009) was estimated for HOFU (NPS-ARD 2013).

Reference Condition and Status of the Resource (current condition and trends)

The NPS ARD (2013) evaluated both total N and S wet deposition as significant concern (Table 9, Figure 15, Figure 16). Isopleth maps of nitrate (NO_3), ammonium (NH_4), and total nitrogen (N) wet deposition indicated that annual average rates for all three deposition measures were towards the higher end (significant concern) of the spectrum of concentrations. Similarly, isopleth maps of average annual sulfate (SO_4) deposition were also towards the higher end of the spectrum (**Error! Reference source not found.**, Figure 18, Figure 19, Figure 20) (NPS 2014a). The NPS-ARD (2013) has not yet estimated trends for either total N or S wet deposition for HOFU.

Condition thresholds for mercury wet deposition have not yet been established; however the trend in mercury deposition at HOFU was evaluated as unchanging from 2000 to 2009 Table 9, Figure 21) (NPS 2013).

Sullivan et al. (2011) estimated the potential effects caused by acidifying atmospheric deposition and ranked HOFU as very high for pollutant exposure, and moderate for ecosystem sensitivity and park protection. The overall summary risk for potential acidification effects caused by atmospheric deposition was assessed as significant concern for HOFU (Sullivan et al. 2011).

Table 9. Condition thresholds and estimated annual average atmospheric wet deposition for HOFU.

Metric	Good Condition	Moderate Concern	Significant Concern	HOFU Condtition and Trend
Total N wet deposition (kg ha^{-1} yr^{-1})	< kg ha^{-1} yr^{-1}	1-3 kg ha^{-1} yr^{-1}	>3 kg ha^{-1} yr^{-1}	5.0 kg ha^{-1} yr^{-1} (1) No trend estimated[2] (2008-2012)
Total S wet deposition (kg ha^{-1} yr^{-1})	< kg ha^{-1} yr^{-1}	1-3 kg ha^{-1} yr^{-1}	>3 kg ha^{-1} yr^{-1}	3.7 kg ha^{-1} yr^{-1} (1) No trend estimated[2] (2008-2012)
Mercury wet deposition (ng L^{-1} yr^{-1})	Thresholds not yet developed			-0.10 ng L^{-1} yr^{-1} (2) Stable trend[2] (2000-2009)

[1] Data source NPS ARD 2015.

[2] The NPS-ARD (2013) has not estimated trends for this metric.

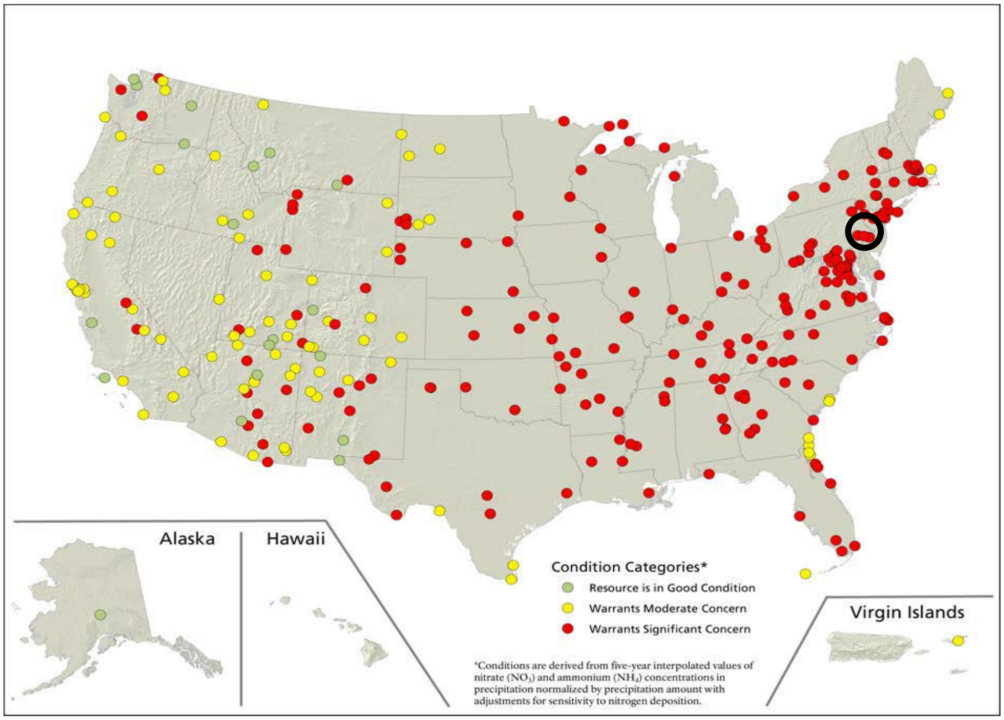

Figure 15. NPS-ARD (2013) air quality condition assessments for nitrogen wet deposition, 2005–2009. Condition assessments derived from 5-year interpolations of nitrate and ammonium wet deposition concentrations in kilograms per hectare per year (kg ha-1yr-1). HOFU is indicated by the black circle.

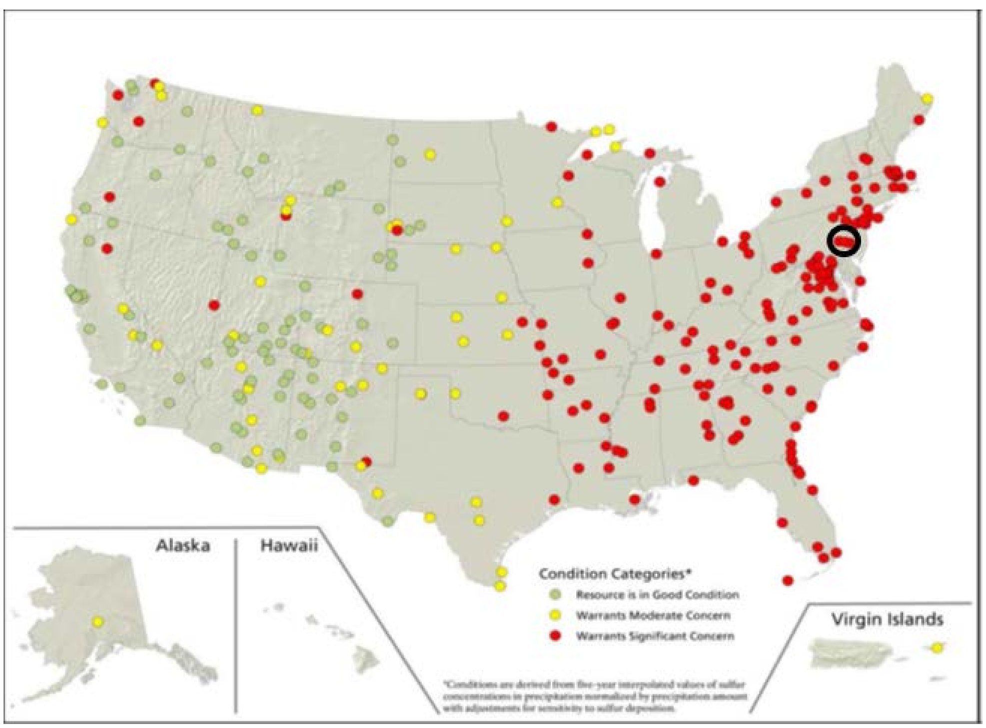

Figure 16. NPS-ARD (2013) of air quality condition assessments for sulfur wet deposition, 2005–2009. Condition assessments derived from 5-year interpolations of sulfur wet deposition concentrations in kilograms per hectare per year (kg ha-1yr-1). HOFU is indicated by the black circle

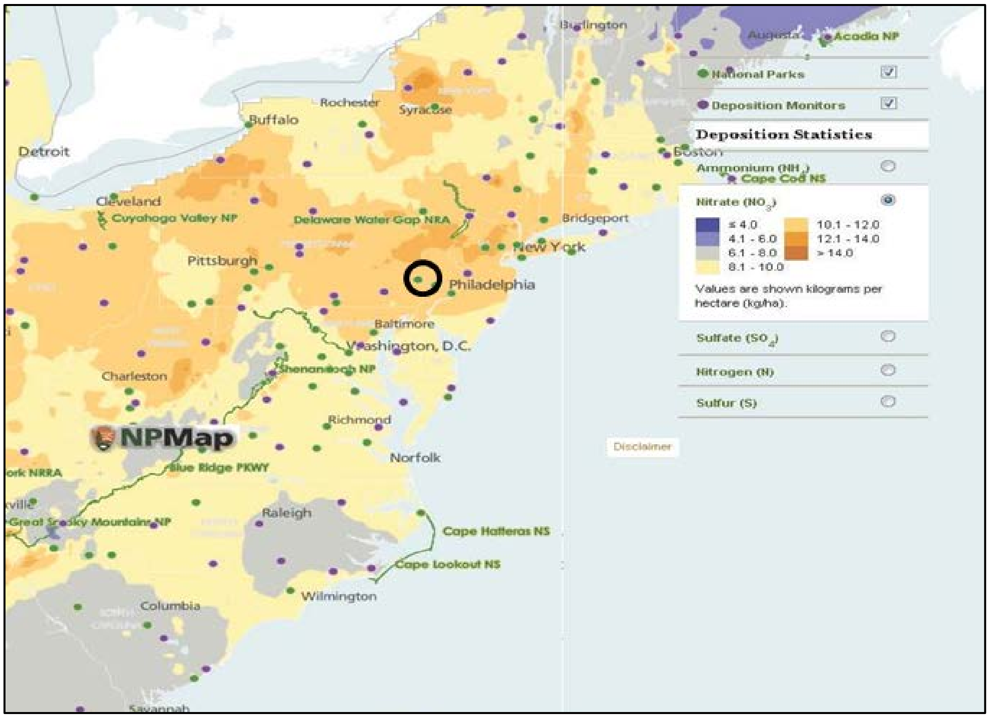

Figure 17. Annual nitrate (NO3) deposition statistics for 2006-2010. HOFU is indicated by black circle (NPS-ARD 2014a).

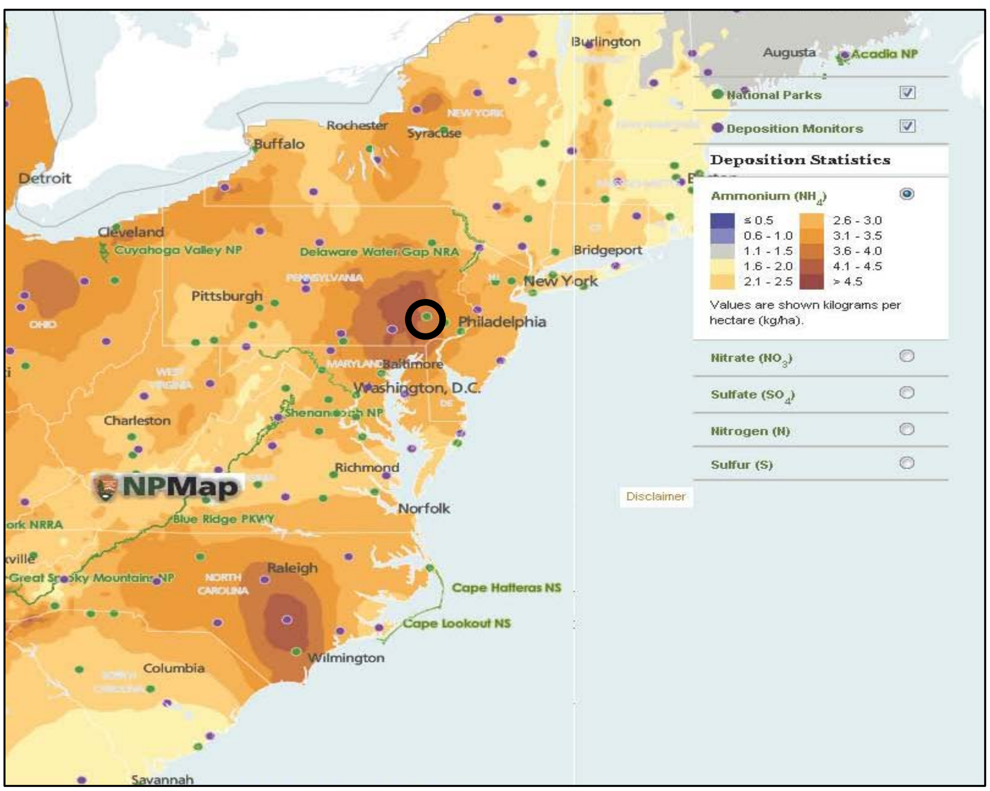

Figure 18. Annual average ammonium (NH4) deposition statistics for 2006-2010. HOFU is indicated by black circle (NPS-ARD 2014a).

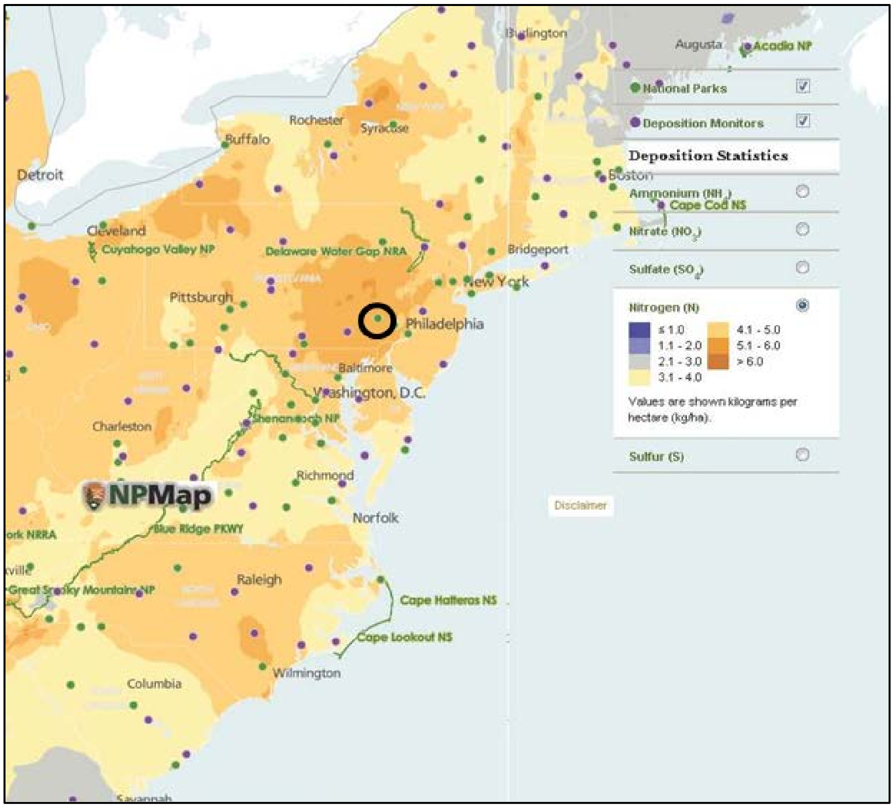

Figure 19. Annual average nitrogen (N) deposition statistics for 2006-2010. HOFU is indicated by black circle (NPS-ARD 2014a).

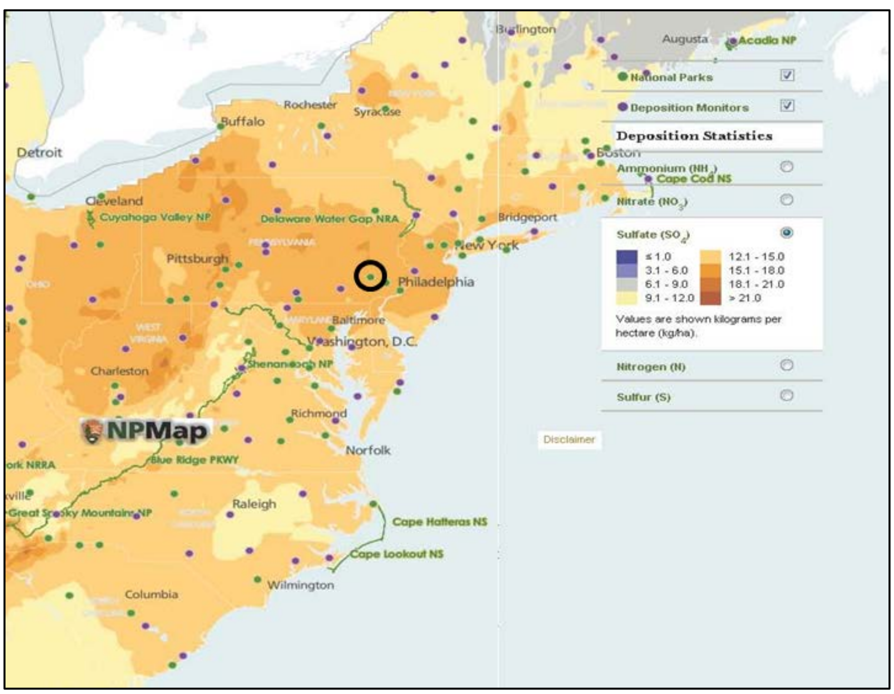

Figure 20. Annual average sulfate (SO4) deposition statistics for 2006-2010. HOFU is indicated by black circle (NPS-ARD 2014a).

Figure 21. Trends in mercury concentrations in precipitation (ng liter-1 yr-1), 2000–2009. HOFU is indicated by black circle (Figure excerpted from NPS ARD 2013).

Confidence in Assessment

The data used to assess wet deposition were recent and of good quality. The confidence in the current condition and trend was assessed as medium since the data were interpolated for HOFU.

Data Gaps

There were no data gaps for wet deposition as air quality is regularly monitored and interpreted by both federal and state agencies (e.g., , NADP/NTN, NPS, PA Department of Environmental Protection).

Threats

While HOFU contains very little emission sources that contribute to air pollution, air quality at the park is highly influenced by local and regional air pollution transport as it is influenced by both local (adjacent urban areas such as Philadelphia and Reading, PA) and regional (Northeast) emissions from automobile traffic and industry.

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4.1.3. Air Quality-Visibility

Relevance and Context

Air pollution causes haze and reduces visibility. The NPS ARD examined the haze levels on the clearest and haziest days to characterize visibility conditions at National Park units (NPS ARD 2013). Visibility was estimated using a Haze Index, as the Haze Index increases, visibility decreases.

The EPA's Regional Haze Program protects visibility in Class I areas. Class I areas include national parks greater than 6,000 acres and wilderness areas greater than 5,000 acres that were in existence when the Clean Air Act (CAA) was amended in 1977. Class I areas receive the highest degree of air quality protection under the CAA and have specific national regional haze goals (NPS ARD 2013, US EPA 2014). Generally, all other parks that do not meet the criteria for Class I are considered Class II areas. HOFU is considered a Class II area. The nearest visibility monitors to HOFU, Interagency Monitoring of Protected Visual Environments (IMPROVE) stations, are located at Edwin B. Forsythe National Wildlife Refuge, NJ, (145 km NE) and in Arendtsville, PA, (135 km SW) (NPS 2014a).

Data and Methods

The NPS ARD obtained visibility data from the IMPROVE network. The NPS ARD examined visibility in 10-year trends and computed Haze Index values in deciviews (dv) on the 20% haziest days and the 20% clearest days, consistent with Regional Haze Rule visibility goals (NPS ARD 2013, US EPA 2014). For an overall visibility trend, trends for clearest and haziest days were combined. If the Haze Index trend on the 20% clearest days was deteriorating, the overall visibility trend was reported as deteriorating. Otherwise, the Haze Index trend on the 20% haziest days was reported as the overall visibility trend (NPS ARD 2013).

Reference Condition and Status of the Resource (current condition and trends)

Visibility goals set by the CAA requires no visibility degradation on the 20% clearest days and visibility improvement on the 20% haziest days. The visibility at HOFU, as interpreted by the NPS-ARD (2013), was evaluated as significant concern (Figure 22). On the 20% clearest days there was no change in trend and on the 20% haziest days there was a possible improving trend (NPS ARD 2013) (Figure 23, Figure 24). The Haze Indices for HOFU were towards the higher end of the spectrum (significant concern) on both the 20% clearest days (12.1-14 dv) and 20% haziest days (23.1-25 dv) for 2006-2010 (NPS ARD 2013) (Figure 25, Figure 26).

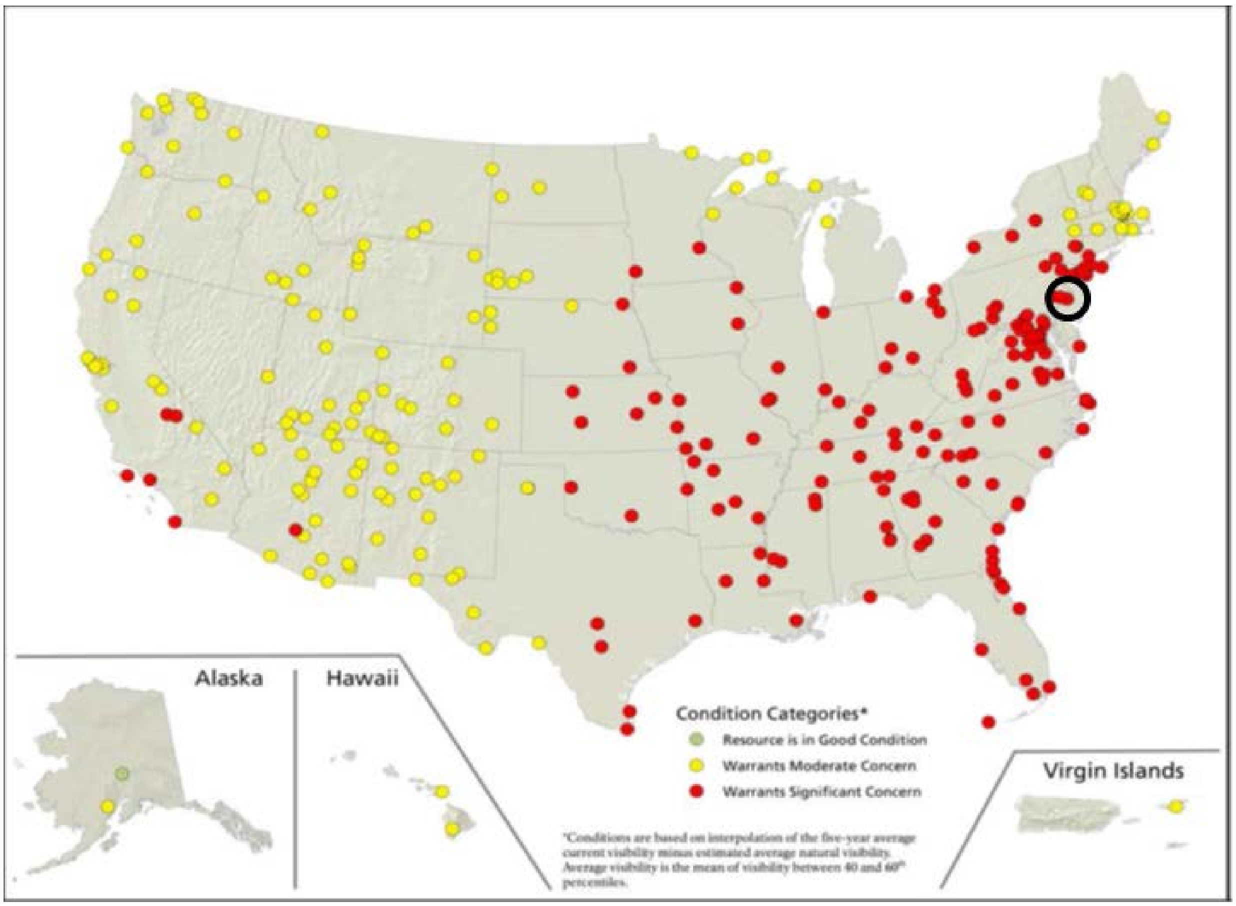

Figure 22. NPS ARD (2013) trend in haze index (dv) on the clearest days, 2000-2009. HOFU is indicated by black circle.

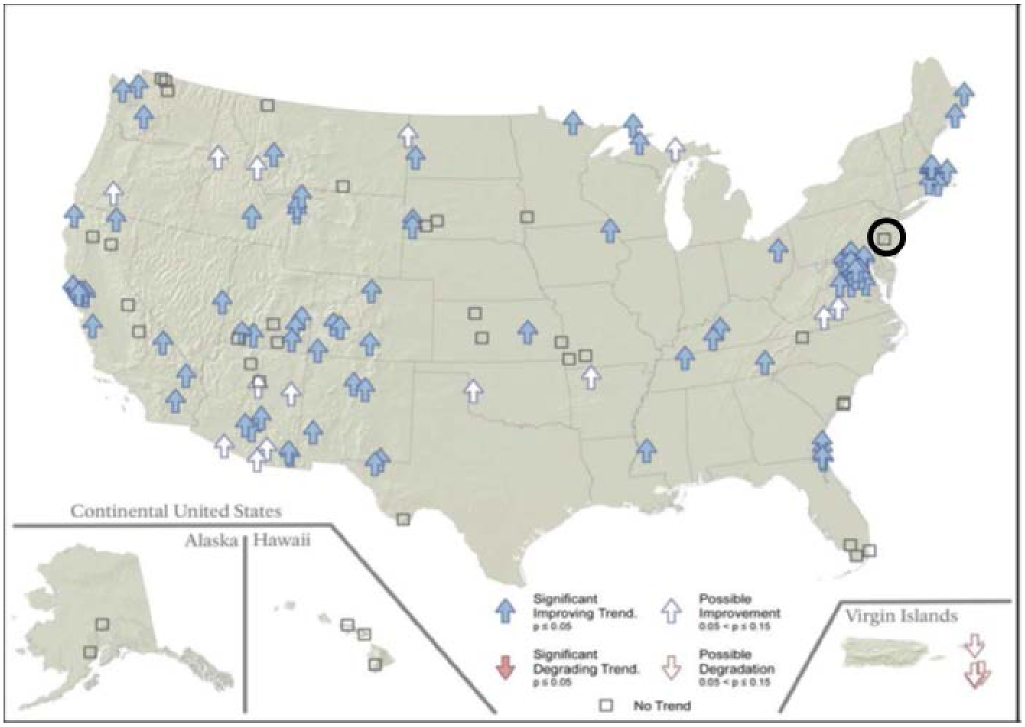

Figure 23. NPS ARD (2013) condition assessment for visibility for 2005-2009. HOFU is indicated by black circle.

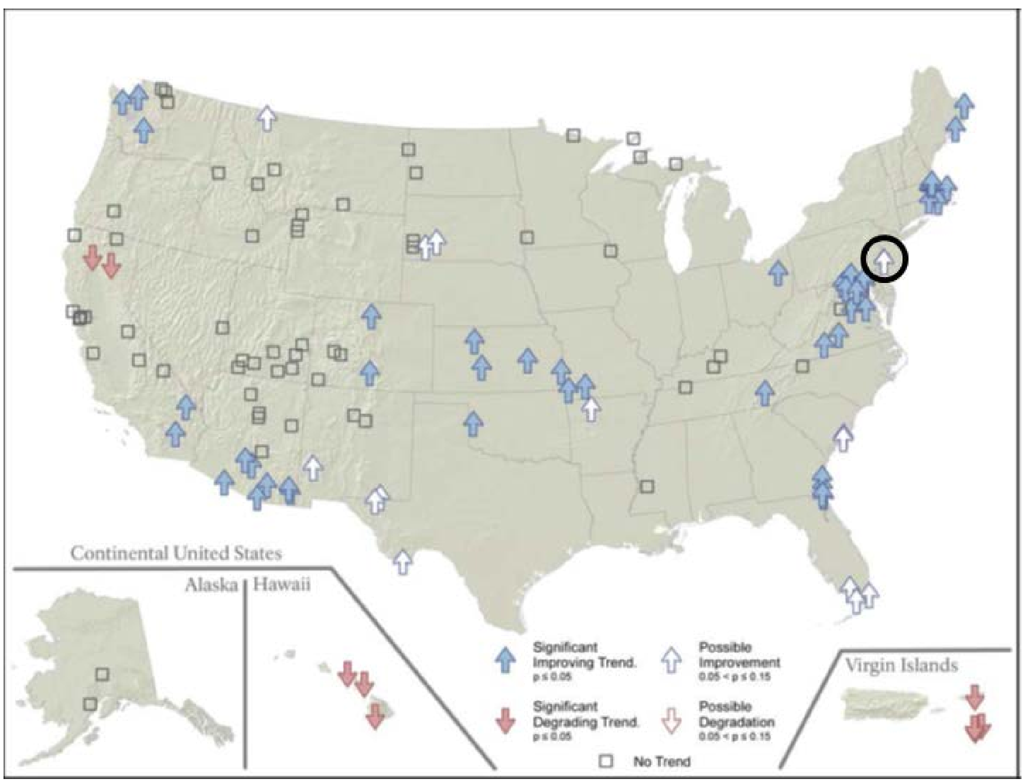

Figure 24. NPS ARD (2013) trend in haze index (dv) on the haziest days, 2000-2009. HOFU is indicated by black circle.

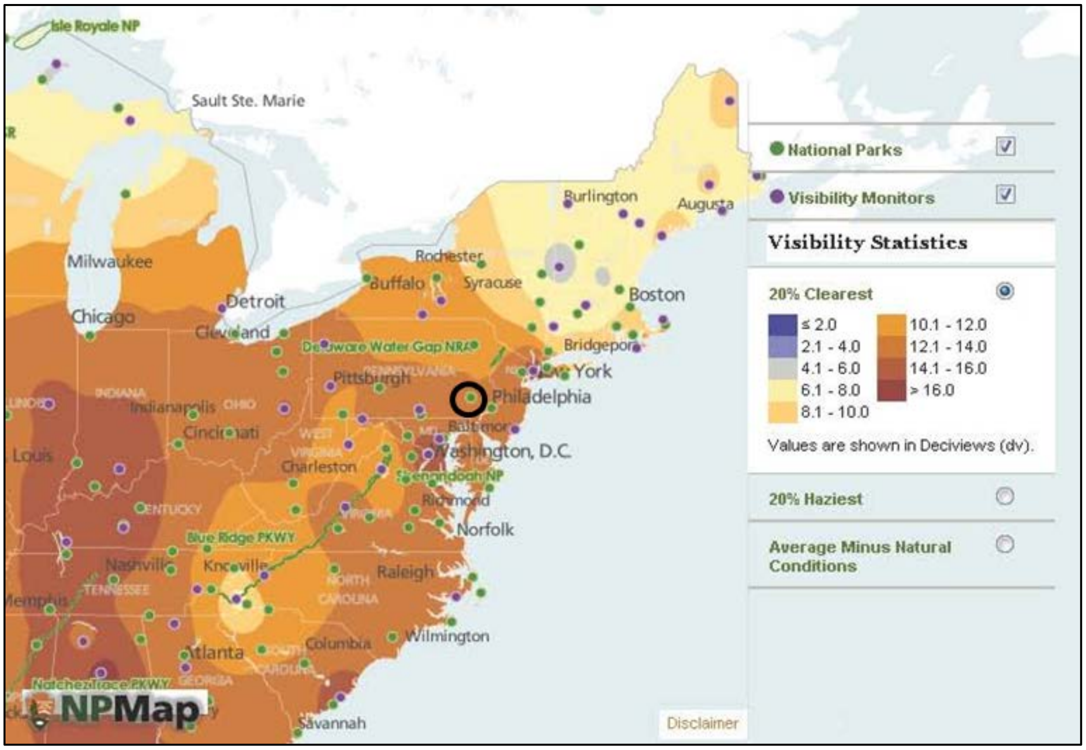

Figure 25. Visibility shown as 20% clearest days for 2006-2010. HOFU is indicated by black circle (NPS ARD 2014a).

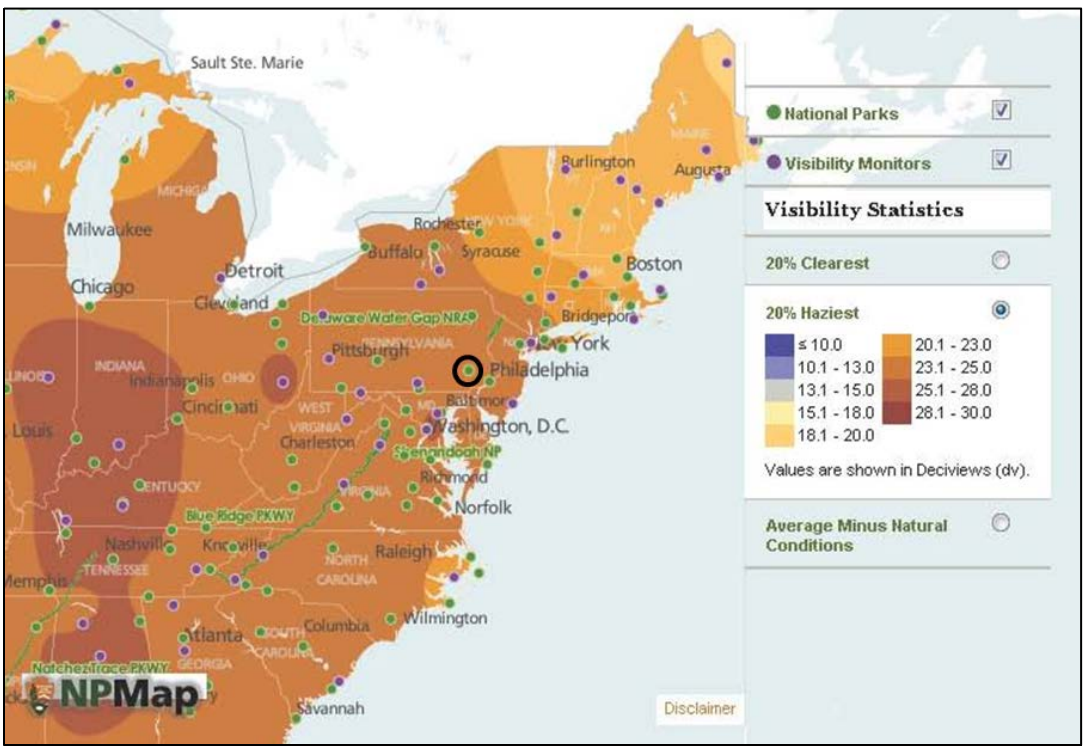

Figure 26. Visibility shown as 20% haziest days for 2006-2010. HOFU is indicated by black circle (NPS ARD 2014a).

Confidence in Assessment

The data used to assess visibility were recent and of good quality and the data presented in this NRCA were taken directly from the NPS-ARD assessments; however, it should be noted that the NPS-ARD estimates were based on visibility data from a station located 129 km from the park; therefore, the confidence in the current condition was assessed as medium. Trends in visibility were not estimated by the NPS ARD.

Data Gaps

There were no data gaps for visibility it is regularly monitored and interpreted by both federal and state agencies (IMPROVE, NPS, US EPA).

Threats

While HOFU contains very little emission sources that contribute to the Haze Index, air quality and thus visibility, at the park is highly influenced by local and regional air pollution transport as it is influenced by both local (adjacent urban areas such as Philadelphia, PA) and regional (Northeast) emissions from automobile traffic and industry.

Table 10. Estimated annual average visibility 2006-2010 time period (NPS ARD 2013).

Metric[1]	Good Condition	Moderate Concern	Significant Concern	HOFU Condition and Trend
Average visibility – estimated average natural conditions (dv)	<2 dv	2-8 dv	>8 dv	20% clearest days: 11.3 dv[1] 20% haziest days: 24.1 dv[1]

[1] Visibility thresholds and values based on NPS-ARD (2015) 2008-2012 estimates.

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NPS-Air Resources website. 2008-2012 5-year average visibility estimates. Available at http://www.nature.nps.gov/air/Maps/AirAtlas/docs/Air_Atlas_Values_Tables/Visibility/NPS_AQC_Vis_0812_web.pdf (accessed 29 January 2015).

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4.1.4. Night Sky Resources

<u>Relevance and Context</u>

The quality of the nighttime environment is relevant to nearly every unit in the NPS System. The 2006 NPS Management Policies (section 4.10) speak of the importance of a natural photic environment to ecosystem function and the importance of the natural lightscape for aesthetics. A lightscape can be important as a natural feature, a cultural feature, or both. Natural lightscapes are also important to wilderness character and have been identified under the Clean Air Act Amendments as an air quality related value. Therefore, the importance of lightscapes and photic environments is related to an array of park resources and values and has broad implications for park management (NPS 2014a).

The night sky as we see it is a combination of both natural and human-caused sources of light. Natural light sources include moonlight, starlight from individual stars and planets, and other celestial bodies. The NPS uses the term "natural lightscape" to describe resources and values that exist in the absence of human-caused light at night. Natural lightscapes are critical for nighttime scenery, such as viewing a starry sky, but are also critical for maintaining nocturnal habitat for a variety of species. The Natural Sounds and Night Skies Division (NSNSD) draws a distinction between the *lightscape* – the human perception of the nighttime scene, including both the night sky and the faintly illuminated terrain, and the *photic environment* – the totality of the pattern of light at night at all wavelengths. *Lightscapes* include aesthetic and experiential qualities that are integral to natural resources and cultural resources. The *photic environment* affects a broad range of species, is integral to ecosystems, and is a natural physical entity (NPS 2013). In the highest quality skies, human-caused sources of light are less luminous than natural sources, and natural features of the night sky predominate. In a degraded natural lightscape, human-caused light is greater than that produced by natural sources, in some cases, many tens of times brighter (NPS 2014b).

Alteration of night sky resources can be in the form of astronomical light pollution, where stars and other celestial bodies are obscured from view, or in the form of ecological light pollution where lighting (e.g., glare, illumination, fluctuations in lighting) can disrupt natural ecosystem processes and wildlife behavior (Longcore and Rich 2004). The largest human-caused source of ecological light pollution is outdoor electrical lighting, but other sources include skyglow (human-caused light scattered through the atmosphere), aircraft, fishing boats, vehicle lights, and satellites (Longcore and

Rich 2004, NPS 2014b). Ecological light pollution can alter behavior and affect the population ecology of organisms in the natural world. Such effects include, but are not limited to, changes in orientation or disorientation, and attraction or repulsion from altered lightscape, changes in the timing of diurnal or crepuscular behaviors that may in turn influence foraging, reproduction, migration, communication, and survivorship (Longcore and Rich 2004). Lightscapes can be cultural as well, and may be integral to the historical fabric of a park. Human-caused light may be obtrusive in the same manner that noise can disrupt a contemplative or peaceful scene (NPS 2014). Kulesza et al. (2013) conducted an assessment of the importance of dark skies to visitors in Parks Service-wide. Although, dark skies were not specifically addressed at HOFU in that report, a few parks in the Northeast Region (NER) were included in the study (e.g., Minute Man NHS, Delaware Water Gap NRA). This study found that dark night skies were found to be extremely or very important to visitors in some NER parks.

The quality of natural lightscapes and starry night skies are dependent on the weather, the clarity of the air, and the amount of light pollution present (NPS 2014b). The brightness and appearance of skyglow depends on atmospheric factors such as moisture, air pollution, and dust particles. Clean, dry air scatters light pollution less, resulting in darker skies for observers close to the light source. Poor air quality has the opposite effect, increasing light pollution close to the source and decreasing it at longer distance (NPS 2014b).

Hopewell Furnace National Historic Site offers a relatively dark night sky viewing opportunity considering its proximity to major urban centers (Reading and Philadelphia, PA). Additionally the park, as a part of Hopewell Big Woods and with Schuylkill Highlands is actively seeking certification as a Dark Sky Reserve with the International Dark Sky Association in cooperation. Therefore, night sky quality should be considered an important resource to the park (NPS 2014a).

Data and Methods

The NSNSD measures the quality of the photic environment by measuring total sky brightness averaged across the entire sky and comparing that value to natural nighttime light levels. This measure, called the Anthropogenic Light Ratio (ALR), can be directly measured or modeled when observational data is unavailable. The ALR is calculated by taking the total observed sky brightness and then removing the natural night sky component from the observed conditions, yielding the anthropogenic quanta. A natural night sky has an average brightness across the entire sky of 78 nL (nanolamberts, a measure of luminance), and includes components such as the Milky Way, Zodiacal light, airglow, and other starlight. For example, a ratio of 0.0 would indicate pristine natural conditions where the anthropogenic component was 0 nL and natural component was 78 nL. A ratio of 1.0 would indicate that anthropogenic light was 100% brighter than the natural light from the night sky, equating to an anthropogenic component of 78 nL and natural component of 78 nL (NPS 2013). Therefore, lower ALR levels reflect higher quality night sky conditions (NPS 2014b) (Table 11). The ALR is a robust and descriptive metric that can be modeled relatively easily.

Table 11. Threshold conditions for anthropogenic light ratio (ALR) for night sky resources. Table excerpted from NSNSD 2013. HOFU is a Level 2 park.

Indicator	Condition	Threshold for Level 1 Parks	Additional Threshold for Areas Managed as Wilderness	Threshold for Level 2 Parks
Anthropogenic Light Ratio (ALR) Average Anthropogenic All-Sky Luminance : Average Natural All-Sky Luminance Light flux is totaled above the horizon (the terrain is omitted) and the anthropogenic and natural components are expressed as a unit less ratio The average natural sky luminance is 78 nL	Good Condition	ALR < 0.33 (<26 nL average anthropogenic light in sky) *At least half of park area should meet these criteria.*	ALR < 0.33 (<26 nL average anthropogenic light in sky) *At least 90% of wilderness area should meet these criteria.*	ALR < 2.00 (<156 nL average anthropogenic light in sky) *At least half of park area should meet these criteria.*
	Moderate Concern	ALR 0.33–2.00 (26–156 nL average anthropogenic light in sky) *At least half of park area should meet this criteria.*	ALR 0.33–2.00 (26–156 nL average anthropogenic light in sky) *At least 90% of wilderness area should meet these criteria.*	ALR 2.00–18.00 (156–1404 nL average anthropogenic light in sky) *At least half of park area should meet this criteria.*
	Significant Concern	ALR > 2.00 (>156 nL average anthropogenic light in sky) *At least half of park area should meet these criteria.*	ALR > 2.00 (>156 nL average anthropogenic light in sky) *At least 90% of wilderness area should meet these criteria.*	ALR > 18.00 (>1404 nL average anthropogenic light in sky) *At least half of park area should meet these criteria.*

However, the utility of a single metric to describe the quality of a complex resource such as the photic environment metric is limited and as such the NSNSD also suggests using additional parameters, if possible, to determine the condition of night sky resources (NPS 2013). The NSNSD has determined threshold values for good, moderate concern and significant concern (Table 12) for both urban and non-urban parks for these parameters (HOFU is classified as a non-urban park):

- The Bortle Dark-Sky Scale (Bortle 2001) – The Bortle Dark-Sky Scale is a nine-step scale, based on the visibility of certain celestial features (e.g., Milky Way, Zodiacal features), that can be used to estimate night sky quality. This is a simple way to make qualitative appraisals of night sky resources that can be done quickly by a dark-adapted individual, but can be biased from one person to another (Bortle 2006; NPS 2013, 2014b) (see: http://www.skyandtelescope.com/resources/darksky/3304011.html).

- Typical Limiting Magnitude (Moore 2001): Limiting magnitude is semi--quantitative visual estimate of sky brightness determined by the dimmest star one can see. It works on the principle that brighter skies mask out faint stars, but varies with the training and visual acuity of the observer and with air quality (NPS 2013).

- Sky Quality Meter (SQM): Measures the amount of light in the night sky using a broad spectrum brightness band that roughly corresponds to the entire human visual range. The SQM measure the aggregate average brightness for the entire sky.

- Celestial Feature Appearance: The ability to see celestial features such as the Milky Way.

- Lightscape Appearance: The appearance of the lightscape to visitors in the park.

- Human Vision: The influence of the natural lightscape on dark adaptation to human vision.

- Sky Quality Index: The Sky Quality Index is an experimental 1-100 index being developed by the National Park Service that features units of equal aesthetic value.

Reference Condition and Status of the Resource (current condition and trends)

The NSNSD has collected data on night sky resources at HOFU in 2014. A 360-degreee panoramic of HOFU captured the night sky and depicts sky brightness in false colors and shows nearby light domes and other sources of anthropogenic light (Figure 27).

Ground based observations at HOFU were collected in August of 2014 by the NSNSD. Based on measurements collected from the park, ALR was 9.26, falling within the moderate concern range for a Level 2 Park (Figure 28). The median modeled ALR for the park was 11.36 (moderate concern) (NPS 2014a). An ALR of 0.0 would indicate pristine natural conditions, while an ALR of 1.0 would indicate that anthropogenic light was 100% brighter than the natural light from the night sky. Therefore, at Hopewell Furnace National Historic Site, the sky is predicted to be 926% brighter than a natural night sky. Both the ground based and modeled values fall within the moderate concern condition (Table 12). Bortle Class was 5 (significant concern) based on visual observations during the site visit in August 2014. Sky Quality Meter measurements were also collected during the site visit. The median SQM value was 19.88 (significant concern). Vertical Illuminance was calculated from ground based measurements with a maximum measure of 5.51 milli-lux. At these light levels, the Milky Way may be visible overhead but has typically lost most of its detail and is not visible along the horizon. Zodiacal light is rarely seen (moderate concern). Anthropogenic light likely dominates natural celestial features and shadows from distant lights may be seen. Dark adaptation may not be possible due to direct glare or background sky brightness. Although the park night sky quality is partially degraded due to the proximity of the multiple population centers, the contrast with nearby urban areas can still be stark, providing views not easily seen in urban areas while also providing a refuge for nocturnal wildlife (NPS 2014a). Overall the condition of the night sky at HOFU was scored as significant concern (Table 12). Since night sky resources have only been evaluated once by the NSNSD no trends could be estimated.

Confidence in Assessment

The quality of the data used to assess night sky resources was good; however, since there has only been one assessment the confidence was assessed as medium.

Threats

There are wildlife species at HOFU that have specific nocturnal behaviors that may be negatively impacted by ecological light pollution (e.g., bats). The dark sky and natural lightscape resources are influenced by the proximity of HOFU to large urban centers (e.g., skyglow from Philadelphia) and populated areas of in proximity to the park that illuminate the night and consequently managing for dark skies at HOFU may be difficult.

Table 12. Threshold condition indicators for night sky resources. Table excerpted from NSNSD 2013.

Qualitative Description	Sensitivity	Good Condition	Moderate Concern	Significant Concern
Bortle Class	Non-urban	Bortle Class 1-3	Bortle Class 4	Bortle Class 5-9
	Urban	Bortle Class 1-4	Bortle Class 5-6	Bortle Class 7-9
Typical Limiting Magnitude	Non-urban	6.8–7.6	6.3–6.7	<6.2
	Urban	6.3–7.6	5.6–6.2	<5.6
Sky Quality Meter	Non-urban	≥21.60	21.20-21.59	<21.20
	Urban	≥21.20	19.70-21.19	<19.70
Celestial Feature Appearance	Non-urban	Zodiacal light can be seen under favorable conditions, Milky Way shows detail and stretches from horizon to horizon	Milky Way has lost most of its detail and is not visible near horizon, Zodiacal light is rarely seen	Milky Way may be visible when it is directly overhead, otherwise not apparent, Andromeda Galaxy may be barely visible
	Urban	Milky Way frequently visible	Milky Way is only visible when it is directly overhead and is not generally apparent	No extended celestial features are visible, only brightest constellations are visible
Lightscape Appearance	Non-urban	Most observers feel they are in a natural environment, with natural features of the night sky readily visible	Anthropogenic light dominates natural celestial features, some shadows from distant lights may be seen	Little sense of naturalness remains in the night sky, landscape is clearly shadowed or illuminated, horizon aglow
	Urban	From within a built environment sky appears largely intact	Discoloration of the sky is likely apparent, shadows are seldom noticed from within a built environment	The sky has lost all aspects of naturalness except for a few hundred visible stars (or less)
Human Vision	Non-urban	Negligible impact to dark adaptation looking in any direction	Dark adaption possible in at least some directions, though visible shadows are likely present	Full dark adaptation not possible, substantial glare may be present, circadian rhythms may be disrupted
	Urban	Full dark adaption possible in at least some directions, though visible shadows may be present	Full dark adaptation not possible, shadows obvious at night from light sources in sky or along horizon, circadian rhythms may be disrupted	Full dark adaptation not possible, significant glare from sky or sources near horizon, higher concern over impact to circadian rhythms
Sky Quality Index	Non-urban	>75	50–74	<50
	Urban	>50	25–49	<25

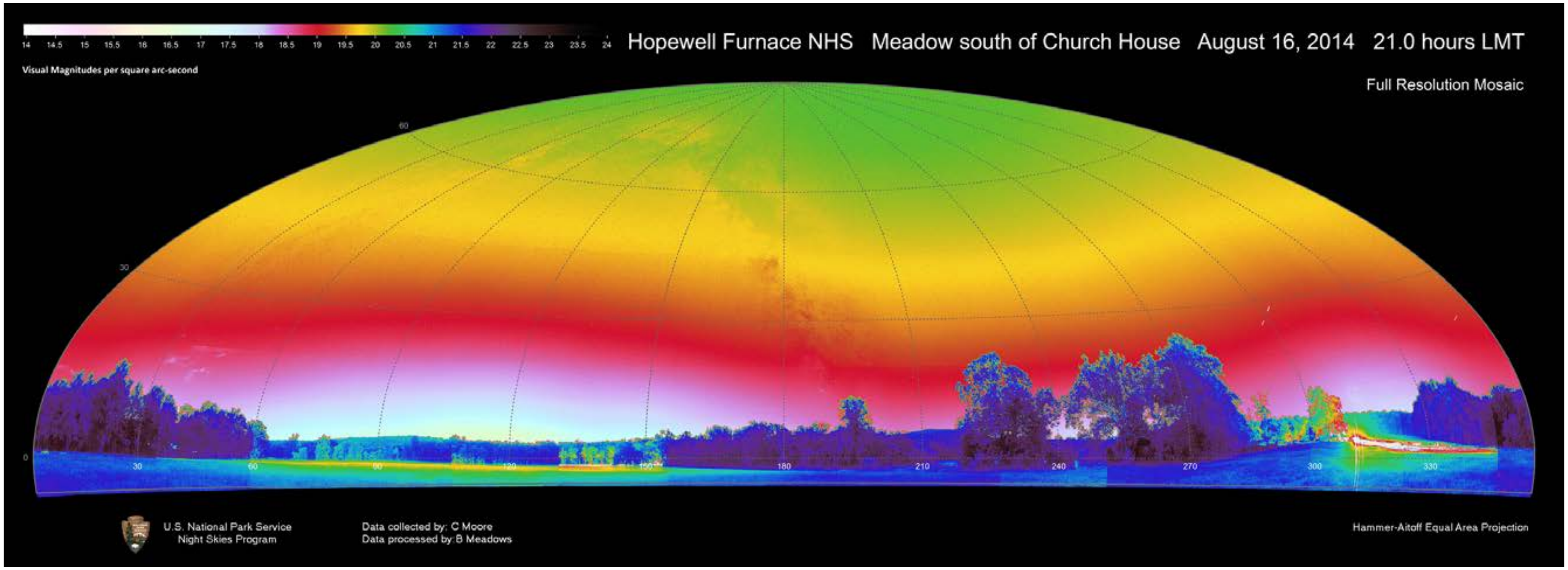

Figure 27. Panoramic Image of natural and anthropogenic light as observed from Hopewell Furnace National Historic Site. Map excerpted from NPS 2014a.

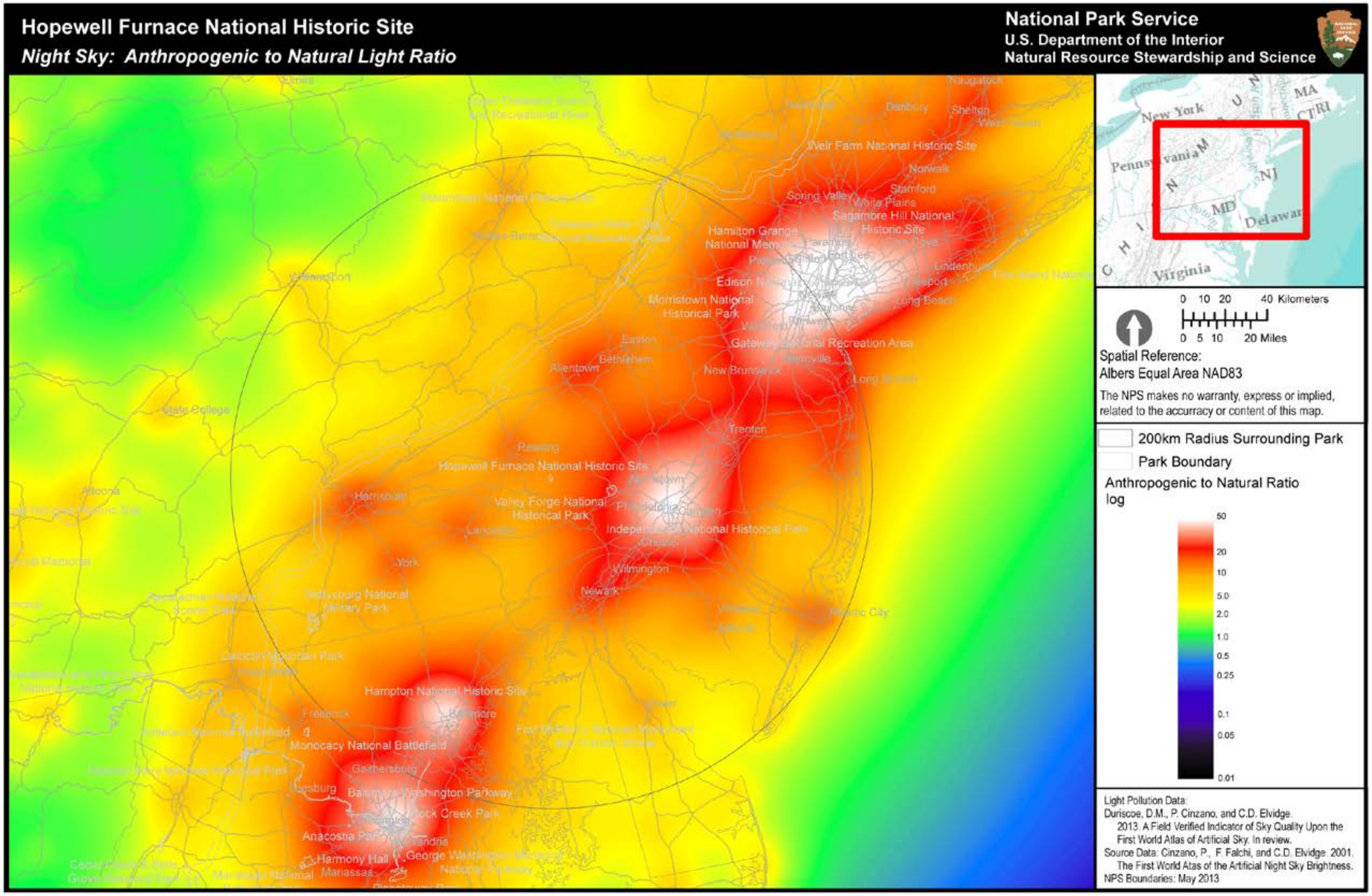

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Figure 28. Modeled anthropogenic to natural light ratio (ALR) for the regional area of HOFU. Map excerpted from NPS 2014a.

Table 13. Condition and trend for night sky resources at HOFU (after NPS 2014a).

Metric	Value	HOFU Condition	HOFU Trend
ALR - ground based, Level 2 Park	9.26		
ALR – modeled, Level 2 Park	11.36		
Bortle Class	5		
Sky Quality Meter	19.88		
Celestial appearance	Milky Way lost most of its detail; Zodiacal light is rarely seen		
Average score of 30 based on NRCA guidelines (refer to Table 5)			

Sources of Expertise

J. White, National Park Service, NPS Natural Sounds and Night Skies Division.

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4.1.5. Acoustic Resources

Relevance and Context

Our ability to see is a powerful tool for experiencing our world, but sound adds a richness that sight alone cannot provide. In many cases, hearing is the only option for experiencing certain aspects of our environment. An unimpaired acoustic environment is an important part of overall visitor experience and enjoyment as well as vitally important to overall ecosystem health.

Visitors to national parks often indicate that an important reason for visiting the parks is to enjoy the relative quiet that parks can offer. In a 1998 survey of the American public, 72% of respondents identified opportunities to experience natural quiet and the sounds of nature as an important reason for having national parks (Haas and Wakefield 1998). Additionally, 91% of NPS visitors “consider enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks” (McDonald et al. 1995). Despite this desire for quiet environments, anthropogenic noise continues to intrude upon natural areas and has become a source of concern in national parks (Lynch et al. 2011).

Sound also plays a critical role in intraspecies communication, courtship and mating, predation and predator avoidance, and effective use of habitat. Studies have shown that wildlife can be adversely affected by sounds that intrude on their habitats. While the severity of the impacts varies depending on the species being studied and other conditions, research strongly supports the fact that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise) and other human disturbances. Documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, and separation of mothers and young (Selye 1956, Clough 1982, USDA 1992, Anderssen et al. 1993, NPS 1994).

The natural soundscape is an inherent component of “the scenery and the natural and historic objects and the wildlife” protected by the Organic Act of 1916. NPS Management Policies (§ 4.9) require the NPS to preserve the park’s natural acoustic environment and restore a degraded acoustic environment to the natural condition wherever possible. Additionally, NPS is required to prevent or minimize degradation of the natural acoustic environment from noise (i.e., inappropriate/undesirable human-caused sound). Although the management policies currently refer to the term *soundscape* as the aggregate of all natural sounds that occur in a park, differences exist between the physical sound sources and human perceptions of those sound sources. The physical sound resources (i.e., wildlife, waterfalls, wind, rain, and cultural or historical sounds), regardless of their audibility, at a particular location are referred to as the *acoustic environment*, while the human perception of that *acoustic environment* is defined as the *soundscape*. Clarifying this distinction will allow managers to create objectives for safeguarding both the *acoustic environment* and the *visitor experience*.

In 2011, the Night Skies Program and the Natural Sounds merged to form the NPS Natural Sounds and Night Skies Division (NSNSD). This program has pioneered techniques for measuring sound and light levels in remote locations, has advanced research into noise and light pollution, and is noted for their application of science to sensory resources. The NPS NSNSD assist park managers with specialized resource management and policy expertise as well as technical expertise in the form of acoustical monitoring, data collections and analysis, and all aspects of park planning and compliance (NPS 2014).

The naturally and culturally appropriate acoustic environment at HOFU could be threatened by human-produced sound outside of the park's boundary. Examples of noise pollution that could negatively impact the park's natural acoustic resource are vehicular traffic from local roads and noise pollution from a nearby gun range.

Data and Methods

Humans and wildlife perceive sound as an auditory sensation created by pressure variations that move through a medium such as water or air. Sound is measured in terms of frequency and amplitude (Templeton and Sacre 1997, Harris 1998). Noise, essentially the negative evaluation of sound, is defined as extraneous or undesired sound (Morfey 2001).

Frequency, measured in Hertz (Hz), describes the cycles per second of a sound wave, and is perceived by the ear as pitch. Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz, and are most sensitive to frequencies between 1,000 Hz and 6,000 Hz. High frequency sounds are more readily absorbed by the atmosphere or scattered by obstructions than low frequency sounds. Low frequency sounds diffract more effectively around obstructions. Therefore, low frequency sounds travel farther.

Besides the pitch of a sound, we also perceive the amplitude (or level) of a sound. This metric is described in decibels (dB). The decibel scale is logarithmic, meaning that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy. This also means that small variations in sound pressure level can have significant effects on the acoustic environment. For instance, a 6 dB increase in a noise source will double the distance at which it can be heard, increasing the affected area by a factor of four. Sound pressure level is commonly summarized in terms of dBA (A-weighted sound pressure level). This metric significantly discounts sounds below 1,000 Hz and above 6,000 Hz to approximate human hearing sensitivity. Table 14 provides examples of A-weighted sound levels measured in national parks.

The natural acoustic environment is vital to the function and character of a national park. Natural sounds include those sounds upon which ecological processes and interactions depend. Examples of natural sounds in parks include:

- Sounds produced by birds, frogs or insects to define territories or attract mates
- Sounds produced by bats to navigate or locate prey
- Sounds produced by physical processes such as wind in trees, flowing water, or thunder

Table 14. Examples of sound levels measured in national parks.

Decibel level (dBA)	Sound Source	Decibel level (dBA)	Sound Source
10	Volcano crater (Haleakala NP)	80	Snowcoach at 30 m (Yellowstone NP)
20	Leaves rustling (Canyonlands NP)	100	Thunder (Arches NP)
40	Crickets at 5 m (Zion NP)	120	Military jet, 100m above ground level (Yukon-Charley Rivers NP)
60	Conversational speech at 5 m (Whitman Mission NHS)	126	Cannon fire at 150m (Vicksburg NMP)

Although natural sounds often dominate the acoustic environment of a park, human-caused noise has the potential to mask these sounds. Noise impacts the acoustic environment much like smog impacts the visual environment; obscuring the listening horizon for both wildlife and visitors. Examples of human-caused sounds heard in parks include:

- Aircraft (i.e., high-altitude and military jets, fixed-wing, helicopters)
- Vehicles
- Generators
- Watercraft
- Grounds care (lawn mowers, leaf blowers)
- Human voices

Characterizing the acoustic environment

Oftentimes, managers characterize ambient conditions over the full extent of the park by dividing total area into "acoustic zones" on the basis of different vegetation zones, management zones, visitor use zones, elevations, or climate conditions. Then, the intensity, duration, and distribution of sound sources in each zone can be assessed by collecting sound pressure level (SPL) measurements, digital audio recordings, and meteorological data. Indicators typically summarized in resource assessments include natural and existing ambient sound levels and types of sound sources. *Natural ambient* sound level refers to the acoustical conditions that exist in the absence of human-caused noise and represents the level from which the NPS measures impacts to the acoustic environment. *Existing ambient* sound level refers to the current sound intensity of an area, including both natural and human-caused sounds. The influence of anthropogenic noise on the acoustic environment is generally reported in terms of SPL across the full range of human hearing (12.5-20,000 Hz), but it is also useful to report results in a much narrower band (20-1250 Hz) because most human-caused sound is confined to these lower frequencies.

Reference Condition and Status of the Resource (current condition and trends)

Reference criteria should address the effects of noise on human health and physiology, the effects of noise on wildlife, the effects of noise on the quality of the visitor experience, and finally, how noise impacts the inherent value of the acoustic environment.

Various characteristics of sound can contribute to how noise may affect the acoustic environment. These characteristics may include rate of occurrence, duration, pitch, and whether the sound occurs consistently or sporadically. In order to capture these aspects, the quality of the acoustic environment is assessed using a number of different metrics including existing ambient and natural ambient sound level (measured in decibels), percent time human-caused noise is audible, and noise free interval. In summary, if we are to develop a complete understanding of a park's acoustic environment, we must consider a variety of sound metrics.

This can make selecting one reference condition difficult. For example, if we chose to use just the natural ambient sound level for our reference condition, we would focus only on sound pressure level and overlook the other aspects of sound mentioned above.

Ideally, reference conditions would be based on measurements collected in the park, but this is not always logistically feasible. In cases where on-site measurements have not been gathered, one can reference meta-analyses of national park monitoring efforts such as those detailed in Lynch et al. (2011) and Mennitt et al. (2013). The former aggregated data from 189 sites in 43 national parks, and reported that the median L_{90} across all sites and hours of the day was 21.8 dBA (between 20 and 800 Hz). L_{90} is the sound level that is heard 90% of the time; an estimate of the background against which individual sounds are heard. The latter, a similarly comprehensive geospatial modeling effort (which assimilated data from 291 park monitoring sites across the nation), revealed that the median daytime existing sound level in national parks rests around 31 dBA. In addition, among 89 acoustic monitoring deployments analyzed for audibility, the median percent time audible of anthropogenic noise during daytime hours was found to be 35%.

In cases where acoustic data have been collected on site, a balanced assessment of acoustical conditions in a park will report natural and existing sound levels (for either daytime, nighttime, or 24 hour time periods), percent time audible for natural sounds and noise sources of interest, and noise free intervals. Human responses can actually serve as a proxy for potential impacts to other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper 2007), so a resource assessment might also consider the time that SPL levels exceeded those mentioned in Table 15. The first value (35 dBA) is designed to address the health effects of sleep interruption. Recent studies suggest that sound events as low as 35 dB can have adverse effects on blood pressure while sleeping (Haralabidis et al. 2008). The second threshold addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al. 1999). Park visitors camping in or near the park could experience either of these two effects. The third level (52 dBA) is based on the EPA's speech interference threshold for speaking in a raised voice to an audience at 10 meters. This threshold addresses the effects of noise on interpretive programs in parks. The final threshold (60 dBA) provides a basis for estimating impacts on normal voice communications at 1 meter. Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

Table 15. Effects of sound pressure levels (SPL) on humans.

SPL (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al. 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund et al. 1999)
52	Speech interference for interpretive programs (U.S. Environmental Protection Agency 1974)
60	Speech interruption for normal conversation (U.S. Environmental Protection Agency 1974)

In cases where ability to collect acoustic data on site is limited, alternatives for assessing condition and trend are also available. Using acoustic data collected at 244 sites and 109 spatial explanatory layers (such as location, landcover, hydrology, wind speed, and proximity to noise sources such as roads, railroads, and airports), NSNSD has developed a geospatial sound model which predicts natural and existing sound levels with 270 meter resolution (see Figure 29) (Mennitt et al. 2013). In addition to predicting these two ambient sound levels, the model also calculates the difference between the two metrics, providing a measure of impact to the natural acoustic environment from anthropogenic sources. The resulting metric (L_{50} dBA impact) indicates how much anthropogenic noise raises the existing sound pressure levels in a given location.

To gain insight into the condition of the acoustic environment in parks where acoustic data have not been collected, it is also useful to have an inventory of audible sounds. The important variables to track are what sounds are audible, how often they are audible, and how many times they are audible. These data are best collected by a single, focused listener in calm weather conditions during a series of listening sessions. It is advisable to conduct the sound inventory in a number of different locations and across different times of day to capture spatial and temporal variation in acoustic conditions. A listening session of this nature can be conducted with tools as simple as a pen, paper, and stopwatch, or with custom software produced by the NSNSD which runs on most Apple iOS products. The ultimate goal of the inventory is to gather information about what sounds presently contribute to the acoustic environment, which are the most common, and which could possibly threaten the quality of the acoustic environment.

To assess the condition of the acoustic environment, it is also useful to consider the functional effects that increases in sound level might produce. For instance, the *listening area*, the area in which a sound can be perceived by an organism, will be reduced when background sound levels increase. The failure to perceive a sound because other sounds are present is called *masking*. Masking interferes with wildlife communication, reproductive and territorial advertisement, and acoustic location of prey or predators (Barber et al. 2010). However, the effects of masking are not limited to wildlife. Masking also inhibits human communication and visitor detection of wildlife sounds. In urban settings, masking can prevent people from hearing important sounds like approaching people or vehicles, and interfere with the way visitors experience cultural sounds or interpretive programs. Keep in mind that seemingly small increases in sound level can have substantial effects, particularly when quantified in terms of loss of listening area (Payne and Webb 1971, Barber et al. 2010). Each 3 dB increase in the background sound level will reduce a given listening area by half. See Table 16 for additional information.

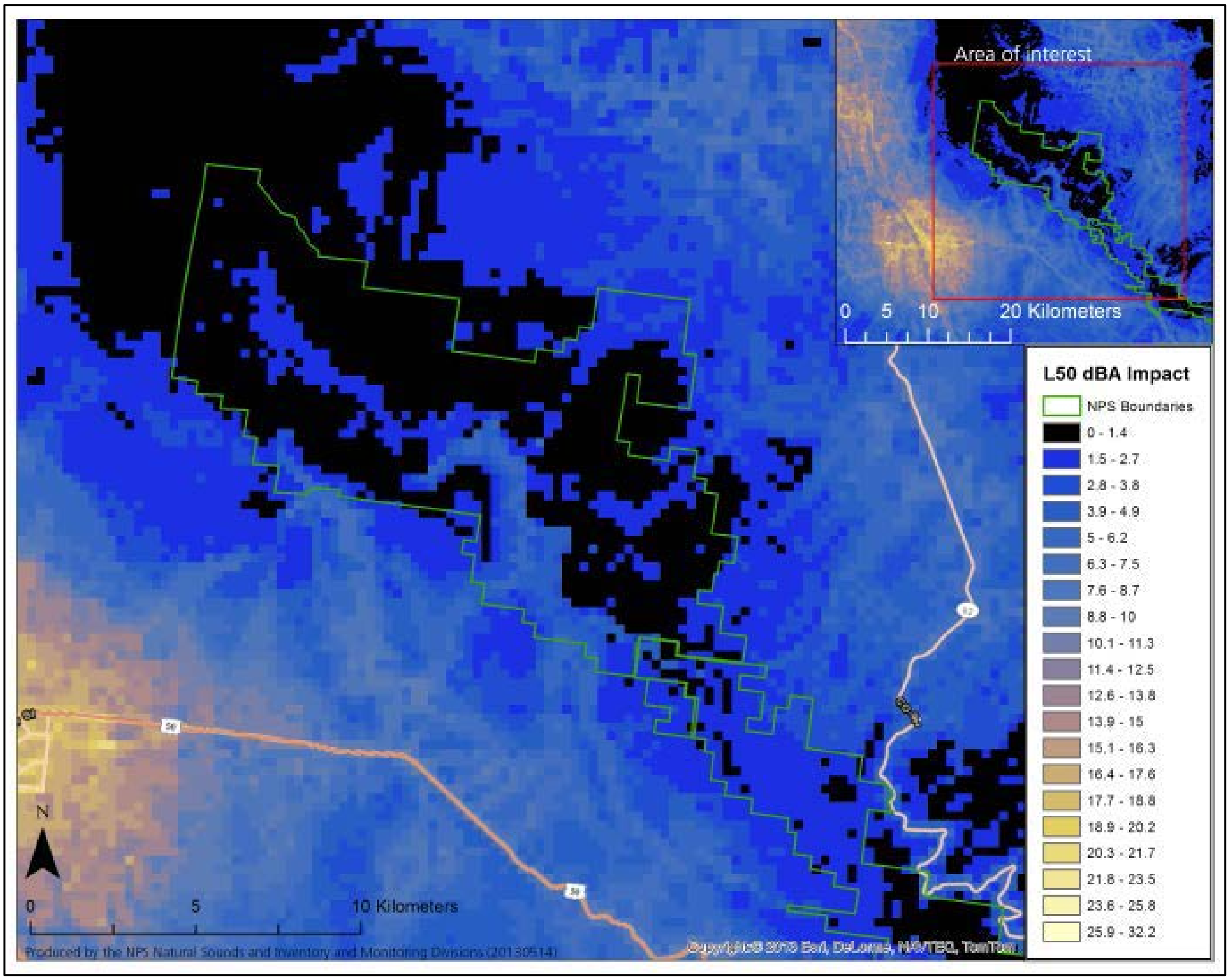

Figure 29. Map displaying modeled L_{50} dBA impact levels in a park.

Table 16. Increases in background sound level (dB) with resulting decreases in listening area.

Increase in background sound level (dB)	Decrease in listening area
1	21%
2	37%
3	50%
4	60%
5	68%
6	75%
7	80%
8	84%
9	87%
10	90%

Evaluating trends in condition is straightforward for parks where repeated measurements have been conducted because measurements can be compared. But inferences can also be made for parks where fewer data points exist. Nationwide trends indicate that prominent sources of noise in parks (namely vehicular traffic and aircraft) are increasing. However, it is possible that conditions in specific parks differ from national trends. The following events might contribute to a declining trend in the quality of the acoustic environment: expansion of traffic corridors nearby, increases in traffic due to industry, changes in zoning or leases on adjacent lands, changes in land use, planned construction in or near the park, increases in population, and changes to airspace (particularly those which bring more aircraft closer to the park). Most states post data on traffic counts on department of transportation websites, and these can be a good resource for assessing trends in vehicular traffic. Changes to airport operations, air space, and land use will generally be publicized and evaluated through the National Environmental Policy Act (NEPA) process.

Conversely, the following events may signal improvements in trend: installation of quiet pavement in or near parks, use of quiet technology for recreation in parks, decrease in vehicle traffic, use of quiet shuttle system instead of passenger cars, building utility retrofits (e.g. replacing a generator with solar array), or installation of "quiet zone" signage.

There is an ongoing effort to assess condition and trend of acoustic resources for the state of the parks (SOP) project, and although SOPs generally report one metric per resource (while NRCAs often incorporate multiple metrics), it may serve as a useful template (see this link for more information: https://irma.nps.gov/App/Reference/Profile/2206094). Table 17 reports suggested thresholds for the mean L_{50} impact, which is a measure of the impact of anthropogenic sources on the acoustic environment. Because the National Park System is comprised of a wide variety of park units, two threshold categories are considered (urban and non-urban), based on proximity to urban areas (U.S. Census Bureau 2010). The urban criteria are applied to park units that have at least 90% of the park property *within* an urban area. The non-urban criteria were applied to units that have at least 90% of the park property *outside* an Urban Area. Parks that are distant from urban areas possess lower sound levels, and they exhibit less divergence between existing sound levels and predicted natural sound levels. These quiet areas are more susceptible to subtle noise intrusions than urban areas. Visitors and wildlife have a greater expectation for noise-free environments. Accordingly, the thresholds for the moderate concern and significant concern condition ratings are lower for these park units than for units near urban areas. Urban areas tend to have higher ambient sound levels than non-urban areas (U.S. EPA 1971, Schomer et al. 2011). Higher thresholds are used for parks in urban areas. However, acoustic environments are important in all parks: units in urban areas may seek to preserve or restore low ambient sound levels to offer respite for visitors. HOFU is considered a non-urban park.

A common source of noise in national parks is transportation (i.e., airplanes, vehicles). Growth in transportation is increasing faster than is the human population (Barber et al. 2010). Between 1970 and 2007, traffic on US roads nearly tripled to almost 5 trillion vehicle km/yr (http://www.fhwa.dot.gov/ohim/tvtw/tvtpage.cfm). Aircraft traffic grew by a factor of three or more between 1981 and 2007 (http://www.bts.gov/programs/airline_information/ air_carrier_traffic_statistics/airtraffic/annual/1981_present.html). As these noise sources increase throughout the United States, the ability to protect pristine and quiet natural areas becomes more difficult (Mace et al. 2004).

Although data have not been collected at HOFU, the NSNSD has developed a continental noise model which has been used to inform NRCAs and state of the parks analyses and other planning documents. It predicts mean sound level impacts using measurements made in hundreds of national park sites as well as 109 explanatory variables such as location, climate, land cover, hydrology, wind speed, and proximity to noise sources such as roads, railroads, and airports (NSNSD personal communication). The methods that were used to generate the model have been peer-reviewed (Mennitt et al. 2014). The NSNSD have generated model results for HOFU. According to modeled noise impacts HOFU had a mean of 4.6 dBA (Table 17), the current condition of acoustical resources at this non-urban park would be considered cause for significant concern (NSNSD personal communication).

Confidence in Assessment

The condition of significant concern for the acoustic environment was based on modeled data that predicts mean sound level impacts using measurements made in hundreds of national park sites as well as 109 explanatory variables such as location, climate, land cover, hydrology, wind speed, and proximity to noise sources such as roads, railroads, and airports (NSNSD personal communication). The confidence in the assessment was based as medium simply for reason that the condition was based on modeled data and not field data for HOFU.

Table 17. Example condition thresholds for non-urban and urban parks courtesy of the NSNSD. HOFU is considered a non-urban park by the NSNSD.

Indicator	Condition	Threshold for non-urban parks (dBA)	Threshold for urban parks (dBA)
Mean L_{50} impact (dBA) Calculated as difference between existing ambient and natural ambient models	Good Condition	Threshold ≤ 1.5 *Listening area reduced by ≤ 30%*	Threshold ≤ 6.0 *Listening area reduced by ≤ 75%*
	Moderate Concern	1.5 < Threshold ≤ 3.0 *Listening area reduced by 30 - 50%*	6.0 < Threshold ≤ 12 *Listening area reduced by 75 - 94%*
	Significant Concern	3.0 < Threshold *Listening area reduced by > 50%*	12 < Threshold *Listening area reduced by > 94%*
HOFU Condition	Significant Concern	HOFU modeled noise impacts: 4.6 dBA	

Data Gaps

Baseline acoustic ambient data collection will clarify existing conditions and provide greater confidence in resource condition trends. Wherever possible, baseline ambient data collection should be conducted. In addition to providing site specific information, this information can also strengthen the national noise model.

With respect to the effects of noise, there is compelling evidence that wildlife can suffer adverse behavioral and physiological changes from noise and other human disturbances, but the ability to translate that evidence into quantitative estimates of impacts is presently limited. Several recommendations have been made for human exposure to noise, but no guidelines exist for wildlife and the habitats we share. The majority of research on wildlife has focused on acute noise events, so further research needs to be dedicated to chronic noise exposure (Barber et al. 2011). In addition to wildlife, standards have not been developed yet for assessing the quality of physical sound resources (the acoustic environment), separate from human or wildlife perception. Scientists are also working to differentiate between impacts to wildlife that result from the noise itself or the presence of the noise source.

An inventory and/or monitoring of the acoustic environment would be beneficial for the HOFU.

Threats

The naturally and culturally appropriate acoustic environment at HOFU could be threatened by human-produced sound outside of the park’s boundary. Examples of noise pollution that could negatively impact the park’s natural acoustic environment are vehicular traffic from local roads and noise pollution from a nearby gun range.

Sources of Expertise

The NPS Natural Sounds and Night Skies Division scientists help parks manage sounds in a way that balances the various expectations of park visitors with the protection of park resources. They provide technical assistance to parks in the form of acoustical monitoring, data collection and analysis, and in developing acoustic baselines for planning and reporting purposes. For more information, see http://www.nature.nps.gov/sound/.

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4.2. Water and Water-related Resources

4.2.1. Stream Water Quality

Relevance and Context

Water quality is ecologically significant as it affects aquatic communities and ecosystems (Karr et al. 1986). MIDN parks such as HOFU are affected by industrial, agricultural, and airborne pollutants (Carpenter et al. 1996). The National Park Service (2002) has identified minimum core water chemistry standards for temperature, pH, dissolved oxygen, and specific conductance for freshwater resources. Other parameters that were deemed important, but not crucial monitoring parameters, were water flow/discharge for flowing waters and some qualitative assessment of stage/level and water column profiles for non-flowing waterbodies (NPS 2002).

Water resources (water quantity and quality) are arguably the most significant cultural and natural features associated with the park. French Creek and its tributary systems have not only historically provided the vital energy resource needed to power the furnace, but also the primary means of sustaining life on the plantation by supplying the water for livestock and human consumption. Much has changed since Hopewell Furnace was last in commercial operation, but even today French Creek provides the water powering the park's interpretative iron operations and the creek itself still provides sustenance to the parks livestock and is key component of the cultural and natural viewshed. French Creek, a tributary of the Schuylkill River, is a PA designated Exceptional Value (EV) stream and for Migratory Fishes (MF) and flows through the heart the park near the creek's headwaters. Downstream of the park French Creek is designated as a High Quality-Trout Stocked Fishery (TSF) (Pennsylvania Code §93.7). French Creek State Park contains nearly all of the French Creek Basin upstream of the park, and therefore it is the source of much of the stream water found in French Creek within the park's boundaries. French Creek drains from Hopewell Lake, which is located within French Creek State Park, and thus activities and water quality of the lake greatly influence the water quality of French Creek (Keener and Sharpe 2004). The main tributaries of French Creek are Baptism Creek and Spout Run.

Locally, water quality at HOFU may be influenced by agricultural uses (agricultural fields, livestock), the leachate from historic slag piles, and/or runoff from park grounds. The release of water from the dam and spillway upstream at Hopewell Lake may also influence the water quality of French Creek within HOFU. For example, drawdown events from Hopewell Lake may change the water temperature and/or water chemistry and thus impact the park's water resources (Keener and Sharpe 2004). Additionally, Hopewell Furnace has experienced flooding and localized erosion problems since its inception in the late 1700s (USACE 2011). Flooding originates from French Creek (from storm overflow events at the Hopewell Lake spillway) and from local runoff from park gravel roads and the parking lot. Flooding has damaged historic structures (e.g., the Cast House) in the past. Erosion and flooding occur along park waterways during seasonal storms and could threaten park infrastructure (Thornberry-Ehrlich 2010, USACE 2011).

Data and Methods

Baseline water quality data, inventory, and analyses were conducted at HOFU in 1998 (NPS 1998). The baseline inventory presented results from surface water quality data retrievals from six of the EPA's national databases from 1950 to 1996. Seventy-eight monitoring stations were located within the baseline study area (3 miles upstream and 1 mile downstream of park boundaries) with only six stations within park boundaries (Figure 30). The stations within the park boundary represented either one-time or intensive single-year sampling (e.g., Sharpe and Neff 1993) with none of the stations yielding longer-term records.

Water quality surveys were conducted in 1992 and again in 2002 that sampled the same six locations in HOFU, during both low flow and high flow conditions (Sharpe and Neff 1993, Keener and Sharpe 2004). Samples were analyzed for pH, conductivity, nitrogen species, turbidity, sulfates, choline, lead, nickel, cadmium, iron, aluminum, and bacterial contamination. Additional parameters measured only in 2002 were dissolved oxygen, temperature, and flow rate (Keener and Sharpe 2002).

Sloto and Reif (2011) sampled water quality and streambed sediments at five stream sites in HOFU as part of their 2009 assessment of trace metals. Stream sites were sampled during base-flow conditions in November 2008, to determine if trace metal or other contamination from the slag piles at Hopewell Furnace was affecting the water quality in French Creek (Figure 31). One site was selected to represent reference conditions (Baptism Creek, site HF-4) and another site was upstream of Hopewell Furnace on French Creek (site HF-1). The other three sites were downstream of the furnace on French Creek (sites HF-2, HF-3, and HF-5) (Sloto and Reif 2011).

The USGS initiated continuous water quality monitoring at two stations in HOFU (HOFU-1 and HOFU-2) from April 2010 to September 2010; The MIDN has monthly observations (HOFU-1) on core water quality parameters: water temperature, specific conductance, pH, and dissolved oxygen from April 2010-December 2013. In October 2012, continuous water quality using an YSI 6920-V2 was reestablished at the USGS HOFU-1 monitoring site by the MIDN (J. Comiskey, personal communication, email 17 April 2014. Note: only the 2010 were currently available). The MIDN also takes monthly grab samples for water chemistry (April 2010-December 2011) for major anions/cations, ANC, DOC, SiO_2, NH_4, NO_3, and PO_4 at this site (N. Dammeyer, personal communication, email 3 April 2014). As of this writing, these data have not yet been interpreted, but are presented herein as they are the most recent data for the park.

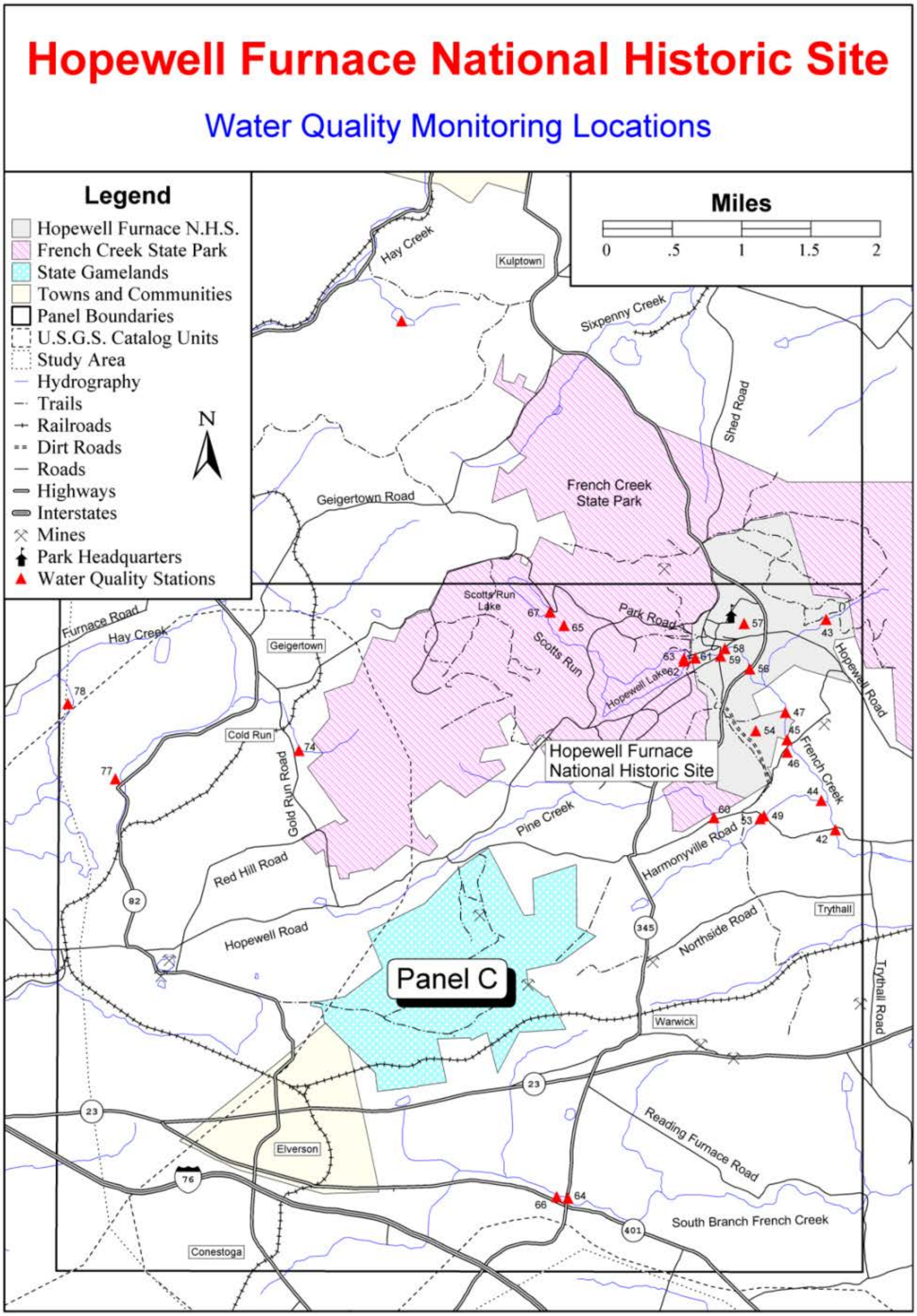

Figure 30. Historic (1998) water quality stations within HOFU (stations in gray shaded area) as summarized by the NPS baseline water quality survey of 1998 (map excerpted from NPS 1998).

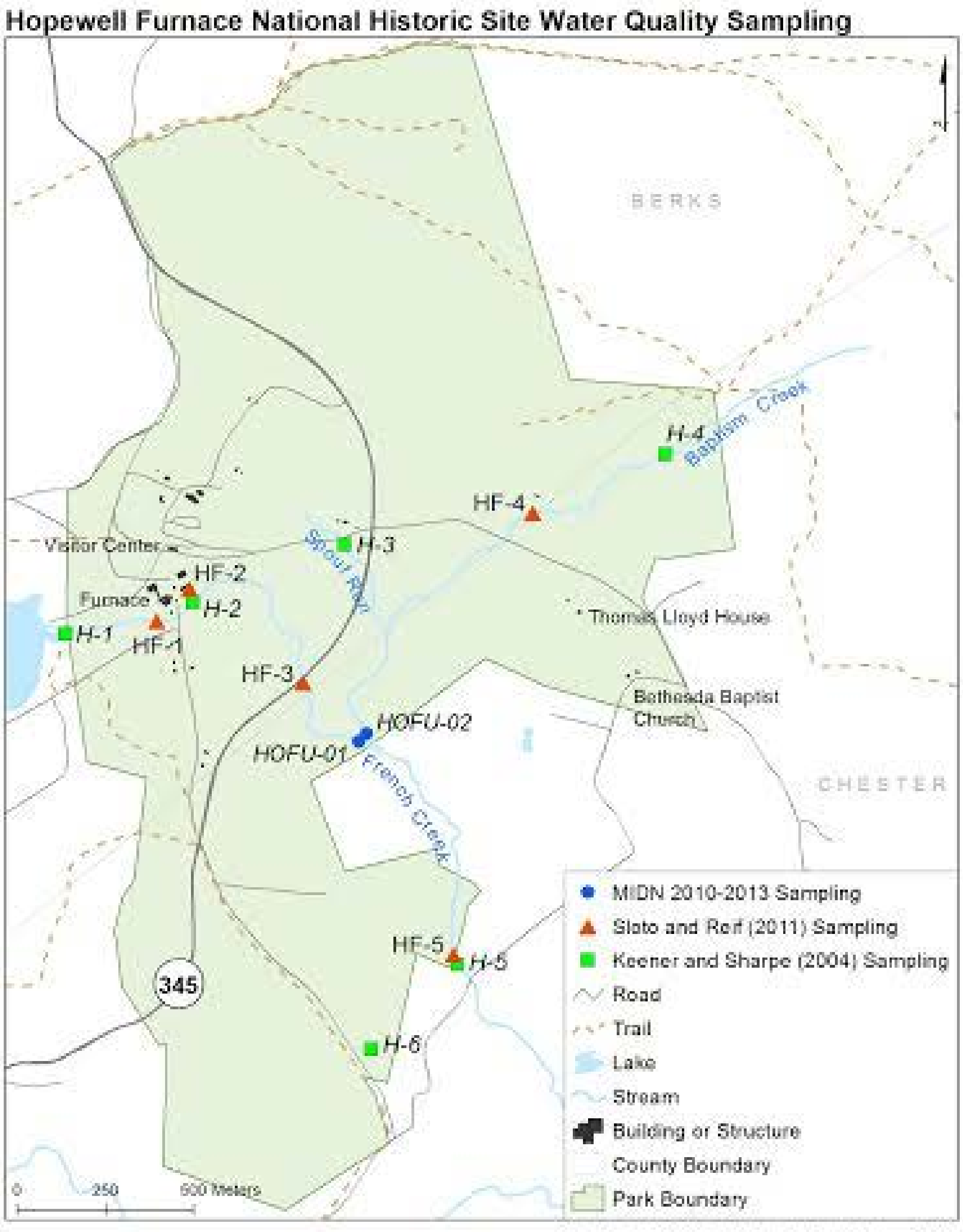

Figure 31. Location of stream sites sampled for water quality. Map indicates location of sites sampled by the MIDN, Sloto and Reif (2011), and Keener and Sharpe (2004).

<u>Reference Condition and Status of the Resource (current condition and trends)</u>

French Creek and its tributaries are classified as an Exceptional Value streams and with protected uses for Migratory Fishes (Pennsylvania Code §93.7) and as such established Pennsylvania water quality stands were used as the metrics to assess this resource (refer to Appendix Table 49, Appendix Table 50, Appendix Table 51).

French and Baptism Creek have not been sampled as part of the Pennsylvania water quality assessment (EPA 2014). However, Sloto and Reif (2011) used EPA established aquatic-life criteria to assess water quality in French and Baptism Creek as part of their trace metal assessment for HOFU. Their criteria categories included criteria maximum concentration (CMC) and criteria continuous concentration (CCC). The CMC was an estimate of the highest concentration of a constituent in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. The CCC was an estimate of the highest concentration of a constituent in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. Aquatic-life criteria were created for aluminum, arsenic, cadmium, chromium, iron, lead, nickel, selenium, silver, and zinc. No metal concentrations measured at the five sites exceeded the CMC or CCC (Table 18).

Base-flow water samples indicated good overall base-flow surface-water quality. The five sites generally had low concentrations of nutrients and major ions but had elevated concentrations of iron, manganese, and strontium when compared to sites sampled from the adjacent Pickering and Pigeon Creek watersheds for the same time period (Sloto and Reif 2011). The Baptism Creek background site (HF-4) generally had the lowest concentrations and yields of constituents. Although the concentrations at the other four sites were higher, all stream-water samples met drinking-water and aquatic-life criteria. Low concentrations of nutrients and major ions at all five sites indicate that measured concentrations can be attributed to general land use and geology and not to point sources. Concentrations of ammonia at sites upstream (HF-1) and downstream (HF-2) of the ironworks were greater than at the background Baptism Creek (HF-4) site. Ammonia concentrations further downstream of the ironworks (HF-3 and HF-5) decreased to background concentrations (Sloto and Reif 2011).

MIDN monthly water quality data (2010-2014) indicated that dissolved oxygen and pH were within acceptable limits (TSF value for minimum dissolved oxygen was used as values for EV/MF were not available, refer to Appendix Table 50) (Figure 32). Specific conductance was also within acceptable ranges except on one occasion. Water temperature exceeded the maximum acceptable temperature for TSF waters (Appendix Table 51) 45% of the time at HOFU_1 and 23% of the time at HOFU_2 (Figure 32, bottom graph). Based on best professional judgement stream water quality related to dissolved oxygen, pH, and conductance were evaluated as good condition with a stable trend. Water temperature was assessed as moderate concern due to elevated temperatures at HOFU_1. The trend for all four parameters was assessed as stable; however, water quality assessment may change pending further analyses of recent water quality data (Table 19).

Table 18. Comparison of published criteria maximum and continuous concentrations[1] to measured maximum concentrations of selected trace metals in stream surface water at HOFU (Table after Sloto and Reif 2011).

Element	Criteria maximum concentration (mg gm^{-1})	Criterion continuous concentration (mg gm^{-1})	Maximum concentration at sampled sites (mg gm^{-1})	Maximum concentration site location[2]	Condition
Aluminum	750	87	37	HF-4	
Arsenic	340	150	0.39	HF-1	
Cadmium	2	0.25	<0.06	All sites	
Chromium (VI)	16	11	<0.04	All sites	
Iron	--	1,000	346	HF-2	
Lead	65	2.5	0.61	HF-2	
Nickel	470	52	0.6	HF-4	
Selenium	--	5	0.14	HF-2	
Silver	3.2	--	<0.06	All sites	
Zinc	120	120	5.5	HF-3	
Overall condition based on trace metal concentration					

[1] Based on US EPA water quality criteria (from Sloto and Reif 2011).

[2] Refer to Figure 31 for sampling site locations.

Table 19. Water quality metrics and condition estimates based on recent MIDN water quality monitoring. Refer to Appendix Table 50 and Appendix Table 51 for water quality criteria thresholds.

Metric[1]	Condition and Trend Estimate	Description
Temperature	Moderate concern	Temperature exceeded threshold for Trout Stocked Fisheries more than 45% (HOFU_1) and 22% (HOFU_2) of the time.
Dissolved oxygen	Good	Dissolved oxygen was within thresholds over the monitoring period.
pH	Good	pH was within thresholds over the monitoring period.
Specific conductance		Specific conductance was within thresholds, except on one sampling date, over the monitoring period.

1. Condition based on preliminary raw data from MIDN monthly water quality monitoring. Condition and trend may be subject to change after further analyses are completed.

Confidence in Assessment

Confidence in the assessment of trace metals in surface waters was good. The confidence in the assessment of other water quality parameters was medium because the water quality data have not been completely analyzed by the MIDN.

Data Gaps

The MIDN has recently initiated continuous water quality monitoring at one stream site at HOFU. The Network currently monitors water temperature, dissolved oxygen, pH, and specific conductivity. Future continuous monitoring may include water discharge rates. Water temperature exceedances suggest that thermal pollution is occurring in French Creek within park boundaries. To specifically target the source of stream temperature fluctuations the park may want to initiate a stream water temperature study, sampling water temperature upstream of Hopewell Lake and along various portions of French Creek.

Threats

Threats to the water resources at HOFU include water quality and activities upstream of French Creek (e.g., French Creek State Park, Hopewell Lake water quality, land development). Livestock (horses, sheep) currently graze in the fields within the park and the have access to French Creek. Runoff from the barn stockyard drains directly into French Creek and is a source of fecal bacterial contamination that may result in depleted dissolved oxygen concentrations, increased turbidity, and eutrophication. However, Keener and Sharpe (2004) concluded that these issues were not serious enough to compromise the historical integrity of park through corrective actions.

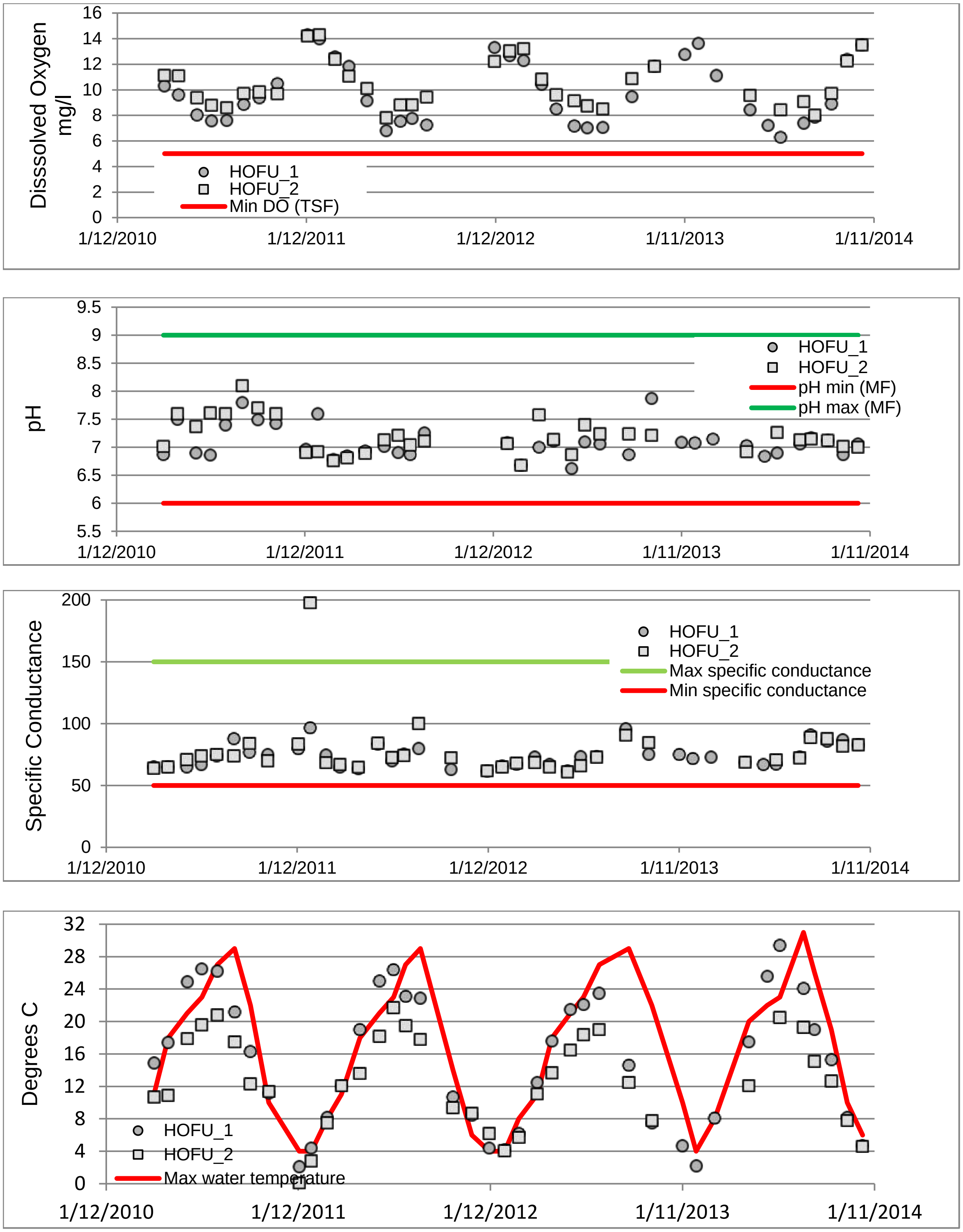

Figure 32. MIDN monthly water quality monitoring from two stations at HOFU. Top: dissolved oxygen, middle: pH and specific conductance; bottom: temperature. Threshold values for are indicated by red and green lines.

Hopewell Lake, upstream of the park, may threaten water quality in French Creek within the parks boundaries. Since the lake is typically maintained at its maximum pool elevations, it has a minimal capacity for flood storage during storm events. Erosion and flooding occur along park waterways during seasonal storms and threatens park infrastructure. In an effort to identify the source and reduce the frequency of flooding and erosion to HOFU facilities, the park sought the assistance of the USACE. Recommendations from the USACE study were to remove the existing footbridge and abutments in the park, install a new longer span footbridge over French Creek, possible channelization within French Creek, and modification to the existing storm management system within HOFU park grounds (USACE 2011). Hopewell Lake is a shallow lake and the top-release spillway may also contribute to thermal pollution downstream (P. Sharpe, personal communication, 29 August 2014). Additionally, drawdown events at Hopewell Lake also threaten the water quality of French Creek. Keener and Sharpe (2004) noted that iron staining one the rocks at the outflow of Hopewell Lake Dam (observed in 1992-1993). Extensive oxidation of lake water may result from drawdowns due to the exposure of iron-rich sandstone bedrock to oxidization conditions which in turn may increase concentrations of dissolved and suspended iron in French Creek stream water and may negatively impact water quality and aquatic biota of French Creek (Keener and Sharpe 2004). Since 2002, there have been five major drawdowns of Hopewell Lake; however, the effect of repeated drawdowns on the water quality of French Creek has not been examined (Keener and Sharpe 2002).

Although trace metal concentrations in surface water were within acceptable ranges for water quality criteria, the slag piles, which in places form the banks of French Creek (Sloto and Reif 2011), could also be a threat to water quality. Leachate experiments on slag samples found that four metals (Al, Cu, Fe, and Mn) had potential environmentally problematic concentrations, exceeding thresholds for both drinking water and aquatic life criteria (Piatak and Seal 2012). Weathering rates affect which elements and how much these metals are leached and released into the environment. For example, weathering rates of Fe metal and Fe oxides, which host Cu and some Fe, are likely higher than the silicate glass, which hosts a significant portion of the Al and Mn present the slag piles at HOFU (Piatak and Seal 2012).

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4.2.2. Streambed Habitat and Stream Morphology

Relevance and Context

Streambed sediment and habitat quality can affect aquatic communities. Harmful effects in aquatic communities are likely to be observed when concentrations of certain contaminants are above the probable effect concentration (PEC). Sediment-quality concentration guidelines for arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc in sediments have been established to identify environmental conditions that may pose a threat to aquatic resources (MacDonald et al. 2000). PECs have not been established in the United States for aluminum, iron, and manganese (Sloto and Reif 2011). The structure of the stream and adjacent riparian zone (e.g., vegetative cover, riparian buffer, substrate quality) can be used as a measure of habitat quality as the surrounding physical habitat can influence the water quality and the condition of the aquatic macroinvertebrate and fish communities (Sloto and Reif 2011, PA DEP 2013).

Data and Methods

Sharpe and Keener (2003) used the EPA Rapid Bioassessment (Barbour et al. 1999, P. Sharpe, Northeast Hydrologist personal communication, phone communication 27 August 2014) method to evaluate stream habitat in 90-m sections of French Creek, Spout Run, and Baptism Creek during their 2002 fish survey at HOFU. Sloto and Reif (2011) sampled streambed sediments at five stream sites within the park as part of their 2009 assessment of trace metals (Figure 33). Samples were collected from depositional areas within the 100-m stream reach selected for aquatic macroinvertebrate sampling (refer to Aquatic Macroinvertebrate Section). The top 15 cm (6 in) of fine-grained sediments were collected, sieved to remove gravel, and analyzed for trace metals (Sloto and Reif 2011).

Sloto and Reif (2011) also measured physical parameters that were pertinent to stream habitat quality and evaluated the variety and quality of the substrate, channel morphology, bank structure, and riparian areas. The selected parameters were: epifaunal substrate and available cover, embeddedness, velocity and depth, sediment deposition, channel flow, channel alteration, riffle or bend frequency, bank stability, vegetative protection, and riparian vegetative zone width. These parameters were rated on a numerical scale of 0 to 20, with a maximum score of 200 (after Barbour et al. 1999) for each sampling reach with higher scores indicating improved habitat quality. Sloto and Reif (2011) divided the scores into four habitat assessment groups which were then interpreted as an estimate of condition for this report: optimal (good: 20-16), suboptimal (moderate concern: 15-10), marginal (moderate concern: 9-6), and poor (significant concern: 6 to 0) (Table 20).

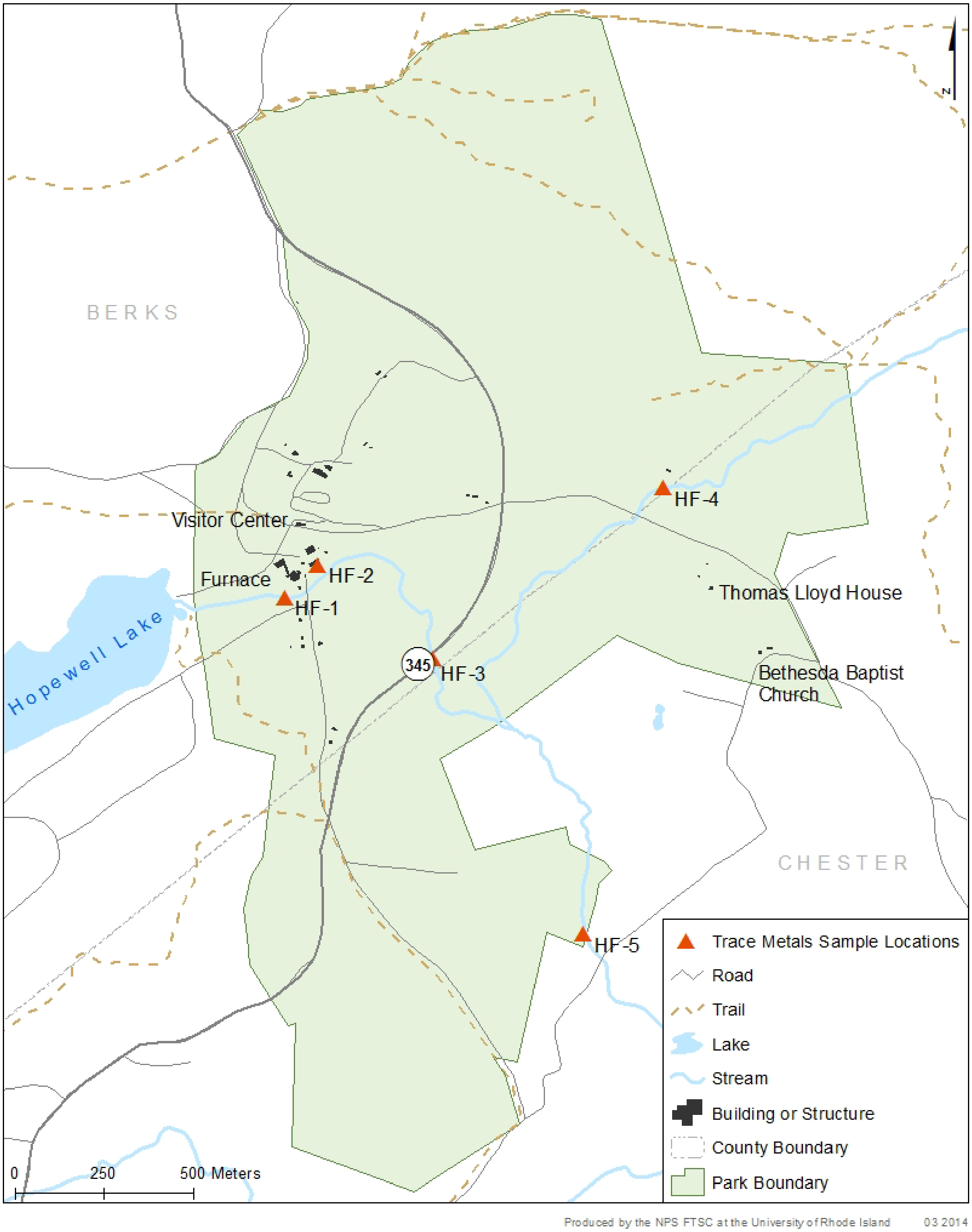

Figure 33. Streambed sediment and aquatic macroinvertebrate locations sampled by Sloto and Reif (2011).

Table 20. Reference thresholds for streambed habitat condition.

PA DEP condition category	NRCA condition value	Individual metric score[1]	Sum of Scores for 12 metrics[2]	Sum of Scores for 10 metrics[3]
Optimal	Good	20-16	240-192	200-160
Sub-optimal	Moderate concern	15-10	180-132	150-110
Marginal	Moderate Concern	9-6	120-72	100-60
Poor	Significant Concern	5-0	<60	<50

[1] Ranges based on categories put forth by Sloto and Reif (2011).

[2] The gaps between the categories are left to the discretion of the investigator's best professional judgment as stated in the PA DEP protocol (PA DEP 2013).

[3] Score range for 10 metrics was based on a percentage value in relation to the 12 metric score ranges.

The MIDN continued streambed habitat sampling as part of their aquatic macroinvertebrate monitoring that was initiated in 2009 and continues to present (only data up to 2012 have been interpreted, J. Comiskey, personal communication, 27 August 2014). Their assessment was based on the Pennsylvania Department of Environmental Protection (PA DEP) wadeable stream assessment protocol (PA DEP 2013). This protocol rated 12 attributes of streambed habitat as excellent, good, fair, or poor by assigning a value of 0 to 20 to each parameter with a score of 20 being the best condition. The MIDN used 10 of the 12 parameters in their assessment. These were the same 10 parameters that Sloto and Reif (2011) used as previously mentioned above. The PA DEP (2013) protocol sums the parameters and based on the total score assigns a condition (Table 20). The score range for the 10 metrics based on the PA DEP (2013) condition scores was used to evaluate the condition of streambed habitat for the MIDN 2009-2012 data.

<u>Reference Condition and Status of the Resource (current condition and trends)</u>
Sharpe and Keener (2003) concluded that the stream habitat quality of their fish sampling stations was good with scores for the three locations approaching the maximum score of 200 (indicative of pristine habitat): Baptism Creek: 177, French Creek: 122, Spout Run: 143 (further details were not provided in the Sharpe and Keener 2003 report).

Sloto and Reif (2011) observed that streambed sediments in French Creek (sites HF-1, HF-2, HF-3, HF-5) had higher concentrations for all metals except nickel compared to the background site on Baptism Creek (HF-4) (refer to Figure 33). Although trace metals were detected at all stations, only copper, at station HF-3, was above established PECs (Table 21). Stations HF-1 and HF-3 had the highest concentrations of 12 of 13 detected trace metals (Table 21). Concentrations of aluminum, cadmium, and nickel were highest at site HF-1 and generally decreased in concentration downstream. Sloto and Reif (2011) hypothesized that the source of these metals was likely upstream of the ironworks (upstream from site HF-1) and may have been related to discharge from Hopewell Lake. This assumption was also supported by Keener and Sharpe (2004) who noted that iron staining of the rocks at the outflow of Hopewell Lake may be the result of oxidation of lake water during drawdown events that may result in increased concentrations of trace metals in French Creek. The highest concentrations of arsenic, boron, cobalt, copper, iron, lead, manganese, mercury, and zinc were detected below Hopewell Furnace at site HF-3. Sloto and Reif (2011) hypothesized that the source of these metals may have been in Hopewell Furnace NHS between sites HF-1 and HF-3.

Table 21. Comparison of published probable effects concentration and maximum measured concentration of trace metals in streambed sediments at HOFU.

Element	Probable effect concentration[1]	Maximum concentration at sampled sites (mg gm^{-1})	Maximum concentration site location[2]	Condition[2]
Aluminum	n/a	34,000	HF-1	
Arsenic	33	7.5	HF-1	
Boron	n/a	41	HF-3	
Cadmium	4.98	0.54	HF-1	
Chromium	111	59.7	HF-2	
Cobalt	n/a	19.8	HF-3	
Copper	149	190	HF-3	
Iron	n/a	45,000	HF-3	
Lead	128	86.1	HF-3	
Manganese	n/a	2,300	HF-3	

[1] Probable effect concentration (PEC) after MacDonald et al. 2000, "n/a" indicates PEC has not yet been established.

[2] Condition was determined based on PEC value, if the concentration was lower than the PEC, condition was rated as good; if concentration was higher than the PEC, the condition was rated as significant concern.

[3] Average condition was estimated only for elements with established PEC values and was based on NRCA guidance for combining condition estimates.

Table 21 (continued). Comparison of published probable effects concentration and maximum measured concentration of trace metals in streambed sediments at HOFU.

Element	Probable effect concentration[1]	Maximum concentration at sampled sites (mg gm^{-1})	Maximum concentration site location[2]	Condition[2]
Mercury	1.06	0.13	HF-3	
Nickel	48.6	28.5	HF-1	
Zinc	459	155	HF-3	
Average condition of streambed sediment related to trace metal concentration[3]				

[1] Probable effect concentration (PEC) after MacDonald et al. 2000, “n/a” indicates PEC has not yet been established.

[2] Condition was determined based on PEC value, if the concentration was lower than the PEC, condition was rated as good; if concentration was higher than the PEC, the condition was rated as significant concern.

[3] Average condition was estimated only for elements with established PEC values and was based on NRCA guidance for combining condition estimates.

The Sloto and Reif (2011) sampling site above the ironworks and just below the outfall of Hopewell Lake on French Creek (site HF-1) had the best habitat quality of all the sampling sites, with only two of the ten parameters ranked as sub-optimal, with a total PA DEP score in the “optimal” range (Table 22). The site had some minor sedimentation that caused the embeddedness and sediment deposition scores to be ranked suboptimal (Sloto and Reif 2011). The other three sites sampled by Sloto and Reif (2011) were located downstream of the ironworks on French Creek (sites HF-2, HF-3, and HF-5; Note that HF-2 and HF-3 are located within active cultural agriculture areas of the park). All of these sites had major habitat quality issues including: lack of canopy cover (site HF-2), unstable substrate (sites HF-2, HF-3, and HF-5), pasture riparian zones (site HF-2), and heavy sedimentation (site HF-2, HF-3, and HF-5) and overall scored as “sub-optimal” (Table 22) (Sloto and Reif 2011). The habitat at Baptism Creek (HF-4) also scored as “sub-optimal” and had issues with bank stability, velocity, and sedimentation. The lack of stable bottom substrate and heavy sand and gravel deposition may limit the diversity of the aquatic macroinvertebrate community at these sites (refer to Aquatic Macroinvertebrate Section) (Sloto and Reif 2011).

Table 22. Estimated condition of habitat quality based on stream morphology. Numbers indicate numerical score, ranging from 0 (poor habitat) to 20 (pristine habitat) as evaluated by Sloto and Reif (2011).

Streambed Habitat Parameter	Baptism Creek (HF-4)	Upstream of HOFU (HF-1)	Downstream of HOFU (HF-2,3,& 5)[1]
Epifaunal substrate and cover	(16)	(17)	(7.6)
Embeddedness	(15)	(14)	(11.3)
Velocity and depth	(10)	(15)	(10.3)
Sediment deposition	(13)	(13)	(8.3)
Channel flow	(16)	(17)	(16.7)
Channel alteration	(18)	(15)	(16.3)
Riffle and bend frequency	(16)	(16)	(7.7)
Bank stability (average of left and right bank)	(14)	(17)	(13.3)
Vegetative protection width (average of left and right bank)	(16)	(18)	(12.7)
Riparian vegetative zone width (average of left and right bank)	(17)	(18)	(15.7)
Average condition of site(s) based on total score[2]	(151)	(160)	(120)

[1] Scores for downstream sites on French Creek were averaged using data from Sloto and Reif (2011).

[2] Refer to Table 20 for threshold score values.

The MIDN continued with streambed habitat sampling as part of their aquatic macroinvertebrate monitoring in 2009 and continues to present (only data to 2012 have been interpreted). The MIDN sampled the same parameters as Sloto and Reif (2011), but only sampled one site on French Creek (HOFU-01) and one site on Baptism Creek (HOFU-02, sampled in 2009 and 2010 only) (Table 23). In the MIDN assessment, the Baptism Creek site had suboptimal scores for epifaunal substrate cover, embeddedness, velocity and depth, sediment deposition, channel flow, riffle frequency, and bank stability. The overall condition for the two sampling events (2009 and 2010) was moderate concern for the Baptism Creek site. The French Creek site (monitored in 2009-2012) had suboptimal scores for epifaunal substrate cover, embeddedness, sediment deposition, riffle frequency, and bank stability, but overall scored in better condition (good condition) than the Baptism Creek reference site (Table 23). Based on the recent MIDN sampling, the condition of French Creek was evaluated as good condition with a stable trend; while the condition of Baptism Creek was assessed as moderate concern with a stable trend (Table 24).

Table 23. Estimated condition of habitat quality based on stream morphology. Numbers indicate numerical score, ranging from 0 (poor habitat) to 20 (pristine habitat) as evaluated by the MIDN in 2009-2012.

Streambed Habitat Parameter	Baptism Creek (HOFU-02)			French Creek (HOFU-01)		
	2009	2010	2009	2010	2011	2012
Epifaunal substrate and cover	(12)	(13)	(15)	(18)	(16)	(15)
Embeddedness	(14)	(15)	(15)	(17)	(15)	(17)
Velocity and depth	(14)	(13)	(16)	(16)	(16)	(16)
Sediment deposition	(13)	(12)	(13)	(16)	(15)	(14)
Channel flow	(16)	(15)	(16)	(16)	(14)	(16)
Channel alteration	(20)	(20)	(20)	(20)	(20)	(20)
Riffle and bend frequency	(15)	(14)	(15)	(15)	(14)	(14)
Bank stability (average of left and right bank)	(14)	(15)	(14)	(16)	(14)	(16)

Table 23 (continued). Estimated condition of habitat quality based on stream morphology. Numbers indicate numerical score, ranging from 0 (poor habitat) to 20 (pristine habitat) as evaluated by the MIDN in 2009-2012.

Streambed Habitat Parameter	Baptism Creek (HOFU-02)		French Creek (HOFU-01)			
	2009	2010	2009	2010	2011	2012
Vegetative protection width (average of left and right bank)	(16)	(16)	(16)	(18)	(14)	(16)
Riparian vegetative zone width (average of left and right bank)	(20)	(20)	(20)	(20)	(20)	(20)
Average condition of site(s) based on total score[1]	(154)	(153)	(160)	(172)	(158)	(164)

[1] Refer to Table 20 for threshold score values.

Table 24. Condition assessment scores for streambed habitat based on MIDN data.

Sampling Location	Condition and Trend Estimate[1]	Description
French Creek (HOFU-01)	Good	The streambed habitat was assessed as good condition with a stable trend based on the 2009-2012 on MIDN data.
Baptism Creek (HOFU-02)	Moderate Concern	The streambed habitat was assessed as moderate concern condition with a stable trend from 2009-2010 based on MIDN data.

Confidence in Assessment

The confidence in the assessment was high since the data were recent and of good quality (2009-2012).

Data Gaps

The MIDN is currently monitoring streambed habitat as part of their aquatic macroinvertebrate sampling. Baptism Creek has not been assessed for as many years as French Creek and this site should be monitored more frequently if possible. Additionally, if the Baptism Creek site is representing a "reference" site for the MIDN, this may need to re-evaluated, as it is scoring lower on several streambed parameters than the French Creek site.

Threats

Trace metal contamination in sediments can negatively impact water quality, stream habitat quality, and aquatic communities. Sloto and Reif (2011) hypothesized that the source of the trace metal contamination could be a related to discharge from Hopewell Lake as well as from within the park, likely a result of the past landuse impacts from the ironworks. Based on the 2008 streambed habitat survey, bank stability, erosion, and sedimentation were the biggest threats to streambed habitat quality, although at some sites (HF-2) the loss of canopy cover and riparian buffers were also threats. The park could try to restore the riparian buffer in areas where the buffer zone has been lost (e.g., pasturelands).

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4.2.3. Aquatic Macroinvertebrates

Relevance and Context

The MIDN vital signs program recognized aquatic macroinvertebrates as among the most important components of the MIDN Inventory and Monitoring program (Comiskey and Callahan 2008). Aquatic macroinvertebrates perform essential roles in stream ecosystem function and are often used by regulatory agencies to document stream condition under the Clean Water Act (Barbour et al. 1999, MIDN 2011, PA DEP 2013). They are useful for stream monitoring because they are easy to sample and identify, common in most freshwater habitats, represented by many taxa with varying degrees of sensitivity to their environment, are mostly sedentary and cannot readily escape pollution or environmental stress, and are sufficiently long lived enough that they will respond to stress (Barbour et al. 1999).

Data and Methods

Crayfish were inventoried at ten Pennsylvania National Parks, including HOFU, in 2005, when two streams, Baptism Creek and Spout Run were sampled (Lieb et al. 2007) (Figure 34). Sloto and Reif (2011) sampled five stream sites for benthic invertebrates in 2008 as part of their assessment of trace metals at HOFU (Figure 34). One reference site was selected on Baptism Creek (site HF-4). Another site was just downstream of the outfall from Hopewell Lake but upstream from Hopewell Furnace on French Creek (site HF-1). The other three sites were downstream of the furnace on French Creek (sites HF-2, HF-3, and HF-5) (Sloto and Reif 2011). Macroinvertebrates were identified, counted, and several condition metrics were calculated by Sloto and Reif (2011) including: total taxa richness, Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa richness, Hilsenhoff Biotic Index (HBI), Beck's Index, Percent Sensitive Individuals, and Shannon Diversity (Table 25).

Aquatic macroinvertebrate sampling was initiated by the MIDN in eight parks, including HOFU, in 2009 and continues to the present (a 5-year report is in preparation and was not available as of the writing of this NRCA) (MIDN 2011, J. Comiskey, personal communication, 27 August 2014). The MIDN (2011, J. Comiskey, Program Manager MIDN, personal communication, email 3 April 2014) sampled French Creek (HOFU-1) from 2009 to present (only data up to 2012 have been analyzed) and Baptism Creek (HOFU-2, a reference site) in 2009-2010 (Figure 34). The MIDN sampled macroinvertebrates in 100-m stream lengths using a 500-micron, D-frame net and calculated an Index of Biotic Integrity (IBI) to estimate aquatic macroinvertebrate community condition based on the PA DEP wadeable stream assessment protocol (PA DEP 2013) (Figure 35). The MIDN calculated IBI is based on ten biological metrics that measure relevant aspects of benthic macroinvertebrate community composition. These metrics were total taxa richness, EPT taxa richness, percent of Diptera and non-insects, percent abundance of the dominant two taxa, percent abundance of scrapers, modified Beck's index, percent abundance of intolerant taxa with a pollution tolerance value of ≤ 2, percent abundance of clingers, Shannon diversity index, and percent abundance of Plecoptera and Trichoptera-Hydropsychidae (J. Comiskey, Program Manager MIDN, personal communication, email 3 April 2014). Many of the metrics used by the MIDN (2011) and Sloto and Reif (2011) were similar although there were some metrics that were different. Additionally, the sampling locations on French Creek and Baptism Creek were not in the same locations and as such the data from these monitoring efforts were presented separately in this NRCA.

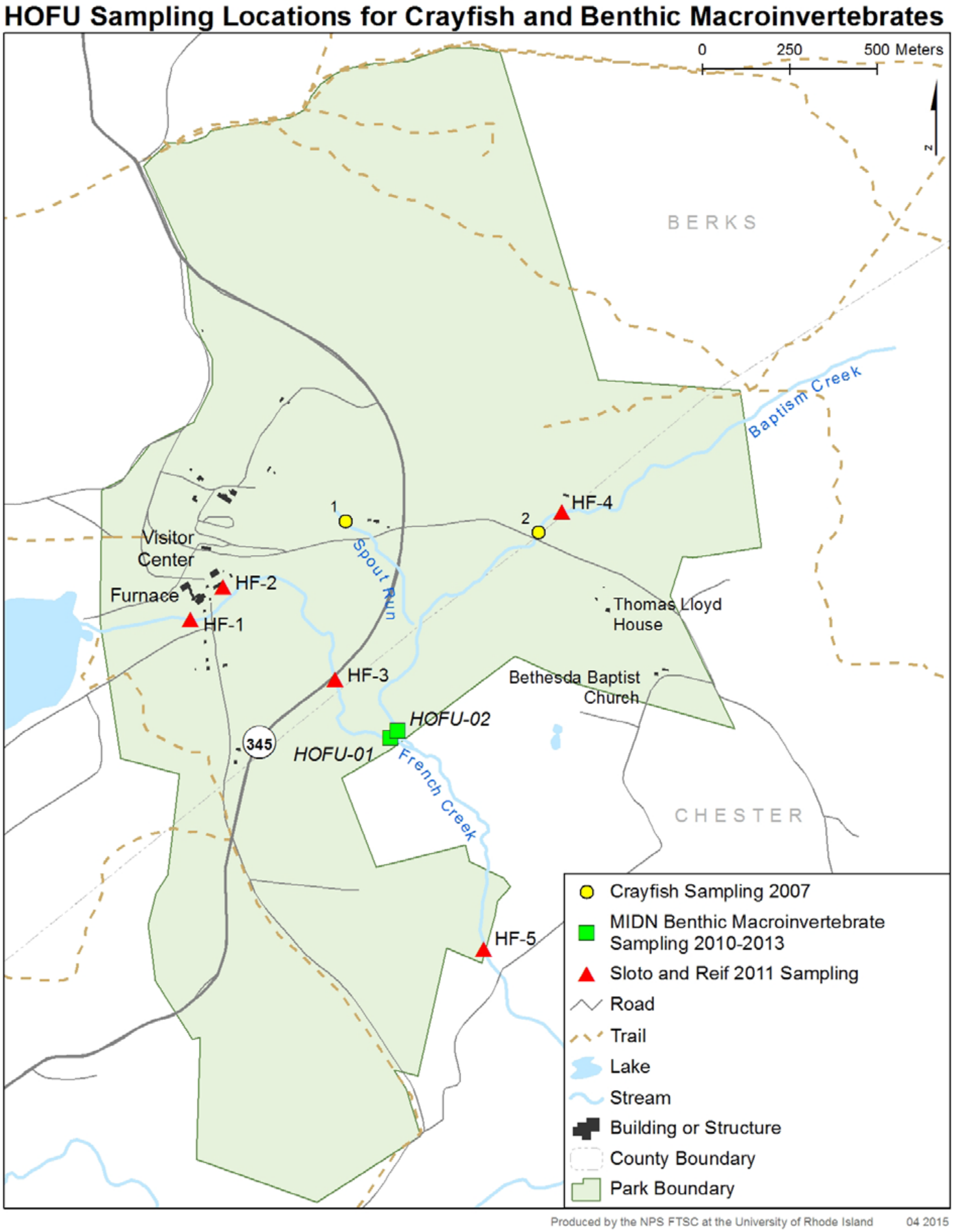

Figure 34. Macroinvertebrate (Sloto and Reif 2011 and MIDN) and crayfish (Lieb et al. 2007) sampling locations at HOFU.

Table 25. Metrics used by Sloto and Reif (2011) to access condition of the aquatic macroinvertebrate community structure at HOFU in 2008.

Metric[1]	Description	Inference	Good	Slightly Impacted	Moderately Impacted	Severely Impacted
Total taxa richness[1]	Measurement of total species present.	Higher number of taxa generally indicates healthier community.	> 30	21 - 30	11 - 20	0 - 10
EPT taxa richness[1]	Number of taxa belonging to pollution sensitive mayflies, stoneflies, and caddisflies.	EPT richness generally decreases with increasing ecosystem stress.	> 10	6 - 10	2 - 5	0 - 1
HBI[1]	Summarizes overall pollution tolerance of community.	Values 1-10, with higher values indicative of increasing ecosystem stress and reflects increasing presence of pollution-tolerant species.	0 – 4.50	4.51 – 6.50	6.51 - 8.50	8.51 - 10
Percent Sensitive Individuals with Pollution Tolerance Value (PVT) of 0 to 3[2]	Community composition and tolerance measure that is based on the percentage of individuals with PTVs between 0 and 3.	Value generally decreases with increasing ecosystem stress because of the loss of pollution-sensitive taxa.	> 40	20-40		<20
Beck's Index[3]	A weighted count of taxa with PTVs of 0 to 2.	Values generally decrease with increasing ecosystem stress because of the loss of pollution-sensitive taxa.	15.2-19	9.5-15.1		<9.5
Shannon Diversity[3]	Measures community-composition as taxonomic richness and evenness of individuals across taxa.	Value generally decreases with increasing ecosystem stress because of the loss of pollution-sensitive taxa and increasing dominance of a few pollution-tolerant taxa.	2.0-2.3	1.9-1.2		<1.2

[1] Condition estimate values for total taxa richness, EPT taxa richness, and HBI were based on Reif 2002.

[2] Condition estimate values for Percent Sensitive Individuals were based on US EPA 1997.

[3] Condition estimate thresholds for Beck's Index and Shannon Diversity metrics were based on best professional judgment using values from the Baptism Reference site as follows: >80% of value: good; 80-50% of value: moderate concern; <50% of value: significant concern.

Reference Condition and Status of the Resource (current condition and trends)

Crayfish were inventoried at ten Pennsylvania National Parks, including HOFU, by Lieb et al. (2007) in 2005, when two streams, Baptism Creek and Spout Run were sampled (Figure 34). During the crayfish inventory, Lieb et al. (2007) observed two species *Cambarus bartonii* and *Cambarus species*, with *C. bartonii* comprising 94% of the relative abundance. *Cambarus bartonii* is native to Pennsylvania. No invasive crayfish were observed at HOFU.

The aquatic macroinvertebrate communities sampled by Sloto and Reif (2011) at the French Creek sites (HF-1, HF-2, HF-3, and HF-5) were similar to each other but differed greatly from the community at the Baptism Creek reference site (HF-4) (Sloto and Reif 2011) (Table 26). The Baptism Creek reference site was dominated by pollution-sensitive aquatic macroinvertebrates. Compared to the four French Creek sites, the reference site had the lowest HBI score (4.05) and highest values for total taxa richness (33), EPT taxa richness (17), Beck's Index (19), Shannon Diversity (2.3), and percent sensitive individuals (46.67) and was assessed to be in good condition (Table 26). All the metric values for the Baptism Creek site indicated a diverse community low in pollution-tolerant taxa and high in pollution-sensitive taxa; whereas, the aquatic macroinvertebrate communities at the French Creek sites contained fewer taxa and were dominated by pollution-tolerant taxa, and were assessed as being of moderate concern (upstream French Creek site) and of significant concern (downstream French Creek sites) (Table 26 and **Error! Reference source not found.**). Overall, the macroinvertebrate community at HOFU in 2008 (average of sites) was assessed as moderate concern, due to the condition of the communities observed in French Creek.

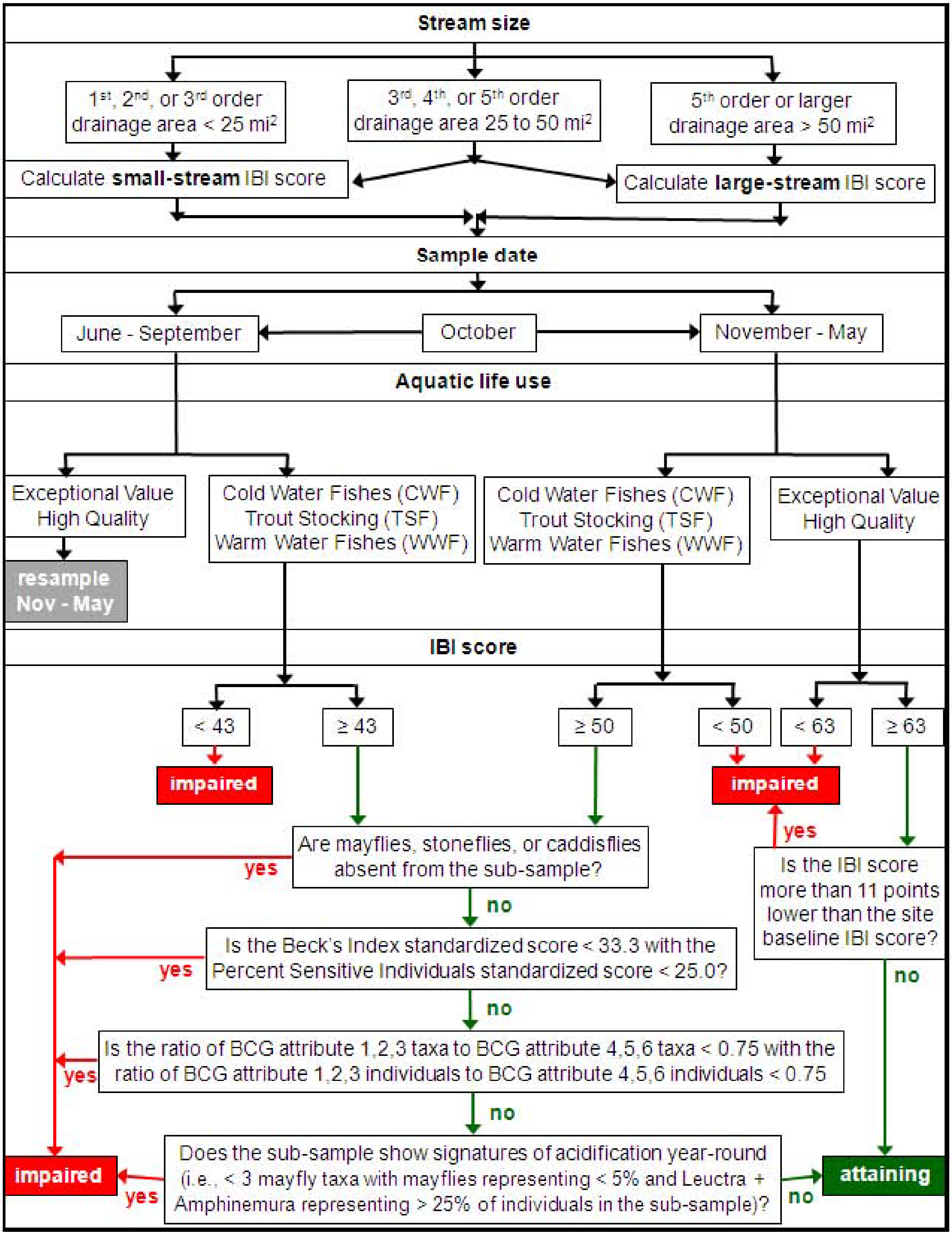

Figure 35. PA DEP (2013) IBI schematic diagram of the estimation of aquatic macroinvertebrate community condition (diagram excerpted from PA DEP 2013).

Table 26. Metrics values (in parentheses) and condition assessment[1] of the aquatic macroinvertebrate community structure at HOFU using data collected in 2008 by Sloto and Reif (2011).

Metric	Baptism Creek (HF-4 Reference site)	Upstream of HOFU below outfall of Hopewell Lake (HF-1)	Downstream of HOFU (HF-2[1],3,& 5)[2]
Total taxa richness	(33)	(21)	(28, 25, 19)
Ephemeroptera, Plecoptera, Trichoptera (EPT) Richness	(17)	(3)	(3.5, 8, 5)
Hilsenhoff Biotic Index (HBI),	(4.05)	(5.27)	(5.91, 5.46, 5.26)
Percent Sensitive Individuals with Pollution Tolerance Value (PVT) of 0 to 3	(46.67)	(21.7)	(6.94, 14.9, 24.73)
Beck's Index	(19)	(1)	(3, 5, 6)
Shannon Diversity Index	(2.3)	(1.6)	(1.9, 2.0, 2.3)
Average Condition Assessment[3]	Good	Moderate Concern	Significant Concern

[1] Average value of replicate H-2 samples, values represent stations HF-2, HF-3, and HF-5, respectively.

[2] Condition assessment based on average values for HF-2, HF-3, and HF-5.

[3] Average condition was estimated only for metrics that had established threshold values and was based on NRCA guidance for combining condition estimates.

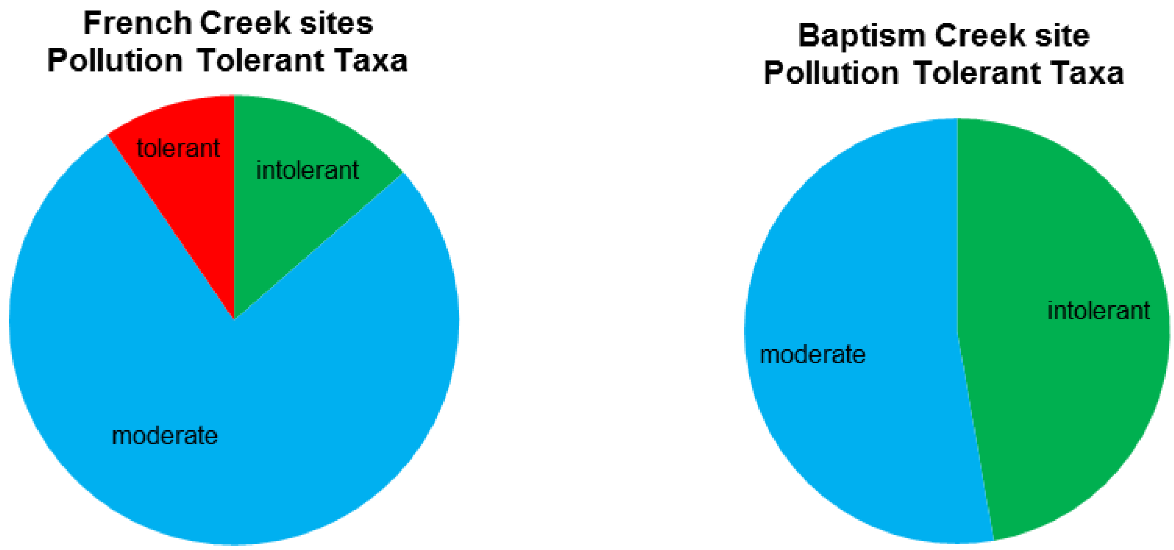

Figure 36. Distribution of intolerant, moderately tolerant, and intolerant aquatic macroinvertebrate taxa for Baptism Creek (reference site) and French Creek sites in 2008 (based on data in Sloto and Reif 2011).

The MIDN aquatic macroinvertebrate study in 2009 compared sites sampled at Gettysburg National Military Park (GETT), and sites sampled at HOFU (HOFU-01 and HOFU-02). The HOFU sites had a less impaired aquatic macroinvertebrate community compared to GETT (Figure 37). The MIDN collected additional data at HOFU in 2010-2012 at French Creek (HOFU-01) and at the Baptism Creek (HOFU-02) reference site (J. Comiskey, MIDN Program Manager, personal communication, email 3 April 2014). The MIDN IBI was reflective of an impaired condition at French Creek in all four sampling years. The reference site at Baptism creek showed an impaired condition in 2009, while in 2010 the IBI was within the healthy range (Figure 38).

Based on the data from Sloto and Reif (2011) and the MIDN aquatic macroinvertebrate monitoring, the condition of the community for French Creek was evaluated as moderate concern, while Baptism Creek was evaluated as good. The trend for both sites was estimated as stable since the condition has been relatively stable for past 4-5 sampling years. Water quality and streambed-sediment quality did not indicate that the degraded benthic-macroinvertebrate communities observed at HOFU were the result of poor water quality (refer to Water & Water-related Resources sections). Habitat conditions (erosion and sedimentation) and physical alterations (water temperature) from the outfall of Hopewell Lake were the most likely causes of the impaired macroinvertebrate communities (Sloto and Reif 2011). The Hopewell Lake dam influence coupled with park specific impacts associated with agricultural use and associated riparian habitat degradation may also contribute to the degraded aquatic macroinvertebrate communities.

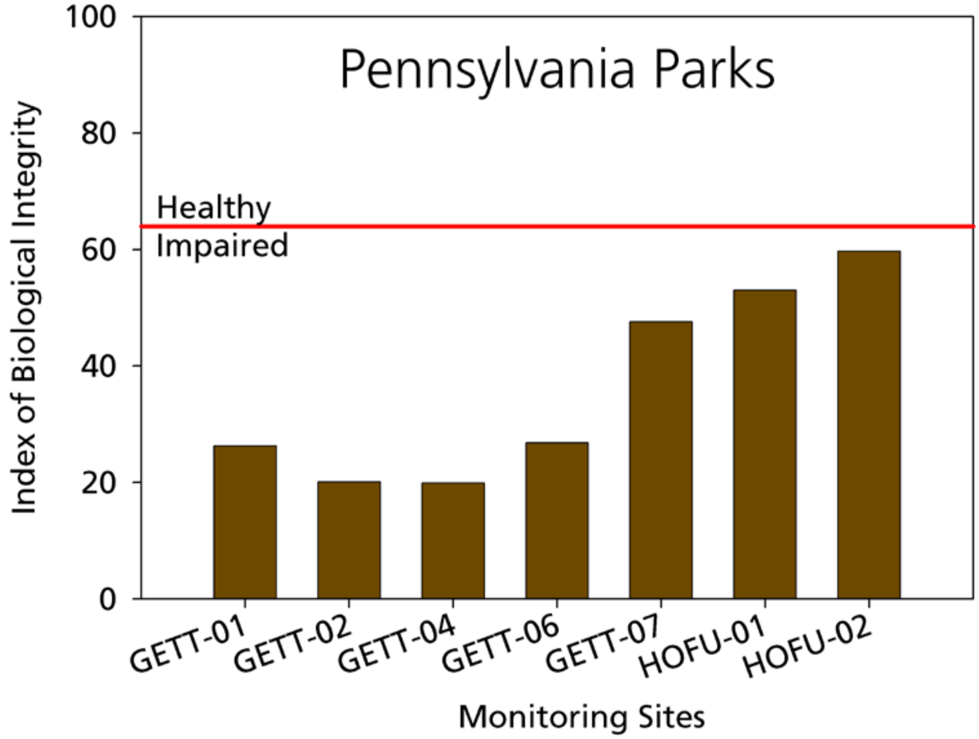

Figure 37. MIDN calculated IBI for aquatic macroinvertebrate monitoring site in Pennsylvania Parks for 2009 (figure excerpted from MIDN 2011).

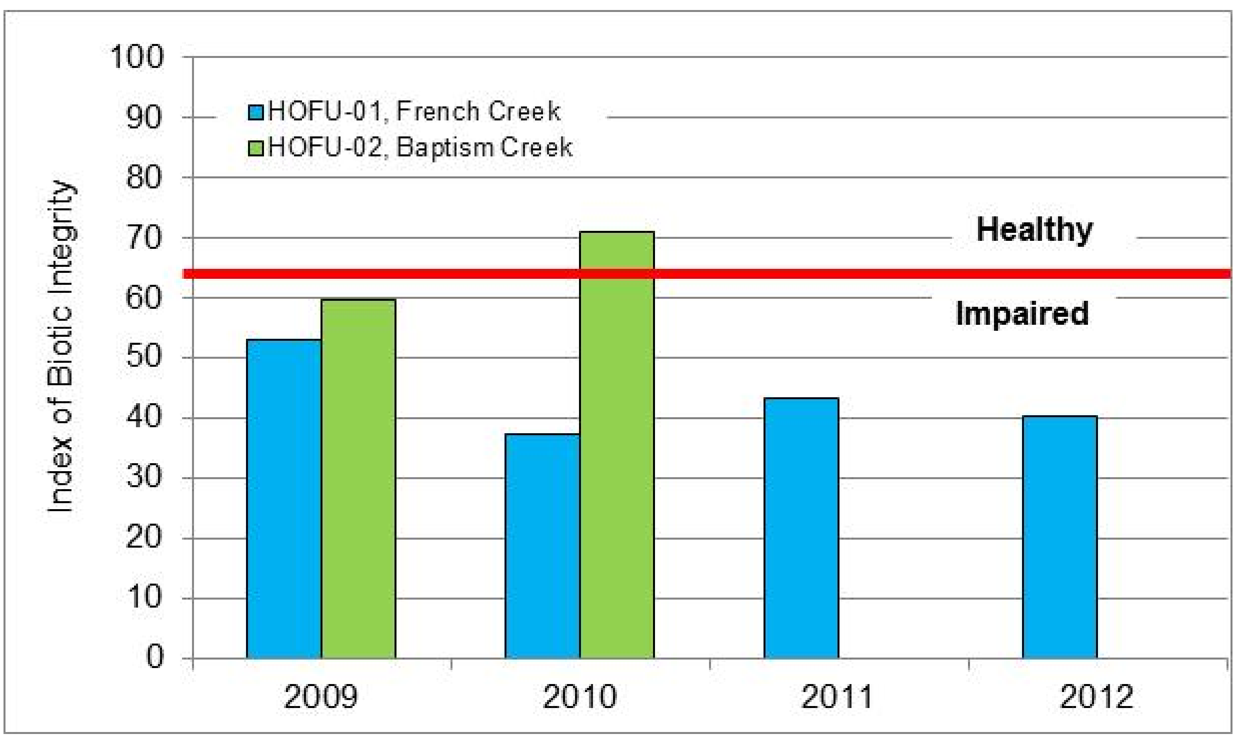

Figure 38. MIDN calculated IBI for aquatic macroinvertebrates at HOFU (Baptism Creek was only sampled in 2009 and 2010).

Table 27. Assessment of condition for aquatic macroinvertebrate communities at HOFU.

Metric[1]	Condition and Trend Estimate[1]	Description
French Creek	Moderate concern	The community has been evaluated as impaired over the last four sampling years, but is better than other PA parks.
Baptism Creek	Good	The community has been evaluated as healthy or approaching healthy over the past sampling years.

[1] Condition based on Sloto and Reif 2008 data (2011) and MIDN 2009-2010 data.

Confidence in Assessment

The confidence in the assessment was high since the data were recent (2008-2012).

Data Gaps

The MIDN plans to continue to sample benthic macroinvertebrates so additional trend data will be available in the future.

Threats

Water and habitat quality can influence benthic macroinvertebrate community structure. The water in the streams at HOFU was generally evaluated as good (refer to Stream Water Quality section). Trace metals were found in water samples, but the concentrations were all within acceptable ranges to support for aquatic-life (refer to Stream Water Quality section). The historic slag piles may be a threat to water quality and thus a threat to aquatic macroinvertebrates. Four metals (Al, Cu, Fe, and Mn) that could possibly leach from the slag piles had potential environmentally problematic concentrations in leachate experiments (Piatak and Seal 2012, refer to Stream Water Quality section), exceeding thresholds for both drinking water and aquatic-life criteria. Drawdown events in Hopewell Lake could negatively impact both water quality and quantity (refer to Stream Water Quality section). Based on the Sloto and Reif (2011) data (HF-1, HF-2, HF-3, HF-5, Table 26) it appears that there could be a gradient of impairment from just below the Hopewell Lake Dam and decreasing at the most downstream most sites. Impacts from agricultural uses may be addressed be the park (e.g., protecting riparian buffers, minimizing runoff from park grounds); however, the most significant threats were likely related to the outfall of Hopewell Lake (e.g., drawdown events, thermal changes, water quality). Some streambed habitat parameters, such as bank stability, erosion, and sedimentation were also threats to stream habitat quality (refer to Streambed Habitat and Stream Morphology section).

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4.2.4. Fish Community

Relevance and Context

Freshwater fish communities are useful indicators of environmental condition and fish community structure is often used as an Index of Biotic Integrity (IBI) (e.g., Karr 1986, Barbour et al. 1999, Vile 2008). Fish assemblages generally include a range of species that represent a variety of trophic levels (e.g., insectivore, generalists, piscivores, herbivores, planktivores). For example, the structure of fish assemblages tends to be reflective of environmental health. The environmental requirements, life history, and distributions for fish are comparatively well known. Fish are relatively easy to collect and identify, and can be sampled and released back into the environment unharmed. Aquatic life uses for water quality are typically characterized in terms of fisheries assemblages and the ability of water quality (e.g., temperature, alkalinity, bacteria concentrations, and water chemistry) to support viable communities (Vile 2008, Pennsylvania Code §93.7). French Creek, which flows through the heart of Hopewell Furnace NHS, is designated as an Exceptional Value and Migratory Fishes waterway. Hopewell Lake, upstream of the park, is classified as a Warm Water Fishery. Scotts Run Lake, which is upstream of Hopewell Lake, is classified as a Cold Water Fishery (Sloto and Reif 2011). Contamination and trace metal leachate (e.g., Al, Cu, Fe, and Mn) from the historic slag piles, that in some areas make up the banks of French Creek, could influence the water quality, and therefore the fish community of French Creek (Sloto and Reif 2011, Piatak and Seal 2012). The structure of the stream (e.g., erosion, sedimentation, canopy cover, water depth), adjacent riparian zone (e.g., vegetative cover, riparian buffer, substrate quality), and upstream influence from the outfall of Hopewell Lake (e.g., drawdown events, storm overflow) can also influence the quality of the water resources and the condition of the fish community (Keener and Sharpe 2004, Sloto and Reif 2011).

Data and Methods

Fish have been surveyed at HOFU during two separate monitoring efforts (Figure 39). Electrofishing surveys were conducted in French Creek 1990, 1991, and 1992 (Gutowski 1996 as cited in Sharpe and Keener 2003). The second survey was in 2002 when three 90-m stream sections were sampled at Spout Run, Baptism Creek, and French Creek (Sharpe and Keener 2003). These two survey efforts identified eighteen fish species that were present at HOFU (Table 28). None of these species were threatened or endangered and only one native transplant, the green sunfish (*Lepomis cyanellus*), was observed (Table 28). In a fish inventory report for the MIDN, Atkinson (2008) summarized the Sharpe and Keener (2003) data for HOFU in comparison with other MIDN parks.

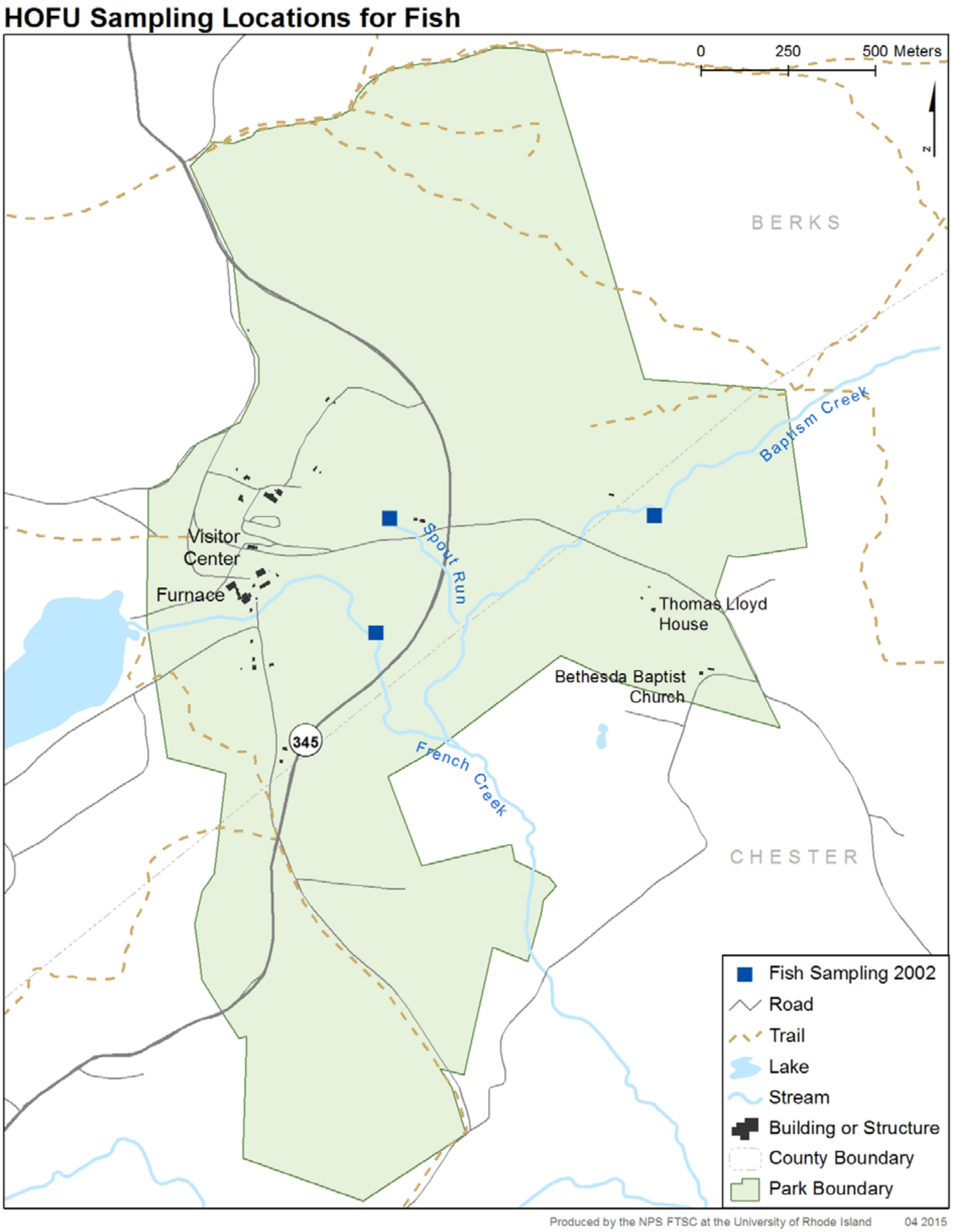

Figure 39. Fish (Sharpe and Keener 2003) sampling locations at HOFU.

Table 28. Fish species observed at HOFU.

Scientific Name	Common Name	Tropic Guild[1]	Nativity Status[2]	NPSpecies	1990-1992	2002
Ameiurus natalis[2]	Yellow bullhead	BI, TS	native	X	X	X
Anguilla rostrata	American eel	P, TS	native	X	X	X
Catostomus commersoni[2]	White sucker	BI, TS	native	X	X	X
Clinostomus funduloides	Rosyside dace	BI	native	X	X	X
Esox a. americanus	Redfin pickerel	P	native	X	X	
Esox niger	Chain pickerel	P	native	X	X	X
Etheostoma olmstedi	Tessellated darter	BI	native	X	X	X
Exoglossum maxillingua	Cutlips minnow	BI, IS	native	X	X	X
Lepomis cyanellus	Green sunfish	G, TS	native transplant	X	X	
Lepomis gibbosus	Pumpkinseed	G	native	X	X	
Lepomis macrochirus	Bluegill	G, TS	native	X	X	X
Luxilus cornutus	Common shiner	I	native	X	X	
Micropterus salmoides	Largemouth bass	P	native	X	X	X
Noturus insignis	Margined madtom	BI, IS	native	X	X	X
Rhinichthys atratulus	Blacknose dace	BI	native	X	X	X
Salvelinus fontinalis	Brook trout	I/P	native	X		X
Semotilus atromaculatus	Creek chub	I	native	X	X	X
Semotilus corporalis	Fallfish	I	native	X	X	X
Total Taxa				18	17	14

[1] Tropic guilds after Vile (2008): BI: benthic insectivore; G: generalist; I: insectivore; IS: intolerant species; P: piscivore; O: omnivore; TS: tolerant species.

[2] Nativity status from USGS-NAS (2014).

[3] *Ameiurus natalis* (yellow bullhead) and *Catostomus commersoni* (white sucker) were omitted from IBI calculation as they are pollution tolerant species (Vile 2008).

An IBI developed by New Jersey Department of Environmental Protection was applied to the fish survey data as a general indication of the condition of the HOFU fish community. The New Jersey IBI is consistent with theoretical framework designed by Karr et al. (1986) for analyzing fish assemblage data in its use of several biological metrics to assess fish community richness, trophic composition, abundance, and condition. Karr's (1986) framework is also the basis for the US EPA fish community bioassessment of wadeable streams (Author's note: the author is not aware of an IBI specific to the regional area of HOFU). The New Jersey method scores 10 metrics based upon the degree of deviation from appropriate reference conditions and is scored as: 5 (none to slight deviation); 3 (moderate deviation); and 1 (significant deviation) (Vile 2008) (Table 29). The scores are summed and assigned to a condition category based on the score. The maximum score for these 10 metrics is 50, with a score of 50 representing excellent biotic integrity. A score less than 29 indicates a stream has poor biological integrity, with a score of 10 being the lowest a site can receive. Nine of the 10 metrics used by Vile (2008) could be estimated for the fish community of HOFU (the metric of proportion for fish with external anomalies was not used). The ranges for the condition ratings were modified for nine metrics and three condition estimates, but still adhered to Vile's (2008) rating system, yielding a maximum score of 45 (33 to 45: excellent/good, 26 to 32: moderate, and 9 to 26: poor) (Table 29). The IBI was calculated for both the Sharpe and Keener (2003) and the comparison of the French Creek data from 1990-1992 (average of the 3-yr period) (Gutowski 1996) and 2002 data (Sharpe and Keener 2003).

Table 29. Reference IBI metrics for HOFU fish assemblages (based on Vile 2008).

IBI Metric	(Good, score=5)	(Moderate, score=3)	(Poor, score=1)
Total number of fish species[1]	>15	10-15	<10
Number of benthic insectivores[1]	>4	2-4	<2
Number of trout and/or sunfish (not including green sunfish or bluegill)[1]	>4	2-4	<2
Number of pollution intolerant species[1]	>2	1-2	<1
Percent of pollution tolerant individuals	<20%	20-45%	>45%
Percent of individuals as generalists	<20%	20-45%	>45%
Percent of individuals as insectivorous cyprinids	>45%	20-45%	<20%
Percent of individuals as trout OR Percent of individuals piscivores (whichever gives higher score)	>10% >5%	3-10% 1-5%	<3% <1%
Number of individuals in sample, excluding tolerant species	>250	75-250	<75
Total Score	33-45	26-32	9-32

[1] Metric values were based on the French Creek watershed size of 70.129 sq. mi.

Reference Condition and Status of the Resource (current condition and trends)

Vile's (2008) reference condition metrics were applied to the fish assemblage data for HOFU. The fish assemblage scored as good condition for all sampling efforts (Table 30). Although data were available for French Creek from both the 1990-1992 and 2002 sampling, the details of the sampling methodology in the 1990-1992 (Gutowski 1996 as cited in Sharpe and Keener 2003) were unknown, therefore the trend in the condition of the fish community was not evaluated. However, the overall condition scores were similar (good condition) between the two survey periods for fish sampled from French Creek (Table 30).

Atkinson (2008) noted in the MIDN fish inventory report, based on data from the Sharpe and Keener (2003) surveys, that HOFU had the lowest species diversity (14 species) of all the MIDN parks sampled. There was slight decline in species diversity in French Creek from 1990-1992 to the 2002 sampling effort (a decline from 17 to 12 species); however, this did not change the estimate of condition which was still assessed as good (based on Vile 2008) (Table 30).

American eel populations have recently declined in several states in the eastern US (Haro et al. 2000). American eels are currently found within several of the MIDN parks including HOFU. However, the densities observed at HOFU were very low (a total of four in 1990-1992, and one individual observed in 2002) and trends in American eel densities could not be evaluated (Sharpe and Keener 2003).

Water temperature exceeded the maximum acceptable temperature for TSF waters (refer to Stream Water Quality section) 45% of the time at HOFU_1 and 23% of the time at HOFU_2, and thermal pollution may be an issue for the fish community in French Creek. French Creek is listed as an Exceptional Value stream and has no designation as either a Cold Water or Warm Water Fishery, although downstream of the park it is listed as a Trout Stocked Stream which has specific seasonal thermal criteria (Appendix Table 51). Hopewell Lake is classified as a Warm Water Fishery, while upstream of Hopewell Lake; Scotts Run Lake is classified as a Cold Water Fishery.

The distribution of trace metals released into the environment from the historical ironworks were assessed in 2009 (Sloto and Reif 2011). Hopewell Furnace used iron ore from local mines that contained abundant magnetite and accessory sulfide minerals enriched in arsenic, cobalt, copper, and other metals. These trace metals could have entered the environment as volatilized air emissions or leached from the slag, the glass-like waste material discarded near the furnace in slag piles. In some locations the historic slag piles make up the banks of French Creek (Sloto and Reif 2011). Sloto and Reif (2011) reported that concentrations of toxic elements were not present in concentrations of concern in water, soil, or stream sediments, despite being elevated in ore, slag, and cast iron furnace products. However, leachate experiments on slag samples found that four metals (Al, Cu, Fe, and Mn) had potential environmentally problematic concentrations, exceeding thresholds for both drinking water and aquatic life criteria (Piatak and Seal 2012). Weathering rates affect which elements and how much these metals are leached and released into the environment. For example, weathering rates of Fe metal and Fe oxides, which host Cu and some Fe, are likely higher than the silicate glass, which hosts a significant portion of the Al and Mn present the slag piles at HOFU (Piatak and Seal 2012).

<u>Confidence in Assessment</u>
Confidence in the data was medium as they were collected over ten years ago. Another fish survey would be beneficial, especially in French Creek, to determine current condition and assess trends in the fish community.

Table 30. IBI values for fish community biotic metrics and score (after Vile 2008) in parentheses for stream fish sampled at HOFU.

Index of Biotic Integrity Metric[1]	All streams 2002	French Creek (1990-1992)[2]	French Creek (2002 only)
Total number of fish species	14 (3)	17 (5)	12 (3)
Number of benthic insectivores	8 (5)	8 (5)	6 (5)
Number of trout and/or sunfish (not including green sunfish or bluegill)	1 (1)	1 (1)	0 (1)
Number of pollution intolerant species	3 (5)	4 (5)	3 (5)
Percent of pollution tolerant individuals	3% (5)	7% (5)	9% (5)
Percent of individuals as generalists	3% (5)	6% (5)	9% (5)
Percent of individuals as insectivorous cyprinids	89% (5)	82% (5)	80% (5)
Percent of individuals as trout OR Percent of individuals piscivores (whichever gives higher score)	4% (3)[3]	4% (3)[3]	9% (5)[3]
Number of individuals in sample, excluding tolerant species	495 (5)	87 (3)	131 (3)
Sum of scores (out of a maximum of 45)[1]	35	37	37
Condition and trend			

[1] Index of Biotic Integrity metrics after Vile (2008). Condition for scores for metrics (in parentheses): 1=poor, 3=moderate, 5=good. Index was modified for nine of ten available metrics.

[2] Average values of the three sampling years (1990, 1991, and 1992) were used to determine IBI metrics.

[3] The percent of individuals as piscivores gave the highest score.

Data Gaps

The only data gap was age of the fish assemblage data which were over 10 years old. A current survey of HOFU fish assemblages would be beneficial.

Threats

The principal threats and management issues that may impact water quality and/or fish populations within HOFU streams or aquatic systems are potential effects from activities associated with development, agriculture or other disturbances upstream of the parks (Atkinson 2008). While it is generally acknowledged that aquatic systems within Atlantic Slope drainages have been somewhat degraded from pre-colonial conditions, the primary challenge would be to limit future degradations in an attempt to preserve and/or restore water quality and associated fish species assemblages (Atkinson 2008). Based on the 2008 streambed habitat survey (Sloto and Reif 2011), bank stability and sedimentation were the biggest threats to stream habitat quality, although at some stream sites the loss of canopy cover and riparian buffers were also threats. Some streambed habitat parameters, such as bank stability, erosion, and sedimentation were also threats to stream habitat quality (refer to Streambed Habitat and Stream Morphology section). Other threats to fish communities could be related to the outfall of Hopewell Lake (e.g., drawdown events, thermal changes, water quality). The park could try to restore the riparian buffer in areas where the buffer zone has been lost (e.g., pasturelands) and where feasible, park staff should encourage programs and projects that result in improved water quality in areas upstream of individual parks or park units.

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4.3. Ecosystem Integrity

4.3.1. Forest Communities

Relevance and Context

The identification, description, and mapping of plant communities provide important information about these habitats and allow inferences about the location and abundance of other species associated with these communities. A current (less than five years old) and accurate map of park vegetation is one of the 12 basic natural resource inventories recommended by the NPS Inventory and Monitoring Program (Edinger et al. 2008). Mapping efforts allow for the identification of various vegetation types in the field and supply resource managers with a detailed accurate digital map of the park's vegetation communities. The resulting digital map and spatial data layer can be used for assessing park resources as well as planning and management needs (Podniesinski et al. 2005).

The Mid-Atlantic region is primarily a forested ecoregion and forests are an essential part the regional landscape and provide habitat for a diversity of wildlife (Comiskey and Callahan 2008, Comiskey et al. 2009). Information on forest community structure and composition is critical to developing desired conditions and park management goals relating to native and non-native plant communities. The MIDN has selected several vital signs associated with forest ecosystem health that are currently monitored at HOFU (Comiskey et al. 2009).

Data and Methods

Russell (1987) conducted a vegetation inventory of the forested uplands in 1987 at HOFU using plots established at regular intervals along transects through the forest. Thirty-five plots were sampled and all herbaceous species and seedling of woody species were recorded. Plots were located in oak, tulip popular, and red maple dominated stands. Additional measurements included the distance to the nearest tree (>5 cm diameter at breast height [DBH]) and sapling (2-5 cm DBH) in each of the four quadrants and DBH of the species. In areas where tree density was low and shrub density was high (e.g., swamps) vegetation was sampled using a combination of long belt transects (for trees) and line intercept transects (for shrubs) (Russell 1987). Vanderwerff (1994) inventoried the vascular flora of HOFU in 1994 and noted their occurrence and distribution. In his report he also incorporated the observations by Russell (1987).

The vegetation of HOFU was mapped in 2002 to 2003 as part of the U.S. Geological Survey (USGS) / National Park Service (NPS) Vegetation Mapping Program (Podniesinski et al. 2005). The goal of the mapping effort was to produce an up-to-date digital geospatial vegetation database for the park. Data analysis identified 12 natural or semi-natural vegetation types or classifications that were cross-walked with National Vegetation Classification System (NVCS) alliance types. Disturbed vegetation types, especially the modified successional forest, had no NVCS equivalent and were noted as park-specific types. Agricultural grasslands (anthropogenic vegetation) were classified within the Orchard Grass–Sheep-sorrel Herbaceous Alliance. The resulting vegetation mapping product represents current vegetation types within the park and is consistent with the standards of the USGS/NPS Vegetation Mapping Program (Figure 40) (Podniesinski et al. 2005). The park conducted a rare plant inventory in 2014 - 2015, but those data were not yet available to include in this NRCA (A. Ruhe, personal communication, 25 July 2014).

Since 2007, the MIDN has monitored forest plots at HOFU at assess forest ecosystem integrity. Plots were randomly located within the forested area at HOFU using a generalized random-tessellation stratified approach. Each 20-m X 20-m plot contains three nested microplots and 12 quadrats (Comiskey and Wakamiya 2011). There are 16 forest monitoring plots at HOFU, one-fourth of which are monitored every four years (Figure 41). Specific MIDN forest monitoring objectives are (after Comiskey et al. 2009):

- determine the status and trends in forest structure, composition, and dynamics of canopy and understory woody species;
- determine the status and trends in the density and composition of tree seedlings and selected herbaceous species that are indicators of deer browse;
- detect and monitor the presence of invasive exotic plants, exotic plant diseases and pathogens, and forest pests;

- determine the status and trends in forest coarse woody debris and the availability of snags; and,
- determine the status and trends in soil chemistry by measuring Ca:Al and C:N ratios to assess the extent of base cation depletion, increased aluminum availability and/or nitrogen saturation impacting MIDN forest soils.

The MIDN also focused on indicator plant species and taxa for monitoring. Species selected included invasive exotics, deer-browse indicators (plants preferred or avoided by deer), and vines that may reach into the forest canopy (refer to Appendix Table 48, Comiskey and Wakamiya 2011).

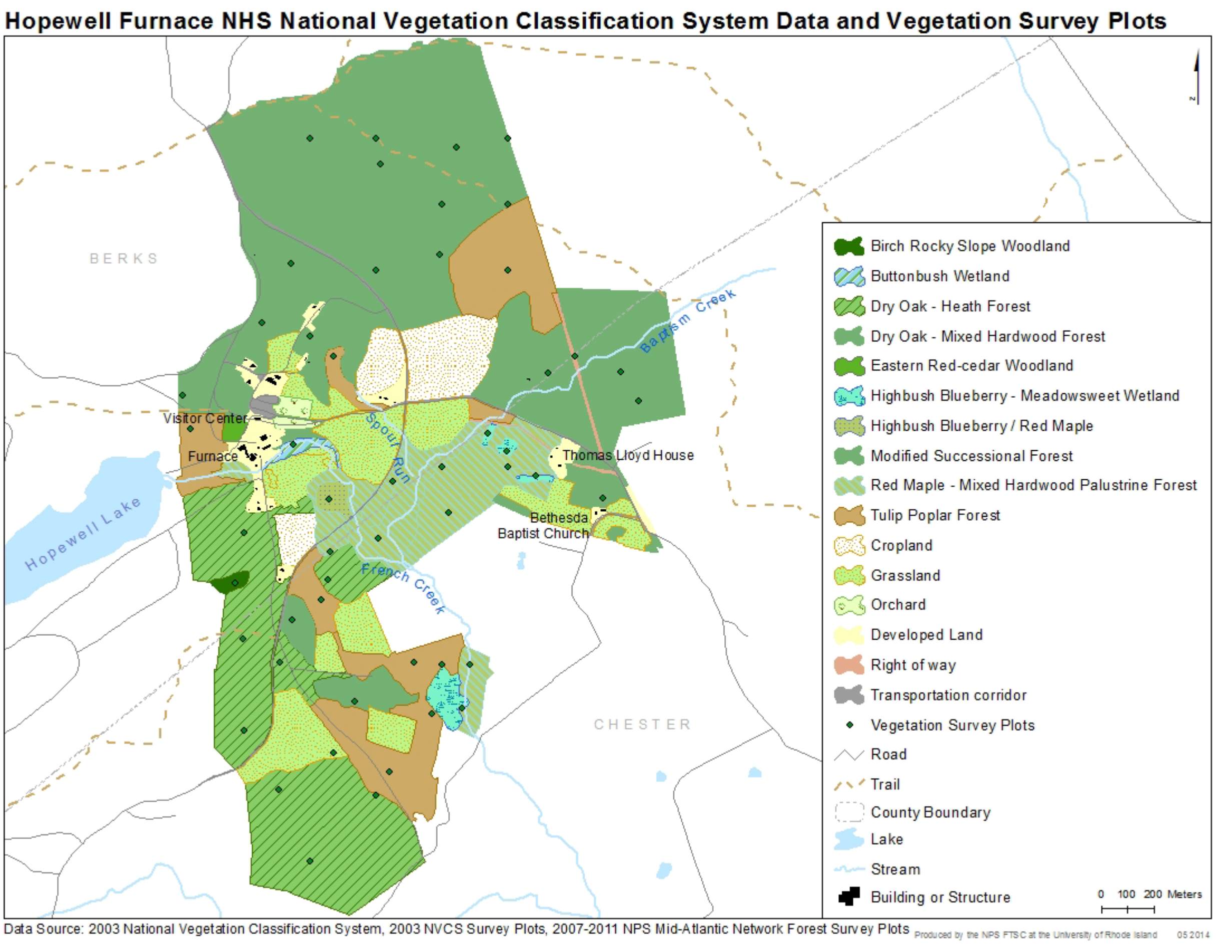

Figure 40. Vegetation associations and survey plots at HOFU. Vegetation was mapped in 2002-2003 as part of the NVC program (Podniesinski et al. 2005).

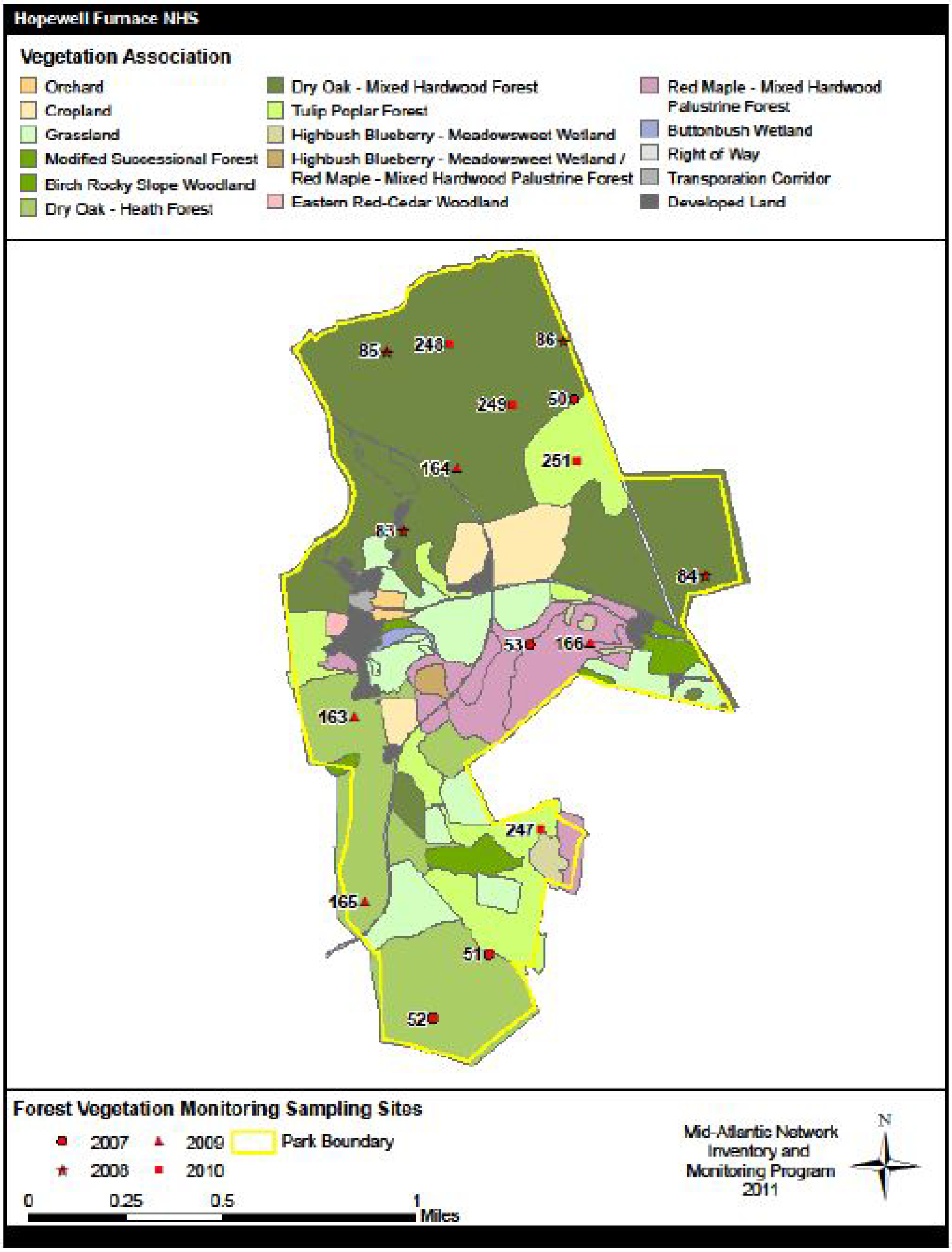

Figure 41. Vegetation plots sampled by the MIDN on a rotating basis (4 plots sampled per year).

Reference Condition and Status of the Resource (current condition and trends)

Russell (1987) identified 499 plant species, Vanderwerff (1994) observed 344, and the NPSpecies (2015) database listed 691 species for HOFU. Ambrose and Åkerson (2006) noted an additional six invasive species that were not observed by either Russell (1987), Vanderwerff (1994), nor were listed in the NPSpecies database (NPSpecies 2015). Combined these databases yielded 700 plant species observed in the park, 22% of which were either PA state-listed invasive (32 species) or non-native (118 species) (refer to Invasive Vegetation section and to Appendix Table 48). Six species were PA listed threatened or endangered.

The most current and comprehensive data for forest integrity were those reported by Comiskey and Wakamiya (2011) in their 2007 to 2011 report that included data from all 16 forest monitoring plots. Their results are summarized herein and were used to evaluate the condition of forest vegetation (refer to Table 31).

- Structural Stage of forest (an indicator of disturbance and habitat availability for species dependent on specific structural stages): The structural stage of the forests at HOFU was good with 73% of the forest observed to be late successional and 93% to be mature and late successional stages.
- Canopy Tree Condition (an assessment of foliage condition in canopy trees, extensive foliar damage can be an indicator of a wide variety of stressors including, but not limited to: forest pests, pathogens, air quality and/or climate change impacts): Seven of the vegetation plots at HOFU were assessed as in good condition for canopy tree condition, while seven were of moderate concern and one was rated as significant concern. Based on NRCA guidelines (refer to Table 5) the average condition was assessed as good for this metric. Comiskey and Wakamiya (2011) did not observe any high priority pests (e.g., Asian longhorned beetle [ALB], emerald ash borer [EAB], and sudden oak death [SOD]) in the vegetation plots at HOFU.
- Snags (snags are standing dead biomass that are an important element of forests, providing nesting and feeding habitat for birds and other vertebrates, additionally, they are an indicator of the structural age and health of the forest): HOFU forests had fewer than five medium-large snags per hectare and this metric was rated as significant concern.
- Coarse Woody Debris (a measure of tree volume): The amount of coarse woody degree (CWD) was rated as moderate concern for HOFU, with CWD accounting for 8% of the live tree volume.
- Forest Regeneration (regeneration, as measured by the density of saplings and seedlings, in the mid-Atlantic region is primarily affected by deer browsing; however, dense undergrowth can also be an indicator of invasive exotic species that can suppress seedling growth): Forest regeneration at HOFU, expressed as a stocking index of seedlings, was rated as significant concern, with only 13% of the plots having adequate regeneration under low deer density and 0% of the plots having adequate regeneration under high deer density.
- Soil Chemistry measured as the ratio of Ca:Al (measure of acidification) and C:N (measure of nitrification): Both soil chemistry metrics (only measured in 2007-2010) were assessed as significant concern for HOFU.

The average score of the forest vegetation integrity metrics measured by Comiskey and Wakamiya (2011) from 2007 to 2010 was moderate concern. The average score based on sampling data from 2011-2011 (Comiskey and Wakamiya 2012; Comiskey 2013) when eight of 16 plots were sampled, also scored as moderate concern (Table 31). Since the full suite of data from the second round of sampling for all 16 forest plots is not yet available, the trend was assessed as unknown (Comiskey and Wakamiya 2012).

Table 31. Forest integrity condition metrics and scores (based on MIDN monitoring 2007-2010, Comiskey and Wakamiya 2011, 2012; Comiskey 2013). Data from all plots (2007-2010) were used in the assessment of current condition.

Metric	Good	Moderate Concern	Significant Concern	HOFU Condition (2007-2010) All plots included	HOFU Condition (2011-2012) – based on 8 of 16 plots[2]
Structural Stage	>25% late successional	<25% late successional	<25% combined mature and late successional	73% late successional, 93% mature and late successional	(Based on MIDN data)
Canopy Tree Condition[1]	<10% with foliar damage, and no pests present, and BBD severity ≤2	10-50% with foliar damage, or evidence of HWA, EHS, or BC, BBD severity >2	>50% with foliar damage, or evidence of ALB, EHS, or BC	Average score[2] = 70 (7 plots: good condition, 7 plots: moderate condition, 1 plot: significant concern)	Average score[2] = 56.5 (1 plot: good condition, 7 plots: moderate condition)
Snags	≥10% trees and shrubs ≥10 cm DBH are snags and >10% trees ≥30 cm DBH are snags	<10% trees and shrubs ≥10 cm DBH are snags or <10% trees ≥30 cm DBH are snags	<5per ha, 30 cm DBH are snags	4.69 snags per ha	Average of 3.75 snags/ha
Course Woody Debris	>15% of live tree volume	5-15% of live tree volume	<5% of live tree volume	8% of live tree volume	Average of 2.5% of live tree volume
Forest Regeneration (stocking index)	>8 seedlings m^{-2}	2-8 seedlings per m^{-2}	<2 seedlings per m^{-2}	Average score[2] = 0.1 (0 plots: good condition, 2 plots: moderate condition, 14 plot: significant concern)	Average ~ 4 seedlings per m^{-2}
Soil Chemistry (acidification)	Ca:Al ratio >4	Ca:Al ratio 1-4	Ca:Al ratio <1	Ca:Al ratio = 0.73	Ca:Al ratio = 1.25 (2012 data only)[4]

[1] Pest and disease abbreviations: ALB: Asian longhorned beetle, BBD: Birch bark disease, BC: Butternut canker, EAB: Emerald ash borer, EHS: Elongate hemlock scale, HWA: Hemlock woody adelgid, SOD: Sudden oak death. DBH: Diameter at breast height.

[2] This average score is based on 50% of the total 16 forest plots, as plots are surveyed on a rotating basis each year. Data from future monitoring on the full set of plots could change the condition scores for the metrics as well as the overall condition.

[3] Average score based on NRCA guidelines for combining condition metrics (refer to Table 5).

[4] Soil chemistry data taken in 2012 was not used in the overall average condition for the 2011-2012 data since there was only one year of data.

Table 31 (continued). Forest integrity condition metrics and scores (based on MIDN monitoring 2007-2010, Comiskey and Wakamiya 2011, 2012; Comiskey 2013). Data from all plots (2007-2010) were used in the assessment of current condition.

Metric	Good	Moderate Concern	Significant Concern	HOFU Condition (2007-2010) All plots included	HOFU Condition (2011-2012) – based on 8 of 16 plots[2]
Soil Chemistry	C:N ratio >25	C:N ratio 20-25	C:N ratio <20	C:N ratio = 15.89	C:N ratio = 20.44 (2012 data only)[4]
Average condition of forest integrity				Average score[2] = 36	Average score[2,3] = 40

[1] Pest and disease abbreviations: ALB: Asian longhorned beetle, BBD: Birch bark disease, BC: Butternut canker, EAB: Emerald ash borer, EHS: Elongate hemlock scale, HWA: Hemlock woody adelgid, SOD: Sudden oak death. DBH: Diameter at breast height.

[2] This average score is based on 50% of the total 16 forest plots, as plots are surveyed on a rotating basis each year. Data from future monitoring on the full set of plots could change the condition scores for the metrics as well as the overall condition.

[3] Average score based on NRCA guidelines for combining condition metrics (refer to Table 5).

[4] Soil chemistry data taken in 2012 was not used in the overall average condition for the 2011-2012 data since there was only one year of data.

Table 32. Insect forest pests, and their host species, that are present in Berks (B) or Chester (C) Counties (USDA Forest Service 2014). Bold text indicates species used by the MIDN as indicator forest pest species.

Scientific Name[1]	Common Name	Counties Present	Host Tree(s)
Acantholyda erythrocephala	Pine false webworm	C	Red pine, white pine, scotch pine, and other pines
Adelges tsugae	Hemlock woolly adelgid	B, C	Eastern and Carolina Hemlock
Asterolecanium minus	Oak Pit Scale	C	Various oak species
Callidellum rufipenne	Japanese cedar longhorn beetle	C	Northern white cedar
Carulaspis juniperi	Juniper scale	C	Junipers, cypresses, false cypresses and incense cedar
Cronartium ribicola	White pine blister rust	B, C	White pine, other pines
Cryphonectria parasitica	Chestnut blight	B, C	American chestnut, chinkapins
Cryptodiaporthe populea	Dothichiza canker of popular	C	Lombardy poplar, other poplar species, quaking aspen, bigtooth aspen; most common in nurseries and plantations and rare in native stands
Discula destructiva	Dogwood anthracnose	B, C	Flowering and Pacific dogwood
Drycosmus kuriphilus	Chestnut gall wasp	B	American chestnut, chinkapins
Fiorinia externa	Elongate hemlock scale	B	Hemlock, fir, and spruce, as well as nearby cedar, Douglas-fir, pine, and yew
Hylastes opacus	European bark beetle	C	Scots pine, other pines, occasionally other conifers
Lymantria dispar	Gypsy moth	B, C	Hardwood trees
Neonectria faginata	Beech bark disease	B	Beech previously infested with the exotic scale *Cryptococcus fagisuga*
Popillia japonica	Japanese beetle	B, C	Numerous host plants, including trees, shrubs, and garden crops
Pristiphora erichsonii	Larch sawfly	B	Larch, tamarack
Sirococcus clavigignenti juglandacearum	Butternut canker	B, C	Butternut; may infest but not damage other *Juglans* spp.
Taeniothrips inconsequens	Pear thrips	C	Maples, fruit trees
Tomicus piniperda	Pine shoot beetle	B, C	Pines

[1] Note: The emerald ash borer (Agrilus planipennis) has been found in neighboring Montgomery and Bucks Counties but not in Berks or Chester counties. If its range expands into Berks or Chester counties is could become a potential threat to host ash trees in the park.

Confidence in Assessment

The confidence in the assessment was high, as the MIDN has established protocols and metrics to evaluate forest vegetation integrity and vegetation plots are monitored on a routine basis.

Data Gaps

Deer are present in the park and deer densities in PA can be high depending on the locale (Comiskey and Wakamiya 2011). The park may even be a sanctuary for deer since hunting is not allowed in the park but is common in the surrounding lands (Kate Jensen, ecologist, personal communication, 4 April 2014). A formal deer density study would be beneficial for the park.

Threats

Both Russell (1987) and Comiskey and Wakamiya (2011) mentioned damage from deer grazing was apparent in the park. The impacts of white-tailed deer in some areas of the park appear to be significant, primarily near the village. In these areas, the forest stands have few tree seedlings or saplings less than two meters in height due to deer browse (Comiskey and Callahan 2008). In some oak stands the only significant ground layer vegetation is hay-scented fern (*Dennstaedtia punctilobula*) and New York Fern (*Thelyptris nova-boracensis*), both of which are avoided by deer. Deer may also be a contributing factor to the weedy nature of the Modified Successional Forest stands by heavily browsing desirable native species and avoiding the exotic species (Comiskey and Callahan 2008). In some eastern parks white-tailed deer have been responsible for over-browsing native vegetation and reducing woody regeneration, thereby changing the cultural and natural landscapes and affecting ecosystem health (NPS 2014). However, there was no information on the density of deer in the park and a deer density study should be a priority.

Comiskey and Wakamiya (2011) did not observe any high priority pest species in the vegetation plots at HOFU. Although there are several forest pests that are present in Berks and Chester Counties (Table 32), the USDA Forest Service risk assessment for the area in the vicinity of HOFU was rated as low with only 1-4% of the treed area at risk (Figure 42).

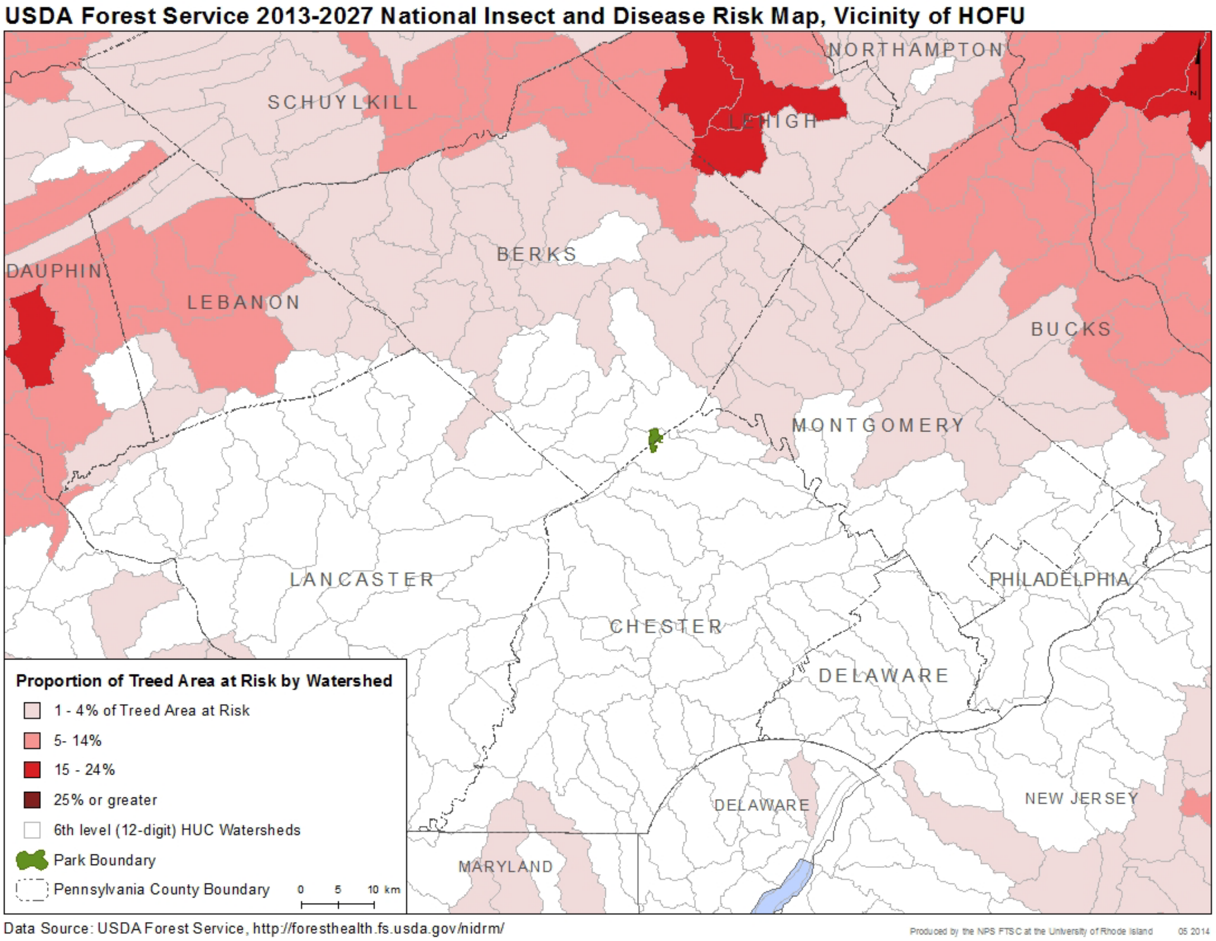

Figure 42. USDA Forest Service forest pest and disease risk map for the area in the vicinity of HOFU (USDA, Forest Service 2014).

<u>Sources of Expertise</u>

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4.3.2. Agricultural Fields

Relevance and Context

Fields and grasslands provide habitat for a variety of flora and fauna, such as grassland obligate bird species, turtles and snakes, and small mammals. The fields at HOFU are agriculturally managed cultural areas that consist of 12 fields totaling 55 ha (~16% of the park area) that are maintained as pastures, hay fields, crops, and orchards (Comiskey and Callahan 2008). The number and location of fields mowed for hay has varied over the past decade from as few as seven fields to as many as 12 (NPS 2007). Even though the agricultural fields are primarily a cultural resource, they can provide habitat for other natural resources and as such are addressed in this NRCA.

Data and Methods

The NVC vegetation mapping effort classified the agricultural fields (anthropogenic vegetation) within the Orchard Grass–Sheep-Sorrel Herbaceous Alliance (Podniesinski et al. 2005) (Figure 43). The fields at HOFU have not been specifically surveyed except when they were included as a habitat during focal surveys for other species such as mammals and herpetofauna (Yahner et al. 1997, 1999, Tiebout 2003). Therefore, there were little data to assess the condition of the agricultural grassland/field ecosystem.

Reference Condition and Status of the Resource (current condition and trends)

There have been no focal studies on the agricultural field habitat at HOFU, therefore the condition of the grassland field habitat was assessed as unknown (Table 33). However, Yetter et al. (2013) in their NRCA for Allegheny Portage Railroad NHS developed a suite of potential metrics and thresholds to assess the condition of agricultural fields in cultural parks. Their metrics were field patch size, perimeter to area ratio of the fields, mow plans, and Floristic Quality Index (FQI) score (Table 34). Yetter et al. (2013) listed five criteria that must be met for inclusion of agricultural fields for grassland habitat (e.g., grassland birds) in an assessment of condition. Two of these criteria were patch size (>5 ha) and small perimeter to area (P:A) ratio (< 0.141). Only three fields (fields #6 [9.23 ha], #8 [6.38 ha], and #16 [6.86 ha]) of the 17 fields at HOFU were greater than 5 ha (Figure 43), and none had a P:A less than 0.141. Therefore, the small size and fragmentation of open field habitat (17 fields comprising 55 ha) at HOFU and conversion of grasslands to agricultural fields make it difficult for the park to manage the fields as grassland habitat.

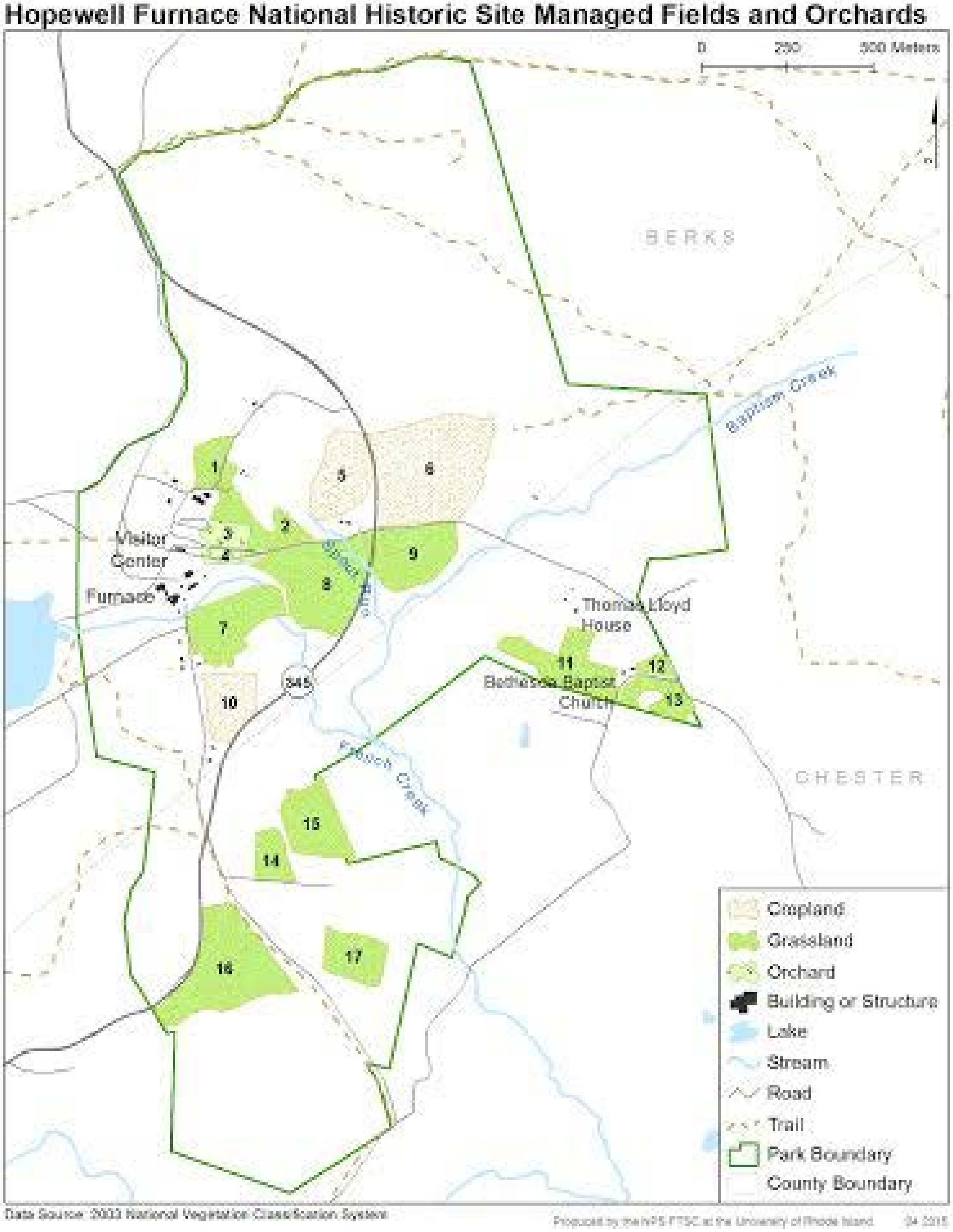

Figure 43. Agricultural fields at HOFU. Field identification number is shown in each field polygon.

Table 33. Condition assessment for agricultural fields at HOFU.

Metric	Good	Moderate Concern	Significant Concern	HOFU Condition
Agricultural Fields	Metric and thresholds not yet established			

Table 34. Potential metrics that could be used to assess the condition of agricultural fields (after Yetter et al. 2013).

Metric	Good	Moderate Concern	Significant Concern	Description
Field size for grassland obligate bird species	10-20 ha	4.9-10 ha[1]	< 4.9 ha	Calculated as contiguous habitat
Perimeter to Area (P:A) ratio	> 66	33 - 66	< 33	Calculated as the ratio[2] of (Reference P:A /Actual P:A)*100
Mow plans	Mow in Sept/Oct	Mow before July 4 & in Sept/Oct	Mow before June 19, July 17, Aug 21, & Sept 18 Or No mow plans	Rated as percentage of potential grassland habitats in each of these categories
Floristic Quality Index (FQI)	35 - 52	18 - 34	0 - 17	Calculated as: $I' = \left(\frac{\bar{C} \times \sqrt{N}}{10 \times \sqrt{N + A}} \right) \times 100$ Where $\bar{C}$ is the average coefficient of conservatism for native species, *N* is native species richness and *A* is the number of non-native species (after Miller and Wardrop 2006).

[1] In landscapes with large tracks of grasslands.

[2] Reference P:A is calculated as the perimeter to area ratio of a circle the same area of the field's polygon.

Confidence in Assessment

Since the condition of the grassland/field habitat was unknown the confidence in the assessment was low.

Data Gaps

There were no data on the grassland/field habitat as they relate to a natural resource. These areas are maintained as agricultural fields and/or livestock pastures and are part of the cultural landscape of the park.

Threats

The agricultural fields are part of the cultural landscape of the park and are currently maintained as such. Because they are part of the cultural agricultural landscape there are no threats as they are currently managed.

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4.3.3. Wetlands

Relevance and Context

The wetland areas at HOFU generally lay within riparian zones and depressions associated with seeps within the park. These habitats comprise a variety of natural and anthropogenically influenced plant community types ranging from shrub wetlands such as the Buttonbush/Highbush Blueberry-Meadowsweet Wetland alliance (Podniesinki et al. 2005), to Sensitive Fern-Woolgrass dominated wetlands (P. Sharpe, Northeast Regional Hydrologist, personal communication 29 August 2014). Tiebout (2003) mentioned the possible existence of vernal pools in the floodplain of French Creek but the existence of these habitats has not yet been verified by the ongoing wetlands survey in 2014-2015 (P. Sharpe, Northeast Regional Hydrologist, personal communication 29 August 2014). Large seepage wetlands at geologic fracture zones occur throughout the Hopewell Big Woods area, and this same pattern of seepage wetlands may occur within HOFU (J. Thorne, Former Sr. Director, Natural Lands Trust, personal communication, 29 August 2014). Seepage wetlands are important habitat for herpetofauna and are occupied by native species of grasses and sedges (Thorne and Eisman 2011).

Data and Methods

Wetlands subject to jurisdiction under Section 404 of the Clean Water Act and all wetlands subject to National Park Service (NPS) procedures for implementing *Director's Order #77–1: Wetland Protection* (2012) were surveyed within Hopewell Furnace National Historic Site (HOFU) from August-October 2014 and October 2015. The wetland survey adhered to the U.S Army Corps of Engineers (USACE) 1987 wetland delineation manual and the Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Eastern Mountains and Piedmont (2012) as the primary methodology for making wetland determinations in the field. All of the surveyed wetlands possessed vegetation and soils, therefore, D.O. #77.1 (section 4.1.2) guidelines stipulated the use of the Army Corps three-parameter approach for all of the parks non-riverine (i.e., stream) wetland systems. Wetland boundaries were mapped using a Trimble GPS (Global Positioning System) capable of obtaining sub-meter accurate readings at flags hung along the wetland edge. No new riverine systems were identified and mapped over the course of this investigation within the park boundary. The wetland spatial data contained within this NRCA is based off of the August-October 2014 work which is a sub-set of the final wetlands layer for the park. At the time of this NRCA several refinements to the 2014 wetlands data were made following some re-mapping work performed in October 2015 (unpublished), therefore the data and wetland analysis contained here-in should be considered provisional and subject to change. Despite these limitations – the 2014 wetlands data and associated mapping provide the reader with a significantly improved inventory of the existing palustrine wetlands systems within HOFU compared to National Wetland Inventory or USGS/NPS Vegetation Mapping wetland data sources. A final wetlands layer for HOFU incorporating the October 2015 work is anticipated for release by May 2016 (P. Sharpe, Northeast Regional Hydrologist, personal communication, 14 December 2015).

Reference Condition and Status of the Resource (current condition and trends)

The NVC vegetation mapping effort identified shrub wetlands and classified them as Buttonbush Wetland and Highbush Blueberry–Meadowsweet Wetland (Podniesinski et al. 2005). The single occurrence of the Buttonbush Wetland was within the active pasture and was described by Podniesinski et al. (2005) as very degraded. The 2014 mapping effort by P. Sharpe is currently on-going as such the results and data products were not available to support this NRCA.

Tiebout (2003) mentioned the presence of vernal pools in the French Creek floodplain; however, recent survey work by P. Sharpe in 2014-2015 did not observe any vernal pools during his wetland survey. Two obligate vernal pool amphibians, the wood frogs and spotted salamander, have been recorded in the park, with the most recent observation of the wood frog in 2014 (P. Sharpe, Northeast Regional Hydrologist, personal communication 29 August 2014). Additionally, there were several plants that are found in association with vernal pool habitat that have also been recorded in the park (PHNP 2014b) (Table 35).

Possible metrics to assess the condition of wetlands could be the presence of wetland obligate species, the lack of invasive vegetation, and water quality and quantity (e.g., pH, conductivity, nutrient concentration, hydroperiod). However, before thresholds for these metrics can be established the data from the wetland survey conducted in 2014-2015 need to be analyzed and interpreted before the development of appropriate metrics and threshold values for condition can be finalized, and as such the condition of the wetlands was rated as unknown (Table 36).

Confidence in Assessment

The confidence in the assessment was low as the condition for wetlands was unknown.

Data Gaps

There is currently a detailed wetland inventory being conducted within the park (P. Sharpe, Northeast Regional Hydrologist, personal communication, 29 August 2014). The results of this study were not available at the writing of this NRCA, but the results of that work will significantly improve park baseline knowledge of these critical habitat types.

Threats

Wetlands can be threatened by a variety of anthropogenic and natural threats. Road runoff (e.g., salt) can negatively impact water quality. Groundwater withdrawals can impact wetland hydroperiods and may negatively impact wetland flora and fauna. Invasive and exotic plants and animals also can threaten wetlands by crowding out native species. In fact, Comiskey and Callahan (2008) commented that invasive plants were a threat to the riparian wetlands along French Creek.

Table 35. Obligate vernal pools animals and common wetland plants found in association with vernal pool habitat (PNHP 2014b).

Scientific Name	Common Name	Recorded in Park
Animals		
Ambystoma maculatum	Spotted salamander	Yes
Ambystoma opacum	Marbled salamander	No
Ambystoma jeffersonianum	Jefferson salamander	No
Eubranchipus vernalis	Springtime fairy shrimp	Unknown
Lithobates sylvaticus	Wood frog	Yes
Scaphiopus holbrookii	Eastern spadefoot	No
Plants		
Acer rubrum	Red maple	Yes
Carex canescens	Silvery sedge	No
Carex crinita	Fringed sedge	Yes
Carex gynandra	Nodding sedge	Yes
Carex lupulina	Hop sedge	Yes
Carex vesicaria	Blister sedge	No
Cephalanthus occidentalis	Buttonbush	Yes
Dulichium arundinaceum	Three-way sedge	Yes
Glyceria acutiflora,	Creeping mannagrass	No
Glyceria canadensis	Rattlesnake mannagrass	No
Glyceria melicaria	Melic mannagrass	Yes
Glyceria septentrionalis	Floating mannagrass	Yes
Ilex verticillata	Winterberry	Yes
Leersia oryzoides	Rice cut-grass	Yes
Nyssa sylvatica	Black gum	Yes
Osmunda regalis	Royal fern	Yes
Osmunda cinnamomea	Cinnamon fern	Yes
Quercus bicolor	Swamp white oak	Yes
Quercus palustris	Pin oak	Yes
Torreyochloa pallida	Pale false mannagrass	No

Table 35 (continued). Obligate vernal pools animals and common wetland plants found in association with vernal pool habitat (PNHP 2014b).

Scientific Name	Common Name	Recorded in Park
Plants (continued)		
Thelypteris palustris	Marsh fern	Yes
Scirpus ancistrochaetus	Northeastern bulrush	No
Scirpus cyperinus	Wool-grass	Yes
Vaccinium corymbosum	Highbush blueberry	Yes

Table 36. Condition assessment for wetlands at HOFU.

Metric	Good	Moderate Concern	Significant Concern	HOFU Condition
Wetlands	Metrics and thresholds not yet established			

Sources of Expertise

P. Sharpe, Northeast Regional Hydrologist, National Park Service, 200 Chestnut Street, Philadelphia, PA 19106.

J. Thorne, former Senior Director of Science Natural Lands Trust.

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4.3.4. Invasive Plants

Relevance and Context

Documenting and managing non-native and invasive plants is part of the NPS Strategic Plan for Managing Invasive Non-native Plants on NPS lands (NPS 1996) and as such, vegetation monitoring and management fits within a context of NPS policy and law aiming to preserve and protect native species, functioning ecosystems, and cultural and historical resources. Non-native invasive plants can negatively affect and/or threaten native species diversity and ecosystems, and seriously degrade the cultural landscape. Current NPS base funding of Hopewell Furnace provides minimal support for invasive plant management. Past invasive plant control took place by assigning Student Conservation Association interns, among many other duties, to cut and uproot specific plants that infringed upon trails and the Historic Village. There has never been sufficient funding to support a robust approach that would address the expanding invasives infestations of the area (Ambrose and Åkerson 2006).

Data and Methods

Invasive vegetation has been recorded at various times in the park either as focal surveys or in the context of vegetation monitoring (Russell 1987, Ambrose and Åkerson 2006, Comiskey and Wakamiya 2011, Comiskey 2013).

Russell (1987) surveyed the forested uplands in 1987. Ambrose and Åkerson (2006) developed a strategic plan for monitoring invasive exotic vegetation in 2006. These authors described the intensity and type of invasive vegetation in various park areas. The MIDN (Comiskey 2013, Comiskey and Wakamiya 2011) uses several metrics to assess forest ecosystem integrity. One of the metrics recorded during MIDN forest monitoring was to detect and monitor the presence of invasive exotic plants.

Combined these databases yielded 558 plant species observed in the park, 20% of which were either PA state-listed invasive (27 species, Table **37**) or non-native (85 species) (Appendix Table 48).

Reference Condition and Status of the Resource (current condition and trends)

Invasive, exotic vegetation was prevalent within the park with a continuous gradient that was lightest in the northern section of the park and heaviest in the southern portion of the park (Ambrose and Åkerson 2006). The most invasive species and heaviest infestations were found in the southern border areas of the Lower Village, Horseshoe, Baptism Creek, and Bethesda Church areas (Figure 44). Typically infested areas included road sides, field edges, and along rock walls and stream banks, with the most troubling invasives being mile-a-minute (*Persicaria perfoliata*), Oriental bittersweet (*Celastrus orbiculatus*), garlic mustard (*Alliaria petiolata*), and Japanese stiltgrass (*Microstegium* *vimineum*). Mile-a-minute is a highly invasive vine and was detected all along French Creek and in the Horseshoe area at the park boundary along the Harrison-Lloyd road and southern park boundary. In 2006, the density of mile-a-minute was only 1-5% cover (Ambrose and Åkerson 2006); the current density of this highly invasive species within HOFU was not known.

Table 37. Pennsylvania state listed invasive species observed at HOFU (PA DCNR 2014).

Scientific Name	Common Name
PA DCNR listed Invasive Plants	
Acer platanoides	Norway maple
Ailanthus altissima	Tree of heaven
Alliaria petiolata	Garlic mustard
Berberis thunbergii	Japanese barberry
Carduus nutans	Nodding plumeless thistle
Celastrus orbiculatus	Asian bittersweet
Cirsium arvense	Canada thistle
Cirsium vulgare	Bull thistle
Elaeagnus umbellata	Autumn olive
Euonymus alata	Winged euonymus
Hedera helix	English ivy
Lespedeza cuneata	Chinese lespedeza
Ligustrum obtusifolium	Border privet
Lonicera japonica	Japanese honeysuckle
Lonicera morrowii	Marrow's honeysuckle
Lonicera tatarica	Tartarian honeysuckle
Microstegium vimineum	Japanese stiltgrass
Ornithogalum umbellatum	Star of Bethlehem
Persicaria perfoliata	Mile-a-minute
Perilla frutescens	Beefsteakplant
Potamogeton crispus	Curly pondweed
Rosa multiflora	Multiflora rose
Rubus phoenicolasius	Wine raspberry

Table 37 (continued). Pennsylvania state listed invasive species observed at HOFU (PA DCNR 2014).

Scientific Name	Common Name
PA DCNR Watch Listed Invasive Plants	
Broussonetia papyrifera	Paper mulberry
Hemerocallis fulva	Orange daylily
Holcus lanatus	Common velvetgrass
Morus alba	White mulberry
Poa trivialis	Rough bluegrass
Phyllostachys aurea	Golden bamboo
Schedonorus arundinaceus	Tall fescue
Vinca minor	Common periwinkle
Wisteria sinensis	Chinese wisteria

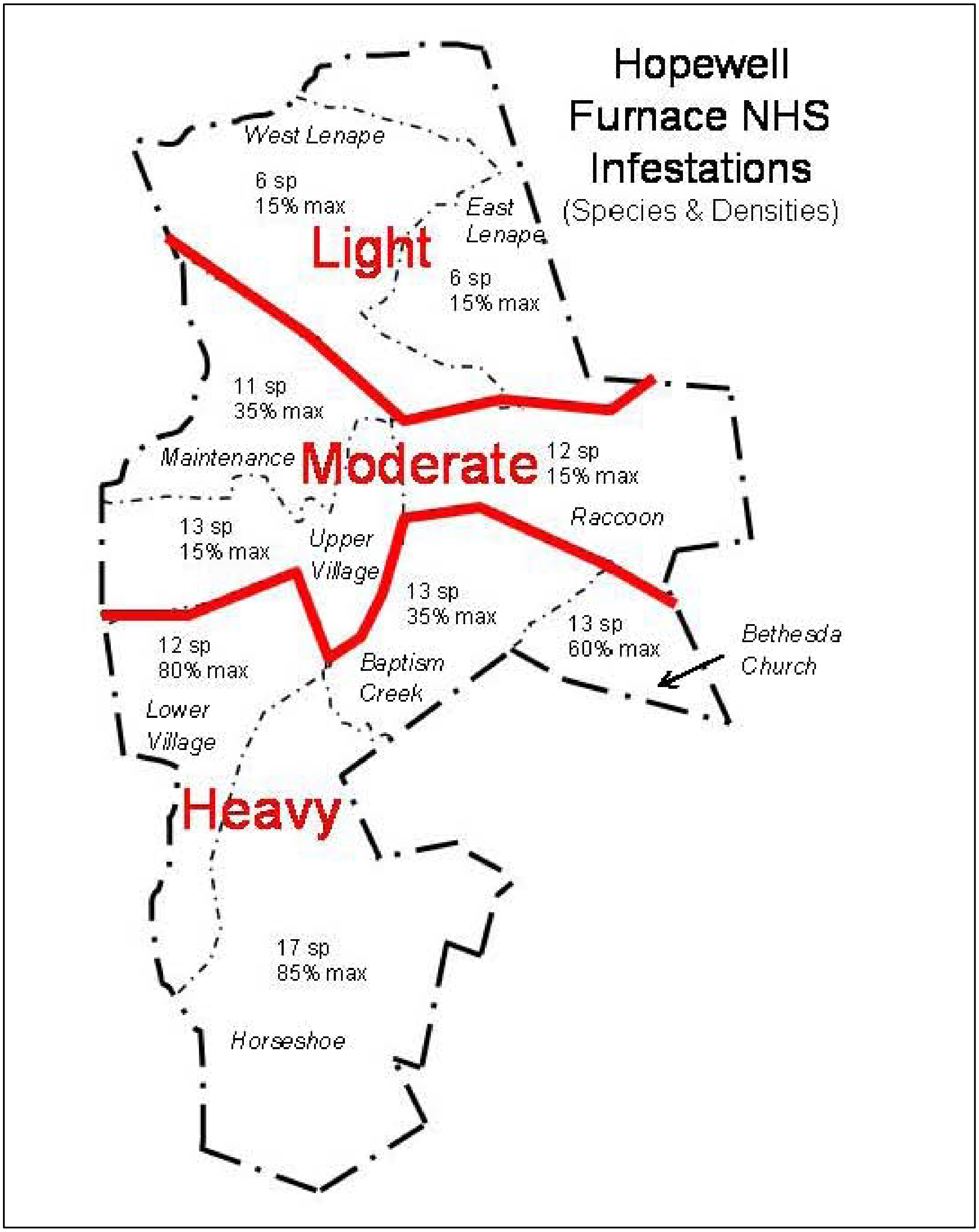

Figure 44. Invasive exotic vegetation infestation levels at HOFU in various areas (figure modified from Ambrose and Åkerson 2006).

Comiskey (2013) noted that compared to the rest of the MIDN Network, HOFU had a moderate percent cover of exotics in the forest vegetation plots that were monitored, and that based on the plot data (4 plots sampled in 2008, and 4 in 2012) that some invasive species (e.g., Japanese stiltgrass) had decreased in cover from 2008 to 2012.

The NPS Strategic Plan of 2001-2005 established goals related to invasive plant management. One of the long-term goals was that exotic vegetation should be contained on 6.3% of targeted acres of parkland (Goal Ia1B) at the National level (NPS 2000, Table 38). Based on the mapping effort by Ambrose and Åkerson (2006), it appears that invasive vegetation was prevalent throughout the park, and in densities greater than 9.4% of the park area in every unit surveyed (refer to Figure 44), therefore the condition for invasive vegetation was evaluated as significant concern. The trend was unknown as there has not been additional invasive vegetation mapping and the MIDN forest monitoring program (Comiskey 2013, Comiskey and Wakamiya 2011) has not yet completed enough long term sampling to determine trends.

Table 38. NPS (2000) guidelines for areal coverage of invasive vegetation within park boundaries.

Metric	Good	Moderate Concern	Significant Concern	HOFU Conditon
Areal cover thresholds for invasive vegetation	<6.3% of park	6.3-9.4% of park	>9.4% of park	Significant Concern Areal coverage: >9.4%[1]

[1] Based on mapping by Ambrose and Åkerson 2006, refer to Figure 44.

Confidence in Assessment

The confidence in the assessment was medium. The invasive vegetation mapping was conducted in 2006, and due to the lack of funding to support invasive vegetation monitoring and eradication, the density of invasive plants could be higher.

Data Gaps

The MIDN (Comiskey and Wakamiya 2011) has established protocols and metrics to evaluate invasive plants, but this is only within the forest vegetation plots and the most troublesome spots for invasive species were along road sides, field edges, along rock walls, and stream banks. The park would benefit from further invasive vegetation monitoring and control measures. Current NPS base funding of Hopewell Furnace provides minimal support for invasive plant management, and the park should pursue funding for invasive plant control.

Threats

Non-native invasive plants can negatively effect and/or threaten native species diversity and ecosystems, and seriously degrade the cultural landscape.

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4.4. Biological Integrity-Focal Animal Communities

4.4.1. Avian Community

Relevance and Context

Birds are an important component of park ecosystems and their prominent position in most food webs make them a good sentinel of local and regional ecosystem change. As high profile taxa, many parks provide information on the status and trends of the park's avian community through their interpretive materials and programs (O'Connell et al. 2003, Faccio et al. 2010). MIDN has a draft protocol for surveying birds that volunteers have implemented in multiple parks Mid-Atlantic parks, but it has not yet been implemented at HOFU (J. Comiskey, personal communication, 29 August 2014).

Continental and local declines in bird populations have led to concern of the future of migratory and resident landbirds (Kearney 2003). The causes of population declines are numerous and complex, and include but are not limited to, habitat loss, degradation, and fragmentation of breeding and wintering grounds, and along migratory routes. Additional factors include predation, nest predation, and brood parasitism (Kearney 2003). In 1990, various government agencies, academic institutions, conservation groups, private industry, and citizens worked together to form Partners in Flight (PIF).

This voluntary, international coalition is dedicated to "keeping common birds common" (Pashley et al. 2000). PIF helps direct resources for the conservation of landbirds and their habitats with a foundation of scientifically-based Bird Conservation Plans focused on physiographic areas. HOFU is located in the Mid-Atlantic Piedmont, Area 10, PIF physiographic area (Kearney 2003).

Data and Methods

The avian community at HOFU was surveyed twice over the past 20 years. The first survey was conducted in 1994 (Yahner et al. 1998) and the second from 1999 to 2001 (Yahner et al. 2001). Both surveys used point-counts and vehicular-road surveys. Avian point-count samples were distributed throughout HOFU using a stratified random design. Sampling points were selected based on vegetation cover type (e.g., deciduous forest, perennial herbaceous), spatial location (e.g., road edge, interior forest), and elevation (e.g., plateau, high, low). Point-count stations were visited during each of the four seasons (spring-migratory: 15 April-25 May, breeding summer: 25 May-15 July, fall-migratory: 25 August-10 October, and winter: 1 December-15 March) (Yahner et al. 1998, 2001). During point-count surveys all birds heard or seen during a 10-min period were recorded. Vehicular-road surveys were used to detect diurnal raptors and vultures. Owls were surveyed at the vehicular-road stations using owl call-back recordings (Yahner et al. 1998, 2001).

The evaluate the condition of the avian community at HOFU a Bird Community Index (BCI) developed for the Mid-Atlantic Piedmont and Coastal Plain by O'Connell et al. (2003) was used. The O'Connell et al. (2003) BCI incorporates the percent of species in nine bird guilds in three biotic elements (structural, functional, and compositional, three guilds per biotic element) to rank the avian community during the breeding season (Table 39). The nine guilds included both specialists and generalist species. Specialist guilds (bark probers, ground gleaners, interior forest, pine associated species, single brooders, and upper canopy foragers) contained species with a narrow range of habitat tolerances or that exhibited low intrinsic rates of population increase. Therefore, these guilds were thought of as indicative of a high-integrity ecological condition while generalist guilds (exotics, nest disrupters, urban/suburban species) were considered indicative of a low-integrity ecological condition (O'Connell et al. 2003). The percent of species in the nine guilds were scored from 1 (bad) to 4 (good) for each guild and then the average rank for each biotic element was calculated. The BCI was calculated by summing the average ranks of the biotic elements and dividing by the number of guilds (9) (refer to Table 40). O'Connell et al. (2003) suggested the following ranking criteria (see below) to evaluate the condition of the breeding avian community based on the nine guild system BCI score. In this NRCA, based on best professional judgement, the condition of the community was assessed as:

BCI score and assessed condition:

- Humanistic: 0.250-.0460 (Significant Concern)
- Moderately disturbed: 0.461-0.600 (Moderate Concern)
- Largely intact: 0.610-0.730 (Good)
- Naturalistic: 0.731-1.000 (Good)

Table 39. Ranks for specific avian guild percentages for nine guilds in the Piedmont/Coastal Plan Bird Community Index (table from O'Connell et al. 2003).

	Bad →			Good
Biotic Element and Guild	**Rank 1**	**Rank 2**	**Rank 3**	**Rank 4**
Structural				
Forest Interior (specialist)	0-10.0	10.1-20.0	20.1-28.0	28.0-100
Pine associated (specialist)	0	0.1-2.0	2.1-5.0	5.1-100
Urban/suburban (generalist)	60.1-100	47.1-60.0	20.1-47.0	0-20.0
Functional				
Bark prober (specialist)	0-9.0	9.1-16.0	16.1-20.0	20.1-100
Upper canopy gleaner (specialist)	0-4.0	4.1-12.0	12.1-18.0	18.1-100
Ground gleaner (specialist)	0	0.1-3.0	3.1-7.0	7.1-100
Compositional				
Single brooder (specialist)	0-16.0	16.1-34.0	34.1-46.0	46.1-100
Nest disrupter (generalist)	23.1-100	16.1-23.0	0.1-16.0	0
Exotic (generalist)	11.1-100	1.1-11.0	0.1-1.0	0

Table 40. MIDN avian guild percentages and condition ranks for the Piedmont/Coastal Plan Bird Community Index (refer to Table 39 for rank ranges). Guild abbreviations are also given. Arrows after guilds indicate the desired direction of species richness to improve condition.

Biotic Element and Guild	**MIDN 1994 Guild %**	**MIDN 1994 Rank**	**MIDN 1999-2001 Guild %**	**MIDN 1999-2001 Rank**
Structural				
Forest Interior, IF (specialist) $\uparrow$	23.5%	3	31.4	4
Pine associated, P (specialist) $\uparrow$	0%	1	2.0%	2
Urban/suburban, U (generalist) $\downarrow$	0%	4	37.3%	3
Functional				
Bark prober, BP (specialist) $\uparrow$	20.6%	4	17.6%	3
Upper canopy gleaner, UC (specialist) $\uparrow$	5.9%	3	15.7%	2
Ground gleaner, GG (specialist) $\uparrow$	14.7%	3	5.9%	3
Compositional				
Single brooder, S (specialist) $\uparrow$	50.0%	4	56.9%	4
Nest disrupter, ND(generalist) $\downarrow$	11.8%	3	15.7%	2
Exotic, E (generalist) $\downarrow$	5.9%	2	5.9%	2
Average Ranks and Conditions				
Structural Average rank (∑ ranks/4)		2.25		2.00
Functional average rank (∑ ranks/4)		2.50		2.25
Compositional average rank (∑ ranks/4)		2.25		2.25
BCI Score and rating (∑ average ranks/9)		0.75 (Naturalistic)		0.72 (Largely Intact)
Avian Community Condition		Good		Good

Reference Condition and Status of the Resource (current condition and trends)

Yahner et al. (1998, 2001) recorded 143 and 121 bird species during 1994 and the 1999-2001 inventories, respectively (all seasons included) (Appendix Table 52). Combined with historical observations the total number of bird species observed at HOFU was 190 (all seasons included). This guild system was applied to both the 1994 (Yahner et al. 1998) and the 1999-2001 (Yahner et al 2001) datasets using only data from the breeding season (data from all habitats were used as individual species per season and habitat could not be determined for the 1994 data as presented in the report).

Yahner et al. (1998, 2001) observed 41 and 73 species, respectively, of birds breeding at HOFU; of these, O'Connell et al. (2003) used 34 and 51 species, respectively, in their guild based system to assess the avian breeding bird community during the breeding season (Table 41). The condition of the forest breeding bird community was assessed as "naturalistic" and "largely intact" for the 1994 and the 1999-2001 surveys, respectively (Table 40). Guilds that ranked as "humanistic" (rank 1) or "moderately disturbed" (rank 2) were the specialist guilds of pine associated and upper canopy foragers (generally, lower than desired species richness was observed for these guilds). The generalist guilds of exotics and nest disrupters had higher than the desired number of species. Overall, the avian community for both datasets was evaluated as good condition with confidence in the assessment rated as medium. The confidence was medium because even though there were two datasets of good quality, the data were over ten years old and may not be reflective of the current avian community at HOFU. A trend was not evaluated due to the lack of long term data.

The NETN protocol had guidelines for evaluating the integrity of grassland bird communities (Faccio et al. 2010). Grassland obligate bird species that utilize field habitats require large, open, unfragmented sections of grassland. While all six of the grassland obligate species (bobolink, [*Dolichonyx oryzivorus*], Eastern meadowlark [*Sturnella magna*], grasshopper sparrow [*Ammodramus savannarum*], Henslow's sparrow, [*Ammodramus henslowii*], Savannah sparrow [*Passerculus sandwichensis*], and Vesper sparrow [*Pooecetes gramineus*]) used by the NETN to assess this community were observed at HOFU in 1994, none were observed during the breeding season; and none of these grassland obligate species were observed during the 1999-2001 HOFU inventory. The small size and fragmentation of open field habitat (17 fields comprising 55 ha) at HOFU and conversion of grasslands to agricultural fields make it unlikely grassland specialists breed at HOFU or that species that require large patches of open habitat will be documented in the park (Yahner et al. 2001).

Table 41. Bird species observed during the breeding season at HOFU (all habitats included). Species in MIDN guild used by O'Connell et al. (2003) to evaluate the avian community are also shown.

Scientific Name	Common Name	MIDN Guild[1]	1994	2001
Agelaius phoeniceus	Red-winged blackbird	n/a		X
Archilochus colubris	Ruby-throated hummingbird	U		X
Baeolophus bicolor	Tufted titmouse	BP	X	X
Bombycilla cedrorum	Cedar waxwing	U		X
Branta canadensis	Canada goose	n/a	X	
Bubo virginianus	Great horned owl	n/a		X
Bucephala clangula	Common grackle	ND, S, U		X
Buteo jamaicensis	Red-tailed hawk	n/a		X
Buteo platypterus	Broad-winged hawk	n/a	X	X
Cardinalis cardinalis	Northern cardinal	U	X	
Carduelis tristis	American goldfinch	U	X	X
Carpodacus mexicanus	House finch	E, U	X	X
Cathartes aura	Turkey vulture	n/a	X	X
Catharus fuscescens	Veery	BP, IF, S	X	X
Chaetura pelagica	Chimney swift	S, U	X	X
Coccyzus americanus	Yellow-billed cuckoo	S, UC		X
Coccyzus erythropthalmus	Black-billed cuckoo	S		X
Colaptes auratus	Northern flicker/yellow shafted flicker	GG, S	X	X
Contopus virens	Eastern wood-pewee	IF, S	X	X
Coragyps atratus	Black vulture	n/a		X
Corvus brachyrhynchos	American crow	ND, U	X	X
Corvus ossifragus	Fish crow	ND, S		X
Cyanocitta cristata	Blue jay	ND, U	X	X
Dendroica petechia	Yellow warbler	S		X
Dendroica striata	Blackpoll warbler	n/a		X
Dryocopus pileatus	Pileated woodpecker	BO, IF, S		X

[1] MIDN Guilds used to assess community condition (after O'Connell et al. 2003) BP: bark prober forager, E: exotic, GG: ground gleaner forager, IF: interior forest, ND: nest disrupter, P: Pine associated, UC: high canopy forager, S: single brooded; U: urban/suburban. n/a: not assigned to one of the nine guilds used by O'Connell et al. (2003) to assess condition.

Table 41 (continued). Bird species observed during the breeding season at HOFU (all habitats included). Species in MIDN guild used by O'Connell et al. (2003) to evaluate the avian community are also shown.

Scientific Name	Common Name	MIDN Guild[1]	1994	2001
Dumetella carolinensis	Gray catbird	U	X	X
Empidonax virescens	Acadian flycatcher	IF, S		X
Falco sparverius	American kestrel	n/a		X
Geothlypis trichas	Common yellowthroat	n/a	X	X
Haliaeetus leucocephalus	Bald eagle	n/a		X
Helmitheros vermivorum	Worm-eating warbler	IF, S		X
Hirundo rustica	Barn swallow	n/a	X	X
Hylocichla mustelina	Wood thrush	IF, S	X	X
Icterus galbula	Baltimore oriole	S, UC	X	X
Icterus spurius	Orchard oriole	S		X
Melanerpes carolinus	Red-bellied woodpecker	ND, U	X	X
Melanerpes erythrocephalus	Red-headed woodpecker	ND		X
Melospiza melodia	Song sparrow	U	X	X
Mimus polyglottos	Northern mockingbird	U	X	X
Mniotilta varia	Black-and-white warbler	BP, IF, S		X
Molothrus ater	Brown-headed cowbird	n/a	X	X
Myiarchus crinitus	Great crested flycatcher	S	X	X
Parula americana	Northern parula	IF, S, UC		X
Passer domesticus	House sparrow	E, ND, U		X
Passerina cyanea	Indigo bunting	n/a	X	X
Petrochelidon pyrrhonota	Cliff swallow	n/a		X
Phasianus colchicus	Ring-necked pheasant	n/a		X
Pheucticus ludovicianus	Rose-breasted grosbeak	IF, UC	X	X
Picoides pubescens	Downy woodpecker	BP, U	X	X
Picoides villosus	Hairy woodpecker	BP, IF, S		X
Pipilo erythrophthalmus	Eastern towhee	IF	X	X

[1] MIDN Guilds used to assess community condition (after O'Connell et al. 2003) BP: bark prober forager, E: exotic, GG: ground gleaner forager, IF: interior forest, ND: nest disrupter, P: Pine associated, UC: high canopy forager, S: single brooded; U: urban/suburban. n/a: not assigned to one of the nine guilds used by O'Connell et al. (2003) to assess condition.

Table 41 (continued). Bird species observed during the breeding season at HOFU (all habitats included). Species in MIDN guild used by O'Connell et al. (2003) to evaluate the avian community are also shown.

Scientific Name	Common Name	MIDN Guild[1]	1994	2001
Piranga olivacea	Scarlet tanager	IF, S, UC	X	X
Poecile atricapilla	Black-capped chickadee	BP, S	X	
Poecile carolinensis	Carolina chickadee	BP, S	X	X
Polioptila caerulea	Blue-gray gnatcatcher	UC	X	X
Progne subis	Purple martin	S, U	X	
Sayornis phoebe	Eastern phoebe	n/a	X	X
Seiurus aurocapilla	Ovenbird	GG, IF, S	X	X
Seiurus motacilla	Louisiana waterthrush	GG, IF, S		X
Setophaga ruticilla	American redstart	IF, S		X
Sialia sialis	Eastern bluebird	n/a	X	X
Sitta carolinensis	White-breasted nuthatch	BP, IF, S	X	X
Spizella passerina	Chipping sparrow	U	X	X
Spizella pusilla	Field sparrow	n/a		X
Sturnus vulgaris	European starling	E, ND, U	X	X
Tachycineta bicolor	Tree swallow	S	X	X
Thryothorus ludovicianus	Carolina wren	U		X
Troglodytes aedon	House wren	n/a	X	X
Turdus migratorius	American robin	U	X	X
Tyrannus tyrannus	Eastern kingbird	S	X	X
Vermivora ruficapilla	Nashville warbler	n/a		X
Vireo flavifrons	Yellow-throated vireo	IF, S, UC		X
Vireo olivaceus	Red-eyed vireo	S, UC	X	X
Zenaida macroura	Mourning dove	ND, U		X
Total species observed during breeding season			41	73

[1] MIDN Guilds used to assess community condition (after O'Connell et al. 2003) BP: bark prober forager, E: exotic, GG: ground gleaner forager, IF: interior forest, ND: nest disrupter, P: Pine associated, UC: high canopy forager, S: single brooded; U: urban/suburban. n/a: not assigned to one of the nine guilds used by O'Connell et al. (2003) to assess condition.

Ten bird species observed at HOFU from 1994-2001 were Pennsylvania state listed species (Appendix Table 52). The blackpoll warbler (*Dendroica striata*) was listed as state endangered, and two (bald eagle [*Haliaeetus leucocephalus*] and long-eared owl [*Asio otus*]) were listed as state threatened. Five species were listed as candidate rare (bank swallow [*Riparia riparia*], Henslow's sparrow [*Ammodramus henslowii*], northern waterthrush [*Parkesia noveboracensis*], purple martin [*Progne subis*], and Swainson's thrush [*Catharus ustulatus*]); and two were listed as candidates at risk (common nighthawk [*Chordeiles minor*] and golden-winged warbler [*Vermivora chrysoptera*]. The blackpoll warbler, bald eagle, and purple martin were observed during the breeding season and could possibly breed in the park.

Additionally, there were 20 species of birds observed by Yahner et al. (1998, 2001) that were listed as priority species by PIF for the Mid-Atlantic Piedmont Physiographic Area (Kearney 2003) (Appendix Table 52). Three of these (American woodcock [*Scolopax minor*], prairie warbler [*Dendroica discolor*], and wood thrush [*Hylocichla mustelina*]) had a PIF status of IA: High Continental Priority-High Regional Responsibility indicating that conservation of these species is of concern throughout their range and that conservation in the region is critical to the overall health of the species. None of these species were observed during the breeding season.

Five species (chimney swift [*Chaetura pelagica*], Eastern screech-owl [*Megascops asio*], Eastern towhee [*Pipilo erythrophthalmus*], field sparrow [*Spizella pusilla*], and rusty blackbird [*Euphagus carolinus*] had a PIF status of IIA: High Regional Priority-High Regional Concern indicating that these species are of moderate continental priority, but important in regional conservation because they are experiencing declines in the core of their range and require short-term conservation to reverse or stabilize trends. The chimney swift, Eastern towhee, and field sparrow were observed during the breeding season.

Three species (Acadian flycatcher [*Empidonax virescens*], Louisiana waterthrush [*Seiurus motacilla*], and scarlet tanager [*Piranga olivacea*] had a PIF status of IIB: High Regional Priority -High Regional Responsibility, indicating the region shares in the responsibility for long-term conservation, even if these species are not currently declining or threatened. All three of these species were observed during the breeding season.

One species, the loggerhead shrike (*Lanius ludovicianus*) was listed as IIC: High Regional Priority, High Regional Threats indicating that this species is of moderate overall priority, that it is uncommon in the region, and whose remaining populations are threatened, usually because of extreme threats to sensitive habitats.

<u>Confidence in Assessment</u>
Confidence in the assessment was medium as there has only been one monitoring effort for birds at HOFU and the surveys were done over 10 years ago. Another avian inventory would be beneficial.

<u>Data Gaps</u>
The only data gap was age of the avian inventory data which were over 10 years old. An updated (2004-2009) interactive web map of the breeding birds of Pennsylvania was not available at the time

this NRCA was written (Pennsylvania Game Commission 2015). When the website is online this could be used as an additional source for birds breeding in the area of HOFU. A current survey of HOFU bird communities would be beneficial. The MIDN has a yearly breeding bird monitoring protocol at many of the mid-Atlantic parks, but HOFU and MIDN Network have not included avian monitoring at HOFU due to time/staffing constraints.

Threats

A primary threat to landbird populations is habitat loss due to development; however, Neotropical migrants (birds that breed in the US and Canada during the summer, but migrate to Mexico, Central America, South America, or the Caribbean Islands during the winter such as flycatchers, warblers, orioles, and vireos) are particularly vulnerable to habitat fragmentation (Robinson and Wilcove 1994, Faaborg et al. 1995). Forest fragmentation leads to increases in edge habitat, an ideal habitat for non-migratory resident species, and results in higher rates of brood parasitism and nest predation in the remaining forest habitat (Faccio et al. 2010). While small parks like HOFU may have some control over forest fragmentation within their boundaries, habitat loss and fragmentation are widespread throughout much of the Northeast region (Faccio et al. 2010). The open field habitat at HOFU is unlikely to support grassland bird communities due to their small size and ongoing agricultural uses (Yahner et al. 2001). Other global treats to landbird populations include, but are not limited to, predation (natural predators and feral cats) and climate change.

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4.4.2. Mammal Community

Relevance and Context

Mammals contribute to species richness and diversity and play a major role in ecosystem dynamics as consumers of plant material and invertebrates and as prey for snakes, raptors, and carnivorous mammals. Small mammals may directly influence population levels of insect pests and disease vectors such as gypsy moths and deer ticks, as well as regionally rare raptorial birds (Cook et al. 2004). The abundance and composition of small mammal communities can also affect the structure, species composition, and successional trends of plant communities (Ostfeld 2002). As fragmentation of the natural landscape increases with urbanization and agriculture, NPS lands and large tracts of public lands, such as Hopewell Big Woods, become increasingly important as migration corridors and refugia that are important for the long-term maintenance of faunal diversity and ecosystem integrity that extend beyond park boundaries (Yahner et al. 1997, Gilbert et al. 2008). Hopewell Big Woods and French Creek State Park are listed as Important Mammal Areas Project (IMAP) by the state. The Pennsylvania IMAP was initiated in 2001 to promote the conservation of mammals by identifying sites or regions that include habitats critical to their survival, and to educate the public about mammals and their needs. While selection as an Important Mammal Area does not provide legal protection, it focuses public awareness on mammals and provides landowners and governmental agencies with information to compliment land management and land use decisions to better protect mammals and their habitat (PA Game Commission 2015).

In the Northeastern U.S., cave and mine hibernating bats are dying at an alarming rate due to white-nose syndrome (WNS). WNS first identified in New York in 2006 and has since rapidly spread to multiple sites throughout the eastern United States and into Canada. WNS is caused by a fungus (*Pseudogymnoascus destructans*) that thrives in the cold, humid conditions of caves and mines where some bat species hibernate. White-nose syndrome has been confirmed in several PA counties and in French Creek State Park and has affected bat populations throughout the state (White-Nose

Syndrome.org 2014, L. Miller, Environmental Education Specialist/Volunteer Coordinator, French Creek State Park Complex, email communication 3 April 2014).

Data and Methods

Mammals were surveyed at HOFU from 1994-1995 in conjunction with the development of an inventory and monitoring protocol for mammals in Eastern National Parks (excluding white-tailed deer [*Odocoileus virginianus*] and black bear [*Ursus americanus*]) (Yahner et al. 1997). Mammal survey areas at HOFU were divided into three habitat types: grassland, old-field, and forest; with surveys occurring at nine randomly selected sites (one grassland, two old-field, four lowland-forest, and two upland-forest areas) (Yahner et al. 1997). Trapping stations were systematically placed along randomly oriented transects within each habitat. Five methods, pitfall trapping, live-trapping, drift fences with pitfall trap and live traps, and vehicular road surveys, were used to evaluate the mammal community. Using these methods, and information from NPS wildlife observation cards, sixteen species (other than bats) were reported at HOFU (Yahner et al. 1997) (Table 42).

Bats were mist-netted in 2005 at HOFU to predict and detect bat communities (Hart 2006). Five sites were selected and mist-netting was done for 10 nights (total of 46 net nights). Sites surveyed were along French Creek, Baptism Creek, and adjacent to an agricultural field and road (Harrison Lloyd site). Four species represented by 18 individuals were captured (Table 42). At the time of the survey the only permanent bat colony at HOFU was observed in the original horse barn and was composed entirely of little brown myotis (*Myotis lucifugus*) (150-200 individuals) (Hart 2006).

During the 2005 survey one pregnant and one post-lactating female northern long-eared bat (or northern myotis, *Myotis septentrionalis*, a state listed candidate rare and federally listed threatened species, was recorded, suggesting that forest resources within Hopewell Furnace NHS were adequate for the formation of small maternity colonies of this species (Hart 2006). Additional bat surveys were conducted 2014 and will continue in 2015 with a resurvey for northern long-eared bat. The report is still in preparation but preliminary results suggest a decline little brown bat abundance and that the northern long-eared is still present at HOFU (A. Ruhe, personal communication, 25 July 2014).

Reference Condition and Status of the Resource (current condition and trends)

Data from Yahner et al. (1997) and Hart (2006) indicate that at least 21 mammal species (including white-tailed deer, *Odocoileus virginianus*) have been observed at HOFU (Table 42). Hopewell Big Woods and French Creek State Park, which surround HOFU, are listed as Important Mammal Areas Project by the state, and at least 45 of the 62 native PA mammals are known to inhabit the area including mink, river otter, bobcat, grey fox, and black bear (French and Pickerings Conservation Trust 2013, County of Berks Pennsylvania Greenway Plan 2013). Most of the species documented during Yahner's et al. (1997) survey were representatives of the Order Rodentia (41%) (e.g., mice, squirrels) (Figure 45). Yahner et al. (1997) predicted that 59 species of mammals could potentially occur at HOFU, but several of these species were not within the expected range of HOFU. Using best professional judgment, Yahner's et al. (1997) list was modified using information from mammals known to exist in Hopewell Big Woods (French and Pickerings Conservation Trust 2013, County of Berks Pennsylvania Greenway Plan 2013), to be present state-wide, and those whose suitable habitat was available within HOFU (this excluded beaver and river otter, A. Ruhe, personal communication, 27 November 2015). This reduced the list 42 potential mammals that could be present at HOFU (Appendix Table 53).

Table 42. Mammals documented to occur at HOFU. Includes habitat where observed (if known) and incidental observations during inventory effort, and NPS wildlife observation cards (refer to Appendix Table 53 for list of all expected mammals).

Scientific Name	Common Name	Habitat
Blarina brevicauda	Northern short-tailed shrew	Grassland, lowland forest, upland forest
Didelphis virginiana	Virginia opossum	Observed by researcher
Eptesicus fuscus[1]	Big brown bat	Baptism Creek, Harrison Lloyd site
Glaucomys volans[2]	Southern flying squirrel	NPS wildlife observation card
Lasiurus borealis[1]	Red bat	Baptism Creek
Marmota monax	Woodchuck	Observed by researcher
Microtus pennsylvanicus	Meadow vole	Lowland forest
Mustela erminea[2]	Ermine	NPS wildlife observation card
Myotis lucifugus[1]	Little brown myotis	Horse barn colony, French Creek, Baptism Creek
Myotis septentrionalis[3]	Northern long-eared bat	French Creek, Baptism Creek, Harrison Lloyd site
Napaeozapus insignis	Woodland jumping mouse	Observed by researcher
Odocoileus virginianus	White-tailed deer	Known to occur
Peromyscus leucopus	White-footed mouse	Old-field, lowland forest, upland forest
Procyon lotor	Raccoon	Observed by researcher
Sciurus carolinensis	Eastern gray squirrel	Road survey (no habitat given)
Sorax cinereus	Masked shrew	Old-field, lowland forest, upland forest
Sylvilagus floridanus	Eastern cottontail	Road survey (no habitat given)
Tamias striatus	Eastern chipmunk	Old-field, lowland forest, upland forest
Tamiasciurus hudsonicus	Red squirrel	Observed by researcher
Vulpes vulpes	Red fox	Observed by researcher
Zapus hudsonius	Meadow jumping mouse	Old-field, lowland forest

[1] Bats were specifically surveyed by Hart (2006).

[2] Species not listed in NPSpecies data base (2013) but were listed in Yahner et al. (1997) as being observed on NPS wildlife observation card.

[3] State and/or federally listed species

Mammal inventories conducted in other NPS Networks (e.g., NCBN) established a goal of detecting 90% of the terrestrial mammal species expected to occur within the park (Gilbert et al. 2008). Using best professional judgment, the condition of the mammal community at HOFU was evaluated based on the percent of species expected to be detected (Table 43). Fifty percent (21 species) of the expected mammal species have been documented in the park (Figure 45), and the condition was evaluated as moderate concern. Since there has only been one mammal survey, trend in the condition of the mammal community could not be evaluated (Table 43).

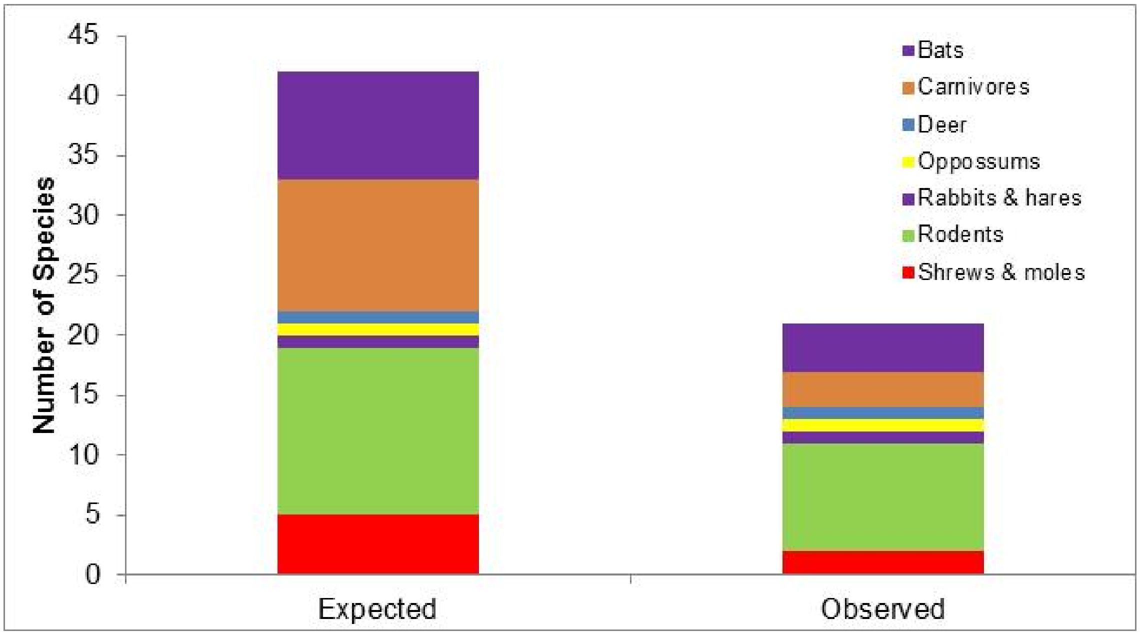

Figure 45. Number of mammals expected and observed at HOFU (refer to Appendix Table 53).

Table 43. Reference condition and current status of the mammal community at HOFU.

Metric	Good	Moderate Concern	Significant Concern	HOFU Condition and Trend
Species Richness	**>80% of species (>33 detected)**	**50-85% of species (33-21 species detected)**	**>50% species (<21 species detected)**	**50% species observed (21 species detected)**

The northern long-eared bat is one of the species most impacted by white-nose syndrome. Due to declines caused by white-nose syndrome as well as continued spread of the disease, the USFWS listed this bat as Federally threatened on 2 April 2015 (USFWS 2015). The northern long-eared bat is also PA state listed as candidate rare indicating that it is a “species which exist only in one of a few restricted geographic areas or habitats within Pennsylvania, or they occur in low numbers over a relatively broad area of the Commonwealth” (Hart 2006, Pennsylvania Natural Heritage Program

[PNHP] 2014). The northern long-eared bat occurs throughout Pennsylvania, but has been found in relatively low numbers (PNHP 2014). This bat is associated with boreal forests, hunting at night over small ponds, in forest clearings, at tree top level, and along forest edges for night-flying insects (e.g., caddisflies, moths, beetles, flies). Maternity roosts are located in tree cavities, under exfoliating tree bark, and in buildings (PNHP 2014).

At French Creek State Park, a bat colony monitored since 2007 has declined from 600 to 60 individuals due to WNS. Recent surveys (2013) indicate that the colony size may be stabilizing since the onset of WNS (L. Miller, Environmental Education Specialist/Volunteer Coordinator, French Creek State Park Complex, email communication 3 April 2014).

Confidence in Assessment

Confidence in the assessment is low as there has only been one monitoring effort for mammals (excluding bats) and one survey for bats as of the time of this report. The mammal inventories for the park were dated as they were collected ten to fifteen years ago and another mammal survey would be beneficial.

Data Gaps

The mammal inventory data were over 10 years old and a current survey of HOFU mammals would be beneficial to adequately document species within the park. A specific study to assess the density and impact of deer on park resources would be beneficial.

Threats

Threats to mammal communities include habitat fragmentation, vehicle mortality, and predation by domestic and feral cats. Standardized mammal surveys conducted at regular intervals would provide better information on the status of mammals in the park.

The impacts of white-tailed deer in some areas of the park appear to be significant, primarily near the village. In these areas, the forest stands have few tree seedlings or saplings less than two meters in height due to deer browse (Comiskey and Callahan 2008). Deer may also be a contributing factor to the weedy nature of the Modified Successional Forest stands by heavily browsing desirable native species and avoiding the exotic species (Comiskey and Callahan 2008). However, there is no information on the density of deer in the park and a deer density study should be a priority.

More than 50% of American bat species are rapidly declining or are already listed as endangered. The loss of bat species in Pennsylvania could great affect plants from pest infestation and the public from enjoying the outdoors (PNHP 2014). National Parks and protected tracts of forest provide habitat refugia for bats. The bat surveys conducted in 2014 will provide additional information on the status and threats to bats at HOFU (A. Ruhe, personal communication, 25 July 2014).

Sources of Expertise

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4.4.3. Herpetofauna- Amphibian and Reptile Communities

Relevance and Context

As tracts of natural land become developed and fragmented, National Parks and protected areas provide increasingly important habitat refugia for herpetofauna. Amphibians and reptiles are sensitive to environmental degradation (e.g., wetland alteration, degraded water quality, habitat loss and alteration). Declines in herpetofauna have been documented on a regional and global scale (Bailey et al. 2007). Habitats for herpetofauna at HOFU are agricultural fields, deciduous woodlands, old fields, streams, wetlands, riparian areas and potential vernal pools (if present).

Data and Methods

Herpetofauna were surveyed at HOFU from 1994-1995 (Yahner et al. 1999) and again in 2000 to 2001 (Tiebout 2003) (Figure 46, Figure 47). The Yahner et al. (1999) survey was done in conjunction with the development of an inventory and monitoring protocol for amphibians and reptiles in Eastern National Parks. During this effort, five types of protocols were used to survey amphibians: coverboards, pitfall traps, drift fences with pitfall traps, amphibian call-surveys, and natural substrate (e.g., turning over rocks and logs) surveys. Habitats that were surveyed were old fields, grassland, lowland forest, riparian and upland forest habitat. A vehicular road survey was also conducted for amphibian call-surveys (Yahner et al. 1999). Tiebout's (2003) survey used two methods: general herpetological collecting (GHC) and anuran calling surveys in 14 habitat types: upland forest, lowland forest, weedy fields, pastures, animal pens, hay and corn fields, open wetlands, vernal pools, small streams, French Creek, stock fields, buildings and grounds, and mixed habitats. The GHC method relies on the investigator's past experiences and professional judgment, and while not quantifiable because it was not constrained by time or transects, it has been found to be the best method for generating species inventory lists (Tiebout 2003).

The Pennsylvania Amphibian and Reptile Survey (PARS 2015) is a state-sponsored atlas project that was initiated in 2013 to determine the distribution of herpetofauna throughout the state. PARS is a joint venture between the PA Fish and Boat Commission and the Mid-Atlantic Center for Herpetology and Conservation (MACHAC). PARS (2015) supports on an online database where herpetofauna sightings can be reported by skilled professional scientists to the most amateur naturalist. A team of professional herpetologists review and approve voucher documentation (photographs, audio recordings) before an observation is considered verified. The PARS databased was used to compile a herpetofauna species lists for Berks and Chester Counties in 2013-2014 and this was used as a baseline list of what herpetofauna might be present in the park (Appendix Table 54).

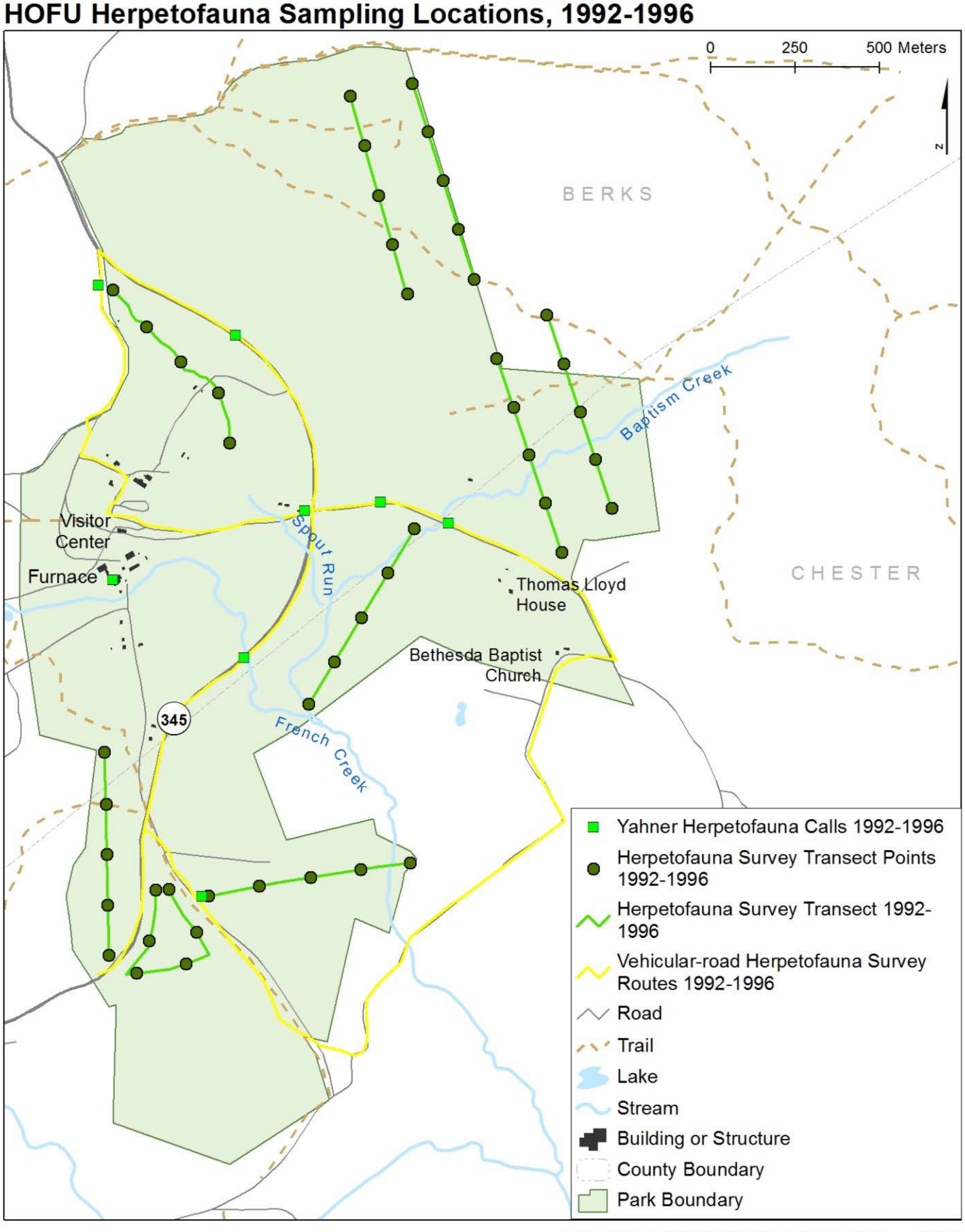

Figure 46. Herpetofauna sampling locations at HOFU (1992-1996 survey, Yahner et al. 1999).

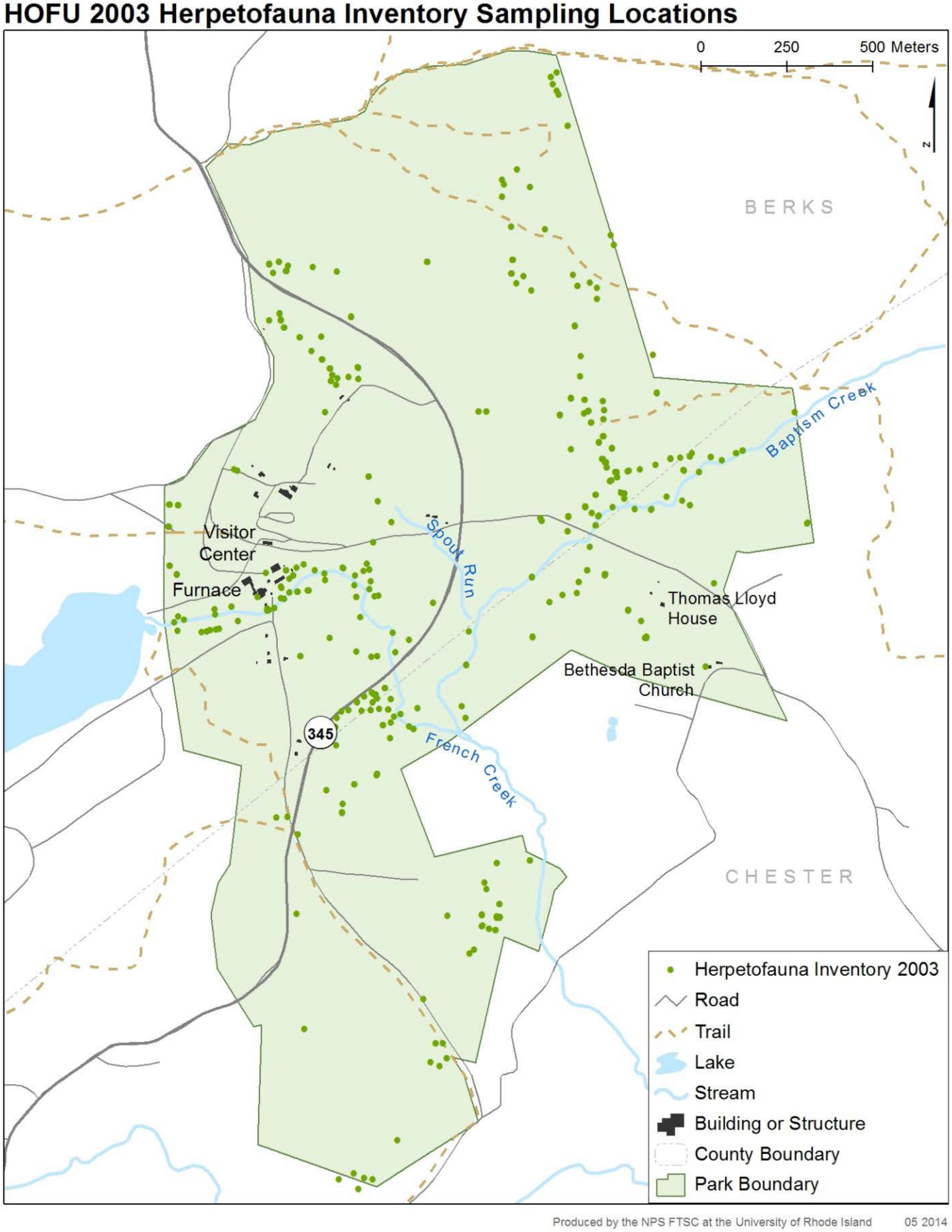

Figure 47. Herpetofauna sampling locations at HOFU (Tiebout 2003 sampling event).

Reference Condition and Status of the Resource (current condition and trends)
The PARS (2015) database listed 20 species of amphibians and 24 species of reptiles (44 species) that were recorded in either Berks or Chester County in 2013-2014. However, five of these species (one amphibian and 4 reptiles) were unlikely to occur in HOFU due to lack of suitable habitat (A. Ruhe, personal communication, 27 November 2015) (Appendix Table 54). Yahner et al. (1999) observed one additional species, the Northern leopard frog (*Lithobates pipiens*), bringing the baseline list of observed and potentially present species to 40 (20 amphibians, and 20 reptiles) (Appendix Table 54). These species included 11 salamanders, 9 frogs and toads, 11 snakes, 8 turtles, and one species of lizard. Yahner et al. (1999) documented 16 amphibians (80%) and 14 reptiles (70%), while Tiebout (2003) documented 14 amphibians (70%) and 10 reptiles (55%) (Figure 48).

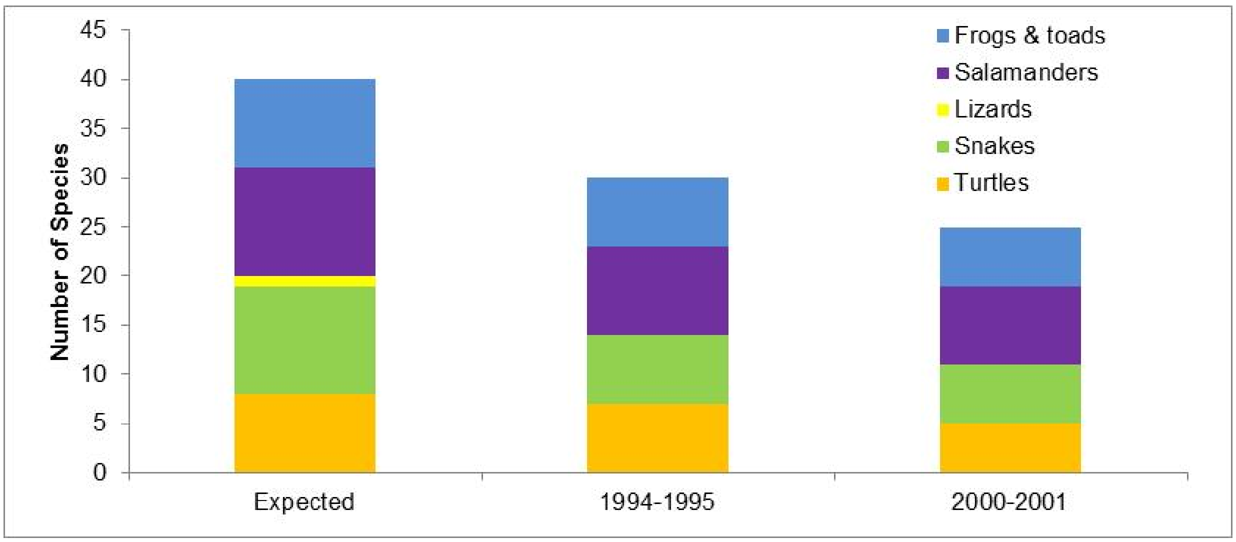

Figure 48. Number of herpetofauna species expected (based on PARS 2015 database) and detected at HOFU.

Declines in herpetofauna diversity and/or species richness are generally viewed as undesirable; additionally, the NPS has adopted a no net loss goal, so declines in any herpetofauna species would be of concern (Cook et al. 2010). Herpetofauna species richness, expressed as a percent of observed amphibian and reptile species as compared to species observed in Berks and Chester Counties (PARS 2015) was used as a metric to evaluate condition, with thresholds for good, moderate concern, significant concern were based on best professional judgment (Table 44). The amphibian community was evaluated as moderate concern as 70% - 80% of the potential species were recorded by the surveys. The reptile community was also evaluated as moderate concern as 55%-70% of the potential reptile species have been recorded in the park. The trend was unknown since the survey methods used by Yahner et al. (1999) and Tiebout (2003) were different.

Confidence in Assessment
Confidence in assessment was medium. There have been two monitoring efforts, but the most recent survey was over ten years old.

Table 44. Reference condition thresholds and current status of herpetofauna community at HOFU.

Metric	Good	Moderate Concern	Significant Concern	1994-1995 Condition and Trend	2000-2001 Condition and Trend
Amphibian species richness	**>80% of species expected (>16 species detected)**	**50-80% of species expected (10-16 species detected)**	**<50% of species expected (<10 species detected)**	**80% of species expected (16 species detected)**	**70% of species expected (14 species detected)**
Reptile species richness	**>80% of species expected (>16 species detected)**	**50-80% of species expected (10-16 species detected)**	**<50% of species expected (<10 species detected)**	**70% of species expected (14 species detected)**	**55% of species expected (10 species detected)**

Data Gaps

The only data gap was age of the herpetofauna inventory data which were over 10 years old. A current survey of HOFU amphibians and reptiles would be beneficial. Since reptile and amphibian populations are considered a vital monitoring sign for park, long-term monitoring of representative groups would also be beneficial.

Threats

Threats to herpetofauna communities include indirect effects due to development, including habitat loss, degradation, and fragmentation, degraded water quality, altered wetland hydrology, vehicular road kill during migration periods, and increased nest and juvenile depredation by unnaturally high raccoon populations, and habitat degradation due to natural succession and encroachment by invasive exotic plant species. In addition, herpetofauna that reside or use agricultural fields may be threatened by livestock trampling and mowing of fields for agriculture. The red-eared slider (*Trachemys scripta elegans*), a native transplant and considered an exotic species in Pennsylvania, has been observed in the park. This turtle poses a threat of outcompeting native turtles for food resources. It has been recommended that the species be eliminated from the park before a breeding population becomes established (Tiebout 2003); however, this has not occurred. One of the most significant threats in the park would be poaching, as many native reptiles and amphibians are highly valued in the black market. In Pennsylvania, fines for illegal possession of some species range from $250 to $500 with the possibility of jail time and additional charges from the USFWS.

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5. Discussion

5.1. NRCA Background

Natural resources for Hopewell Furnace National Historic Site were divided into four general areas: physical resources, water-related resources, ecosystem integrity, and focal animal communities. Within each of these categories specific natural resource areas were discussed (Table 45).

Table 45. Natural resource areas for HOFU.

Physical Resources	Water-Related Resources	Ecosystem Integrity	Focal Animal Communities
Air Quality- ozone	Stream water quality	Forest communities	Avian community
Air quality- wet deposition	Streambed habitat and morphology	Agricultural fields	Mammal community
Air quality - visibility	Aquatic macroinvertebrates	Wetlands	Herpetofauna community
Night sky resources	Fish Community	Invasive plants	
Acoustic resources			

The approach of the Natural Resource Condition Assessment was to use existing data to evaluate the condition of natural resources at HOFU. Thresholds for condition (good, moderate concern, and significant concern) were obtained from a variety of resources such as federal and or state regulations (e.g., water quality criteria), peer-reviewed literature, study reports, and in some cases when threshold values were not available, best professional judgment. If possible, trends in the condition (improving, declining, or stable) were also noted. And finally, an estimate of the confidence in the assessment based on the quality and quantity of available information (high, medium, low confidence) was also provided. The assessment of condition used standardized symbology provided by NRCA guidelines (Table 46).

Table 46. Natural resource condition assessment symbology.

Condition Status		Trend in Condition		Confidence in Assessment	
	Good Condition		Condition is Improving		High
	Moderate Concern		Condition is Unchanging		Medium
	Significant Concern		Condition is Deteriorating		Low
	Condition Status Unknown; Consequently, Trend is also Unknown and Confidence is Low				

5.2. Natural Resource Overview and Condition Assessment

HOFU is located 80.5 km (50 mi) northwest of Philadelphia and straddles the Berks-Chester County border in southeastern Pennsylvania. French Creek State Park and State Game Lands #43 border the park on three sides; additionally, Hopewell furnace lies at the core of the Hopewell Big Woods. Thus, the two-thirds of the park are surrounded by protected lands. These lands help buffer the park's natural resources from impacts related to development beyond the park's boundaries. Private holdings adjacent to the park include small-scale agriculture and low-density residential development. The majority of a visitor's experience at HOFU is shielded from modern development limiting the intrusion of noise, motion, and non-agricultural views. However, some of the physical resources (e.g., air quality, visibility, acoustic environment) within the park are influenced by the larger regional area.

The focus for resource protection emanating from the park's enabling legislation centers on its cultural and historical values. Past human land use disturbances are part of HOFU's historical relevance. Furnace operators sculpted the landscape, logged the surrounding forests, impounded and diverted local streams, and imported ore from surrounding mines. Much of the lands cleared for logging and agriculture have reverted to mixed secondary deciduous forests, which comprises 76% of the park. The principle over story trees are: oak, tulip popular, red maple, sycamore, red cedar, ash, elm and black walnut. Agricultural areas consist of 17 fields (~16% of the park) that are maintained as pastures, hay fields, crops, and orchards. The remaining 8% of the park is developed or historic buildings. Drainage of the area is dominated by French Creek (which originates from Hopewell Lake in French Creek State Park). Baptism Creek drains the east central portion of the park and empties into French Creek. Other small and undefined intermittent tributaries empty into French Creek.

5.2.1. Physical Resources

Metrics used by the NPS ARD to assess air quality were ozone, total nitrogen (N) wet deposition, total sulfur (S) wet deposition, and mercury deposition. Ozone concentration was measured using three specific metrics: the 4th-highest daily maximum 8-hour average ozone concentration (the human health standard), and W126 and SUM06 metrics (both ecological standards that measure exposure to ozone sensitive vegetation). All three ozone metrics were rated as significant concern for HOFU. While trends in these metrics were not specifically evaluated for HOFU, the NPS-ARD regional trend maps for these metrics showed an improving trend in the general regional area of the park. The confidence in the assessment was medium since ozone concentrations were from interpolated data for the region. Both total N and total S wet deposition were rated as significant concern for HOFU. Trends in wet deposition were not estimated by the NPS ARD. Threshold standards for air quality related to mercury deposition have not yet been established; however, the trend in mercury deposition was evaluated as unchanging. The confidence in the assessment was medium as wet deposition concentrations were from interpolated data for the region (Table 47).

Air pollution causes haze and reduces visibility. Visibility was estimated using a Haze Index (based the haze levels on the clearest and haziest days) as the Haze Index increases, visibility decreases. The EPA's Regional Haze Program protects visibility in Class I areas. Class I areas include national parks greater than 6,000 acres and wilderness areas greater than 5,000 acres that were in existence when the Clean Air Act (CAA) was amended in 1977. Class I areas receive the highest degree of air quality protection under the CAA and have specific national regional haze goals. Generally, all other parks that do not meet the criteria for Class I are considered Class II areas. HOFU is considered a Class II area. The visibility at HOFU was evaluated as significant concern. Although the NPS ARD did not estimates trends in visibility for HOFU, NPS ARD regional haze maps indicated no change on the 20% clearest days and a possible improving trend in visibility on the 20% haziest days. The confidence in the assessment was medium as visibility estimates were from interpolated data for the region (Table 47).

The night sky as we see it is a combination of both natural and human-caused sources of light. Natural light sources include moonlight, starlight from individual stars and planets, and other celestial bodies. The NPS uses the term "natural lightscape" to describe resources and values that exist in the absence of human-caused light at night. Natural lightscapes are critical for nighttime scenery, such as viewing a starry sky, but are also critical for maintaining nocturnal habitat for a variety of species. Alteration of night sky resources can be in the form of astronomical light pollution, where stars and other celestial bodies are obscured from view or in the form of ecological light pollution where lighting can disrupt natural ecosystem processes and wildlife behavior. NPS Natural Sounds and Night Skies Division assessed night sky resources and natural lightscape at HOFU in 2014. The Anthropogenic Light Ratios (ground based and modeled), measures of sky brightness related to anthropogenic sources, were found to be of moderate concern for HOFU. The Bortle Dark Sky Scale and Sky Quality Meter readings were found to be in the significant concern range. At these light levels, the Milky Way may be visible overhead but has typically lost most of its detail and is not visible along the horizon. Zodiacal light is rarely seen (moderate concern). Anthropogenic light likely dominates natural celestial features and shadows from distant lights may be seen. Overall the condition of the night sky at HOFU was scored as significant concern. The data were of good quality and were recent; however, since there has only been one assessment the confidence was assessed as medium (Table 47).

In the National Park setting, the total acoustic environment of the park may include natural, cultural, and historic sounds depending on the purpose and values of the park. The acoustic environment, like water, scenery, or wildlife, is a valuable resource that can easily be degraded by inappropriate sounds or sound levels and as a result, the acoustic environment requires careful management just as any other park resource. The NPS Natural Sounds Team collects sound data and provides management objectives based on the needs of the park. The acoustic environment has not yet been monitored at HOFU, but it has been modeled. The modeled noise impacts for the park were estimated as significant concern with an unknown trend, and the confidence in the assessment was medium since the estimate was based on modeled data as opposed to field data (Table 47).

5.2.2. Water Related Resources

Water quality is ecologically significant as it affects aquatic communities and ecosystems. MIDN parks such as HOFU are affected by industrial, agricultural, and airborne pollutants. The primary water resources at HOFU were streams: French Creek, Baptism Creek, Spout Run, and a few smaller unnamed streams. The headwaters of French Creek originate from the outfall of Hopewell Lake which is within French Creek State Park, and therefore the water quality of French Creek is influenced by Hopewell Lake. All streams within HOFU were designated as Exceptional Value streams and protected for Migratory Fishes (MF). Downstream of the park, French Creek is a designated Trout Stocked Fishery (TSF). Water quality and trace metal contaminants in surface water have been monitored periodically in the past (1992, 2002, and 2009), and the MIDN has recently established continuous water quality monitoring (2012 to present). All trace metal concentrations in surface water were within acceptable limits. The MIDN data have not yet been formally analyzed; however, most parameters (dissolved oxygen, pH, and specific conductance) were within acceptable ranges for TSF/MF streams. Water temperature exceeded the maximum limit for TSF on the 23-45% of the sampling dates indicating that water temperature was of moderate concern. The trend for these parameters was assessed as stable based on best professional judgment. The confidence in the evaluation of trace metals in surface waters was high, while the confidence in the assessment of the other parameters measured by the MIDN was medium due to the ongoing analyses of the data by the Network (Table 47).

Streambed sediment and habitat quality can affect aquatic communities. Harmful effects on aquatic communities are likely to be observed when concentrations of certain contaminants are above the probable effect concentration (PEC) in streambed sediments. The structure of the stream and adjacent riparian zone (e.g., vegetative cover, riparian buffer, substrate quality) can be used as a measure of habitat quality as the surrounding physical habitat can influence the quality of the water resources and the condition aquatic communities. Streambed sediment trace metal concentration, streambed habitat, and stream morphology pertinent to habitat quality were evaluated as part of the trace metal study conducted in 2009. The MIDN continues to sample streambed habitat quality at French Creek and a background site at Baptism Creek. Both the trace metal study and the MIDN measured a variety of streambed habitat parameters such as quality of substrate, channel morphology, bank structure, and quality of riparian areas. The only trace metal in streambed sediments that was found to exceed the PEC was copper (in the 2009 study). MIDN monitoring observed that the Baptism Creek site (reference sites) had suboptimal ratings for epifaunal substrate cover, embeddedness, velocity and depth, sediment deposition, channel flow, riffle frequency, and bank stability and was evaluated as moderate concern. The French Creek site had suboptimal ratings for epifaunal substrate cover, embeddedness, sediment deposition, riffle frequency, and bank stability, but overall scored in better condition (good condition) than the Baptism Creek reference site. The trend was assessed as stable with high confidence in the assessment due to the recent nature of the data and the ongoing monitoring by the MIDN (Table 47).

Aquatic macroinvertebrates perform essential roles in stream ecosystem function and are often used by regulatory agencies to document stream condition under the Clean Water Act. The aquatic macroinvertebrate community was surveyed in 2008 at five sites (four on French Creek, and one reference site on Baptism Creek) as part of a trace metal study. The MIDN adopted aquatic macroinvertebrate communities as a vital sign metric and they have been monitored at HOFU at two sites (one on French Creek, and a reference site on Baptism Creek) from 2009 to present (although only data from 2009-2012 have been interpreted). Both the 2008 study and the MIDN used similar metrics (although some were different) to assess the condition of the aquatic macroinvertebrate community. These metrics included: total taxa richness, Ephemeroptera, Plecoptera, Trichoptera (EPT) taxa richness, percent of Diptera and non-insects, percent abundance of the dominant two taxa, percent abundance of scrapers, modified Beck's index, percent abundance of intolerant taxa with a pollution tolerance value of ≤ 2, percent abundance of clingers, Shannon diversity index, percent abundance of Plecoptera and Trichoptera-Hydropsychidae, and Hilsenhoff Biotic Index (HBI). Based on data from both the 2008 sampling and the MIDN aquatic macroinvertebrate monitoring, the condition of the community for French Creek was evaluated as moderate concern, while Baptism Creek was evaluated as good. Habitat conditions (erosion and sedimentation) and physical alterations (water temperature) from the outfall of Hopewell Lake were the most likely causes of the impaired macroinvertebrate communities at the French Creek site. The trend for both sites was estimated as stable since the condition has been relatively stable for past 4-5 sampling years. The confidence in the assessment was high since the data were recent and the MIDN plans to continue aquatic macroinvertebrate sampling at HOFU (Table 47).

Freshwater fish communities are useful indicators of environmental condition and fish community structure is often used as an Index of Biotic Integrity (IBI). Fish assemblages generally include a range of species that represent a variety of trophic levels and the structure of fish assemblages tends to be reflective of environmental health. The fish community at HOFU has been surveyed twice, with the most recent survey occurring in 2002. An IBI developed for New Jersey streams and based on the EPA rapid bioassessment method was used to evaluate the fish community at HOFU. Metrics used in the IBI includes species richness, trophic composition, and abundance. The condition of the fish community was evaluated as good condition for both survey periods. Trends could not be estimated because it was unclear if the two survey efforts used similar sampling protocols. The confidence in the condition for the survey efforts was rated as medium due to the age of the data (Table 47).

5.2.3. Ecosystem Integrity

The vegetation at HOFU has been inventoried or mapped at various times over the past several decades, with most studies concentrating on the forested woodlands as these comprise the majority of the park's lands. Information on forest community structure and composition is critical to developing desired conditions and park management goals relating to native and non-native plant communities. The MIDN has selected several vital signs associated with forest ecosystem health that have been monitored since 2011. Metrics used by the MIDN to evaluate forest health include forest community structure, density and composition of tree seedlings, monitoring selected herbaceous species as indicators of deer browsing, detection of forest pests and diseases, detection of invasive plants, status of coarse woody debris and snags, and measures of soil chemistry. The most recent monitoring by the MIDN in 2011 indicated that overall the condition of forest health at HOFU was of moderate concern. Three metrics, snags, coarse woody debris, and seedling stocking density, were evaluated as significant concern. Canopy tree condition was rated as moderate concern and only forest structural stage was rated as good condition. Soil chemistry was not sampled in 2011, but sampling in earlier years (2007 to 2010) indicated that both soil chemistry parameters were of significant concern. The MIDN has not yet analyzed the forest health data for trends but with the continued sampling of the metrics, trends can be estimated. The confidence in the assessment was high (Table 47).

Fields and grasslands provide habitat for a variety of flora and fauna, such as grassland obligate bird species, turtles and snakes, and small mammals. The fields at HOFU are agriculturally managed areas that are maintained as hay fields, pastures for livestock, and crops. The fields are important as part of the historic and cultural interpretation of the park. They are small parcels of land totaling ~55 ha over 17 fields. The fields have never been surveyed for vegetation communities and have only been mentioned in passing in surveys of other focal communities (e.g., birds and mammals). Their small size and agricultural management makes it unlikely that they are able to support grassland bird communities. There were no data on the condition of the agricultural fields and the condition was rated as unknown. Since the condition was unknown trends could not be estimated and the confidence in the assessment was low (Table 47).

Wetlands are important habitats that can support a diverse array of flora and fauna. The wetlands at HOFU generally lie within riparian zones and depressions associated with seeps within the park. These habitats comprise a variety of natural and anthropogenically influenced plant community types ranging from shrub wetlands (Buttonbush/Highbush Blueberry-Meadowsweet Wetland alliance) to Sensitive Fern-Woolgrass dominated wetlands. Two obligate vernal pool amphibians, the wood frog and spotted salamander, have been recorded in the park, but as of 2015 vernal pools have not been documented in the park. The wetlands at HOFU are currently being mapped (in 2014-2015) but the report was not available as of the writing of this NRCA. Therefore, the condition of the wetlands was evaluated as unknown. Since the condition was unknown trends could not be estimated and the confidence in the assessment was low (Table 47).

Invasive plants are prevalent at HOFU and have been recorded at various times over the past several decades. Documenting and managing non-native and invasive plants is part of the NPS Strategic Plan for Managing Invasive Non-native Plants. Invasive plants can negatively affect and/or threaten native species diversity and ecosystems, and seriously degrade the cultural landscape. Twenty percent of the plant species recorded in the park were Pennsylvania listed invasive species or non-native. When the invasive vegetation was mapped in 2006, approximately two-thirds of park had heavy infestation (greater than 6.3% of the park area). Typically infested areas included road sides, field edges, and along rock walls and stream banks, with the most troubling invasives being mile-a-minute, Oriental bittersweet, garlic mustard, and Japanese stiltgrass. Based on the 2006 mapping invasive plants were rated as significant concern. There is a strategic plan to monitor and control invasive vegetation in the park; however, current NPS base funding of HOFU provides minimal support for invasive plant management. The confidence in the assessment was medium since the last survey effort was done in 2006 and the density of invasive plants could be higher due to a lack of funding to support invasive plant control (Table 47).

5.2.4. Focal Animal Communities

Birds are an important component of park ecosystems and their prominent position in most food webs make them good sentinels of local and regional ecosystem change. The avian community at HOFU has been surveyed twice over the past two decades with the most recent one occurring in 2001. One hundred nine (109) bird species have been observed at HOFU (data from all surveys and all seasons) with potentially 75 species breeding within the park. The condition of the avian community was evaluated using a guild based Bird Community Index (BCI) developed for the Mid-Atlantic Piedmont and Coastal Plain region. The BCI, based on birds observed during the breeding season, incorporated the percent of species in nine bird guilds from three biotic elements (structural, functional, and compositional, three guilds per biotic element) to assess the condition of the avian community. The guilds were broadly categorized as specialist or generalist. Specialist guilds contained species with a narrow range of habitat tolerances or that exhibit low intrinsic rates of population increase. Therefore, these guilds were thought of as indicative of a high-integrity ecological condition while generalist guilds were considered indicative of a low-integrity ecological condition. The condition of the breeding bird community was assessed as "naturalistic" (good condition) and "largely intact" (good condition) for the 1994 and the 1999-2001 surveys, respectively. Guilds that ranked as "humanistic" (significant concern) or "moderately disturbed" (moderate concern) were the specialist guilds of pine associated and upper canopy foragers (generally, lower than desired species observed in these guilds). The generalist guilds of exotics and nest disrupters had higher than the desired number of species. Overall, the avian community for both datasets was evaluated as good condition. Long term data were not available to evaluate trends in the bird community and confidence in the assessment was medium due to the age of the data. The grassland bird community was not assessed because the agricultural fields at HOFU are likely too small to support grassland bird communities (Table 47).

Mammals contribute to species richness and diversity and play a major role in ecosystem dynamics as consumers of plant material and invertebrates and as prey for snakes, raptors, and carnivorous mammals. Small mammals can affect the structure, species composition, and successional trends of plant communities, and may directly influence population levels of insect pests and disease vectors such as gypsy moths and deer ticks, as well as regionally rare raptorial birds. The mammal community, excluding bats, was surveyed at HOFU once in the mid-1990s. Focal studies on bats were completed in 2005 and 2014-2015 (the final report from the 2014-2015 survey was not available as of this writing). During the 2005 survey one pregnant and one post-lactating female northern long-eared bat or northern myotis (a state listed candidate rare species and federally threatened species) were recorded suggesting the possible presence of small maternity colony in the park. In the Northeastern U.S., hibernating bats are dying at an alarming rate due to white-nose syndrome, a fungus that infects hibernating bats. White-nose syndrome has been confirmed in several PA counties and in French Creek State Park. Mammal inventories conducted in other NPS Networks (e.g., NCBN) established a goal of detecting 90% of the terrestrial mammal species expected to occur within the park. Using best professional judgment, the condition of the mammal community at HOFU was evaluated based on the percent of species expected to be detected. Fifty percent (21 species) of the expected mammal species have been documented in the park, and the condition was evaluated as moderate concern. Since there has only been one mammal survey, trend in the condition of the mammal community could not be evaluated. The confidence in the assessment was low (Table 47).

Amphibians and reptiles are sensitive to environmental degradation. Habitats for herpetofauna (amphibians and reptiles) at HOFU include grasslands, deciduous woodlands, old fields, tussock wetlands, riparian areas and vernal pools (if present in the park). Amphibian and reptile communities have been surveyed twice over the past three decades, with the most recent survey occurring in 2000 to 2001. These surveys have documented a total of 32 species (17 amphibians and 15 reptiles). The metric used to evaluate the condition of the herpetofaunal community was the percent of observed species as compared to the percent of species recorded in Berks and Chester Counties and the availability of suitable habitat within the park. Based on the most recent data and best professional judgment both the amphibian and reptile communities were assessed as moderate concern. The trend was unknown as the two herpetofauna surveys used different methods. The confidence in the assessment was medium due to the age of the data used to assess this community (Table 47).

Table 47. Summary condition table for natural resources at Hopewell Furnace National Historic Site.

Metric	HOFU Condition/Trend		Recommendation
Air Quality			
Ozone (human health standard)		*significant concern with improving trend*	Continued monitoring by local, state , and federal agencies (data interpolated by the NPS ARD)
Ozone, SUM06 (ecological standard)		*significant concern with improving trend*	
Ozone, W126 (ecological standard)		*significant concern with improving trend*	
Wet N deposition		*significant concern, no trend estimated*	
Wet S deposition		*significant concern, no trend estimated*	
Mercury wet deposition		*Condition threshold not established but trend was stable*	
Visibility		*significant concern, no trend estimated*	
Night sky resources		*significant concern, no trend estimated*	Continued monitoring of night sky resources based on NSNSD guidance
Acoustic environment		*significant concern, no trend estimated*	Based on modeled data, field data from HOFU would be beneficial
Water Resources			
Water quality- trace metal		*good condition, trend unknown*	Continue with MIDN water quality monitoring

Table 47 (continued). Summary condition table for natural resources at Hopewell Furnace National Historic Site.

Metric	HOFU Condition/Trend		Recommendation
Water Resources (continued)			
Water quality-temperature		*moderate concern, stable trend*	Continue with MIDN water quality monitoring
Water quality-dissolved oxygen		*good condition, stable trend*	
Water quality- pH		*good condition, stable trend*	
Water quality- specific conductance		*good condition, stable trend*	
Stream habitat-trace metals in sediment		*good condition, trend unknown*	
Stream habitat-morphology		*French Creek: good concern, stable trend*	Continue monitoring the aquatic macroinvertebrate community using the MIDN protocol.
		Baptism Creek: *moderate condition, stable trend*	
Aquatic macroinvertebrates		*French Creek: moderate concern, stable trend*	
		Baptism Creek: *good condition, stable trend*	
Fish community		*good condition, trend unknown*	
Terrestrial Resources			
Forest structural stage		*good condition, trend unknown*	Continue with MIDN forest monitoring. Data are currently being analyzed by the MIDN with respect to trends.
Forest canopy tree cover		*moderate condition, trend unknown*	
Forest snags		*significant concern, trend unknown*	

Table 47 (continued). Summary condition table for natural resources at Hopewell Furnace National Historic Site.

Metric	HOFU Condition/Trend		Recommendation
Terrestrial Resources (continued)			
Forest course woody debris		*significant concern, trend unknown*	Continue with MIDN forest monitoring. Data are currently being analyzed by the MIDN with respect to trends.
Forest regeneration (stocking index)		*moderate concern, trend unknown*	
Forest soil chemistry (acidification)		*moderate concern, trend unknown*	
Forest soil chemistry		*moderate concern, trend unknown*	
Agricultural fields		*condition and trend were unknown*	Review management goals and set criteria for either cultural or natural resource management.
Wetlands		*condition and trend were unknown*	Wetlands were surveyed in 2014-2015; data are not yet available.
Invasive plants		*significant concern, trend unknown*	Pursue efforts for funding to monitor and eradicate invasive vegetation.
Focal Communities			
Avian community		*good condition, trend unknown*	Conduct avian monitoring.
Mammal community		*moderate concern, trend unknown*	Conduct mammal monitoring and a focal deer density study.
Amphibian community		*moderate concern, trend unknown*	Conduct herpetofauna monitoring.
Reptile community		*moderate concern, trend unknown*	

5.2.5. Threats to Natural Resources

Air quality (e.g., ozone, wet deposition, visibility) at HOFU it is influenced by both local (adjacent urban areas such as Philadelphia, PA) and regional (Northeast) pollution such as emissions from automobile traffic and industry. The night sky and natural lightscape of HOFU are influenced by the proximity of the park to large urban centers (e.g., skyglow from Philadelphia) and populated areas in proximity to the park that illuminate the night. There are wildlife species at HOFU that have specific nocturnal behaviors that may be negatively impacted by ecological light pollution (e.g., bats). The acoustic environment can be threatened by intrusive sounds that are not part of the natural or cultural backdrop of the park. Both the visitor experience and wildlife can be negatively impacted by intrusive sound such as vehicular traffic from local roads and noise pollution from the nearby gun range.

Threats to water resources (streams and wetlands) and aquatic communities (aquatic macroinvertebrates and fish) at HOFU include water quality, activities upstream of French Creek (e.g., French Creek State Park, Hopewell Lake water quality, land development), runoff from park grounds, and stream habitat degradation. Thermal pollution, from the top-release spillway at Hopewell Lake, and drawdown events at the lake may negatively impact water quality of French Creek by increasing water temperature and elevating concentrations of dissolved and suspended iron in the stream. Runoff from the barn stockyard drains directly into French Creek is a source of fecal bacterial contamination that may result in depleted dissolved oxygen concentrations, increased turbidity, and eutrophication. Although trace metal concentrations in surface water were within acceptable ranges for water quality criteria, the slag piles, which in places form the banks of French Creek, could also be a threat to water quality. Leachate experiments on slag samples found that four metals (Al, Cu, Fe, and Mn) had potential environmentally problematic concentrations, exceeding thresholds for both drinking water and aquatic life criteria. Trace metal contamination in streambed sediments can negatively impact water quality, stream habitat quality, and aquatic communities. The source(s) of the trace metal contamination observed in streambed sediments were likely related to discharge from Hopewell Lake and the past landuse impacts from the ironworks. Stream bank stability, erosion, and sedimentation were the biggest threats to stream habitat quality, at some areas the loss of canopy cover and riparian buffers were also threats. Although wetlands are currently being mapped (in 2014-2015), these data were not yet available for inclusion in this NRCA. Possible threats to wetlands can be a variety of anthropogenic and natural threats. Surface water runoff from gravel roads and the parking lot can negatively impact water quality. Groundwater withdrawals can impact the hydroperiods of wetlands and may negatively impact wetland flora and fauna. Invasive and exotic plants and animals also can threaten riparian buffers and wetlands by crowding out native species.

Forested lands make up the majority of the area at HOFU. Non-native invasive vegetation is prevalent in the park, and is likely the biggest threat to the terrestrial natural resources at HOFU. Non-native invasive plants can negatively effect and/or threaten native species diversity and ecosystems, and seriously degrade the cultural landscape. Damage from white-tailed deer browsing in some areas of the park appeared to be significant, primarily near the village. In these areas, the forest stands have few tree seedlings or saplings less than two meters in height due to deer browse. However, there has never been a study on the deer density within the park. In some eastern parks white-tailed deer have been responsible for over-browsing native vegetation and reducing woody regeneration, thereby changing the cultural and natural landscapes and affecting ecosystem health. Forest pests, although present in Berks and Chester Counties, do not currently seem to be a threat to the vegetation at HOFU. The agricultural fields are part of the cultural landscape of the park and are currently maintained as such. Because they are part of the cultural landscape there are no threats as they are currently managed.

The focal animal communities at HOFU are birds, mammals, amphibians and reptiles. A primary threat to landbird populations is habitat loss due to development, with Neotropical migrants being particularly vulnerable to habitat fragmentation. Forest fragmentation leads to increases in edge habitat, an ideal habitat for non-migratory resident species, and results in higher rates of brood parasitism and nest predation in the remaining forest habitat. While small parks like HOFU may have some control over forest fragmentation within their boundaries, habitat loss and fragmentation are widespread throughout much of the Northeast region. Threats to mammal communities include habitat fragmentation, vehicle mortality, and predation by domestic and feral cats. Bats at HOFU could be threatened by white-nose syndrome, which has been observed in colonies in French Creek State Park. Threats to herpetofauna communities include altered wetland hydrology, degraded water quality, habitat loss and fragmentation, and habitat degradation due to natural succession and encroachment by invasive exotic plant species, vehicular road kill during migration periods, poaching, and predation. The red-eared slider, a native transplant and considered an exotic species in Pennsylvania, has been observed in the park. This turtle poses a threat of outcompeting native turtles for food resources.

5.2.6. Suggested Management Actions and Research Needs

There are many natural resources at HOFU that would benefit from natural resource management plans and/or goals. Several of the natural resources were surveyed over ten years ago and the park would benefit by resurveying these resources. Budgetary constraints must be weighed against the benefit of such surveys and staggering surveys over an extended time period (e.g., five years) may be helpful in terms of scheduling and cost effectiveness. Listed below are suggestions for management plans and research needs. These are listed by higher priority and lower priority, based on best professional judgment.

<u>Higher Priority (based on best profession judgment)</u>

- Develop management plans and goals to protect and preserve habitat for rare or sensitive species.
- Continue MIDN water quality monitoring. Water quality should be monitored during drawdown events in Hopewell Lake to determine if these events impair water quality.
- Assess deer density in the park to determine impact on forest regeneration
- Investigate additional funding options or methods to assist with invasive plant control.
- Evaluate current status of high priority invasive plants such as mile-a-minute being mile-a-minute, Oriental bittersweet, garlic mustard, and Japanese stiltgrass and develop a strategy to manage these species
- Determine key focal species communities for monitoring and develop long-term monitoring protocols

Lower Priority (based on best profession judgment)

- Conduct another amphibian and reptile survey (existing data are greater than 10 years old).
- Conduct a stream temperature study to determine if thermal pollution is occurring in French Creek.
- Conduct another mammal survey (existing data are greater than 10 years old).
- Conduct another fish survey (existing data are greater than 10 years old).
- Conduct another avian survey (existing data are greater than 10 years old) using the MIDN bird protocol.
- Conduct another sediment trace metal study to determine if conditions have changed since 2009.
- Conduct an acoustic environment study and establish goals and plans to manage the acoustic environment.
- The vegetation of the park was last mapped in 2003, A current (less than five years old) and accurate map of park vegetation is one of the 12 basic natural resource inventories recommended by the NPS Inventory and Monitoring Program.
- Encourage programs and projects that result in improved water quality in areas upstream of the park.

6. Appendix Tables

Appendix Table 48. Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	Common Name	Nativity	Russell 1987	Vanderwerff 1994	NPSpecies (2015)
Acalypha rhomboidea	Common threeseed mercury	Native	X	X	X
Acalypha virginica	Virginia threeseed mercury	Native			X
Acer platanoides[1, 2]	**Norway maple**	**Invasive (PA DCNR)**			**X**
Acer rubrum	Red maple	Native	X		X
Acer negundo	Box elder	Native	X		X
Acer saccharinum	Silver maple	Native	X		X
Acer saccharum	Sugar maple	Native	X	X	X
Achillea millefolium	Common yarrow	Native	X	X	X
Acorus calamus	Sweetflag	Native	X		X
Actaea racemosa	Black baneberry	Native	X	X	X
Adiantum pedatum	Northern maidenhair	Native	X		X
Ageratina altissima var. altissima	White snakeroot	Native		X	X
Agrimonia gryposepala	Tall hairy agrimony	Native	X	X	X
Agrimonia parviflora	Harvestlice	Native		X	X
Agrimonia rostellata	Beaked agrimony	Native			X
Agrostis gigantea	Redtop	Non-native		X	X
Agrostis scabra	Rough hairgrass	Native			X
Agrostis hyemalis	Winter bentgrass	Native	X		X
Agrostis perennans	Upland bentgrass	Native	X	X	X

[1] Invasives noted Ambrose and Åkerson 2006, but not documented by Russell (1987) , Vanderwerff (1994) or listed in NPSpecies

[2] Invasive and state listed species (also indicated in bold type).

[3] MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines – also indicated in green shading).

[4] PA-E: Pennsylvania state listed endangered species (as designated by USDA Plants Database)

Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Agrostis stolonifera	Creeping bentgrass	Non-native	X		X
Ailanthus altissima [2]	**Tree of heaven**	**Invasive (PA DCNR)**	**X**		**X**
Alisma triviale [2]	**Northern water plantain**	**Native (PA-PE)** [4]			**X**
Alisma subcordatum	American water plantain	Native	X		X
Alliaria petiolata [2, 3] **(invasive)**	**Garlic mustard**	**Invasive (PA DCNR)**	**X**		**X**
Allium canadense	Meadow garlic	Native	X	X	X
Allium vineale	Wild garlic	Non-native	X	X	X
Alnus glutinosa	Black Alder	Non-native		X	X
Alnus incana ssp. rugosa	Speckled alder	Native	X		X
Alnus serrulata	Hazel alder	Native	X	X	X
Alopecurus pratensis	Meadow-foxtail	Non-native		X	X
Amaranthus retroflexus	Redroot amaranth	Native	X		X
Ambrosia artemisiifolia	Annual Ragweed	Native	X	X	X
Ambrosia trifida	Great ragweed	Native	X		X
Amelanchier arborea	Common serviceberry	Native	X		X
Amelanchier canadensis	Canadian serviceberry	Native	X	X	X
Amphicarpaea bracteata	American hogpeanut	Native	X	X	X
Anagallis arvensis	Scarlet pimpernel	Non-native	X	X	X
Andropogon virginicus	Broomsedge bluestem	Native	X	X	X
Anemone americana	Roundlobe hepatica	Native	X		X
Anemone quinquefolia	Wood anemone	Native		X	X
Anemone virginiana	Tall thimbleweed	Native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Antennaria howellii ssp. neodioica	Howell's pussytoes	Native	X		X
Antennaria neglecta	Field pussytoes	Native	X	X	X
Antennaria plantaginifolia	Woman's tobacco	Native	X	X	X
Anthoxanthum odoratum	Sweet vernal grass	Non-native	X	X	X
Apios americana	Groundnut	Native		X	X
Apocynum androsaemifolium	Spreading dogbane	Native	X		X
Apocynum cannabinum	Indianhemp	Native	X		X
Apocynum X floribundum	Hybrid dogbane	Native		X	X
Aralia nudicaulis [3] (deer prefer)	Wild sarsaparilla	Native	X		X
Arctium minus	Lesser burdock	Non-native	X		X
Arenaria serpyllifolia	Thyme-leaf sandwort	Non-native		X	X
Arisaema triphyllum [3] (deer avoid)	Jack-in-the-pulpit	Native	X		X
Arrhenatherum elatius	Tall oatgrass	Non-native	X		X
Asarum canadense	Canadian wildginger	Native	X		X
Asclepias exaltata	Poke milkweed	Native	X		X
Asclepias syriaca	Common milkweed	Native	X		X
Asimina triloba	Pawpaw	Native	X		X
Asparagus officinalis	Garden asparagus	Non-native	X		X
Asplenium platyneuron	Ebony spleenwort	Native	X	X	X
Athyrium filix-femina	Common ladyfern	Native	X		X
Athyrium filix-femina var. *asplenioides*	Asplenium ladyfern	Native		X	X
Barbarea vulgaris	Garden yelowrocket	Non-native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Berberis thunbergii **[2, 3] (invasive)**	**Japanese barberry**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Betula alleghaniensis	yellow birch	Native	X	X	X
Betula lenta	Sweet birch	Native	X	X	X
Betula nigra	River birch	Native	X		X
Bidens connata	Purplestem beggarticks	Native	X		X
Bidens frondosa	devil's beggartick	Native	X		X
Boehmeria cylindrica	False stinging-nettle	Native	X	X	X
Botrychium dissectum	Cutleaf grapefern	Native	X	X	X
Botrychium oneidense	Bluntlobe grapefern	Native	X		X
Botrychium virginianum	Rattlesnake fern	Native	X	X	X
Brachyelytrum erectum	Bearded shorthusk	Native	X		X
Bromus commutatus	Bald brome	Non-native		X	X
Bromus inermis	Smooth brome	Native	X	X	X
Bromus japonicus	Field brome	Non-native		X	X
Bromus sterilis	Poverty brome	Non-native		X	X
Broussonetia papyrifera **[2]**	**Paper mulberry**	**Invasive watch list (PA DCNR)**	**X**		**X**
Callitriche heterophylla	Callitriche heterophylla	Native	X	X	X
Caltha palustris	Yellow marsh marigold	Native	X		X
Campanula aparinoides	Marsh bellflower	Native	X	X	X
Campsis radicans [3] (vine)	Trumpet creeper	Native	X		X
Cardamine bulbosa	Bulbous bittercress	Native	X		X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Cardamine concatenata	Cutleaf toothwort	Native	X		X
Cardamine hirsuta	Hairy bittercress	Non-native		X	X
Cardamine pensylvanica	Pennsylvania bitter-cress	Native	X	X	X
Carduus nutans [2]	**Nodding plumeless thistle**	**Invasive (PA DCNR)**	**X**		**X**
Carex aggregata	Glomerate sedge	Native		X	X
Carex albicans var. *albicans*	Whitetinge sedge	Native			X
Carex albicans var. *emmonsii*	Emmon's sedge	Native		X	X
Carex albolutescens	Greenwhite sedge	Native	X		X
Carex albursina	White bear sedge	Native		X	X
Carex amphibola	Eastern narrowleaf sedge	Native	X		X
Carex annectens	Yellowfruit sedge	Native	X		X
Carex atlantica	Prickly bog sedge	Native	X		X
Carex blanda	Eastern woodland sedge	Native	X	X	X
Carex bromoides	Brome sedge	Native	X	X	X
Carex bushii	Bush's sedge	Native		X	X
Carex cephalophora	Oval-leaf sedge	Native	X		X
Carex comosa	Longhair sedge	Native			X
Carex conjuncta	Soft fox sedge	Native		X	X
Carex crinita	Fringed sedge	Native	X	X	X
Carex debilis	White edge sedge	Native		X	X
Carex glaucodea	Blue sedge	Native		X	X
Carex gracilescens	Slender looseflower sedge	Native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Carex gracillima	Graceful sedge	Native	X	X	X
Carex granularis	Limestone meadow sedge	Native	X	X	X
Carex grisea	Inflated narrow-leaf sedge	Native		X	X
Carex gynandra	Nodding sedge	Native	X		X
Carex hirsutella	Fuzzy wuzzy sedge	Native	X		X
Carex interior	Inland sedge	Native			X
Carex intumescens	Greater bladder sedge	Native	X	X	X
Carex laxiculmis	Spreading sedge	Native	X		X
Carex laxiflora	Broad looseflower sedge	Native	X	X	X
Carex leptalea	Bristlystalked sedge	Native			X
Carex lupulina	Hop sedge	Native	X		X
Carex lurida	Shallow sedge	Native	X	X	X
Carex normalis	Greater straw sedge	Native	X		X
Carex ovalis	Eggbract sedge	Native			X
Carex peckii	Peck’s sedge	Native	X	X	X
Carex pensylvanica	Pennsylvania sedge	Native	X		X
Carex prasina	Drooping sedge	Native	X		X
Carex radiata	Eastern star sedge	Native		X	X
Carex rosea	Rosy sedge	Native	X		X
Carex scoparia	Broom sedge	Native	X		X
Carex stipata	Awlfruit sedge	Native	X	X	X
Carex stricta	Uptight Sedge	Native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	Common Name	Nativity	Russell 1987	Vanderwerff 1994	NPSpecies (2015)
Carex swanii	Swan's sedge	Native	X	X	X
Carex vulpinoidea	Fox sedge	Native	X	X	X
Carpinus caroliniana	American hornbeam	Native	X		X
Carya cordiformis	Bitternut Hickory	Native			X
Carya glabra	Pignut Hickory	Native	X		X
Carya laciniosa	Shellbark hickory	Native	X		X
Carya ovata	Shagbark Hickory	Native	X		X
Carya tomentosa	Mockernut hickory	Native	X		X
Castanea dentata	American chestnut	Native	X		X
Catalpa bignonioides	Southern catalpa	Native		X	X
Catalpa speciosa	Southern catalpa	Native		X	X
Celastrus orbiculatus [2, 3] **(invasive, vine)**	**Asian Bittersweet**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Celtis occidentalis	Common hackberry	Native	X		X
Centaurea jacea	Brown-ray knapweed	Non-native		X	X
Centaurium pulchellum	Branched centaury	Non-native			X
Cephalanthus occidentalis	Buttonbush	Native	X	X	X
Cerastium arvense	Field chickweed	Native	X		X
Cerastium fontanum	Common mouse-ear chickweed	Non-native		X	X
Cerastium glomeratum	Sticky chickweed	Non-native		X	X
Cerastium nutans	Nodding chickweed	Native	X	X	X
Ceratophyllum demersum	Coon's tail	Native	X		X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Cercis canadensis	Eastern redbud	Native		X	X
Chaenorhinum minus	Dwarf snapdragon	Non-native	X	X	X
Chaiturus marrubiastrum	Lion's tail	Non-native			X
Chamaecrista nictitans var. nictitans	Sensitive partridge pea	Native	X	X	X
Chelone glabra	White turtlehead	Native	X		X
Chenopodium album	Lambsquarters	Native	X		X
Chimaphila maculata	Striped princes pine	Native	X	X	X
Chimaphila umbellata	Pipsissewa	Native			X
Chrysanthemum parthenium	Feverfew	Native			X
Chrysosplenium americanum	American golden saxifrage	Native	X	X	X
Cichorium intybus	Chicory	Non-native	X	X	X
Cinna arundinacea	Sweet woodreed	Native	X	X	X
Cinna latifolia	Drooping woodreed	Native			X
Circaea lutetiana	Broadleaf enchanter's nightshade	Non-native		X	X
Circaea canadensis ssp. canadensis	Enchanter's nightshade	Native	X		X
Cirsium species	Thistle	Native			X
Cirsium arvense [2, 3] **(invasive)**	**Canada thistle**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Cirsium discolor	Field thistle	Native		X	X
Cirsium pumilum	Pasture thistle	Native		X	X
Cirsium vulgare [2]	**Bull thistle**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Claytonia virginica	Virginia springbeauty	Native	X		X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Clematis virginiana	Devil's darning needles	Native	X		X
Clethra alnifolia	Coastal sweetpepperbush	Native	X		X
Clinopodium vulgare	Wild basil	Native	X	X	X
Coleataenia anceps	Beaked panic grass	Native	X	X	X
Collinsonia canadensis	Richweed	Native	X		X
Commelina communis	Asiatic dayflower	Non-native	X	X	X
Comptonia peregrina	Sweet Fern	Native		X	X
Convolvulus species	Bindweed	Non-native			X
Conyza canadensis	Canadian horseweed	Native	X		X
Cornus amomum	Silky dogwood	Native	X		X
Cornus florida	Flowering dogwood	Native	X	X	X
Corylus americana	American hazelnut	Native	X	X	X
Crataegus coccinea	Scarlet hawthorn	Native			X
Crataegus holmesiana	Holmes' hawthorn	Native			X
Crataegus species	Hawthorn	Native	X		X
Cryptotaenia canadensis	Canadian honewort	Native	X	X	X
Cunila origanoides	Common dittany	Native	X		X
Cuscuta species	Dodder	Non-native			X
Cynoglossum virginianum	Wild comfrey	Native	X		X
Cyperus bipartitus [3] (deer avoid)	Slender flatsedge	Native	X		X
Cyperus flavescens	Yellow flatsedge	Native		X	X
Cyperus lupulinus ssp. *macilentus*	Great Plains flatsedge	Native		X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Cyperus strigosus [3] (deer avoid)	Strawcolored flatsedge	Native	X	X	X
Cypripedium acaule	Moccasin flower	Native	X		X
Dactylis glomerata	Orchard-grass	Non-native	X	X	X
Dactylis glomerata ssp. *glomerata*	Orchardgrass	Non-native			X
Danthonia compressa	Flattened oatgrass	Native	X		X
Danthonia spicata	Poverty oatgrass	Native	X	X	X
Daucus carota	Queen Anne's lace	Non-native	X	X	X
Dennstaedtia punctilobula [3] (deer avoid)	Eastern hay-scented fern	Native	X	X	X
Deparia acrostichoides	Silver false spleenwort	Native	X		X
Desmodium canescens	Hoary ticktrefoil	Native	X		X
Desmodium nudiflorum	Nakedflower ticktrefoil	Native	X	X	X
Desmodium paniculatum	Panicledleaf ticktrefoil	Native	X	X	X
Desmodium perplexum	Perplexed ticktrefoil	Native	X	X	X
Desmodium rotundifolium	Prostrate ticktrefoil	Native	X		X
Desmodium species	Ticktrefoil	Native			X
Dianthus armeria	Deptford pink	Non-native	X	X	X
Dichanthelium acuminatum	Tapered rosette grass	Native			X
Dichanthelium acuminatum var. *acuminatum*	Tapered rosette grass	Native		X	X
Dichanthelium acuminatum var. *fasciculatum*	Western panic grass	Native		X	X
Dichanthelium acuminatum var. *lindheimeri*	Lindheimer panicgrass	Native		X	X
Dichanthelium boscii	Bosc's panicgrass	Native		X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Dichanthelium clandestinum	Deer-tongue grass	Native	X	X	X
Dichanthelium depauperatum	Starved panicgrass	Native		X	X
Dichanthelium dichotomiflorum	Fall panicgrass	Native	X		X
Dichanthelium dichotomum	Cypress panicgrass	Native	X	X	X
Dichanthelium dichotomum* var *dichotomum [2]	**Cypress panicgrass**	**Native (PA-E)** [4]		**X**	**X**
Dichanthelium stigmosum	Western panic grass	Native	X		X
Dichanthelium sphaerocarpon	Roundseed panicgrass	Native		X	X
Digitaria ischaemum	Smooth crabgrass	Non-native	X	X	X
Digitaria sanguinalis	Hairy crabgrass	Non-native	X	X	X
Dioscorea villosa	Wild yam	Native	X		X
Dryopteris carthusiana [3] (deer avoid)	Spinulose woodfern	Native	X	X	X
Dryopteris cristata [3] (deer avoid)	Crested woodfern	Native	X	X	X
Dryopteris intermedia [3] (deer avoid)	Intermediate woodfern	Native	X		X
Dryopteris marginalis [3] (deer avoid)	Marginal woodfern	Native	X	X	X
Dryopteris X *boottii*	Woodfern	Native		X	X
Dryopteris X *triploidea*	Triploid woodfern	Native			X
Dulichium arundinaceum	Threeway sedge	Native	X	X	X
Dysphania ambrosioides	Mexican tea	Native	X		X
Echinochloa crus-galli	Barnyardgrass	Non-native	X	X	X
Echinochloa muricata	Rough barnyardgrass	Native		X	X
Echium vulgare	Common viper's bugloss	Non-native	X		X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	Common Name	Nativity	Russell 1987	Vanderwerff 1994	NPSpecies (2015)
Elaeagnus umbellata [2]	**Autumn olive**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Eleocharis acicularis	Needle spikerush	Native	X		X
Eleocharis erythropoda	Bald spikerush	Native	X		X
Eleocharis obtusa [2]	**Blunt spikerush**	**Native (PA-E)** [4]	**X**		**X**
Eleocharis tenuis	Slender spikerush	Native	X	X	X
Eleusine indica	Indian goosegrass	Non-native	X	X	X
Elodea nuttallii	Western waterweed	Native	X		X
Elymus hystrix	Eastern bottlebrush grass	Native			X
Elymus repens	Quackgrass	Non-native		X	X
Elymus villosus	Hairy wildrye	Native			X
Epifagus virginiana	Beechdrops	Native	X		X
Epilobium species	Willowweed	Native			X
Epilobium coloratum	Purpleleaf willowherb	Native	X		X
Equisetum arvense	Field horsetail	Native	X	X	X
Equisetum sylvaticum	Woodland horsetail	Native	X		X
Eragrostis spectabilis	Purple lovegrass	Native	X	X	X
Erechtites hieraciifolius	American burnweed	Native	X	X	X
Erigeron annuus	Eastern daisy fleabane	Native	X	X	X
Erigeron philadelphicus	Philadelphia fleabane	Native	X	X	X
Erigeron pulchellus	Robin's plantain	Native	X	X	X
Erigeron strigosus	Prairie fleabane	Native	X	X	X
Erythronium americanum	Dogtooth violet	Native	X		X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	Common Name	Nativity	Russell 1987	Vanderwerff 1994	NPSpecies (2015)
Euonymus alatus [2]	**Winged euonymus**	**Invasive (PA DCNR)**		**X**	**X**
Euonymus americanus	Bursting-heart	Native	X		X
Eupatorium perfoliatum	Common boneset	Native	X	X	X
Eupatorium pilosum	rough boneset	Native			X
Eupatorium sessilifolium	Upland boneset	Native	X	X	**X**
Euphorbia maculata	Spotted sandmat	Native	X		X
Euphorbia nutans	Eyebane	Native		X	X
Eurybia divaricata	White wood aster	Native		X	X
Eurybia macrophylla	Bigleaf aster	Native			X
Euthamia graminifolia	Flat-top goldentop	Native	X		X
Eutrochium fistulosum	Trumpetweed	Native	X	X	X
Fagus grandifolia	American beech	Native	X	X	X
Fallopia scandens	Climbing false buckwheat	Native	X		X
Festuca rubra	Red fescue	Native	X	X	X
Festuca subverticillata	Nodding fescue	Native	X		X
Forsythia spp.[1]	Forsythia	Non-native			
Fragaria virginiana	Virginia strawberry	Native	X		X
Fraxinus americana	White ash	Native	X	X	X
Fraxinus nigra	Black ash	Native	X		X
Fraxinus pennsylvanica	Green ash	Native	X	X	X
Galearis spectabilis	Showy orchid	Native			X
Galinsoga quadriradiata	Shaggy soldier	Non-native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Galium aparine	Stickywilly	Native	X		X
Galium asprellum	Rough bedstraw	Native		X	X
Galium circaezans	Licorice bedstraw	Native	X	X	X
Galium circaezans var. *hypomalacum*	Licorice bedstraw	Native			X
Galium concinnum	Shining bedstraw	Native			X
Galium mollugo	False baby's breath	Non-native			X
Galium obtusum	Bluntleaf bedstraw	Native	X	X	X
Galium palustre	Common marsh bedstraw	Native			X
Galium pilosum	Hairy bedstraw	Native		X	X
Galium tinctorium	Stiff marsh bedstraw	Native		X	X
Galium triflorum	Fragrant bedstraw	Native	X	X	X
Gaylussacia baccata	Black huckleberry	Native	X	X	X
Gaylussacia frondosa	Blue huckleberry	Native			X
Gentiana andrewsii	Virginia strawberry	Native	X		X
Gentianopsis crinita	Greater fringed gentian	Native	X		X
Geranium maculatum	Spotted geranium	Native	X		X
Geum canadense	White avens	Native	X	X	X
Geum species	Avens	Native			X
Glechoma hederacea	Ground ivy	Non-native	X		X
Glyceria grandis	America mannagrass	Native			X
Glyceria melicaria	Melic mannagrass	Native	X		X
Glyceria canadensis	Rattlesnake mannagrass	Native			X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Glyceria septentrionalis	Floating mannagrass	Native	X	X	X
Glyceria striata	Fowl mannagrass	Native	X	X	X
Goodyera pubescens	Downy rattlesnake plantain	Native	X	X	X
Gratiola neglecta	Clammy hedgehyssop	Native	X		X
Hackelia virginiana	Beggar slice	Native		X	X
Hamamelis virginiana	American witch-hazel	Native	X	X	X
Hedera helix **[1, 2, 3] (invasive, vine)**	**English ivy**	**Invasive (PA DCNR)**			
Helenium flexuosum	Purplehead sneezeweed	Native			X
Hemerocallis fulva **[2, 3] (invasive)**	**Orange daylily**	**Invasive watch list (PA DCNR)**	**X**	**X**	**X**
Heuchera americana	American alumroot	Native	X		X
Hibiscus trionum	Flower of an hour	Non-native	X		X
Hieracium caespitosum	Yellow hawkweed	Non-native	X	X	X
Hieracium flagellare	Hawkweed	Non-native	X	X	X
Hieracium paniculatum	Allegheny hawkweed	Native			X
Hieracium piloselloides	Tall hawkweed	Non-native		X	X
Hieracium scabrum	Rough hawkweed	Native	X		X
Hieracium venosum	Rattlesnakeweed	Native	X		X
Holcus lanatus **[2]**	**Common velvetgrass**	**Invasive watch list (PA DCNR)**	**X**		**X**
Houstonia caerulea	Azure bluet	Native	X	X	X
Huperzia lucidula	Shining clubmoss	Native		X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Hydrocotyle americana	American marshpennywort	Native	X		X
Hydrophyllum virginianum	Eastern waterleaf	Native	X		X
Hylotelephium telephium	Witch's moneybags	Non-native	X		X
Hypericum mutilum	Dwarf St. Johnswort	Native	X	X	X
Hypericum mutilum ssp. boreale	Northern St. Johnswort	Native			X
Hypericum perforatum	Common St. Johnswort	Non-native	X	X	X
Hypericum punctatum	Spotted St. Johnswort	Native	X	X	X
Hypericum ascyron ssp. *pyramidatum*	Great St. Johnswort	Native			X
Hypoxis hirsuta	common goldstar	Native	X		X
Ilex verticillata	Common winterberry	Native	X	X	X
Impatiens capensis [3] (deer prefer)	Jewelweed	Native	X	X	X
Iris pseudacorus	Paleyellow iris	Non-native		X	X
Isotria verticillata	Large whorled pogonia	Native	X		X
Jeffersonia diphyll	Twinleaf	Native		X	X
Juglans nigra	Black walnut	Native	X		X
Juncus biflorus	Bog rush	Native			X
Juncus dichotomus [2]	**Forked rush**	**Native, PA-E** [4]	**X**		**X**
Juncus effusus	Common rush	Native	X		X
Juncus effusus ssp. *solutus*	Lamp rush	Native		X	X
Juncus marginatus	Grassleaf rush	Native	X		X
Juncus subcaudatus	Woodland rush	Native	X		X
Juncus tenuis	Poverty rush	Native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Juniperus communis	Common juniper	Native		X	X
Juniperus virginiana	Eastern red cedar	Native	X		X
Kalmia latifolia	Mountain laurel	Native	X		X
Kalmia angustifolia	Sheep laurel	Native			X
Krigia biflora	Twoflower dwarfdandelion	Native	X	X	X
Lactuca canadensis	Canada lettuce	Native	X		X
Lamium amplexicaule	Henbit deadnettle	Non-native	X		X
Lamium purpureum	Purple deadnettle	Non-native	X		X
Laportea canadensis [3] (deer prefer)	Canadian woodnettle	Native	X		X
Leersia oryzoides	Rice cutgrass	Native	X	X	X
Leersia virginica	Whitegrass	Native	X	X	X
Lemna minor	Common duckweed	Native	X		X
Lemna species	Duckweed	Native			X
Lepidium campestre	Field pepperweed	Non-native	X		X
Lespedeza cuneate **[2, 3]**	**Chinese lespedeza**	**Non-Native**		**X**	**X**
Lespedeza frutescens	Shrubby lespedeza	Native	X		
Lespedeza repens	Creeping lespedeza	Native	X		X
Lespedeza violacea	Violet lespedeza	Native			X
Lespedeza virginica	Slender lespedeza	Native	X		X
Leucanthemum vulgare	Oxeye daisy	Non-native	X	X	X
Liatris spicata	Dense blazing star	Native			X
Ligustrum obtusifolium **[2, 3] (invasive)**	**Border privet**	**Invasive (PA DCNR)**	**X**		**X**

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Linaria vulgaris	Butter-and-eggs	Non-native	X	X	X
Lindera benzoin	Northern spicebush	Native	X	X	X
Liriodendron tulipifera	Tulip poplar	Native	X		X
Lobelia cardinalis	Cardinalflower	Native	X		X
Lobelia inflata	Indian-tobacco	Native	X		X
Lobelia spicata	Palespike lobelia	Native	X		X
Lolium multiflorum	Annual ryegrass	Non-native	X		X
Lonicera japonica **[2, 3] (invasive, vine)**	**Japanese honeysuckle**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Lonicera maacki **[2, 3] *(invasive)***	**Amur honeysuckle**	**Invasive (PA DCNR)**			**X**
Lonicera morrowii **[2, 3] (invasive)**	**Marrow's honeysuckle**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Lonicera tatarica **[2, 3] (invasive)**	**Tartarian honeysuckle**	**Invasive (PA DCNR)**			**X**
Lotus corniculatus	Bird's-foot trefoil	Non-native	X	X	
Ludwigia alternifolia	Seedbox	Native	X	X	X
Ludwigia palustris	Marsh seedbox	Native	X	X	X
Luzula echinata	Hedgehog woodrush	Native		X	X
Luzula multiflora	Common woodrush	Native	X		X
Lycopodium digitatum	Fan clubmoss	Native	X	X	X
Lycopodium obscurum	Rare clubmoss	Native	X	X	X
Lycopus americanus	American water horehound	Native	X	X	X
Lycopus uniflorus	Northern bugleweed	Native	X		X
Lycopus virginicus	Virginia water horehound	Native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Lyonia ligustrina	Maleberry	Native	X		X
Lysimachia ciliata	Fringed loosestrife	Native	X	X	X
Lysimachia quadriflora	Fourflower yellow loosestrife	Native	X	X	X
Maianthemum canadense	Canada mayflower	Native	X	X	X
Maianthemum racemosum ssp. racemosum [3] (deer prefer)	False Solomon's seal	Native	X		X
Malus pumila	paradise apple	Non-native	X		X
Medeola virginiana [3] (deer prefer)	Indian cucumberroot	Native	X		X
Medicago lupulina	Black medick	Non-native	X	X	X
Melampyrum lineare	Narrowleaf cowwheat	Native	X		X
Melampyrum lineare var. lineare	Narrowleaf cowwheat	Native		X	X
Melampyrum lineare var. *pectinatum*	Narrowleaf cowwheat	Native			X
Melilotus albus	Sweetclover	Non-native	X		X
Melilotus officinalis	Sweetclover	Non-native	X	X	X
Mentha aquatica	Water mint	Non-native	X	X	X
Mentha arvensis	Wild mint	Native	X		X
Mentha spicata	Spearmint	Non-native		X	X
Micranthes pensylvanica	Eastern swamp saxifrage	Native	X		X
Microstegium vimineum **[2, 3] (invasive)**	**Japanese stiltgrass**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Mikania scandens	Climbing hempweed	Native	X	X	X
Mimulus alatus	Sharpwing monkeyflower	Native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Mimulus ringens	Ringen monkeyflower	Native	X	X	X
Mitchella repens	Partridgeberry	Native	X		X
Mitella diphylla	Twoleaf miterwort	Native	X		X
Monotropa uniflora	Indianpipe	Native	X	X	X
Morus alba [2]	**White mulberry**	**Invasive watch list (PA DCNR)**	**X**		**X**
Muhlenbergia mexicana	Mexican muhly	Native		X	X
Muhlenbergia schreberi	Nimblewill	Native	X	X	X
Muhlenbergia sobolifera	Rock muhly	Native	X	X	X
Myosotis laxa	Bay forget-me-not	Non-native	X		X
Myosotis scorpioides	True forget-me-not	Non-native	X	X	X
Narcissus pseudonarcissus	Daffodil	Non-native		X	X
Nasturtium microphyllum	Onerow yellowcress	Non-native	X	X	X
Nepeta cataria	Catnip	Non-native			X
Nuphar lutea	Yellow pond-lily	Native	X		X
Nyssa sylvatica	Black gum	Native	X	X	X
Obolaria virginica	Virginia pennywort	Native		X	X
Oenothera biennis	Common evening primrose	Native			X
Oenothera fruticosa ssp. *glauca*	Narrowleaf evening primrose	Native		X	X
Oenothera gaura	Biennial beeblossom	Native	X		X
Onoclea sensibilis	Sensitive fern	Native	X		X
Orchis spectabilis [3] (deer prefer)	Showy orchid	Native	X		X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	Common Name	Nativity	Russell 1987	Vanderwerff 1994	NPSpecies (2015)
Ornithogalum umbellatum [2]	**Star of Bethlehem**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Orobanche uniflora	Oneflowered broomrape	Native	X		X
Osmorhiza claytonii	Clayton's sweetroot	Native	X		X
Osmorhiza longistylis	Longstyle sweetroot	Native	X		X
Osmunda regalis	Royal fern	Non-native	X	X	X
Osmunda claytoniana	Interrupted fern	Native	X	X	X
Osmundastrum cinnamomea	Cinnamon fern	Native	X	X	X
Ostrya virginiana	Eastern hop hornbeam	Native	X		X
Oxalis dillenii	Slender yellow woodsorrel	Native		X	X
Oxalis stricta	Yellow wood sorrel	Native	X		X
Packera aurea	Golden ragwort	Native	X	X	X
Panax trifolius	Dwarf ginseng	Native	X		X
Parthenocissus quinquefolia [3] (vine)	Virginia creeper	Native	X		X
Paspalum laeve	Field paspalum	Native	X		X
Paspalum circulare	Field paspalum	Native		X	X
Paspalum setaceum var. *muhlenbergii*	Thin paspalum	Native		X	X
Paulownia tomentosa	Princesstree	Non-Native		X	X
Pedicularis canadensis	Canadian lousewort	Native	X		X
Pedicularis lanceolata [2]	**Swamp lousewort**	**Native, PA-E** [4]	**X**		X
Pennisetum glaucum	Pearl millet	Non-native	X		X
Penstemon digitalis	Talus slope penstemon	Non-native	X	X	X
Penthorum sedoides	Ditch stonecrop	Native	X		X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Perilla frutescens [2]	**Beefsteakplant**	**Invasive (PA DCNR)**	**X**		**X**
Persicaria arifolia	Halberdleaf tearthumb	Native	X	X	X
Persicaria hydropiper	Marshpepper knotweed	Non-native		X	X
Persicaria maculosa	Spotted ladysthumb	Non-native			X
Persicaria pensylvanica	Pennsylvania smartweed	Native	X		X
Persicaria perfoliata[1, 3] (invasive)	Mile-a-minute	**Invasive (PA DCNR)**			
Persicaria posumbu [3] (invasive)	Oriental ladysthumb	Non-native	X	X	X
Persicaria punctata	Dotted smartweed	Native	X	X	X
Persicaria sagittata	Arrowleaf tearthumb	Native	X	X	X
Persicaria virginiana	Jumpseed	Native	X	X	X
Phalaris arundinacea	Reed canary grass	Native	X	X	X
Phegopteris connectilis	Long beach fern	Native			X
Phegopteris hexagonoptera	Broad becchfern	Native		X	X
Philadelphus coronarius[1]	Sweet mock-orange	Non-native			
Phleum pratense	Timothy	Non-native	X	X	X
Phryma leptostachya	American lopseed	Native	X	X	X
Phyllostachys aurea[1, 2]	**Golden bamboo**	**Invasive watch list (PA DCNR)**			
Physalis longifolia var. subglabrata	Longleaf groundcherry	Native	X		X
Phytolacca americana	American pokeweed	Native	X		X
Picea abies	Norway spruce	Non-native		X	X
Picea glauca	White spruce	Native			X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Picea rubens	Red spruce	Native			X
Pilea pumila	Canadian clearweed	Native	X	X	X
Pilea species	Clearweed	Native			X
Pinus nigra	Austrian pine	Non-native			X
Pinus rigida	Pitch pine	Native	X		X
Pinus strobus	Eastern white pine	Native	X		X
Pinus virginiana	Virginia pine	Native	X		X
Plantago lanceolata	Narrowleaf plantain	Non-native	X	X	X
Plantago major	Common plantain	Non-native	X	X	X
Plantago rugelii	Blackseed plantain	Native		X	X
Platanthera lacera	Green fringed orchid	Native	X		X
Platanus occidentalis	American sycamore	Native	X	X	X
Poa annua	Annual bluegrass	Non-native		X	X
Poa compressa [3] (deer avoid)	Canada bluegrass	Non-native	X	X	X
Poa palustris [3] (deer avoid)	Fowl bluegrass	Native			X
Poa pratensis [3] (deer avoid)	Kentucky bluegrass	Native	X	X	X
Poa trivialis **[2, 3] (deer avoid)**	**Rough bluegrass**	**Invasive watch list (PA DCNR)**	**X**	**X**	X
Podophyllum peltatum [3] (deer avoid)	Mayapple	Native	X		X
Polygala sanguinea	Purple milkwort	Native			X
Polygonatum biflorum [3] (deer prefer)	Smooth Solomon's seal	Native	X	X	X
Polygonatum pubescens	Hairy Solomon's seal	Native		X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Polygonum aviculare	Prostrate knotweed	Non-native	X		X
Polygonum aviculare ssp. *depressum*	Common knotweed	Non-native		X	X
Polypodium virginianum	Rock polypoid	Native	X	X	X
Polystichum acrostichoides [3] (deer avoid)	Christmas fern	Native	X	X	X
Populus grandidentata	Big tooth aspen	Native	X	X	X
Potamogeton crispus [2]	**Curly pondweed**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Potamogeton epihydrus	Ribbonleaf pondweed	Native	X	X	X
Potamogeton foliosus	Leafy pondweed	Native	X		X
Potamogeton foliosus ssp. *foliosus*	Leafy pondweed	Native			X
Potentilla canadensis	Dwarf cinquefoil	Native	X		X
Potentilla intermedia	Downy cinquefoil	Non-native	X		X
Potentilla norvegica	Norwegian cinquefoil	Non-native	X		X
Potentilla recta	Sulphur cinquefoil	Non-native	X		X
Potentilla simplex	Common cinquefoil	Native	X	X	X
Potentilla species	Cinquefoil	Native			X
Prenanthes altissima	Tall rattlesnakeroot	Native	X	X	X
Prenanthes trifoliolata	Gall of the earth	Native			X
Prunella vulgaris	Common selfheal	Native		X	X
Prunella vulgaris ssp. *lanceolata*	Lance selfheal	Native		X	X
Prunus americana	American plum	Native		X	X
Prunus avium	Sweet cherry	Non-native	X		X
Prunus pensylvanica	Pin cherry	Native			X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Prunus serotina	Black Cherry	Native	X		X
Prunus species	Prunus	Non-native			X
Prunus virginiana	Common chokecherry	Native	X		X
Pseudognaphalium obtusifolium	Rabbit-tobacco	Native	X		X
Pteridium aquilinum	Western bracken fern	Native	X	X	X
Pycnanthemum tenuifolium	Narrowleaf mountainmint	Native	X		X
Pycnanthemum virginianum	Virginia mountainmint	Native	X	X	X
Pyrola americana	American wintergreen	Native	X		X
Pyrola elliptica	Waxflower shinleaf	Native			X
Quercus alba	White oak	Native	X	X	X
Quercus bicolor	Swamp White oak	Native	X		X
Quercus coccinea	Scarlet oak	Native	X		X
Quercus montana	Chestnut oak	Native		X	X
Quercus palustris	Pin oak	Native	X		X
Quercus prinus	Chestnut Oak	Native	X		X
Quercus rubra	Red Oak	Native	X	X	X
Quercus velutina	Black Oak	Native	X	X	X
Ranunculus abortivus	Littleleaf buttercup	Native	X	X	X
Ranunculus bulbosus	St. Anthony's turnip	Non-native	X	X	X
Ranunculus hispidus	Bristly buttercup	Native	X		X
Ranunculus hispidus var. *caricetorum*	Bristly buttercup	Native		X	X
Ranunculus recurvatus	Blisterwort	Native	X		X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Rhododendron periclymenoides	Pink azalea	Native	X	X	X
Rhododendron viscosum	Swamp azalea	Native			X
Rhododendron maximum	Great laurel	Native			X
Rhus copallinum	Winged sumac	Native	X		X
Rhus typhina	Stagehorn sumac	Native			X
Rhus copallinum var. *copallinum*	Winged sumac	Native			X
Rhus glabra	Smooth sumac	Native	X		X
Rhynchospora capitellata	Brownish beaksedge	Native	X	X	X
Robinia pseudoacacia	Black locust	Native	X		X
Rorippa sylvestris	Creeping yellowcress	Non-native	X		X
Rosa multiflora **[2, 3] (invasive)**	**Multiflora rose**	**Invasive (PA DCNR)**	**X**		**X**
Rose palustris	Swamp rose	Native	X	X	X
Rubus allegheniensis [3] (deer prefer)	Allegheny blackberry	Native	X	X	X
Rubus flagellaris [3] (deer prefer)	Northern dewberry	Native	X		X
Rubus hispidus [3] (deer prefer)	Bristly dewberry	Native	X		X
Rubus occidentalis [3] (deer prefer)	Black raspberry	Native	X		X
Rubus pensilvanicus [3] (deer prefer)	Philadelphia blackberry	Native		X	X
Rubus phoenicolasius **[2, 3] (deer prefer)**	**Wine rasberry**	**Invasive (PA DCNR)**	**X**	**X**	**X**
Rubus pubescens	Dwarf red blackberry	Native			X
Rubus idaeus	American red raspberry	Native			X
Rudbeckia hirta	Black-eyed Susan	Native	X	X	X
Rudbeckia hirta var. *pulcherrima*	Black-eyed Susan	Native		X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Rudbeckia laciniata	Cutleaf coneflower	Native	X		X
Rumex acetosella	Common sheep sorrel	Non-native	X		X
Rumex crispus	Curly dock	Non-native	X		X
Rumex obtusifolius	Bitter dock	Non-native	X		X
Sagina decumbens	Trailing pearlwort	Native		X	X
Sagittaria australis	Longbeak arrowhead	Native	X		X
Sagittaria latifolia	Broadleaf arrowhead	Native	X	X	X
Salix eriocephala	Missouri River willow	Native			X
Salix nigra	Black willow	Native	X	X	X
Salvia lyrata	Lyreleaf sage	Native	X		X
Sambucus nigra ssp. canadensis	American black elderberry	Native	X		X
Sanguinaria canadensis [3] (deer prefer)	Bloodroot	Native	X	X	X
Sanicula smallii	Small's blacksnakeroot	Native			X
Sanicula canadensis	Canadian blacksnakeroot	Native	X	X	X
Sanicula odorata	Clustered blacksnakeroot	Native			X
Saponaria officinalis	Bouncingbet	Non-native	X	X	X
Sassafras albidum	Sassafras	Native	X	X	X
Schedonorus arundinaceus [2]	**Tall fescue**	**Invasive watch list (PA DCNR)**	**X**	**X**	**X**
Schedonorus pratensis	Meadow fescue	Non-native		X	X
Schizachyrium scoparium	Little bluestem	Native	X	X	X
Schoenoplectus tabernaemontani	Softstem bulrush	Native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Scirpus atrovirens	Green bulrush	Native	X	X	X
Scirpus cyperinus	Woolgrass	Native	X	X	X
Scirpus expansus	Woodland bulrush	Native	X	X	X
Scirpus georgianus	Georgia bulrush	Native	X		X
Scirpus hattorianus	Mosquito bulrush	Native	X		X
Scirpus polyphyllus	Leafy bulrush	Native	X		X
Scutellaria elliptica	Hairy skullcap	Native	X		X
Scutellaria integrifolia	Helmet flower	Native	X	X	X
Scutellaria lateriflora	Blue skullcap	Native	X	X	X
Securigera varia	Crownvetch	Non-native	X		X
Setaria faberi	Japanese bristlegrass	Non-native	X	X	X
Setaria parviflora	Marsh bristlegrass	Native		X	X
Setaria pumila	yellow foxtail	Non-native		X	X
Setaria viridis	Green bristlegrass	Non-native	X	X	X
Sicyos angulatus	Oneseed burr cucumber	Native			X
Silene latifolia	Bladder campion	Non-native	X		X
Silene vulgaris	Maidenstears	Non-native	X		X
Sisymbrium officinale	Hedgemustard	Non-native	X		X
Sisyrinchium angustifolium	Narrowleaf blue-eyed grass	Native	X	X	X
Sisyrinchium mucronatum	Needletip blue-eyed grass	Native	X	X	X
Smilax glauca [3] (deer prefer, vine)	Cat greenbriers	Native	X	X	X
Smilax herbacea [3] (deer prefer. vine)	Smooth carrionflower	Native	X		X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Smilax pseudochina [3] (deer prefer, vine)	Bamboo vine	Native	X		
Smilax pulverulenta	Downy carrionflower	Native		X	X
Smilax rotundifolia [3] (deer prefer, vine)	Roundleaf greenbriers	Native	X	X	X
Smilax tamnoides	Bristly greenbrier	Native		X	X
Solanum carolinense	Carolina horse-nettle	Native		X	X
Solidago species	Goldenrod	Native			X
Solidago altissima	Canada goldenrod	Native	X		X
Solidago altissima ssp. *altissima*	Canada goldenrod	Native			X
Solidago bicolor	White goldenrod	Native	X		X
Solidago caesia	Wreath goldenrod	Native	X	X	X
Solidago canadensis	Canada goldenrod	Native	X		X
Solidago canadensis var. *hargeri*	Harger's goldenrod	Native			X
Solidago juncea	Early goldenrod	Native	X	X	X
Solidago nemoralis	Gray goldenrod	Native	X	X	X
Solidago rugosa	Wrinkleleaf goldenrod	Native	X		X
Sorghastrum nutans	Indiangrass	Native	X	X	X
Sparganium americanum	American burreed	Native	X		X
Sparganium androcladum [2]	**Branched bur-reed**	**Native, PA-PE** [4]		**X**	**X**
Sphenopholis intermedia	Slender wedgescale	Native	X		X
Sphenopholis obtusata	Prairie wedgescale	Native			X
Spiraea species	Spirea	Native			X
Spiranthes cernua	Nodding lady's tresses	Native	X	X	X

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Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Stellaria alsine	Bog chickweed	Native	X		X
Stellaria longifolia	Longleaf starwort	Native	X	X	X
Stellaria media	Common chickweed	Non-native	X	X	X
Stellaria pubera	Star chickweed	Native	X		X
Symphoricarpos orbiculatus	Coralberry	Native	X	X	X
Symphyotrichum cordifolium	Common blue wood aster	Native	X	X	X
Symphyotrichum laeve	Smooth blue aster	Native		X	X
Symphyotrichum lanceolatum var. lanceolatum	White panicle aster	Native	X		X
Symphyotrichum lateriflorum	Calico aster	Native	X	X	X
Symphyotrichum pilosum	Hairy white oldfield aster	Native	X	X	X
Symphyotrichum pilosum var. *pringlei*	Pringle's aster	Native		X	X
Symphyotrichum prenanthoides	Crookedstem aster	Native		X	X
Symphyotrichum subulatum var. ligulatum	Southern annual saltmarsh aster	Native	X		X
Symphyotrichum undulatum	Wavyleaf aster	Native		X	X
Symphytum officinale	Common comfrey	Non-native	X		X
Symplocarpus foetidus	Skunk cabbage	Native	X	X	X
Taraxacum officinale	Common dandelion	Non-native	X		X
Thalictrum pubescens	King of the meadow	Native	X		X
Thalictrum thalictroides	Rue anemone	Native	X	X	X
Thelypteris noveboracensis[3] (deer avoid)	New York Fern	Native	X	X	X

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Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Thelypteris palustris var. *pubescens*	Eastern marsh fern	Native		X	X
Thelyptreis palustris [3] (deer avoid)	Eastern marsh fern	Native	X		X
Thlaspi arvense	Field pennycress	Non-native	X	X	X
Thuja occidentalis	Arborvitae	Native		X	X
Tilia americana	American basswood	Native	X		X
Toxicodendron radicans [3] (vine)	Eastern Poison Ivy	Native	X	X	X
Toxicodendron vernix	Poison sumac	Native	X		X
Tragopogon dubius	Yellow salsify	Non-native		X	X
Tridens flavus	Purpletop tridens	Native	X	X	X
Trientalis borealis	American starflower	Native			X
Trifolium aureum	Golden clover	Non-native		X	X
Trifolium campestre	Field clover	Non-native	X		X
Trifolium pratense	Red clover	Non-native	X	X	X
Trifolium repens	White clover	Non-native	X		X
Triodanis perfoliata	Clasping Venus' looking-glass	Native	X		X
Tsuga canadensis	Eastern hemlock	Native	X		X
Tussilago farfara	Coltsfoot	Non-native	X	X	X
Typha latifolia	Broadleaf cattail	Native		X	X
Ulmus americana	American elm	Native	X	X	X
Ulmus rubra	Slippery elm	Native		X	X
Uvularia perfoliata [3] (deer prefer)	Perfoliate bellwort	Native	X	X	X
Uvularia sessilifolia [3] (deer prefer)	Sessileleaf bellwort	Native	X		X

[1] Invasives noted Ambrose and Åkerson 2006, but not documented by Russell (1987) , Vanderwerff (1994) or listed in NPSpecies

[2] Invasive and state listed species (also indicated in bold type).

[3] MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines – also indicated in green shading).

[4] PA-E: Pennsylvania state listed endangered species (as designated by USDA Plants Database)

Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Vaccinium angustifolium [3] (deer avoid)	Low bush blueberry	Native			X
Vaccinium corymbosum [3] (deer avoid)	Highbush blueberry	Native	X		X
Vaccinium pallidum [3] (deer avoid)	Blue Ridge blueberry	Native	X	X	X
Vaccinium stamineum [3] (deer avoid)	Upland highbush blueberry	Native	X	X	X
Veratrum viride	Green false hellebore	Native	X	X	X
Verbascum blattaria	Moth mullein	Non-native	X	X	X
Verbascum thapsus	Common mullein	Non-native	X	X	X
Verbena hastata	Swamp verbena	Native	X	X	X
Verbena urticifolia	White vervain	Native	X	X	X
Vernonia noveboracensis	New York ironweed	Native			X
Veronica americana	American speedwell	Native	X		X
Veronica arvensis	Corn speedwell	Non-native	X		X
Veronica officinalis	Common gypsyweed	Non-native	X	X	X
Veronica peregrina	Neckweed	Native	X		X
Veronica persica	Birdeye speedwell	Non-native		X	X
Veronica serpyllifolia	Thymeleaf speedwell	Native		X	X
Viburnum acerifolium	Maple-leaved viburnum	Native	X		X
Viburnum dentatum	Southern arrowwood	Native	X		X
Viburnum lentago	Nannyberry	Native	X		X
Viburnum prunifolium	Blackhaw	Native	X		X
Viburnum recognitum	Northern arrowwood	Native		X	X

[1] Invasives noted Ambrose and Åkerson 2006, but not documented by Russell (1987) , Vanderwerff (1994) or listed in NPSpecies

[2] Invasive and state listed species (also indicated in bold type).

[3] MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines – also indicated in green shading).

[4] PA-E: Pennsylvania state listed endangered species (as designated by USDA Plants Database)

Appendix Table 48 (continued). Vegetation observed at HOFU. Invasive and state listed species are indicated in bold type. MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines) are highlighted by gray shading.

Scientific Name	**Common Name**	**Nativity**	**Russell 1987**	**Vanderwerff 1994**	**NPSpecies (2015)**
Vinca minor **[2, 3] (invasive)**	**Common periwinkle**	**Invasive watch list (PA DCNR)**	**X**		**X**
Viola cucullata	Marsh blue violet	Native	X		X
Viola hirsutula	Southern woodland violet	Native	X		X
Viola labradorica	Alpine violet	Native			X
Viola macloskeyi	Small white violet	Native	X		X
Viola palmata	Three-lobe violet	Native	X		X
Viola pubescens	Downy yellow violet	Native			X
Viola rostrata	Longspur violet	Native	X		X
Viola sororia	Common blue violet	Native	X		X
Viola sororia var. affinis	Sand violet	Native	X	X	X
Viola species	Violet	Native			X
Vitis aestivalis [3] (vine)	Summer grape	Native	X		X
Vitis labrusca [3] (vine)	Fox grape	Native	X		X
Vitis riparia [3] (vine)	Riverbank grape	Native	X		X
Vitis vulpine [3] (vine)	Frost grape	Native	X		X
Wisteria sinensis **[1,2, 3] (invasive, vine)**	**Chinese wisteria**	**Invasive watch list (PA DCNR)**			
Total species observed			**499**	**344**	**691**

[1] Invasives noted Ambrose and Åkerson 2006, but not documented by Russell (1987) , Vanderwerff (1994) or listed in NPSpecies

[2] Invasive and state listed species (also indicated in bold type).

[3] MIDN forest vegetation monitoring indicator taxa (invasive, deer browse preference, vines – also indicated in green shading).

[4] PA-E: Pennsylvania state listed endangered species (as designated by USDA Plants Database)

Appendix Table 49. Pennsylvania water quality criteria uses.

Aquatic Life	
CWF	*Cold Water Fishes*—Maintenance or propagation, or both, of fish species including the family *Salmonidae* and additional flora and fauna which are indigenous to a cold water habitat.
WWF	*Warm Water Fishes*—Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
MF	*Migratory Fishes*—Passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which move to or from flowing waters to complete their life cycle in other waters.
TSF	*Trout Stocking*—Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
Water Supply	
PWS	*Potable Water Supply*—Used by the public as defined by the Federal Safe Drinking Water Act, 42 U.S.C.A. § 300F, or by other water users that require a permit from the Department under the Pennsylvania Safe Drinking Water Act (35 P. S. § § 721.1—721.18), or the act of June 24, 1939 (P. L. 842, No. 365) (32 P. S. § § 631—641), after conventional treatment, for drinking, culinary and other domestic purposes, such as inclusion into foods, either directly or indirectly.
IWS	*Industrial Water Supply*—Use by industry for inclusion into nonfood products, processing and cooling.
LWS	*Livestock Water Supply*—Use by livestock and poultry for drinking and cleansing.
AWS	*Wildlife Water Supply*—Use for waterfowl habitat and for drinking and cleansing by wildlife.
IRS	*Irrigation*—Used to supplement precipitation for crop production, maintenance of golf courses and athletic fields and other commercial horticultural activities.
Recreation and Fish Consumption	
B	*Boating*—Use of the water for power boating, sail boating, canoeing and rowing for recreational purposes when surface water flow or impoundment conditions allow.
F	*Fishing*—Use of the water for the legal taking of fish. For recreation or consumption.
WC	*Water Contact Sports*—Use of the water for swimming and related activities.
E	*Esthetics*—Use of the water as an esthetic setting to recreational pursuits.
Special Protection	
HQ	*High Quality Waters*
EV	*Exceptional Value Waters*
Other	
N	*Navigation*—Use of the water for the commercial transfer and transport of persons, animals and goods.

Appendix Table 50. Pennsylvania water quality criteria.

Parameter	**Symbol**	**Critical Uses**[1]	**Criteria**
Alkalinity	ALK	CWF, WWF, TSF, MF	Minimum 20 mg/l as CaCO3, except where natural conditions are less. Where discharges are to waters with 20 mg/l or less alkalinity, the discharge should not further reduce the alkalinity of the receiving waters.
Ammonia Nitrogen	AM	CWF, WWF, TSF, MF	The maximum total ammonia nitrogen concentration (in mg/L) at all times shall be the numerical value given by: un-ionized ammonia nitrogen (NH3-N) x (log-1[pKT-pH] + 1), where un-ionized ammonia nitrogen = 0.12 x f(T)/f(pH); f(pH) = 1 + $10^{1.03(7.32\text{-}pH);}$ f(T) = 1, T >= 10°C; f(T) = 1 + $10^{(9.73\text{-}pH)}$, T ‹ 10°C; 1 + 10($^{pK}{}_{T\text{-}}{}^{pH}$) and pKT =the dissociation 0.090 +…constant for ammonia in water. 2730 (T + 273.2)
Bacteria	Bac_1	WC	(Fecal coliforms/ 100 ml)—During the swimming season (May 1 to September 30), the maximum fecal coliform level shall be a geometric mean of 200 per 100 milliliters (ml) based on a minimum of five consecutive samples each sample collected on different days during a 30-day period. No more than 10% of the total samples taken during a 30-day period may exceed 400 per 100 ml. For the remainder of the year, the maximum fecal coliform level shall be a geometric mean of 2,000 per 100 milliliters (ml) based on a minimum of five consecutive samples collected on different days during a 30-day period.
Bacteria	Bac_2	PWS	(Coliforms/100 ml)—Maximum of 5,000/100 ml as a monthly average value, no more than this number in more than 20 of the samples collected during a month, nor more than 20,000/100 ml in more than 5% of the samples.
Chloride	Ch	PWS	Maximum 250 mg/l.
Color	Col	PWS	Maximum 75 units on the platinum-cobalt scale; no other colors perceptible to the human eye.
Dissolved oxygen	DO_1	CWF	For flowing waters, 7-day average 6.0 mg/l; minimum 5.0 mg/l. For naturally reproducing salmonid early life stages, applied in accordance with subsection (b), 7-day average 9.0 mg/l; minimum 8.0 mg/l. For lakes, ponds and impoundments, minimum 5.0 mg/l.
Dissolved oxygen	DO_2	WWF	7-day average 5.5 mg/l; minimum 5.0 mg/l.
Dissolved oxygen	DO_2	TSF	For the period February 15 to July 31 of any year, 7-day average 5.5 mg/l; minimum 5.0 mg/l.
Fluoride	F	PWS	Daily average 2.0 mg/l.

[1] Refer to Appendix Table 49

Appendix Table 50 (continued). Pennsylvania water quality criteria.

Parameter	Symbol	Critical Uses[1]	Criteria
Iron	Fe_1	CWF, WWF, TSF, MF	30-day average 1.5 mg/l as total recoverable.
Iron	Fe_2	PWS	Maximum 0.3 mg/l as dissolved iron.
Manganese	Mn	PWS	Maximum 1.0 mg/l, as total recoverable.
Nitrite plus Nitrate	N	PWS	Maximum 10 mg/l as nitrogen.
Osmotic Pressure	OP	CWF, WWF, TSF, MF	Maximum 50 milliosmoles per kilogram.
pH	pH	CWF, WWF, TSF, MF	From 6.0 to 9.0 inclusive.
Specific Conductance	Specific Conductance	n/a	Range 150 and 1500 uS/cm
Phenolics	Phen	PWS	Maximum 0.005 mg/l.
Sulfate	Sul	PWS	Maximum 250 mg/l.
Total dissolved solids	TDS	PWS	500 mg/l as a monthly average value; maximum 750 mg/l.
Total residual chlorine	TRC	CWF, WWF, TSF, MF	Four-day average 0.011 mg/l; 1-hour average 0.019 mg/l.

[1] Refer to Appendix Table 49

Appendix Table 51. Pennsylvania standards for maximum water temperatures in the receiving water body resulting from heated waste sources regulated under Chapters 92a, 96 and other sources where temperature limits are necessary to protect designated and existing uses.

Dates	Cold water fishery Temp °F (°C)	Warm water fishery Temp °F (°C)	Trout stocked fishery waters Temp °F (°C)
Jan 1-31	38 (3)	40 (4)	40 (4)
Feb 1-29	38 (3)	40 (4)	40 (4)
March 1-31	42 (6)	46 (8)	46 (8)
April 1-15	48 (9)	52 (11)	52 (11)
April 16-30	52 (11)	58 (14)	58 (14)
May 1-15	54 (12)	64 (18)	64 (18)
May 16-31	58 (14)	72 (22)	68 (20)
June 1-15	60 (16)	60 (16)	70 (21)
June 16-30	64 (18)	84 (29)	72 (22)
July 1-30	66 (19)	87 (31)	74 (23)
Aug 1-15	66 (19)	87 (31)	80 (27)
Aug 16-30	66 (19)	87 (31)	87 (31)
Sept 1-15	64 (18)	84 (29)	84 (29)
Sept 16-30	60 (16)	78 (26)	78 (26)
Oct 1-15	54 (12)	72 (22)	72 (22)
Oct 16-31	50 (10)	66 (19)	66 (19)
Nov 1-15	46 (8)	58 (14)	58 (14)
Nov 16-30	42 (6)	50 (10)	50 (10)
Dec 1-31	40 (4)	42 (6)	42 (6)

Appendix Table 52. Avian species observed at HOFU.

Scientific Name[1]	Common Name	Group	Historical Records	1994	1999 to 2001
Accipiter cooperii	Cooper's hawk	raptor	X	X	X
Accipiter striatus	Sharp-shinned hawk	raptor	X	X	X
Actitis macularius	Spotted sandpiper	shorebird	X		
Aegolius acadicus	Northern saw-whet owl	owl		X	X
Agelaius phoeniceus	Red-winged blackbird	passerine	X	X	X
Aix sponsa	Wood duck	waterfowl	X	X	
Ammodramus henslowii [3] **(IB, PA-CR)**	**Henslow's sparrow**	**passerine**	**X**	**X**	
Ammodramus savannarum	Grasshopper sparrow	passerine	X	X	
Anas acuta	Northern pintail	waterfowl	X		
Anas americana	American wigeon	waterfowl	X		
Anas crecca [3] **(PA-CR)**	**Green-winged teal**	**waterfowl**	**X**		
Anas discors	Blue-winged teal	waterfowl	X		
Anas platyrhynchos	Mallard	waterfowl	X	X	X
Anas rubripes [3] **(I)**	**American black duck**	**waterfowl**	**X**		
Anas strepera	Gadwall	waterfowl	X		
Anthus rubescens	American pipit	passerine	X	X	
Archilochus colubris	Ruby-throated hummingbird	passerine	X	X	X
Ardea alba [3] **(PA-PE)**	**Great egret**	**wader**	**X**		
Ardea herodias	Great blue heron	wader	X	X	
Asio otus [3] **(PA-PT)**	**Long-eared owl**	**owl**			**X**
Aythya affinis	Lesser scaup	waterfowl	X		
Aythya americana [3] **(IIC)**	**Redhead**	**waterfowl**	**X**		

[1] Partners in Flight (PIF) status: IA: High Continental Priority, High Regional Responsibility; IB: High Continental Priority, Low Regional Responsibility; IIA: High Regional Priority, High Regional Concern; IIB: High Regional Priority, High Regional Responsibly; IIC: High Regional Priority, High Regional Threats (Kearney 2003).

[2] Pennsylvania state status: PA-CA: candidate as risk; PA-CR: candidate rare; PA-E: Endangered, PA-SC: special concern, PA-T: threatened; PA-PX: extirpated - Species that have disappeared from Pennsylvania since 1600 but still exist elsewhere.

[3] Indicates state listed and/or Partners in Flight species (status given in parentheses after scientific name – also in bold).

Appendix Table 52 (continued). Avian species observed at HOFU.

Scientific Name[1]	Common Name	Group	Historical Records	1994	1999 to 2001
Aythya collaris	Ringed-neck duck	waterfowl	X		
Aythya marila [3] **(IIA)**	**Greater scaup**	**waterfowl**	**X**		
Aythya valisineria [3] **(IIC)**	**Canvasback**	**waterfowl**	**X**		
Baeolophus bicolor	Tufted titmouse	passerine	X	X	X
Bombycilla cedrorum	Cedar waxwing	passerine	X	X	X
Bonasa umbellus	Ruffed grouse	groundbird	X		X
Branta canadensis	Canada goose	waterfowl	X	X	X
Bubo virginianus	Great horned owl	owl	X	X	X
Bucephala albeola	Bufflehead	waterfowl	X		
Bucephala clangula	Common grackle	passerine	X	X	X
Bucephala clangula	Common goldeneye	waterfowl	X		
Buteo jamaicensis	Red-tailed hawk	raptor	X	X	X
Buteo lagopus	Rough-legged hawk	raptor	X		
Buteo lineatus	Red-shouldered hawk	raptor		X	X
Buteo platypterus	Broad-winged hawk	raptor	X	X	X
Butorides straitus	Green-backed heron	wader	X		
Butorides virescens [3] **(IIA)**	**Green heron**		**X**		
Cardinalis cardinalis	Northern cardinal	passerine	X	X	X
Carduelis tristis	American goldfinch	passerine	X	X	X
Carpodacus mexicanus	House finch	passerine	X	X	X
Carpodacus purpureus	Purple finch	passerine	X	X	X
Cathartes aura	Turkey vulture	raptor	X	X	X

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[2] Pennsylvania state status: PA-CA: candidate as risk; PA-CR: candidate rare; PA-E: Endangered, PA-SC: special concern, PA-T: threatened; PA-PX: extirpated - Species that have disappeared from Pennsylvania since 1600 but still exist elsewhere.

[3] Indicates state listed and/or Partners in Flight species (status given in parentheses after scientific name – also in bold).

Appendix Table 52 (continued). Avian species observed at HOFU.

Scientific Name[1]	Common Name	Group	Historical Records	1994	1999 to 2001
Catharus fuscescens	Veery	passerine	X	X	X
Catharus guttatus	Hermit thrush	passerine	X	X	X
Catharus minimus	Gray-cheeked thrush	passerine	X	X	
Catharus ustulatus **[3] (PA-CR)**	**Swainson's thrush**	**passerine**	**X**	**X**	
Certhia americana	Brown creeper	passerine	X	X	X
Chaetura pelagica **[3] (IIA)**	**Chimney swift**	**passerine**	**X**	**X**	**X**
Charadrius vociferus	Killdeer	shorebird	X	X	X
Chordeiles minor **[3] (PA-CA)**	**Common nighthawk**	**passerine**		**X**	
Circus cyaneus **[3] (PA-SC)**	**Northern harrier**	**raptor**	**X**		
Clangula hyemalis	Oldsquaw	waterfowl	X		
Coccothraustes vespertinus	Evening grosbeak	passerine	X	X	
Coccyzus americanus	Yellow-billed cuckoo	passerine	X	X	X
Coccyzus erythropthalmus	Black-billed cuckoo	passerine		X	X
Colaptes auratus	Northern flicker	woodpecker	X	X	X
Columba livia	Rock dove	groundbird	X	X	X
Contopus cooperi **[3] (PA-PX)**	**Olive-sided flycatcher**	**passerine**	**X**		
Contopus virens	Eastern wood-pewee	passerine	X	X	X
Coragyps atratus	Black vulture	raptor	X	X	X
Corvus brachyrhynchos	American crow	passerine	X	X	X
Corvus corax	Common raven	passerine			X
Corvus ossifragus	Fish crow	passerine	X	X	X
Cyanocitta cristata	Blue jay	passerine	X	X	X

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[2] Pennsylvania state status: PA-CA: candidate as risk; PA-CR: candidate rare; PA-E: Endangered, PA-SC: special concern, PA-T: threatened; PA-PX: extirpated - Species that have disappeared from Pennsylvania since 1600 but still exist elsewhere.

[3] Indicates state listed and/or Partners in Flight species (status given in parentheses after scientific name – also in bold).

Appendix Table 52 (continued). Avian species observed at HOFU.

Scientific Name[1]	Common Name	Group	Historical Records	1994	1999 to 2001
Cygnus columbianus	Tundra swan	waterfowl	X		
Dendroica caerulescens	Black-throated blue warbler	passerine	X	X	X
Dendroica castanea	Bay-breasted warbler	passerine	X	X	X
***Dendroica cerulean*[3] (IB)**	**Cerulean warbler**	**passerine**	**X**	**X**	**X**
Dendroica coronata	Yellow-rumped warbler	passerine	X	X	X
***Dendroica discolor*[3] (IA)**	**Prairie warbler**	**passerine**	**X**	**X**	
Dendroica dominica	Yellow-throated warbler	passerine			X
Dendroica fusca	Blackburnian warbler	passerine	X	X	X
Dendroica magnolia	Magnolia warbler	passerine	X	X	X
Dendroica palmarum	Palm warbler	passerine	X	X	X
Dendroica pensylvanica	Chestnut-sided warbler	passerine	X	X	X
Dendroica petechia	Yellow warbler	passerine	X	X	X
Dendroica pinus	Pine warbler	passerine	X		X
***Dendroica striata*[3] (PA-PE)**	**Blackpoll warbler**	**passerine**	**X**	**X**	**X**
Dendroica tigrina	Cape May warbler	passerine	X	X	
Dendroica virens	Black-throated green warbler	passerine	X	X	X
Dolichonyx oryzivorus	Bobolink	passerine	X	X	
Dryocopus pileatus	Pileated woodpecker	woodpecker	X	X	X
Dumetella carolinensis	Gray catbird	passerine	X	X	X
Egretta caerulea	Little blue heron	wader	X		
Empidonax alnorum	Alder flycatcher	passerine	X	X	
Empidonax minimus	Least flycatcher	passerine	X	X	X

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[3] Indicates state listed and/or Partners in Flight species (status given in parentheses after scientific name – also in bold).

Appendix Table 52 (continued). Avian species observed at HOFU.

Scientific Name[1]	Common Name	Group	Historical Records	1994	1999 to 2001
Empidonax traillii **[3] (IB)**	**Willow flycatcher**	**passerine**			**X**
Empidonax virescens **[3] (IIB)**	**Acadian flycatcher**	**passerine**	**X**	**X**	**X**
Eremophila alpestris	Horned lark	passerine	X	X	
Euphagus carolinus **[3] (IIA)**	**Rusty blackbird**	**passerine**	**X**	**X**	
Falco sparverius	American kestrel	raptor	X		X
Gavia immer	Common loon	waterfowl	X		
Geothlypis trichas	Common yellowthroat	passerine	X	X	X
Haliaeetus leucocephalus **[3] (PA-T)**	**Bald eagle**	**raptor**			**X**
Helmitheros vermivorum **[3] (IB)**	**Worm-eating warbler**	**passerine**	**X**	**X**	**X**
Hirundo rustica	Barn swallow	passerine	X	X	X
Hylocichla mustelina **[3] (IA)**	**Wood thrush**	**passerine**	**X**	**X**	**X**
Icteria virens	Yellow-breasted chat	passerine	X	X	
Icterus galbula	Baltimore oriole	passerine	X	X	X
Icterus spurius	Orchard oriole	passerine	X	X	X
Junco hyemalis	Dark-eyed junco	passerine	X	X	X
Lanius ludovicianus **[3] (IIC)**	**Loggerhead shrike**	**passerine**	**X**	**X**	
Larus argentatus	Herring gull	shorebird	X		
Larus delawarensis	Ring-billed gull	shorebird			X
Lophodytes cucullatus	Hooded merganser	waterfowl	X		
Megaceryle alcyon	Belted kingfisher	passerine	X	X	X
Megascops asio **[3] (IIA)**	**Eastern screech-owl**	**owl**	**X**	**X**	**X**
Melanerpes carolinus	Red-bellied woodpecker	woodpecker	X	X	X

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[2] Pennsylvania state status: PA-CA: candidate as risk; PA-CR: candidate rare; PA-E: Endangered, PA-SC: special concern, PA-T: threatened; PA-PX: extirpated - Species that have disappeared from Pennsylvania since 1600 but still exist elsewhere.

[3] Indicates state listed and/or Partners in Flight species (status given in parentheses after scientific name – also in bold).

Appendix Table 52 (continued). Avian species observed at HOFU.

Scientific Name[1]	Common Name	Group	Historical Records	1994	1999 to 2001
***Melanerpes erythrocephalus*[3] (IB)**	**Red-headed woodpecker**	**woodpecker**	**X**	**X**	**X**
Meleagris gallopavo	Wild turkey	groundbird	X	X	
Melospiza georgiana	Swamp sparrow	passerine	X	X	
Melospiza melodia	Song sparrow	passerine	X	X	X
Mergus merganser	Common merganser	waterfowl	X		
Mergus serrator	Red-breasted merganser	waterfowl	X		
Mimus polyglottos	Northern mockingbird	passerine	X	X	X
Mniotilta varia	Black-and-white warbler	passerine	X	X	X
Molothrus ater	Brown-headed cowbird	passerine	X	X	X
Myiarchus crinitus	Great crested flycatcher	passerine	X	X	X
***Nycticorax nycticora*[3]*x* (PA-E)**	**Black-crowned night-heron**	**wader**	**X**		
Oporornis formosus[3] (IB)	**Kentucky Warbler**	**passerine**	**X**	**X**	
Oporornis philadelphia	Mourning warbler	passerine		X	
Oxyura jamaicensis	Ruddy duck	waterfowl	X		
***Pandion haliaetus*[3] (PA-T)**	**Osprey**	**raptor**	**X**		
***Parkesia noveboracensis*[3] (PA-CR)**	**Northern waterthrush**	**passerine**	**X**	**X**	
Parula americana	Northern parula	passerine	X	X	X
Passer domesticus	House sparrow	passerine	X	X	X
Passerculus sandwichensis	Savannah sparrow	passerine	X	X	
Passerella iliaca	Fox sparrow	passerine	X	X	
Passerina cyanea	Indigo bunting	passerine	X	X	X
Petrochelidon pyrrhonota	Cliff swallow	passerine	X	X	X

[1] Partners in Flight (PIF) status: IA: High Continental Priority, High Regional Responsibility; IB: High Continental Priority, Low Regional Responsibility; IIA: High Regional Priority, High Regional Concern; IIB: High Regional Priority, High Regional Responsibly; IIC: High Regional Priority, High Regional Threats (Kearney 2003).

[2] Pennsylvania state status: PA-CA: candidate as risk; PA-CR: candidate rare; PA-E: Endangered, PA-SC: special concern, PA-T: threatened; PA-PX: extirpated - Species that have disappeared from Pennsylvania since 1600 but still exist elsewhere.

[3] Indicates state listed and/or Partners in Flight species (status given in parentheses after scientific name – also in bold).

Appendix Table 52 (continued). Avian species observed at HOFU.

Scientific Name[1]	Common Name	Group	Historical Records	1994	1999 to 2001
Phalacrocorax auritus	Double-crested cormorant	waterfowl	X		
Phasianus colchicus	Ring-necked pheasant	groundbird	X	X	X
Pheucticus ludovicianus	Rose-breasted grosbeak	passerine	X	X	X
Picoides pubescens	Downy woodpecker	woodpecker	X	X	X
Picoides villosus	Hairy woodpecker	woodpecker	X	X	X
***Pipilo erythrophthalmus*[3] (IIA)**	**Eastern towhee**	**passerine**	**X**	**X**	**X**
***Piranga olivacea*[3] (IIB)**	**Scarlet tanager**	**passerine**	**X**	**X**	**X**
Plectrophenax nivalis	Snow bunting	passerine	X	X	
Podiceps auritus	Horned grebe	waterfowl	X		
***Podilymbus podiceps*[3] (PA-CR)**	**Pied-billed grebe**	**waterfowl**	**X**		
Poecile atricapilla	Black-capped chickadee	passerine	X	X	X
Poecile carolinensis	Carolina chickadee	passerine	X	X	X
Polioptila caerulea	Blue-gray gnatcatcher	passerine	X	X	X
Pooecetes gramineus	Vesper sparrow	passerine	X	X	
***Progne subis*[3] (PA-CR)**	**Purple martin**	**passerine**		**X**	
Regulus calendula	Ruby-crowned kinglet	passerine	X	X	X
Regulus satrapa	Golden-crowned kinglet	passerine	X	X	X
***Riparia riparia*[3] (PA-CR)**	**Bank swallow**	**passerine**	**X**	**X**	
Sayornis phoebe	Eastern phoebe	passerine	X	X	X
***Scolopax minor*[3] (IA)**	**American woodcock**	**shorebird**			**X**
Seiurus aurocapilla	Ovenbird	passerine	X	X	X
***Seiurus motacilla*[3] (IIB)**	**Louisiana waterthrush**	**passerine**	**X**	**X**	**X**

[1] Partners in Flight (PIF) status: IA: High Continental Priority, High Regional Responsibility; IB: High Continental Priority, Low Regional Responsibility; IIA: High Regional Priority, High Regional Concern; IIB: High Regional Priority, High Regional Responsibly; IIC: High Regional Priority, High Regional Threats (Kearney 2003).

[2] Pennsylvania state status: PA-CA: candidate as risk; PA-CR: candidate rare; PA-E: Endangered, PA-SC: special concern, PA-T: threatened; PA-PX: extirpated - Species that have disappeared from Pennsylvania since 1600 but still exist elsewhere.

[3] Indicates state listed and/or Partners in Flight species (status given in parentheses after scientific name – also in bold).

Appendix Table 52 (continued). Avian species observed at HOFU.

Scientific Name[1]	Common Name	Group	Historical Records	1994	1999 to 2001
Setophaga ruticilla	American redstart	passerine	X	X	X
Sialia sialis	Eastern bluebird	passerine	X	X	X
Sitta canadensis	Red-breasted nuthatch	passerine	X	X	X
Sitta carolinensis	White-breasted nuthatch	passerine		X	X
Sphyrapicus varius	Yellow-bellied sapsucker	woodpecker	X	X	X
Spinus pinus	Pine siskin	passerine	X	X	
Spizella arborea	American tree sparrow	passerine	X	X	
Spizella passerina	Chipping sparrow	passerine	X	X	X
***Spizella pusilla*[3] (IIA)**	**Field sparrow**	**passerine**	**X**	**X**	**X**
Stelgidopteryx serripennis	Northern rough-winged swallow	passerine	X	X	X
Strix varia	Barred owl	owl		X	X
Sturnella magna	Eastern meadowlark	passerine	X	X	
Sturnus vulgaris	European starling	passerine	X	X	X
Tachycineta bicolor	Tree swallow	passerine	X	X	X
Thryothorus ludovicianus	Carolina wren	passerine	X	X	X
Toxostoma rufum	Brown thrasher	passerine	X	X	X
Troglodytes aedon	House wren	passerine	X	X	X
Troglodytes troglodytes	Winter wren	passerine	X	X	
Turdus migratorius	American robin	passerine	X	X	X
Tyrannus tyrannus	Eastern kingbird	passerine	X	X	X
Vermivora chrysoptera[3] (PA-CA)	**Golden-winged Warbler**	**passerine**		**X**	
Vermivora peregrina	Tennessee warbler	passerine	X	X	X

[1] Partners in Flight (PIF) status: IA: High Continental Priority, High Regional Responsibility; IB: High Continental Priority, Low Regional Responsibility; IIA: High Regional Priority, High Regional Concern; IIB: High Regional Priority, High Regional Responsibly; IIC: High Regional Priority, High Regional Threats (Kearney 2003).

[2] Pennsylvania state status: PA-CA: candidate as risk; PA-CR: candidate rare; PA-E: Endangered, PA-SC: special concern, PA-T: threatened; PA-PX: extirpated - Species that have disappeared from Pennsylvania since 1600 but still exist elsewhere.

[3] Indicates state listed and/or Partners in Flight species (status given in parentheses after scientific name – also in bold).

Appendix Table 52 (continued). Avian species observed at HOFU.

Scientific Name[1]	Common Name	Group	Historical Records	1994	1999 to 2001
***Vermivora pinus*[3] (IB)**	**Blue-winged warbler**	**passerine**	**X**	**X**	**X**
Vermivora pinus x chrysopt.	Brewster's warbler	passerine			X
Vermivora ruficapilla	Nashville warbler	passerine			X
Vireo flavifrons	Yellow-throated vireo	passerine	X	X	X
Vireo griseus	White-eyed vireo	passerine	X	X	X
Vireo olivaceus	Red-eyed vireo	passerine	X	X	X
Vireo philadelphicus	Philadelphia vireo	passerine		X	X
Vireo solitarius	Blue-headed vireo	passerine	X	X	X
***Wilsonia canadensis*[3] (IB)**	**Canada warbler**	**passerine**	**X**	**X**	**X**
Wilsonia citrina	Hooded warbler	passerine	X	X	X
Wilsonia pusilla	Wilson's sparrow	passerine	X		
Zenaida macroura	Mourning dove	groundbird	X	X	X
Zonotrichia albicollis	White-throated sparrow	passerine	X	X	X
Zonotrichia leucophrys	White-crowned sparrow	passerine	X	X	

[1] Partners in Flight (PIF) status: IA: High Continental Priority, High Regional Responsibility; IB: High Continental Priority, Low Regional Responsibility; IIA: High Regional Priority, High Regional Concern; IIB: High Regional Priority, High Regional Responsibly; IIC: High Regional Priority, High Regional Threats (Kearney 2003).

[2] Pennsylvania state status: PA-CA: candidate as risk; PA-CR: candidate rare; PA-E: Endangered, PA-SC: special concern, PA-T: threatened; PA-PX: extirpated - Species that have disappeared from Pennsylvania since 1600 but still exist elsewhere.

[3] Bold type indicates state listed and/or Partners in Flight species (status given in parentheses after scientific name).

Appendix Table 53. Mammals predicted to occur and those actually observed at HOFU

Scientific name	Common name	Observed[2]	Scientific name	Common name	Observed[2]
Blarina brevicauda	Northern short-tailed shrew	HOFU	***Myotis sodalis*** [1] **(LE, PE)**	**Indiana bat**	**HBW**
Canis latrans	Coyote	SW	*Napaeozapus insignis*	Woodland jumping mouse	HOFU
Castor canadensis	American beaver	SW[3]	*Neotoma floridana*	Eastern woodrat	SW
Clethrionomys gapperi	Southern red-backed vole	SW	***Nycticeius humeralis*** [1] **(CR)**	**Evening bat**	**SW**
Condylura cristata	Starnose mole	SW	*Odocoileus virginianus*	White-tailed deer	SW
Didelphis virginiana	Virginia opossum	HOFU	*Ondatra zibethicus*	Muskrat	SW
Eptesicus fuscus	Big brown bat	HOFU	*Parascalops aquaticus*	Hairytail mole	SW
Glaucomys volans	Southern flying squirrel	HOFU	*Peromyscus leucopus*	White-footed mouse	HOFU
Lasionycteris noctivagans [1] **(CR)**	**Silver-haired bat**	SW	*Peromyscus maniculatus*	Deer mouse	SW
Lasiurus borealis	Red bat	HOFU	*Pipistrellus subflavus*	Eastern pipistrelle	SW
Lasiurus cinereus	Hoary bat	SW	*Procyon lotor*	Raccoon	HOFU
Lontra canadensis [1] **(CA)**	**River otter**	**HBW**[3]	*Sciurus carolinensis*	Eastern gray squirrel	HOFU
Lynx rufus **(CA)** [1]	**Bobcat**	**HBW**	*Sorax cinereus*	Masked shrew	HOFU
Marmota monax	Woodchuck	HOFU	*Sorex fumeus*	Smokey shrew	SW
Mephitis mephitis	Striped skunk	SW	*Sylvilagus floridanus*	Eastern cottontail	HOFU
Microtus pennsylvanicus	Meadow vole	HOFU	*Synaptomys cooperi*	Southern bog lemming	SW
Microtus pinetorum	Woodland vole	SW	*Tamias striatus*	Eastern chipmunk	HOFU
Mustela erminea	Ermine	HOFU	*Tamiasciurus hudsonicus*	Red squirrel	HOFU
Mustela frenata	Long-tailed weasel	SW	*Urocyon cinereoargenteus*	Gray fox	HBW
Mustela vison	Mink	HBW	*Ursus americanus*	Black bear	HBW
Myotis lucifugus	Little brown myotis	HOFU	*Vulpes* vulpes	Red fox	HOFU
Myotis septentrionalis [1] **(EP, CR)**	**Northern myotis**	**HOFU**	*Zapus hudsonius*	Meadow jumping mouse	HOFU

[1] Federal listed codes: LE: Listed endangered, LT: Listed threatened EP: Proposed endangered; State listed status codes: CA: Candidate at risk, CU: Condition undetermined, CR: Candidate rare, PE: Pennsylvania endangered, PX: Pennsylvania extirpated (also in bold).

[2] HOFU: Species observed by Yahner et al. 1997 and from park wildlife observation cards; HBW: Species observed in Hopewell Big Woods; SW: Species present state-wide.

[3] Suitable habitat is lacking within HOFU.

Appendix Table 54. Amphibians and reptiles that have been documented or might be expected to occur at HOFU.

Scientific Name (expected to occur)	Common Name	Recorded in 1994-1995 (Yahner)	Recorded in 2000-2001 (Tiebout)	PARS [2] 2013-2014
Amphibians				
Ambystoma jeffersonianum	Jefferson salamander		X[3]	X
Ambystoma maculatum	Spotted salamander	X	X	X
Anaxyrus americanus americanus	Eastern American toad	X	X	X
Anaxyrus fowleri	Fowler's toad			X
Desmognathus fuscus	Northern dusky salamander	X	X	X
Eurycea bislineata	Northern two-lined salamander	X	X	X
Eurycea longicauda	Longtail salamander	X	X	X
Gyrinophilus p. porphyriticus	Northern spring salamander			U
Hemidactylium scutatum	Four-toed salamander	X	X	X
Hyla versicolor	Gray treefrog	X	X	X
Lithobates clamitans melanota	Green frog	X	X	X
Lithobates catesbeianus	Bullfrog			X
Lithobates palustris	Pickerel frog	X	X	X
Lithobates pipiens	Northern leopard frog	X		
Lithobates sylvaticus	Wood frog	X	X	X
Notophthalmus v. viridescens	Red-spotted newt	X		X
Plethodon cinereus	Redback salamander	X	X	X
Plethodon glutinosus	Slimy salamander	X	X	X
Pseudacris c. crucifer	Northern spring peeper	X	X	X

[1] Indicates state and/or federally listed species, or invasive exotics. Federal listed codes: LT: Listed threatened; State listed status codes: PT: Pennsylvania threatened, PC: Uncommon, could become endangered or threatened in the future (also in bold).

[2] Species observed in Berks and/or Chester Counties in 2013-2014 and recorded in the Pennsylvania Amphibian and Reptile Survey (PARS) online database. X: indicates recorded or likely to be present in park; U: indicates occurs within Berks and/or Chester County but unlikely to occur in HOFU due to lack of suitable habitat.

[3] One additional species is included but not listed due to its sensitive status.

Appendix Table 54 (continued). Amphibians and reptiles that have been documented or might be expected to occur at HOFU.

Scientific Name (expected to occur)	Common Name	Recorded in 1994-1995 (Yahner)	Recorded in 2000-2001 (Tiebout)	PARS [2] 2013-2014
Amphibians (continued)				
Pseudotriton r. ruber	Northern red salamander	X	X	X
***Scaphiopus holbrooki* (PT)** [1]	**Eastern spadefoot toad**			X
Reptiles				
Agkistrodon contortrix mokasen	Northern copperhead	X		X
Chelydra s. serpentina	Common snapping turtle	X	X	X
Chrysemys p. picta	Eastern painted turtle	X		X
Clemmys guttata	Spotted turtle	X		X
Coluber c. constrictor	Northern black racer	X	X	X
***Crotalus horridus* (PC)** [1]	**Timber rattlesnake**			**U**
Diadophis punctatus edwardsii	Ringneck snake	X	X	X
Elaphe alleghaniensis	Eastern ratsnake	X	X	X
Eumeces fasciatus	Five-lined skink			U
Glyptemys insculpta	Wood turtle	X	X	X
Heterodon platirhinos	Eastern hog-nosed snake			X
Lampropeltis t. triangulum	Eastern milk snake	X	X	X
Nerodia s. sipedon	Northern water snake		X	X
Opheodrys aestivus	Northern rough green snake			U
Plestiodon laticeps	Broad-headed skink			U
***Pseudemys rubiventris* (PT)** [1]	**Red-bellied cooter**			U
Regina septemvittata	Queen snake			X

[1] Indicates state and/or federally listed species, or invasive exotics. Federal listed codes: LT: Listed threatened; State listed status codes: PT: Pennsylvania threatened, PC: Uncommon, could become endangered or threatened in the future (also in bold).

[2] Species observed in Berks and/or Chester Counties in 2013-2014 and recorded in the Pennsylvania Amphibian and Reptile Survey (PARS) online database. X: indicates recorded or likely to be present in park; U: indicates occurs within Berks and/or Chester County but unlikely to occur in HOFU due to lack of suitable habitat.

[3] One additional species is included but not listed due to its sensitive status.

Appendix Table 54 (continued). Amphibians and reptiles that have been documented or might be expected to occur at HOFU.

Scientific Name (expected to occur)	Common Name	Recorded in 1994-1995 (Yahner)	Recorded in 2000-2001 (Tiebout)	PARS [2] 2013-2014
Reptiles (continued)				
Sceloporus undulatus	Eastern fence lizard			X
Sternotherus odoratus	Common musk turtle	X	X	X
Storeria d. dekayi	Northern brown snake	X		X
Terrapene c. carolina	Eastern box turtle	X	X	X
Thamnophis sirtalis	Eastern gartersnake	X	X	X
***Trachemys scripta elegans* (invasive)** [1]	**Red-eared slider**	**X**	**X**	**X**
Trachemys scripta	Pond slider			X
Virginia v. valeriae	Eastern smooth earth snake			X
Total species recorded		**30**	**26**	**41 expected** [3]

[1] Indicates state and/or federally listed species, or invasive exotics. Federal listed codes: LT: Listed threatened; State listed status codes: PT: Pennsylvania threatened, PC: Uncommon, could become endangered or threatened in the future (also in bold).

[2] Species observed in Berks and/or Chester Counties in 2013-2014 and recorded in the Pennsylvania Amphibian and Reptile Survey (PARS) online database. X: indicates recorded or likely to be present in park; U: indicates occurs within Berks and/or Chester County but unlikely to occur in HOFU due to lack of suitable habitat.

[3] One additional species is included but not listed due to its sensitive status.

Appendix Table 55. Timeline of Significant benchmarks and project communications for the Hopewell Furnace NHS Natural Resource Condition Assessment report.

Date	Meeting Type	Topics Discussed [1]	Attendees [1]
22 December 2015	personal communication	Completed revision and final NRCA given to C. Roman	URI: MJ James NPS-NER: C. Roman
15 December 2015	email communication	Final revised draft sent to NRCA coordinator	URI: MJ James NPS-NER: C. Arnott, C. Roman
11-14 December 2015	email communication	Clarification email about threatened and endangered species in NRCA	URI: MJ James NPS-HOFU: A. Ruhe, NPS-NER: C. Arnott, C. Roman
November-December 2015	Author revisions to second round of comments	Additional comments incorporated as per reviewer request	URI: MJ James
7 December 2015	In person	Brief discussion on status of revisions with J. Comiskey while JC was at URI on other NPS business	URI: MJ James NPS-NER: J. Comiskey
25 November 2015	Author received final comments from park staff		URI: MJ James NPS-NER: C Roman
Summer 2015	Conference call regarding detail of sensitive information in NRCA	Sensitive information in Draft NRCA	URI: MJ James NPS-NER: W. Gawley, S Cowell, NPS-HOFU: K. Jensen and others
8 April 2015	Final revised NRCA draft sent to park for final approval	Draft NRCA	URI: MJ James NPS-NER: W. Gawley
13 February 2015	Email communication regarding sensitive information in NRCA	Draft NRCA	URI: MJ James NPS-NER: W. Gawley, C. Roman

Appendix Table 55 (continued). Timeline of Significant benchmarks and project communications for the Hopewell Furnace NHS Natural Resource Condition Assessment report.

Date	Meeting Type	Topics Discussed [1]	Attendees [1]
December-April 2015	Author revisions	NRCA revised as per reviewers comments	URI: MJ James, B. Bannon
3-12 December 2014	Email communication	Reviewer's comments received by author	NPS-NER:W. Gawley, URI: MJ James
28 July 2014	Email communication	Draft NRCA distributed for review by C. Roman (NPS-NER)	NPS-HOFU/VAFO: K. Jensen, D. Gibson, E. Shean-Hammond, K. Hammand, A. Ruhe. NPS-MIDN: M. Johnson, N. Dammeyer NPS-NER: P Sharpe, J. Comiskey, S. Colwell, H. Salzer
17 May 2014	Author's revisions	Selected NRCA chapters revised as per reviewers comments and incorporated into final Draft	URI: MJ James, B. Bannon
April 2014	Email communication	Selected chapters sent out to preliminary review	NPS-HOFU/VAFO: K. Jensen, D. Gibson, E. Shean-Hammond, K. Hammand, A. Ruhe. NPS-MIDN: M. Johnson, N. Dammeyer NPS-NER: P Sharpe, J. Comiskey, S. Colwell, H. Salzer
22-24 January 2014	Email communications	GIS data transfer logistics	NPS-MIDN: M. Johnson URI: MJ James-Pirri, B. Bannon NPS-NCBN: D. Skidds
4 November 2013	Phone and email communications	GIS data transfer logistics	NPS-MIDN: M. Johnson URI: MJ James, R. Duhaime, B. Bannon NPS-NCBN: D. Skidds
29-30 October 2013	Email communication	GIS data for HOFU	NLT: M. Boatright, J. Thorne URI: MJ James, R. Duhaime, B. Bannon

Appendix Table 55 (continued). Timeline of Significant benchmarks and project communications for the Hopewell Furnace NHS Natural Resource Condition Assessment report.

Date	Meeting Type	Topics Discussed [1]	Attendees [1]
24 October 2013	Email communication	GIS data for HOFU	NPS-MIDN: M. Johnson NPS-NER: C. Roman NLT: J. Thorne URI: MJ James, R. Duhaime, B. Bannon
22 October 2013	In person	Natural Resource Condition Assessment kickoff meeting, field survey of park habitats.	NPS-HOFU/VAFO: K. Jensen, D. Gibson, E. Shean-Hammond, K. Hammand, A. Ruhe, L. Ritchey. NPS-MIDN: M. Johnson NPS-NER: C. Roman, P. Sharpe. NWT: J. Thorne. POLC: S. Stubbe: URI: MJ James

[1] Acronyms used - NPS-MIDN: National Park Service, Mid-Atlantic Network; NPS-NER: National Park Service, Northeast Region; NPS-NCBN: National Park Service, Northeast Coastal and Barrier Network; NPS-HOFU/VAFO: National Park Service, Hopewell Furnace NHS and Valley Forge NHP; NLT: Natural Lands Trust; URI: University of Rode Island; POLC: Pennsylvania Outdoor Lighting Council.

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