National Park Service
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Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Harriet Tubman Underground Railroad National Historical Park

Natural Resource Report NPS/HATU/NRR—2019/1897

ON THE COVER
Harriet Tubman Underground Railroad National Historical Park
Todd Lookingbill, University of Richmond

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Executive Summary

Harriet Tubman Underground Railroad National Historical Park is located in Dorchester, Caroline, and Talbot counties on the Eastern Shore of Maryland. The park includes the 480-acre Jacob Jackson site administered by the National Park Service, parts of Blackwater National Wildlife Refuge administered by the US Fish and Wildlife Service, Harriet Tubman Underground Railroad State Park, and private land. The park offers abundant natural resources and seeks to preserve them to reflect the landscape and ambiance that was present when Harriet Tubman lived in Maryland more than 150 years ago. The site was formally added to the National Park System as a National Monument in 2013 and as a National Historical Park in 2014, recognizing Harriet Tubman's life and work as a slave and freedom fighter.

Natural resources within the 25,000-acre park include a diverse biota with high ecological integrity, including the presence of the federally-listed northern long-eared bat (*Myotis septentrionalis*) and recovered populations of bald eagles (*Haliaeetus leucocephalus*) and Delmarva fox squirrels (*Sciurus niger cinereus*). Forest resources are abundant but may be at risk from an overabundance of the non-native Sika deer (*Cervus nippon*). Wetlands are wide-spread but are threatened by degraded water quality, rising sea level, increasingly intense and frequent coastal storms, and non-native species. Midnight skies and silent stars are an important historical resource but are diminished by light pollution and road noise.

Harriet Tubman Underground Railroad National Historical Park Visitor Center. Photo: Todd Lookingbill, September 2016.

Natural Resource Condition Assessments (NRCAs) assess and report on park resource conditions and are meant to complement traditional issue and threat-based resource assessments. NRCAs report on current conditions, trends, and critical data gaps for a subset of natural resource indicators. This analysis is designed to help park managers as they prioritize workloads, design studies to acquire data for important park resources, and communicate messages about park natural and cultural resources to varied audiences. The goal of this report is to deliver science-based information that is credible and has practical uses for park decision-making, planning, and partnership activities.

Data for the NRCA were compiled for the park to assess four categories of resources – air quality, water resources, biological integrity, and landscape dynamics – and to calculate an overall park-level condition score. Data were obtained from the Air Resources Division of the National Park Service, the US Fish and Wildlife Service at Blackwater National Wildlife Refuge and at the Chesapeake Bay Field Office, and the US Geological Survey. Additional expertise was provided by staff at the National Park Service Inventory and Monitoring Program, the Olmsted Center for Landscape Preservation, and the Natural Sounds and Night Skies Division, as well as by faculty at the California University of Pennsylvania and the University of Maryland Center for Environmental Science, and biologists at the Maryland Department of Natural Resources.

Strong collaboration with park staff was essential to the success of this assessment. Project collaboration and exchange of data occurred throughout the project during scoping meetings, site visits, and follow-up conference calls. Outcomes of these discussions helped to identify natural resources to be included in the assessment, identify key indicators to assess the condition of these resources, assign desired reference values for the indicators, and interpret findings. These meetings also provided the context for current conditions and background information.

Although the park is not part of any National Park Service Inventory and Monitoring (I&M) network at this time, efforts were made to select indicators that are consistent with those used in I&M programs. NPS I&M ecological monitoring aggregates indicators into broad 'vital signs' categories including the four that formed the basis of the Harriet Tubman Underground Railroad National Historical Park NRCA: Air Quality, Water Resources, Biological Integrity, and Landscape Dynamics. After consultation with park staff and experts, a total of 20 indicators and 30 metrics were used in the assessment. Each indicator assessment includes detailed information of indicator relevance, metrics used to quantify indicator condition, reference thresholds, assessment of current condition and trend, and an assessment of data gaps and level of confidence for that indicator. Reference thresholds ideally were ecologically based and derived from scientific literature. However, when data were not available to support peer-reviewed ecological thresholds, regulatory or management-based thresholds were used. In some cases, thresholds were determined based on best professional judgement in cooperation with park staff. In all instances, the source of the threshold used is stated in the report.

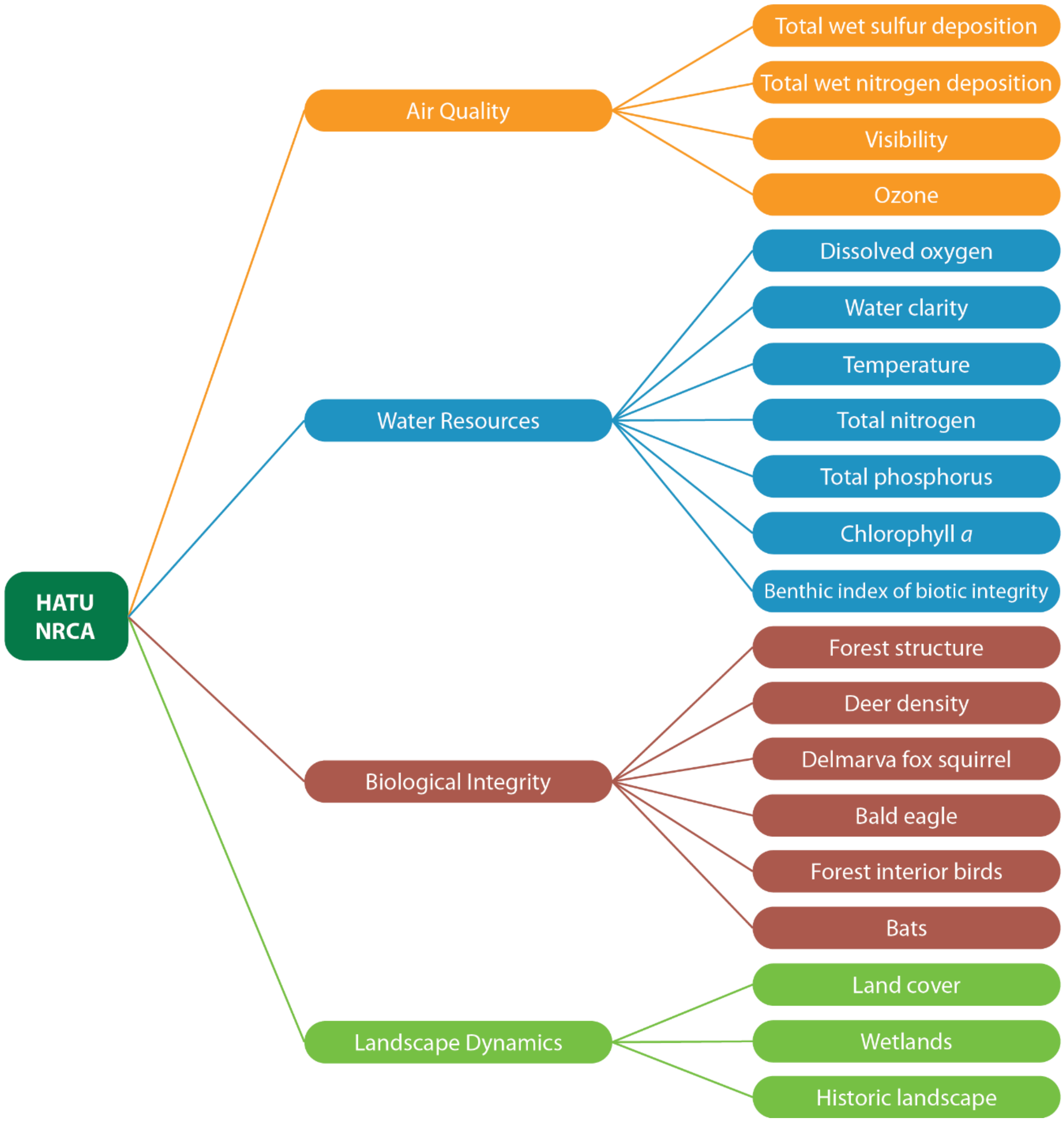


Figure E-1. Vital signs (second column) and indicators (third column) for Harriet Tubman Underground Railroad National Historical Park (HATU) used in its Natural Resource Condition Assessment (NRCA).

Final condition scores were calculated based on the percentage of sites or samples that met or exceeded threshold values for each indicator. An indicator attainment score of 100% reflected that the indicator at all sites and at all times met the threshold identified to maintain natural resources. Once attainment was calculated for each indicator, unweighted means were calculated to determine the condition of each vital sign category and for the park as a whole. This means that indicators were not treated differently in the final park assessment based on differences in their confidence ratings or other considerations. Indicators were assigned a qualitative rating corresponding to the quantitative score: "significant concern" = 0-33% references condition attainment; "moderate concern" = 34-66% reference condition attainment; and "good" = 67-100% reference condition attainment. Indicators were color coded according to standard NPS NRCA symbology where red = "significant concern", yellow = "moderate concern", and green = "good" (Table E-1).

Table E-1. Results of the Natural Resource Condition Assessment of Harriet Tubman Underground Railroad National Historical Park.

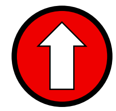
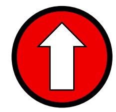
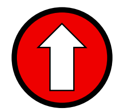
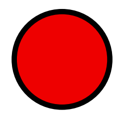
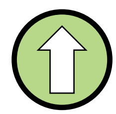
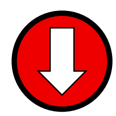
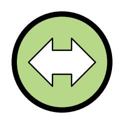
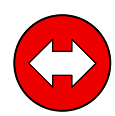
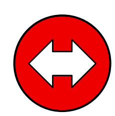
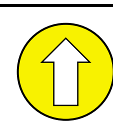
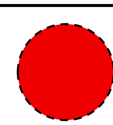
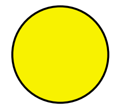
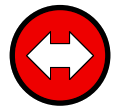
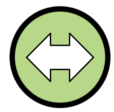
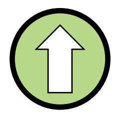
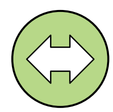
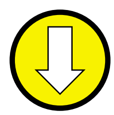
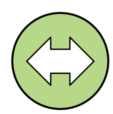
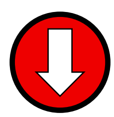
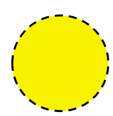
Resource category	Indicator of concern	Condition status/trend	Percent attainment
Air quality	Wet sulfur deposition		25%
Air quality	Wet nitrogen deposition		0%
Air quality	Visibility		0%
Air quality	Ozone		27%
Water resources	Dissolved oxygen		69%
Water resources	Water clarity		32%
Water resources	Temperature		100%
Water resources	Total nitrogen		19%
Water resources	Total phosphorus		29%
Water resources	Chlorophyll a		43%
Water resources	Benthic Index of Biotic Integrity		33%

Table E-1 (continued). Results of the Natural Resource Condition Assessment of Harriet Tubman Underground Railroad National Historical Park.

Resource category	Indicator of concern	Condition status/trend	Percent attainment
Biological integrity	Forest structure		49%
Biological integrity	Deer		0%
Biological integrity	Delmarva fox squirrels		100%
Biological integrity	Bald eagles		90%
Biological integrity	Forest interior birds		100%
Biological integrity	Bats		63%
Landscape dynamics	Land cover		100%
Landscape dynamics	Wetlands		0%
Landscape dynamics	Historic landscape		63%

The average condition of natural resources at Harriet Tubman Underground Railroad National Historical Park was assessed to be of "moderate concern" based on an average attainment of 46% of desired threshold scores for the four vital sign categories. Air quality was identified as the most highly degraded resource, warranting "significant concern" with only 13% attainment of reference conditions. Air quality degradation is a regional issue over which park management has limited control. However, the park can play a leading role in regional education of the causes and consequences of air pollution. Trends in regional air quality for wet nitrogen deposition, wet sulfur deposition, visibility, and ozone are improving.

The condition of aquatic resources was assessed as “moderate concern” with % reference condition attainment. With the exception of benthic macroinvertebrates, data for water resources were available for some parts of the park through a monitoring program administered by the Blackwater National Wildlife Refuge. Dissolved oxygen and temperature were in generally good condition although periods of hypoxia were observed during hot weather. Chlorophyll *a* content of the water was assessed as “moderate concern” and improving, but nutrients and visibility were assessed as “significant concern” and not improving. Benthic macroinvertebrates are good indicators of the general condition of sediments and were assessed as “significant concern”. Continued monitoring of all indicators is warranted, and establishment of sampling stations within the Jacob Jackson site recommended. Best management practices may need to be adopted along streams to minimize nutrient run-off into streams.

Biological integrity was assessed as “good” with 67% reference condition attainment. Bald eagles, Delmarva fox squirrels, and forest interior birds were assessed in “good” condition and either stable or improving. Although bats are diverse in the region, some species are at risk of significant decline owing to white nose syndrome, a disease that plagues many areas of North America. Therefore, bat condition was assessed as “moderate concern” and declining. Forest monitoring protocols were established within Blackwater National Wildlife Refuge and used once to monitor forests. These data allowed assessment of forests within the park as “moderate concern”. However, trend could not be established, highlighting the need for continued monitoring and the establishment of plots within the Jacob Jackson site. Deer may be a particular threat to forest resources and were assessed as “significant concern” given the high density of non-native Sika deer. Impacts of deer on forest resources within the Jacob Jackson site should therefore be assessed and differences in NPS and USFWS management priorities recognized.

Landscape dynamics in the park were assessed as being of “moderate concern” with 54% reference condition attainment. The park has minimal impervious surface cover and large amounts of natural landscapes such that land cover was assessed as “good”. Confidence in this indicator was moderate and could be increased by developing a time-series of high-resolution, classified land cover imagery. Historic landscapes, with its viewshed, soundscapes, and night skies, was assessed as moderate concern with low confidence in the assessment owing to the lack of data. Data collection priorities could therefore include the implementation of noise and light pollution monitoring protocols. Wetlands were assessed as “significant concern” owing to reported surface elevation losses and the prediction that wetlands will become permanently inundated with rising sea levels. Given these trends in wetland losses, a protocol for monitoring surface elevations throughout the park should be considered a management priority.

Acknowledgments

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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 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*

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:

- 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

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[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 visit the NRCA Program website.

[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. History and Enabling Legislation

On March 25, 2013, Harriet Tubman Underground Railroad National Monument was formally added to the National Park System. It was designated a National Historical Park on December 19, 2014 to commemorate the life and work of Harriet Tubman, a former slave who led others into freedom prior to the American Civil War using the Underground Railroad.

2.1.1. Pre-European Settlement

According to archaeological findings such as excavated stone tools and spear heads, Native Americans inhabited the mid-Atlantic region for at least 10,000 years prior to European arrival. Captain John Smith, who explored the Chesapeake Bay in 1607 found mostly Algonquin-speaking tribes with three main chiefdoms - the Powhatan of eastern Virginia, the Piscataway of the western shore, and the Nanticoke of the eastern shore and Delaware. According to Algonquian linguist Blair Rudes, the name Chesapeake Bay is thought to come from the Algonqian word 'chesepiocc' to mean 'village near a big river".

2.1.2. European Arrival

Cecil Calvert, 2nd Lord of Baltimore, founded the Maryland colony in 1632 after his father, George Calvert, had received a royal charter for the land from King Charles I. The first colonists arrived at St. Clements Island in March 1634 aboard the Ark and the Dove to found the settlement of St. Mary's. Dorchester County was formed 37 years later in 1669 and named after the Earl of Dorset, a family friend of the Calverts. People settling in Dorchester County were farmers or watermen, living off of the bounties that the land and water provided.

2.1.3. Slavery

Slavery in the United States started in 1619 when Dutch traders brought ~19 Africans to Jamestown, Virginia. Maryland received its first slaves in 1642 when Africans were brought to St. Mary's City. However, most farmers of tobacco, the chief commodity crop at the time, made use of indentured servants from England, so slavery in Maryland did not start in earnest until the 1690s. By 1755, 40% (ca. 130,000 people) of Maryland's population was African American, with the highest concentrations in tidewater regions, where rivers are influenced by tides and rivers could facilitate the movement and export of produce. Maryland was in the northern tier of slave states, and, as a Union border state, was not included in President Lincoln's Emancipation Proclamation, declaring all slaves in Southern Confederate states to be free. Slavery was abolished in Maryland in 1864, one year before the American Civil War ended.

2.1.4. Harriet Tubman

Harriet Tubman was born as a slave in Dorchester County in 1822 as the daughter of Harriet "Rit" Green and Benjamin Ross. She had 8 siblings. The family was the property of white plantation owners with property at Peter's Neck, 10 miles SW of Cambridge. In 1823, Rit and her 5 children, including young Harriet, were separated from their father when they were required to move several miles SE of Peter's Neck at part of an inheritance. Young Harriet was separated from her mother when she was 6 years old and was required to labor in houses and along the waterfront checking muskrat traps. A blow to her head during the 1830's left Harriet with an epileptic condition and a lifetime of seizures.

As an adult, Tubman was allowed to hire out to a master of her own choosing. During the late 1830s and early 1840s, she worked in the forest and on the docks, where Tubman learned to communicate with mariners. In 1844, she married John Tubman, a local free black man, and continued to labor throughout the region until October 1849 when she escaped to Philadelphia rather than be sold.

My home, after all, was down in Maryland...

-Harriet Tubman

Visitors congregate outside of the Bucktown store, the site where Harriet Tubman was injured as a child. National Park Service.

Although safe in Philadelphia, Tubman missed her family and friends and was determined to rescue as many as she could. With the use of the Underground Railroad network of collaborators, and her own knowledge and skill of how to navigate through and survive in marshes, swamps, and forests of the Choptank and Blackwater area, Tubman returned to the Eastern Shore around 13 times. Her first rescue took place in December 1850, but she did not stop returning to the Eastern Shore until she was able to rescue her parents in 1857 and other remaining family members in 1860. Each time, Tubman traveled mostly at night, following the North Star or moss on trees and observing currents in rivers and streams. She was a survivalist who was able to use the natural resources of the area to her advantage.

> ***I never ran my train off the track and I never lost a passenger.***
> *-Harriet Tubman*

Even when Tubman's time on the Eastern Shore had ended, she provided instructions to others and motivated many other rescues and escapes. Her reputation continued to grow as an activist in the northern abolitionist and suffrage circles, committing her life to the struggle for liberty, equality, and justice for all. Tubman settled on a property near Auburn, New York, with her parents and near other family and friends. She never wanted to be separated again. Tubman married Civil War veteran Nelson Davis and adopted their daughter Gertie. Tubman died on March 10, 1913 of pneumonia. She is buried in Fort Hill Cemetery in Auburn.

Portrait of Harriet Tubman taken between 1871 and 1876 in Auburn, New York. Library of Congress.

2.1.5. Post-Civil War Era

Maryland's Eastern Shore in Dorchester County continues to this day to be dominated by a landscape mosaic of agriculture, forests, and wetlands, similar to Harriet Tubman's time. Forests are mixed pine and oak and have been repeatedly harvested for timber. Farms no longer produce tobacco but instead cultivate corn, soybeans, and sorghum. Sea level rise and eroding marshes have made the landscape wetter, and developed areas around Cambridge have expanded; however, it is still possible to see the landscape that Tubman travelled through and labored in, mostly because the region's vast water resources put constraints on land use.

One notable landscape feature within Harriet Tubman Underground Railroad National Historical Park is the Jacob Jackson Home site. Jacob Jackson was a free black man who was literate and owned 140 acres of land. The property is near Stewart's Canal, a 7-mile long canal constructed from 1810 to 1832 by free and enslaved people. The canal connects Parsons Creek to the Blackwater River, and it helped move timber out to the docks on the Choptank River. Tubman lived in the vicinity while working for John T. Stewart and most likely was acquainted with Jacob Jackson. Thus, Tubman knew that she could appeal to Jackson in helping her rescue her brothers by providing critical means of communication. The property generally reflects the landscape Tubman was familiar with, and it was deeded to the National Park Service by The Conservation Trust to establish the initial Harriet Tubman Underground Railroad National Monument.

The view toward the Jacob Jackson Home site within Harriet Tubman Underground Railroad National Historical Park. Photo: Todd Lookingbill, September 2016.

Another notable landscape feature within the park is the Blackwater National Wildlife Refuge, with its wetlands and rivers. Managed by the US Fish and Wildlife Service and established in 1933, the refuge constitutes a significant portion of Harriet Tubman Underground Railroad National Historical Park. Although known and managed as a migratory bird sanctuary along the Atlantic Flyway, the refuge is culturally significant because it includes landscapes that Harriet Tubman traveled through and worked in. For example, Peter's Neck, where Tubman most likely was born, is adjacent to the refuge and was home to a large free and enslaved black community that Tubman called her community.

Managed by the U.S. Fish and Wildlife Service, Blackwater National Wildlife Refuge constitutes a significant portion of Harriet Tubman Underground Railroad National Historical Park. Photo: Todd Lookingbill, September 2016.

2.1.6. Enabling Legislation

Harriet Tubman Underground Railroad National Historical Park was formally added to the National Park System as a National Monument on March 25, 2013 by President Obama under the Antiquities Act. It was designated a National Historical Park on December 19, 2014 under Public Law 113-291 through the Carl Levin and Howard P. "Buck" McKeon National Defense Authorization Act. This legislation required that the Secretary of the Interior "administer the historical park and the portion of the Harriet Tubman Underground Railroad National Monument administered by the National Park Service (in Maryland) as a single unit of the National Park System, which shall be known as the Harriet Tubman Underground National Historical Park." The historical park in New York was established on January 10, 2017 and is a sister park to the one in Maryland.

Harriet Tubman Underground Railroad National Historical Park preserves and interprets the historical, cultural and natural resources associated with the life, work and legacy of Harriet Tubman and serves as a touchstone for the understanding of the Underground Railroad for the nation.

2.2. Geographic Setting

2.2.1. Location

Harriet Tubman Underground Railroad National Historical Park encompasses 25,000 acres of federal, state, and private land in Dorchester and Caroline Counties of Maryland (Figure 2-1). It is located on the Coastal Plain along the shorelines of the Chesapeake Bay, framed by the Choptank River to the north, the Transquaking River watershed to the east, the Blackwater River to the south, and Taylors Island to the west. The City of Cambridge is located ca. 5 miles to the north of the park boundary.

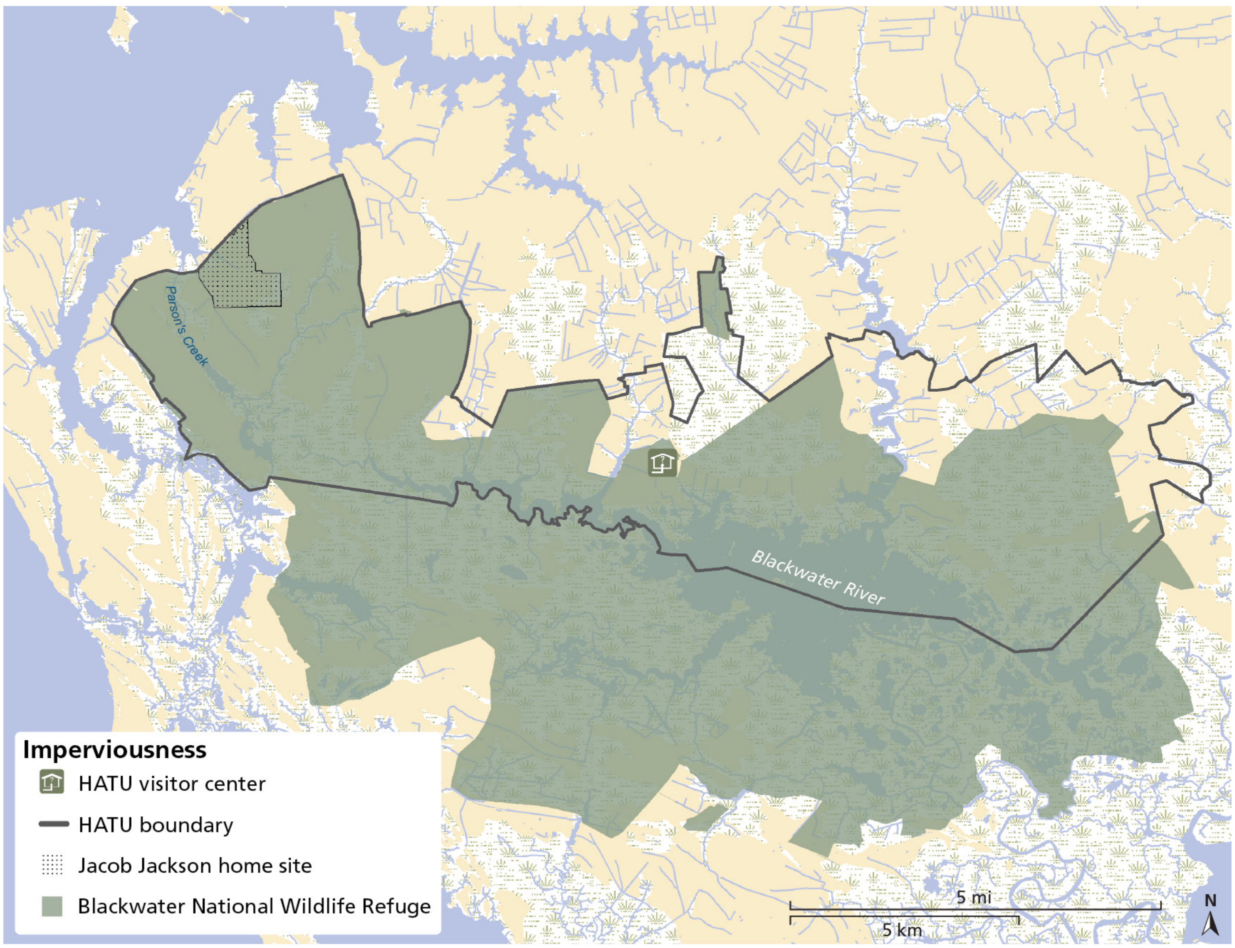


Figure 2-1. Boundary of Harriet Tubman Underground Railroad National Historical Park (Data source: Maryland Department of Natural Resources).

2.2.2. Geomorphology and Land Use

Harriet Tubman Underground Railroad National Historical Park is located in the Mid-Atlantic Coastal Plain Physiographic Area and is at the center of the Chesapeake Bay/Susquehanna River Ecosystem (USFWS 2006). The Chesapeake Bay was formed in the late Eocene epoch by a bolide impact that shaped the largest known impact crater of the US. Since then, the shorelines of the Chesapeake Bay have been shaped by erosion and deposition of sediments that are carried by the major rivers to the Bay. Over time, marsh grasses colonized, which facilitate the accretion process and allow tidal platforms to be maintained relative to sea level. At Harriet Tubman Underground Railroad National Historical Park, these processes have shaped vast expanses of forested swamps and emergent marshes.

The park is largely undeveloped, and much of the park is covered by wetland, forests, and fields. A few roads bisect the park. Visitors Centers for the Harriet Tubman Underground Railroad National Historical Park, Harriet Tubman Underground Railroad State Park, and the Blackwater National Wildlife Refuge are present, as are a few historical structures, such as Bucktown Store and Scott's Chapel.

The region surrounding the park is largely wetland or open water to the west and south, and agriculture and forest to the east and north (Figure 2-2). Small towns dot the landscape. The City of Cambridge approximately 5 miles north of the park (Figure 2-3) is Dorchester County's largest municipality with 12,468 inhabitants in 2016.

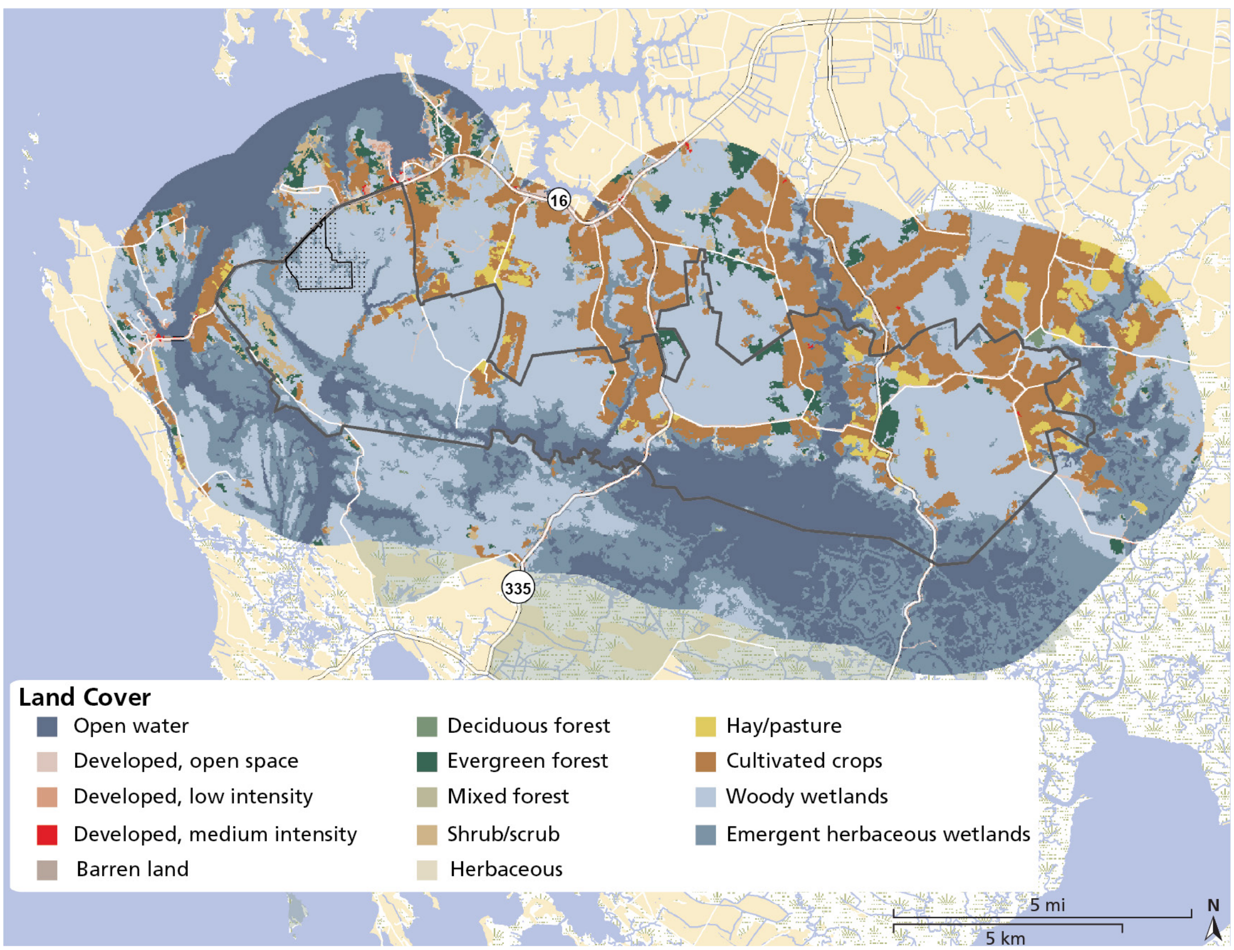


Figure 2-2. Land cover within the park and within a 3-km buffer around Harriet Tubman Underground Railroad National Historical Park (Data source: National Land Cover Dataset 2011).

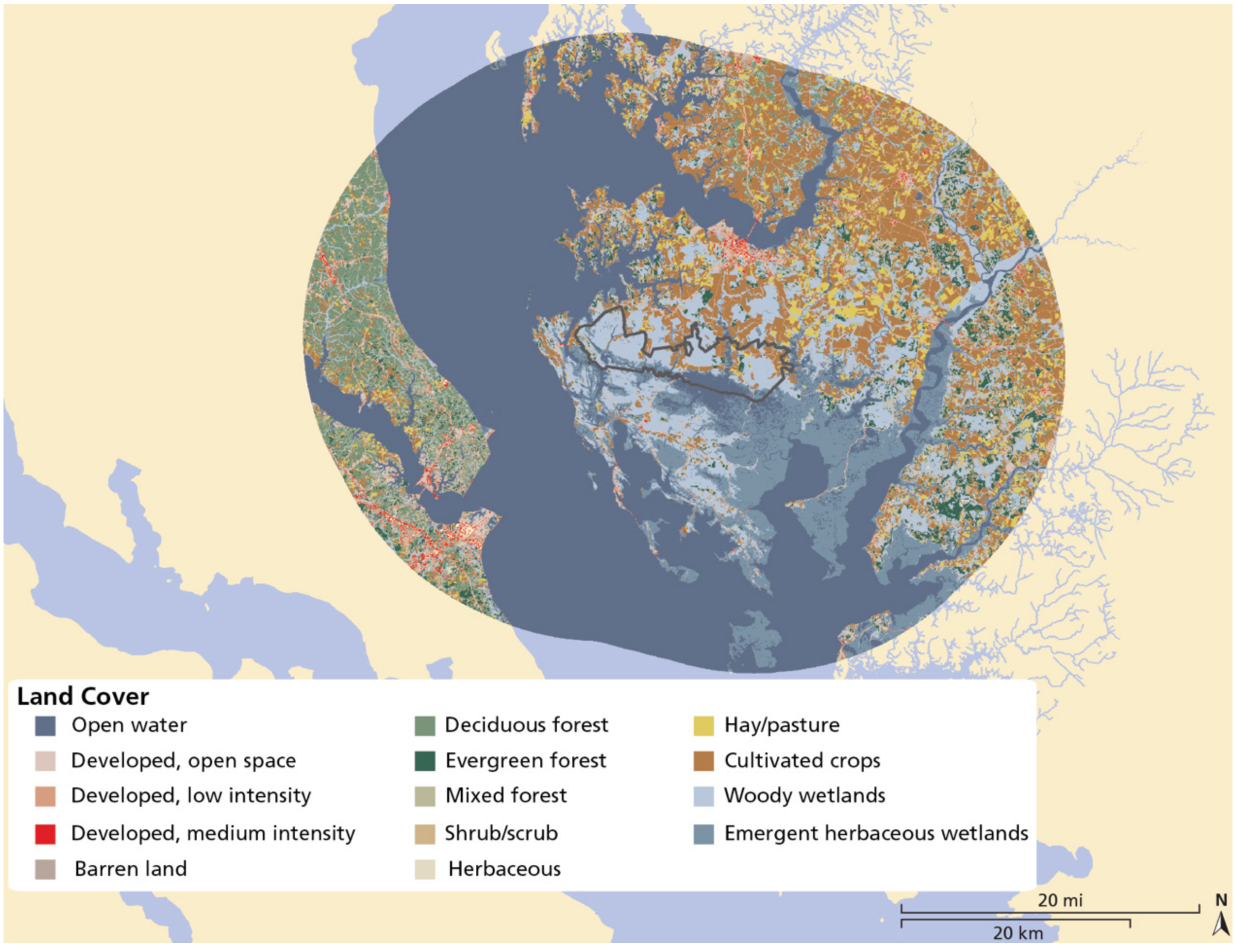


Figure 2-3. Land cover within the park and within a 30-km buffer around Harriet Tubman Underground Railroad National Historical Park (Data source: National Land Cover Dataset 2011).

Most areas within Harriet Tubman Underground Railroad National Historical Park are natural (Figure 2-4). Converted lands are managed mainly as croplands that are used to attract waterfowl for hunting at Blackwater National Wildlife Refuge. Croplands are clustered along tributaries to the Blackwater River (Little Blackwater River, Buttons Creek, Parson's Creek, and Corsey Creek), as well as south of Key Wallace Drive. Converted lands also include several of the park's cultural sites (Bazzel Church, Bucktown General Store, Harriet Tubman Childhood Home) located along Greenbriar Road, Bucktown Road, and Bestpitch Ferry Road.

Converted lands are much more prevalent outside the park boundaries and include croplands and developed areas (Figure 2-5).

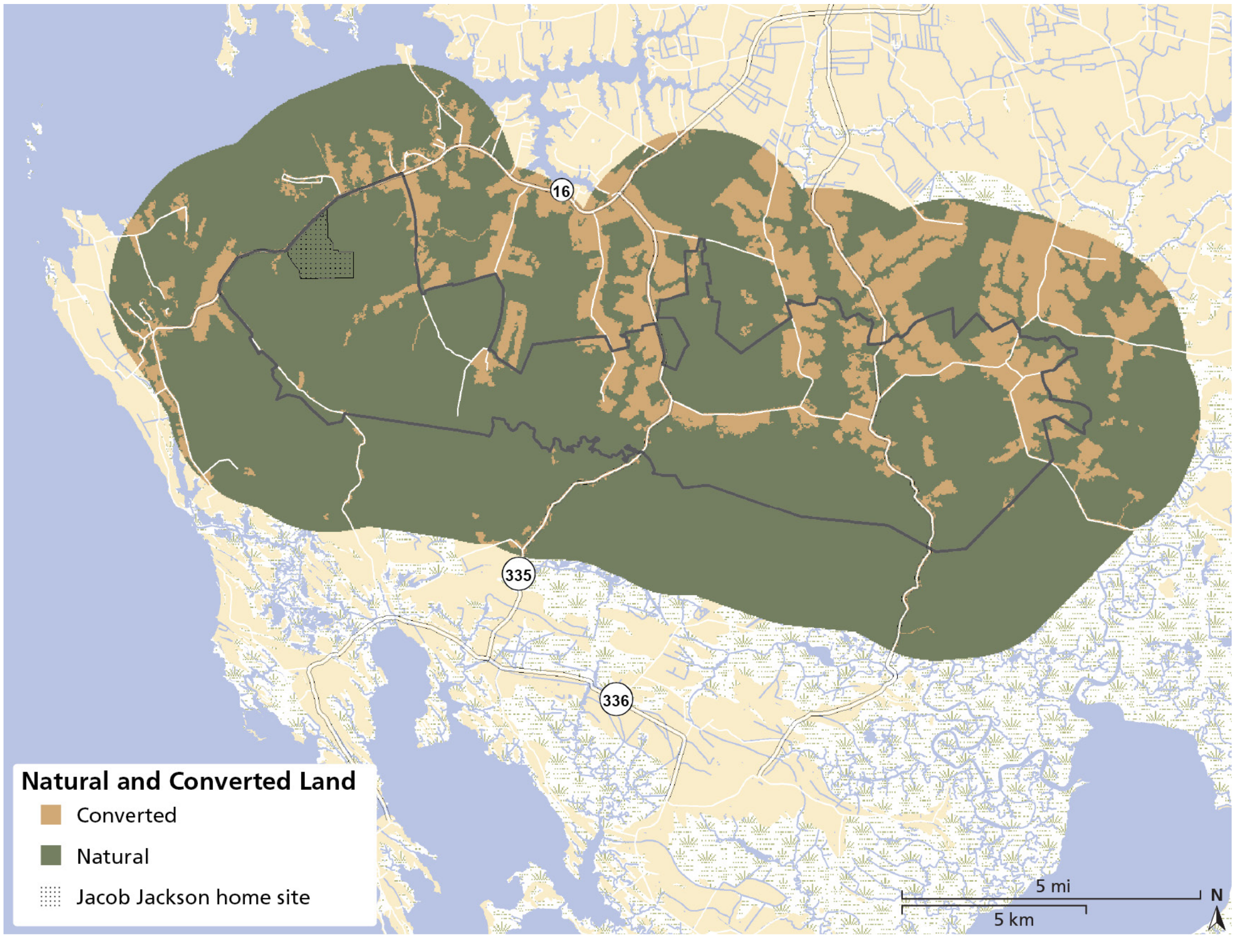


Figure 2-4. Natural and converted land cover within a 3-km buffer around Harriet Tubman Underground Railroad National Historical Park (Data source: NPScape 2011).

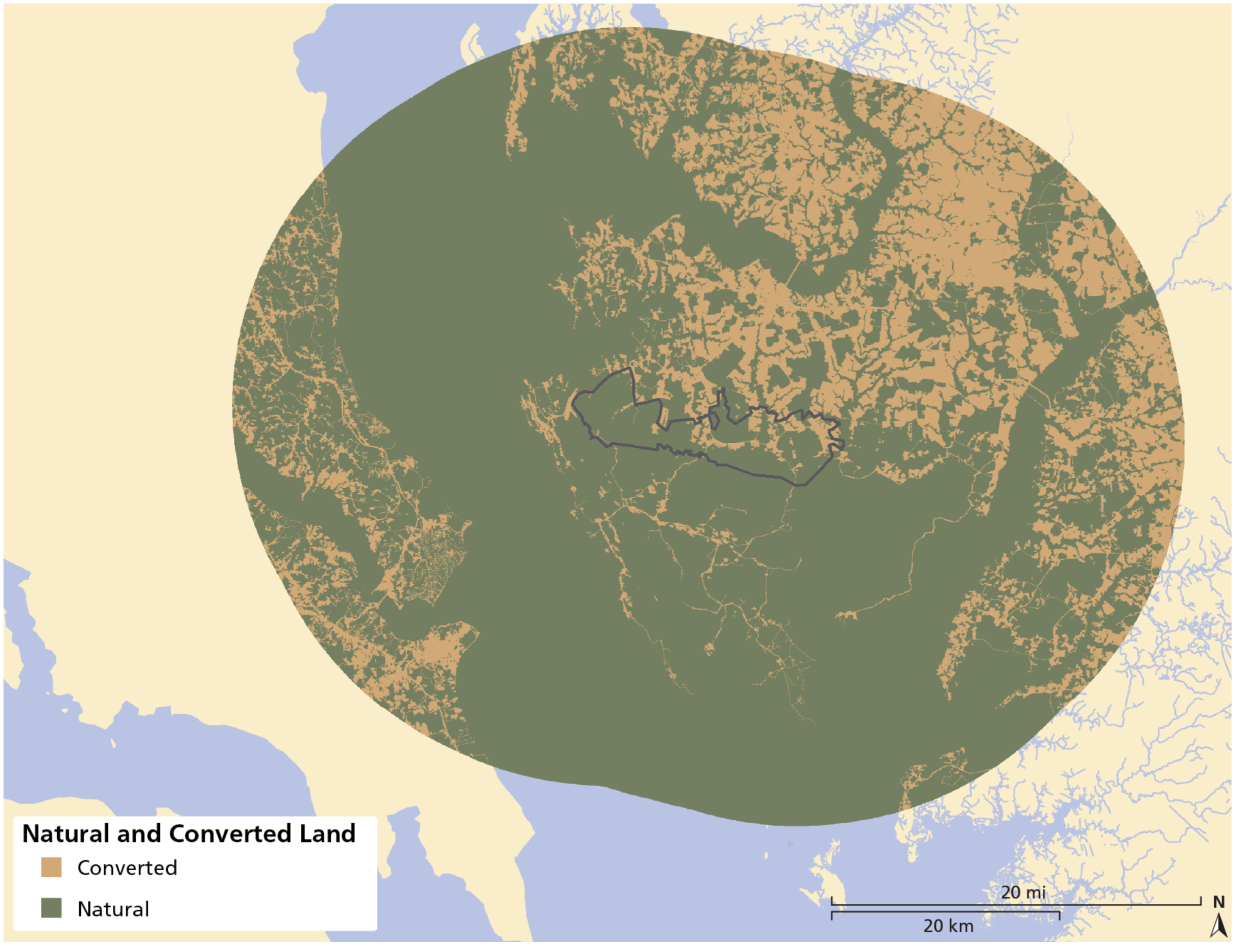


Figure 2-5. Natural and converted land cover within 30-km buffer of Harriet Tubman Underground Railroad National Historical Park (NPScape 2011).

2.2.3. Climate

Modern climatic conditions in the park are temperate with warm humid summers and cool winters. Summer temperatures frequently reach the upper 80s°F although 90°F temperatures are also felt. Average relative humidity is 55 percent in the midafternoon, with humidity rising at night and reaching on average 74 percent at dawn. Thunderstorms in July are frequent. Intense low-pressure systems can bring torrential rains and hurricane force winds between August and October. Winters are short with an average daily low temperature of 26°F. The frost free period is approximately 183 days. Annual rainfall averages 43 inches. About half of the rainfall falls within the growing season from April to September. Average snowfall is 15 inches, ranging from 2-37.5 inches. The sun shines 63 percent of the time in summer and 47 percent in the winter. The prevailing wind is from the south.

2.2.4. Population and Socioeconomic Conditions

The entire population of Dorchester County in 2017 was 32,162. The City of Cambridge is the largest municipality, and its population was estimated at 12,468 inhabitants in 2016. According to the US Census Bureau, approximately 63 percent of the population is Caucasian, 29 percent is African American, 5.6 percent is Hispanic, 1.2 percent is Asian, and 0.5 percent is Native American.

Between 2012 and 2016, the median household income was $47,907, and the median value of owner-occupied housing units was $188,100. Seventeen percent of the population are found living in poverty.

The NPScape landscape monitoring program (NPS 2014) tracks trends in housing density in buffer regions surrounding parks. Past (1970), recent (2010), and future (2050) housing projections are derived from the Spatially Explicit Regional Growth Model, SERGoM (NPS 2015b). Housing density is projected to change little within a 30-km radius around the park, except across the Chesapeake Bay in Prince Frederick County (Figure 2-6).

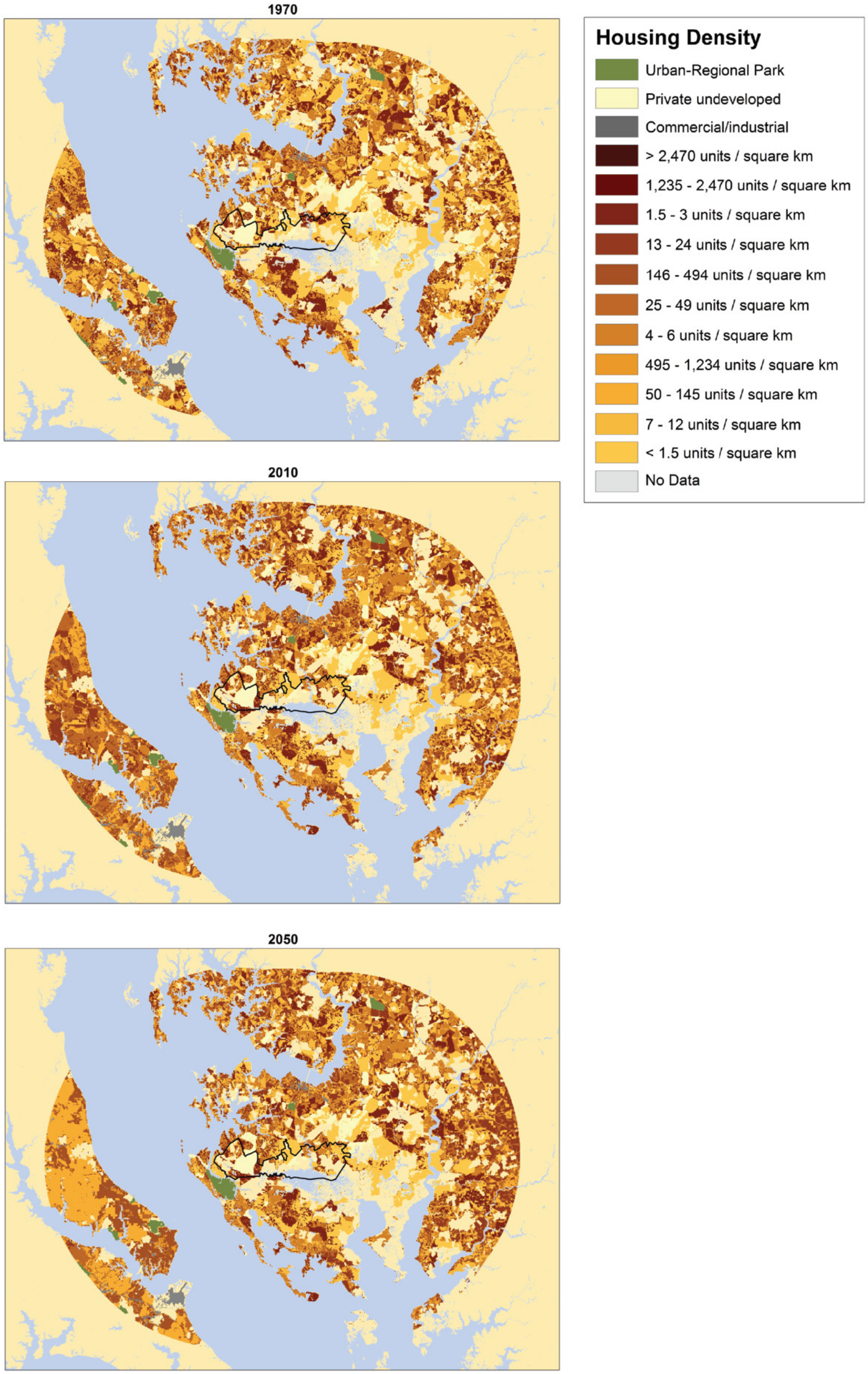


Figure 2-6. Housing density within a 30-km buffer of Harriet Tubman Underground Railroad National Historical Park in 1970, 2010, and 2050 (Data source: NPScape 2011).

2.2.5. Visitation Statistics

The visitor center at Harriet Tubman Underground Railroad National Historical Park was opened in March 2017. In 2017, the park attracted 100,000 visitors from 50 states and 60 countries. Nearby Blackwater National Wildlife Refuge attracts approximately 150,000 visitors annually, which bird watch, hunt, fish, and boat. 80,000 visitors use the refuge's visitor center each year.

2.3. Natural Resources

2.3.1. Ecological Units and Watersheds

<u>Watershed</u>

Harriet Tubman Underground Railroad National Park is situated within three watersheds in the greater Chesapeake Bay watershed: the Little Choptank River watershed in the west, the Transquaking River watershed in the east, and the Blackwater River Watershed to the south, which encompasses most of the park (Figure 2-7). The Chesapeake Bay has a watershed that covers approximately 64,000 square miles and encompasses parts of Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia, and the District of Columbia. The watershed is home to 18 million people with a net influx of people. The Chesapeake Bay estuary contains approximately 11,684 miles of shoreline and is considered the largest and most biologically diverse estuary in the United States, supporting over 3,600 species of plants, fish, and animals (Commonwealth of Virginia 2005).

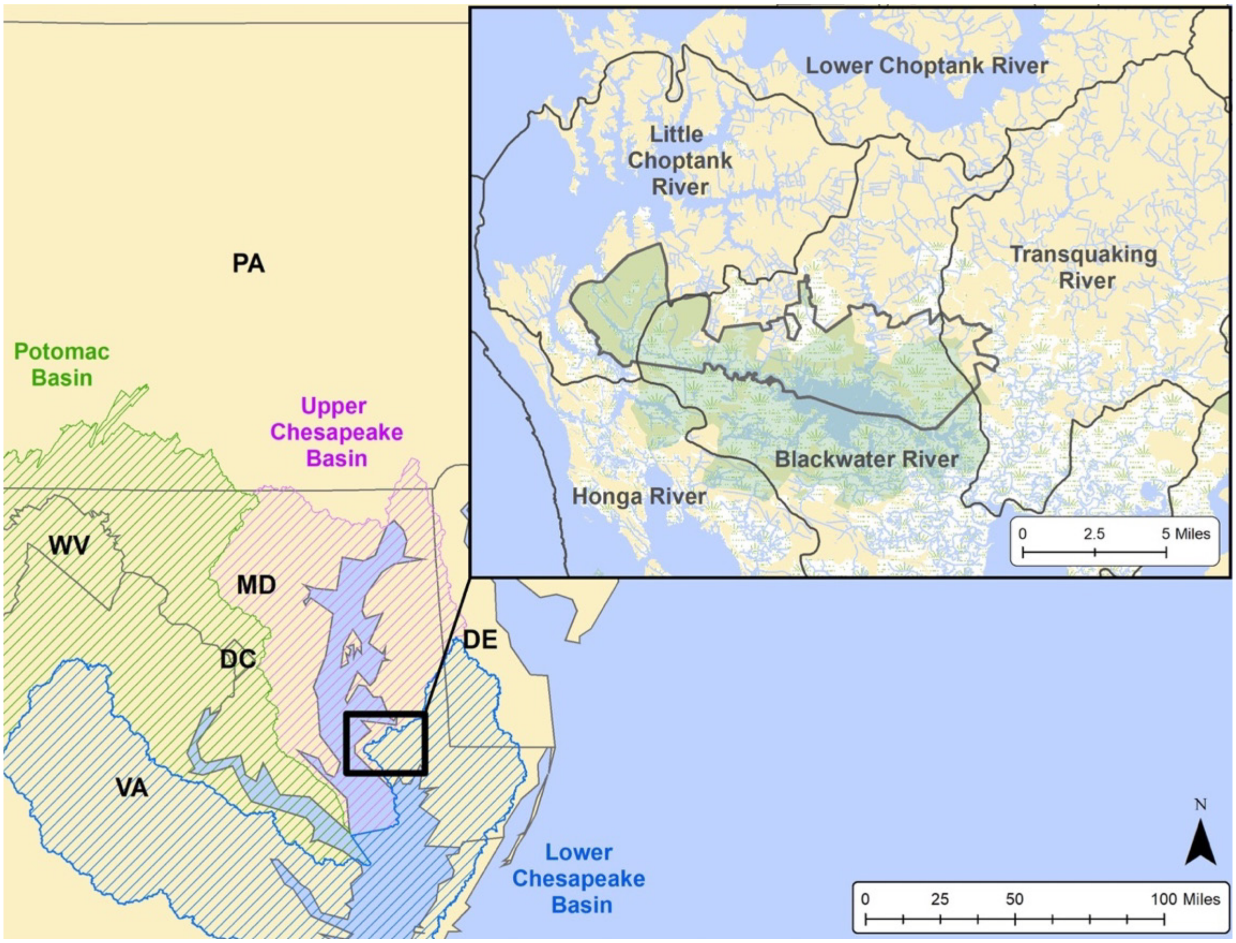


Figure 2-7. Basins and watersheds that intersect with or are near Harriet Tubman Underground Railroad National Historical Park (Data source: USGS National Hydrography Dataset). The park is located within the Upper and Lower Chesapeake Basins and intersects directly with the Choptank River, Blackwater River, and Transquaking River watersheds.

Geology and Topography

Harriet Tubman Underground Railroad National Historical Park is located on the Delmarva Peninsula, which was formed 1.8 - 10 million years ago in the upper Tertiary Period by emergence of the Coastal Plain through regional uplift (USFWS 2006). Uplift was followed by Miocene and late Miocene deposition of gravel sheets (Brandywine, Bridgeton, and Pensauken formations), topped by uplifted Pliocene shallow-marine formations (Beaverdam Sand, Yorktown Formation). The emerging Tertiary landscape surface was then shaped by many episodes of alternating periods of marine-estuarine deposition and fluvial down-cutting in the Pleistocene Epoch, resulting in three generations of paleo channels (Exmore, Eastville and Cape Charles) and the deposition of the Omar Formation (200,000-400,000 years old) and the Kent Island Formation (125,000-80,000 years ago). These Formations underlie Harriet Tubman Underground Railroad National Historical Park and Blackwater National Wildlife Refuge (USFWS 2006). Wetlands and dunes formed between 80,000 to 10,000 years ago, followed by the Holocene Epoch. Wind transported silt over the Delmarva Peninsula with poorly drained deposits ranging between 30 to 236 cm in thickness.

The current topography of Harriet Tubman Underground Railroad National Historical Park is relatively flat and ranges below sea level to approximately 2.5 meters above mean sea level (Figure 2-8). Local topographic highs are lowland flats that are flooded for part of the year depending on rainfall seasonality. Lowland flats are characterized by wetland swamps or have been converted to agricultural fields. The Blackwater River floodplain is characterized by tidal marshes that form peat.

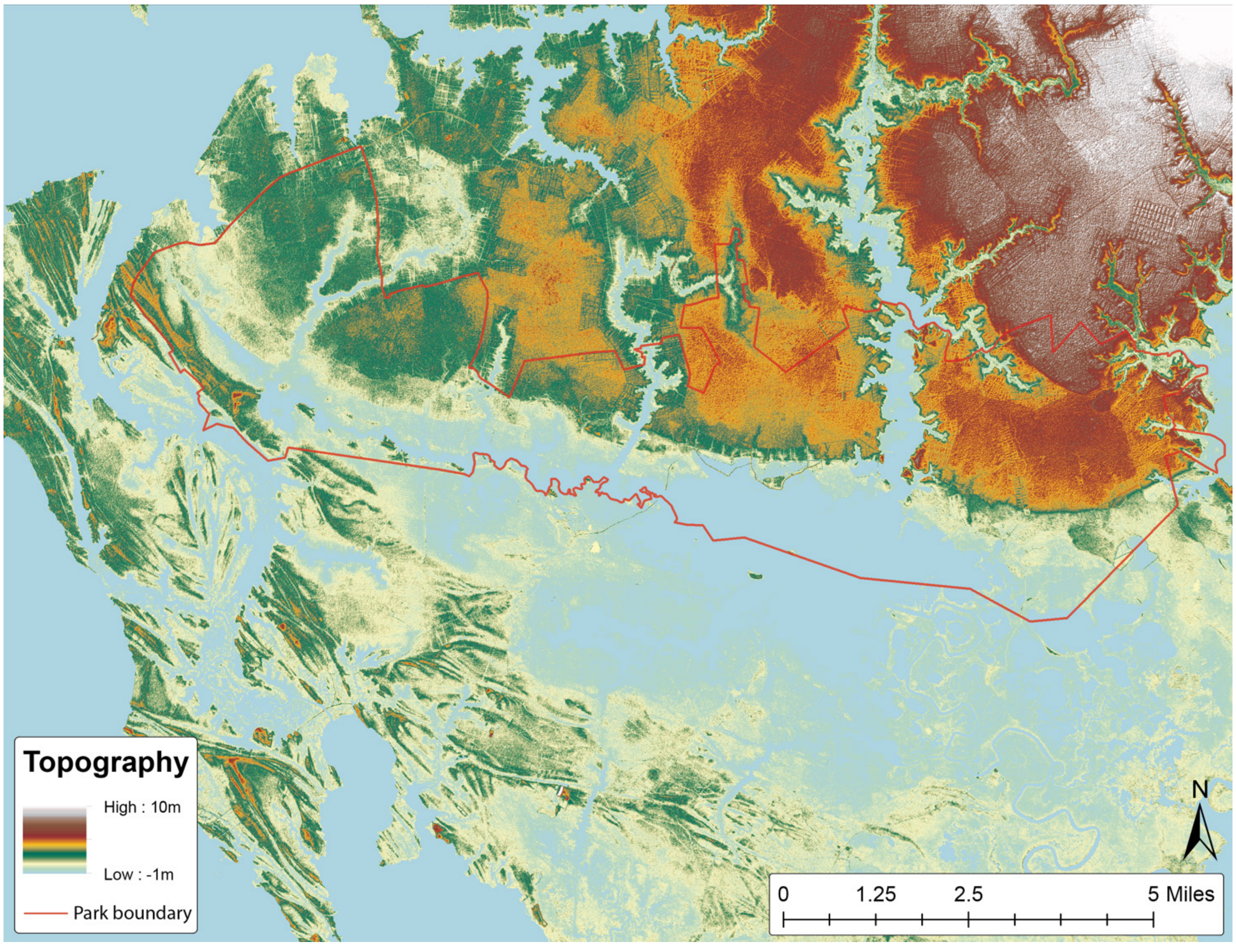


Figure 2-8. Topography/DEM map of Harriet Tubman Underground Railroad National Historical Park outlined in red and its surroundings in Dorchester County, MD (Data source: USGS National Elevation Dataset).

<u>Soils</u>

Soils associations within Harriet Tubman Underground Railroad National Historical Park include Elkton and Othello silt loams are considered prime farmland if properly drained and are found on lowland flats within (Figure 2-9) and outside (Figure 2-10) the park (USFWS 2006). Sunken mucky silt loams and Downer sandy loams are also common on lowland flats. Sunken soils surround the Honga peat and Bestpitch and Transquaking soils along the Blackwater River. Honga peat has a thick (56 cm) organic surface layer that was formed from organic deposits from salt tolerant plants. It overlays silty mineral sediments and is more prevalent in the western portion of the park in tidal marshes of the Blackwater River. The Bestpitch and Transquaking series is prevalent in estuarine tidal marshes along the shorelines of the Blackwater River and the Little Blackwater River. It consists of thick (up to 130 cm) organic deposits that overlay clayey mineral estuarine sediments. Other soil types that are only found in small areas include Chicone silt loam, Fallsington sandy loam, Galestown loamy sand, Hambrook loam, Ingelside sandy loam, Keyport silt loam, Klej-Galloway complex, Mattapex silt loam, Nassawango silt loam, Othello-Kentuck soils, Puckum muck, and Woodstown loam. Most of these soils are poorly to very poorly-drained with the exception of the moderately well-drained Mattapex silt loam.

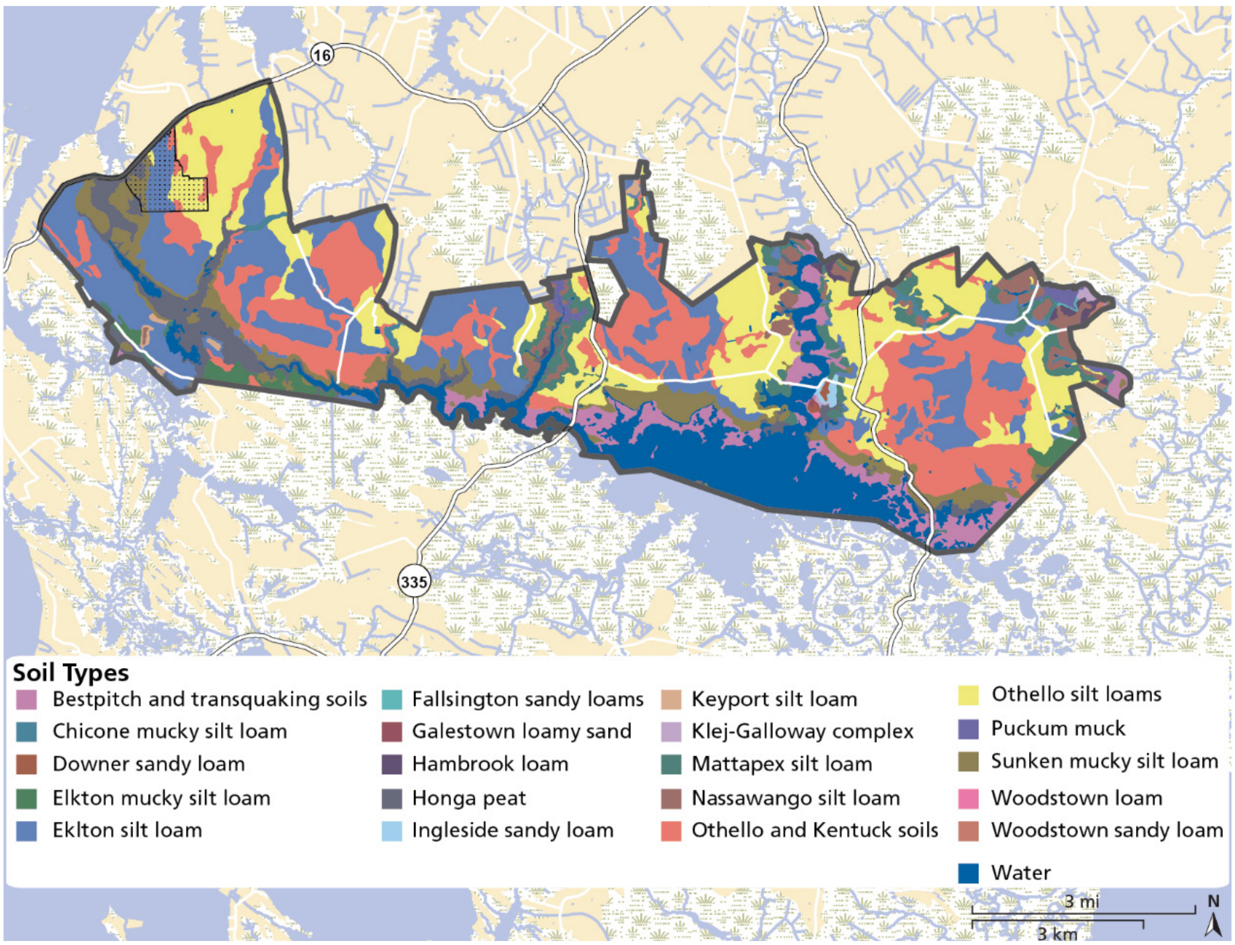


Figure 2-9. Soil types within Harriet Tubman Underground Railroad National Historical Park (Data source: National Resources Conservation Service).

Marsh deposits at Harriet Tubman Underground Railroad National Historical Park are estimated to be 3,800 years old (USFWS 2006). Deposits are, on average, 2-3 m thick and can be up to 4 m thick in the oldest areas of the marsh. The Blackwater and Little Blackwater rivers are the sources for most of the inorganic deposits. Sea level rise, in combination with ground subsidence, erosion, increasing salinities, and disturbance from muskrats, nutria, and geese, are replacing emergent marshes with open water (USFWS 2006).

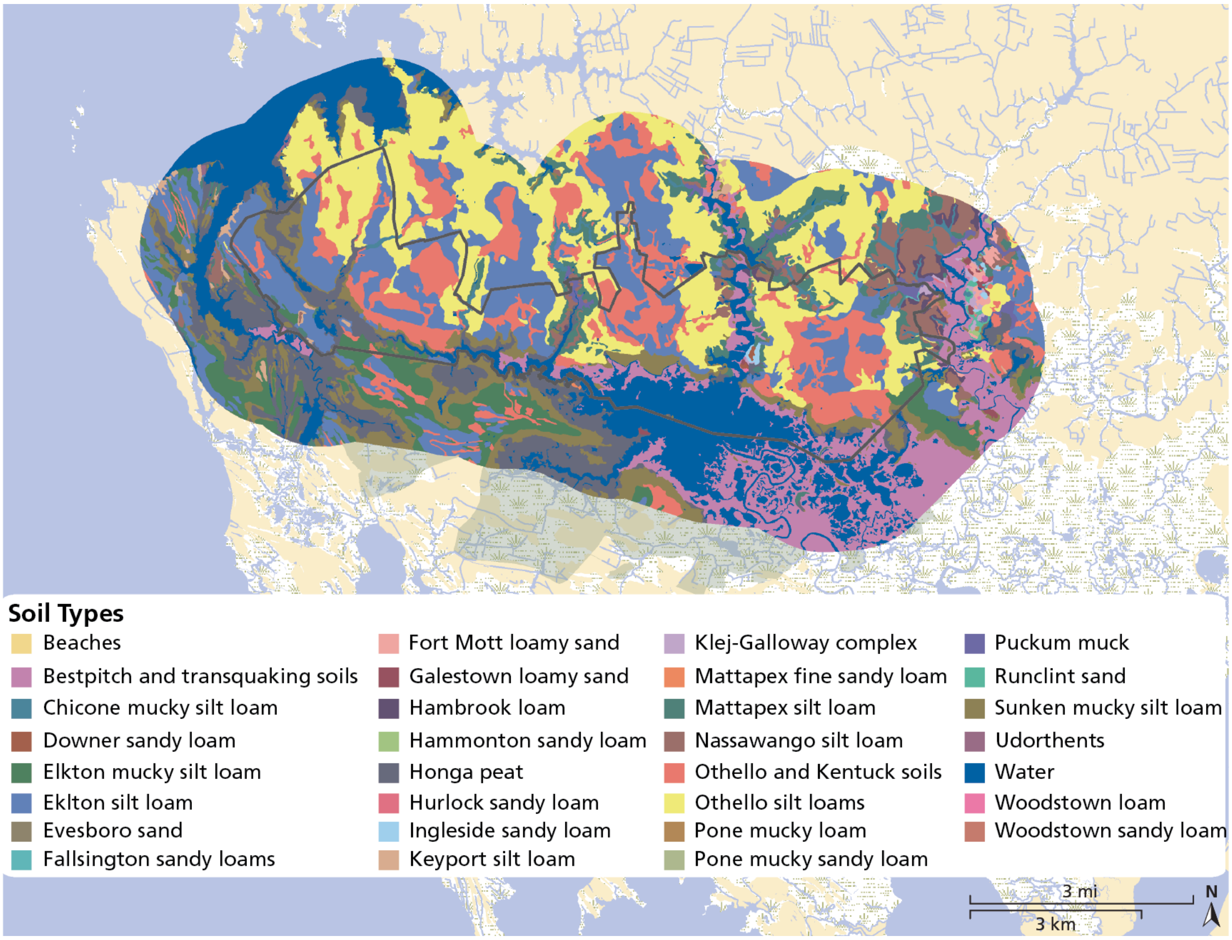


Figure 2-10. Soil types within a 3-km buffer of the Harriet Tubman Underground Railroad National Historical Park boundary (Data source: National Resources Conservation Service).

<u>Surface Waters</u>

Harriet Tubman Underground Railroad National Historical Park's natural landscape is shaped by its surface waters, which derives most of its water from precipitation. The Blackwater River runs west to east through the park until it eventually enters Fishing Bay, a large shallow embayment at the north end of Tangier Sound. The Blackwater River's largest tributary, the Little Blackwater (LB), enters the Blackwater River on the eastern end of the park and grades from upstream, freshwater to downstream, brackish water (Figure 2-11).

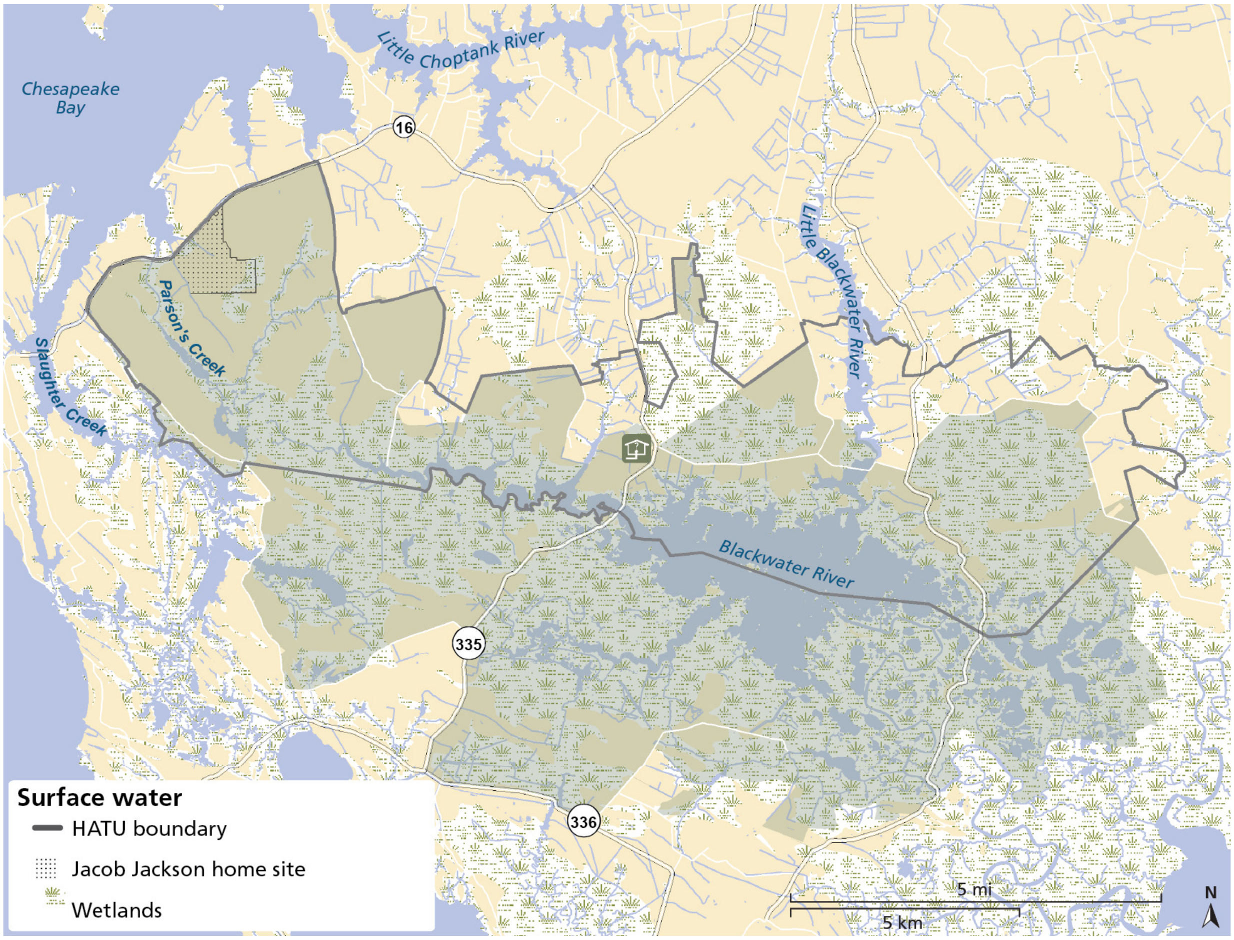


Figure 2-11. Surface waters of Harriet Tubman Underground Railroad National Historical Park (Data source: USGS National Hydrography Dataset).

In the 1800s, a man-made canal was constructed in the upper Blackwater River (UB), connecting the highly saline Little Choptank River to the historically freshwater section of the UB. As a result, the average salinity of the UB is much higher than it would naturally be and is also much higher than the LB tributary that runs into the Blackwater River (Love et al. 2008). In addition, this canal has caused hundreds of acres of freshwater marsh to be converted into saline open water and mud flats. In an effort to restore this habitat to a more natural state, a saltwater exclusion weir was constructed in March 2007 to help block saltwater from entering the UB system (Bessler and Whitbeck 2012).

A visitor standing on the Route 16 bridge over Stewart's Canal looks northward towards the Little Choptank River. Route 16 marks the boundary of Harriet Tubman Underground Railroad National Historical Park. National Park Service.

Tides are asynchronous (4-hour delay) at the opposite ends of the Blackwater River. The freshest water is found at the mouth of Buttons Creek. Salinity fluctuates seasonally.

Groundwater

The groundwater system at Harriet Tubman Underground Railroad National Historical Park is extremely shallow and is significantly affected by the tides. A potential for saltwater intrusion into the water table is high when seasonal hydraulic-gradient reversals between the shallow groundwater system and the Little Blackwater River coincide with inflow of brackish water from the Chesapeake Bay (USFWS 2006).

2.3.2. Resource Description

Flora

A plant inventory does not exist for Harriet Tubman Underground Railroad National Historical Park or for Blackwater National Wildlife Refuge; therefore, it is unclear how many species of plants make the area their home. A vegetation classification was developed for Blackwater National Wildlife Refuge (Figure 2-12).

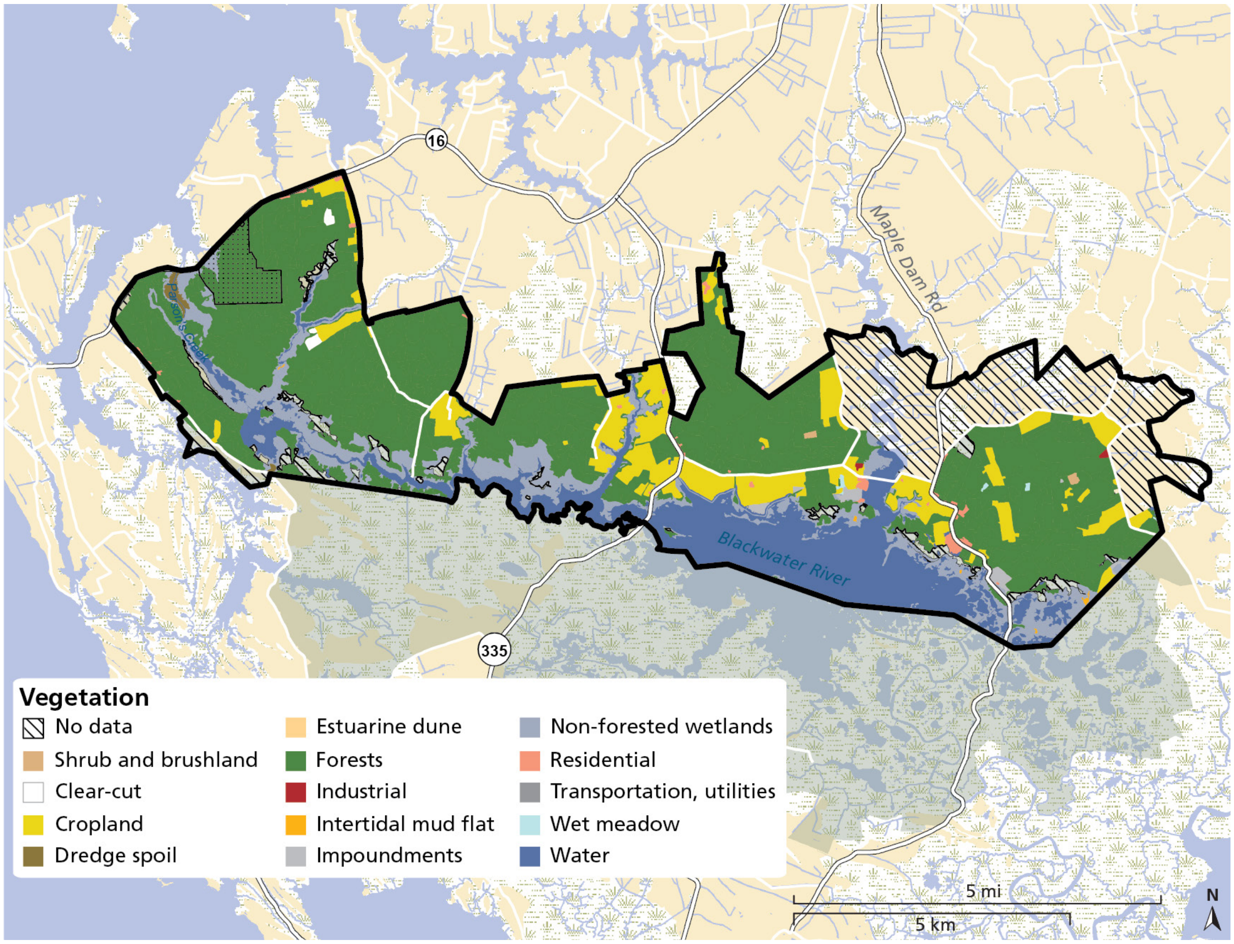


Figure 2-12. Vegetation types present within Harriet Tubman Underground Railroad National Historical Park (Data source: Matt Whitbeck, Supervisory Wildlife Biologist, Chesapeake Marshlands NWR Complex).

<u>Wetlands</u>

Harriet Tubman Underground Railroad National Historical Park currently supports roughly 12,400 acres of wetlands, which include freshwater swamps, inland and tidal freshwater marshes, transitional salt marshes, regularly flooded marsh, irregularly flooded brackish marsh, and tidal swamp land cover classifications. Many of these areas are classified as Wetlands of Special Concern (Figure 2-13).

The park also contains roughly 3,700 acres of land cover classified as 'water,' which includes the land cover types classified as tidal flats, inland open water, riverine tidal open water, and estuarine open water.

The park supports important intertidal wetlands that vary in the degree of freshwater inputs (freshwater to brackish marshes) and elevation (low and high marsh). Open water and mudflats are also common. Brackish low marshes are characterized only by smooth cordgrass (*Spartina alterniflora*). Brackish high marshes are more diverse in the plants they support but are still locally monotypic. These marshes are characterized by needlerush (*Juncus roemerianus*) and Olney three-square bulrush (*Schoenoplectus americanus*), with common three-square bulrush (*Scirpus pungens*) and stout bulrush (*Scirpus robustus*) more common at the landward section of marshes (USFWS 2006). Depending on salinity regime, marsh communities may also be dominated by saltmeadow cordgrass (*Spartina patens*), big cordgrass (*Spartina cynosuroides*), and narrowleaf cattail (*Typha angustifolia*). Marshes may also be inhabited by marsh elder (*Iva frutescens*), groundsel bush (*Baccharis halimifolia*), switchgrass (*Panicum virgatum*), and common reed (*Phragmites australis*).

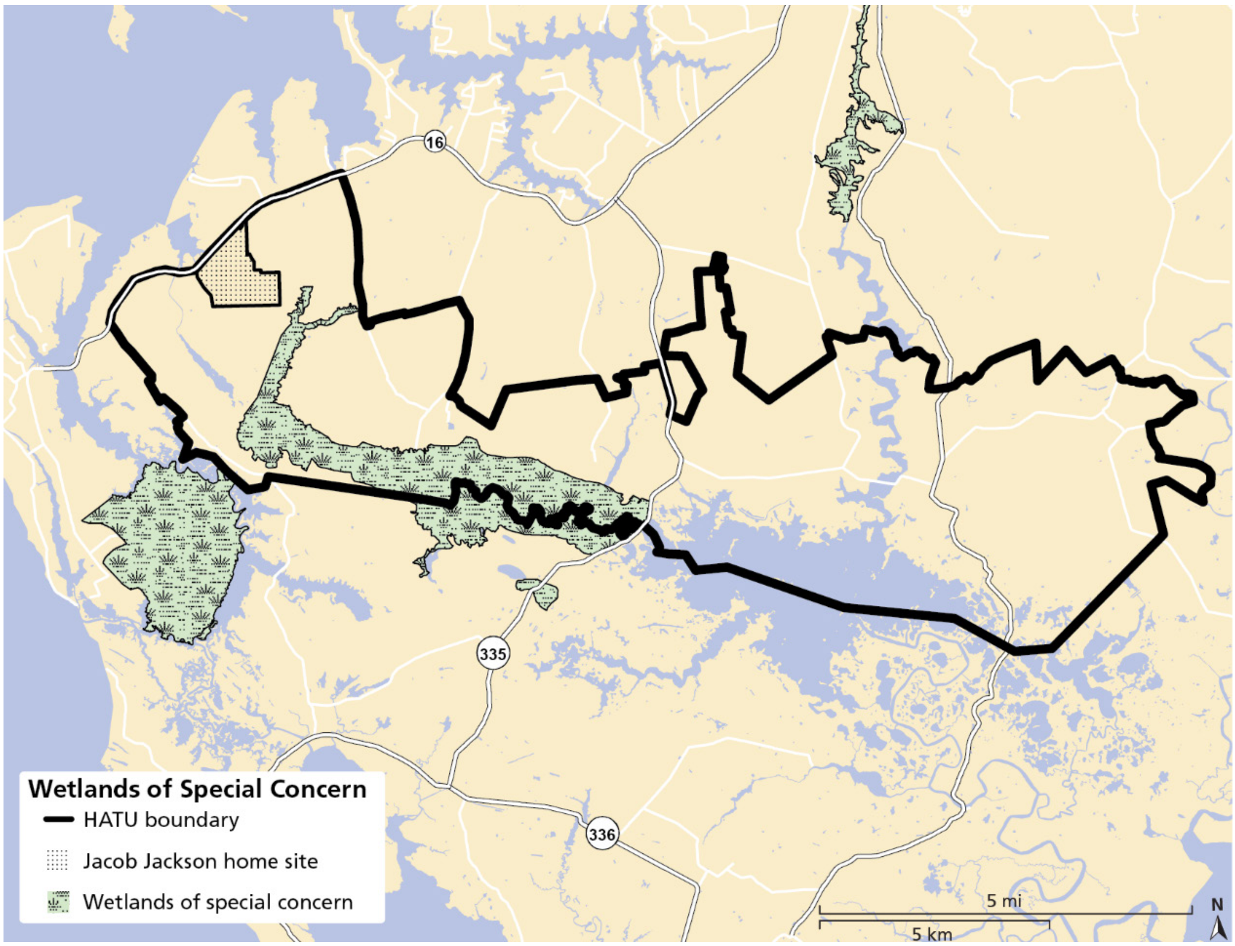


Figure 2-13. Wetlands of special state concern in and around Harriet Tubman Underground Railroad National Historical Park (Data source: State of Maryland, Maryland GIS Data Catalog).

Freshwater tidal marshes provide important ecosystem services in supporting high wildlife productivity and providing fish spawning and nursery grounds. They stabilize shorelines, trap sediments, and immobilize nutrients. Their high plant productivity provides organic carbon for a productive estuarine food web. Dominant plant species include cattail (*Typha spp.),* pickerelweed (*Pontederia cordata*), arrow arum (*Peltandra virginica*), and spatterdock (*Nuphar advena*). Other species that are present include big cordgrass (*Spartina cynosuroides*), smartweeds (*Polygonum spp.*), rice cutgrass (*Leersia oryzoides*), wildrice (*Zizania aquatica*), sweet flag (*Acorus calamus*), rose mallow (*Hibiscus spp.*), and common reed (*Phragmites australis*). Freshwater tidal swamp forests are often located immediately adjacent to freshwater tidal marshes. They are composed principally of loblolly pines at Harriet Tubman Underground Railroad National Historical Park.

Palustrine wetlands are non-tidal ecosystems that are important for protecting the water quality of Harriet Tubman Underground Railroad National Historical Park because they filter nutrients and chemicals, trap sediments, and moderate floodwaters and storm effects. Palustrine wetlands can also provide seasonal sources of hard mast and macroinvertebrates for migrating birds. Forested habitats within the park are primarily palustrine forested wetlands composed of loblolly pine (*Pinus taeda*), loblolly pine mixed with oaks, loblolly pine mixed with hardwoods other than oak, or mixed hardwoods. Loblolly pine is well adapted to soils with poor surface drainage. The species is also shade-intolerant, such that active management is required to maintain the species in the community.

Forests

Harriet Tubman Underground Railroad National Historical Park contains approximately 9,600 acres of 'dry' land, or land cover classified as either undeveloped or developed dry land, which are predominantly forested. These lands have been designated by the State of Maryland as Targeted Ecological Areas (Figure 2-14) to identify them as conservation priorities. Loblolly pine (*Pinus taeda*) stands with an understory of wax myrtle (*Myrica spp.),* holly (*Ilex spp*.), grasses, and hardwoods are particularly common. The primary cause of mortality for pines is red rot disease (*Glomerella tucumanensis*) or heart decay caused by a variety of fungi (USFWS 2006). Salt water intrusion can also affect many loblolly pine stands. As pine stands mature, they are replaced by hardwoods by the age of 100-150 years. The practice of high-grading in parts of the park has resulted in residual stands that may have an over-mature canopy of poor quality hardwoods, little to no mid-story, and a dense shrub understory (USFWS 2006). Remnant hardwoods tend to be stunted owing to years of suppression, and remaining trees are left vulnerable to pests and diseases. In some instances, however, hardwoods have flourished despite high-grading.

Common hardwoods are red maple (*Acer rubrum*), sweet gum (*Liquidambar styraciflua*), black gum (*Nyssa sylvatica*), swamp chestnut oak (*Quercus michauxii*), willow oak (*Quercus phellos*), black oak (*Quercus velutina*), white oak (*Quercus alba*), American beech (*Fagus grandifolia*), and American holly (*Ilex opaca*). Shrubs within forested communities include high bush blueberry (*Vaccinium corymbosum*), sweet pepper bush (*Clethra alnifolia*), maleberry (*Lyonia ligustrina*), swamp sweet bells (*Leucothoe racemosa*), poison ivy (*Toxicodendron radicans*), and greenbriar (*Smilax* spp.). Red maple and sweet gum are fast growing species and therefore take advantage of any gaps in the canopy. Selective thinning is a management approach frequently used to release oaks from competition with red maple and sweet gum at an early stage of succession (USFWS 2006).

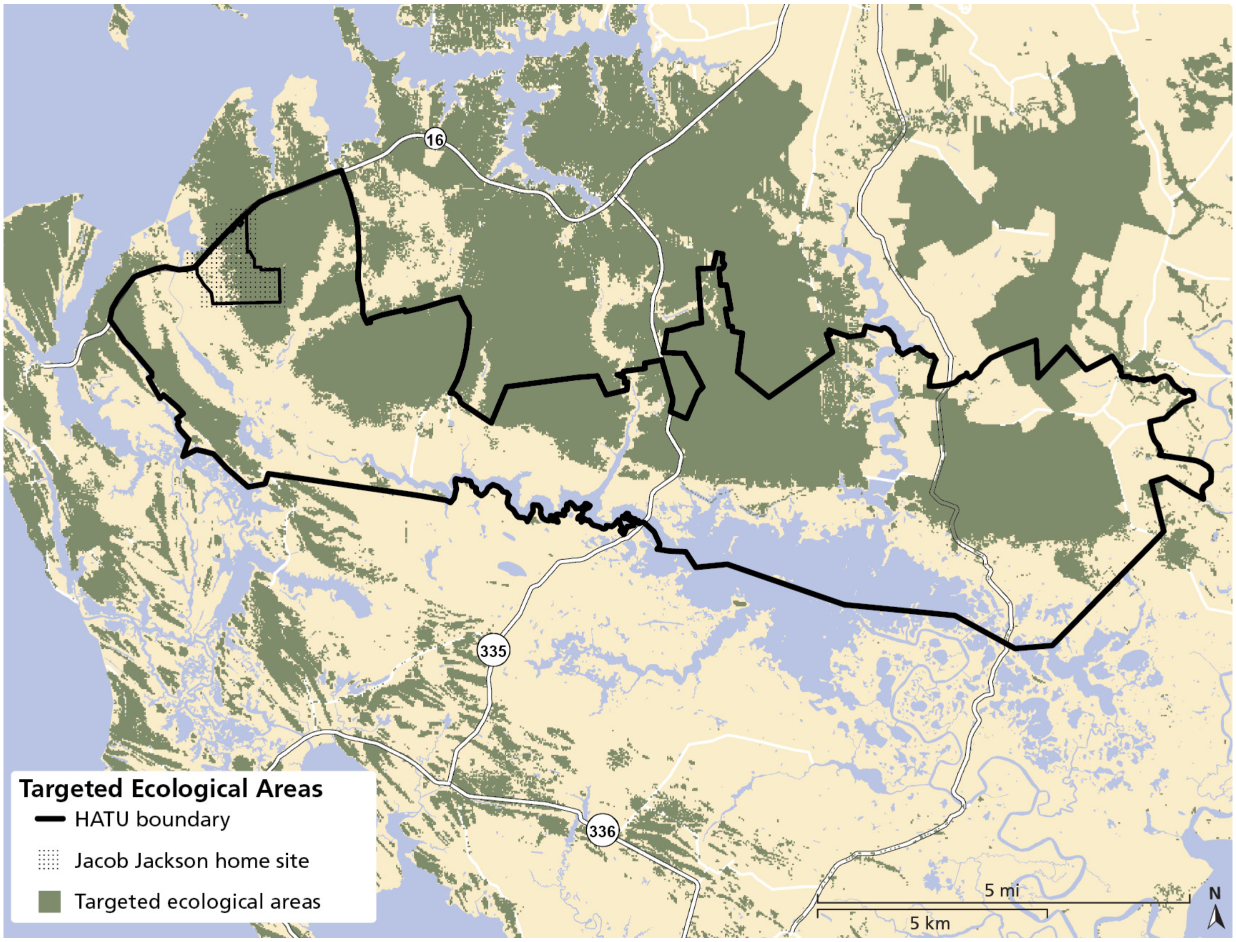


Figure 2-14. Targeted Ecologic Areas at Harriet Tubman Underground Railroad National Historical Park (Data source: State of Maryland, Maryland GIS data catalog).

Agriculture

Some areas of the park are planted with sorghum (*Sorghum* spp.) and corn (*Zea mays*) by Blackwater National Wildlife Refuge to increase wildlife production. Fields are also planted with rye (*Secale cereale*), ladino clover (*Trifolium repens*), and wheat (*Triticum aestivum*), often double-seeded with buckwheat (*Fagopyrum esculentum*) to provide browse for the abundant migrating and wintering waterfowl the area is known for.

Fauna

Although designated a cultural park, Harriet Tubman Underground Railroad National Historical Park is rich in faunal diversity and productivity due to its close association with Blackwater National Wildlife Refuge and its vast natural resources. The area supports at least 34 mammal species (USFWS 2008), including a thriving population of Delmarva fox squirrels. The park also hosts 27 fish species, ranging from freshwater-dependent species (e.g., brown bullhead and black crappie) to euryhaline species (e.g., killifish and silversides) (Love et al. 2008). Although not located within park boundaries, estuarine areas within 3- and 30-km buffers around Harriet Tubman Underground Railroad National Historical Park support productive public shellfish fishing areas (Figure 2-15).

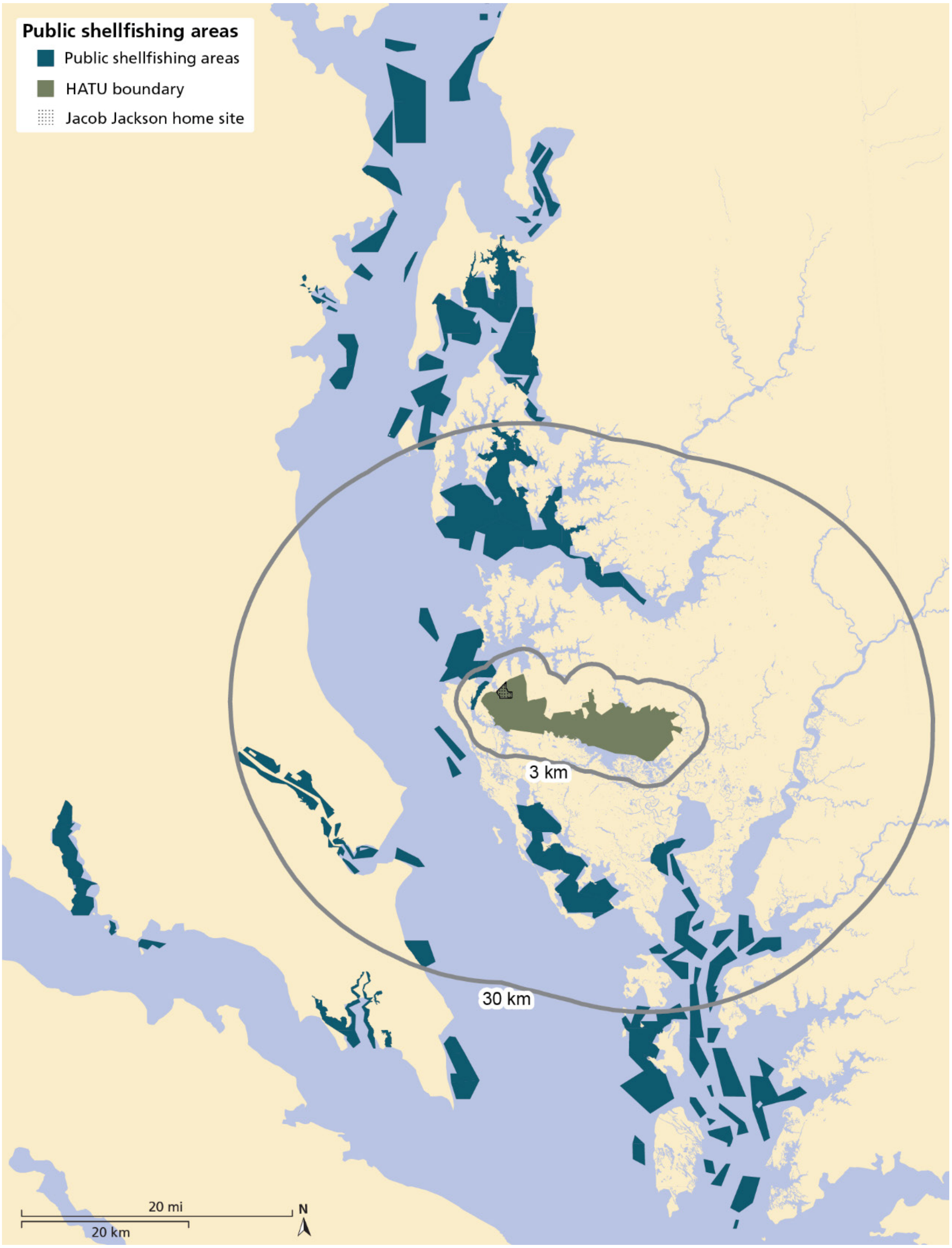


Figure 2-15. Public shellfish fishing areas (blue polygons) within tidal portions of the Chesapeake Bay that are within a 3km and 30km buffer around Harriet Tubman Underground Railroad National Historical Park (shaded green) (Data source: State of Maryland, Maryland GIS Data Catalog).

However, what the area is mostly known for is its abundance of upland and wetland bird species. Harriet Tubman Underground Railroad National Historical Park is located in the middle of an internationally-recognized Important Bird Area (IBA), designated by the American Bird Conservancy in 1996 and by the Audubon Society in 2005 owing to the area's high abundance and diversity of waterfowl (ducks, geese, swans), forest interior dwelling species, raptors, shorebirds, gulls and terns, marsh and water birds, and breeding songbirds (Figure 2-16).

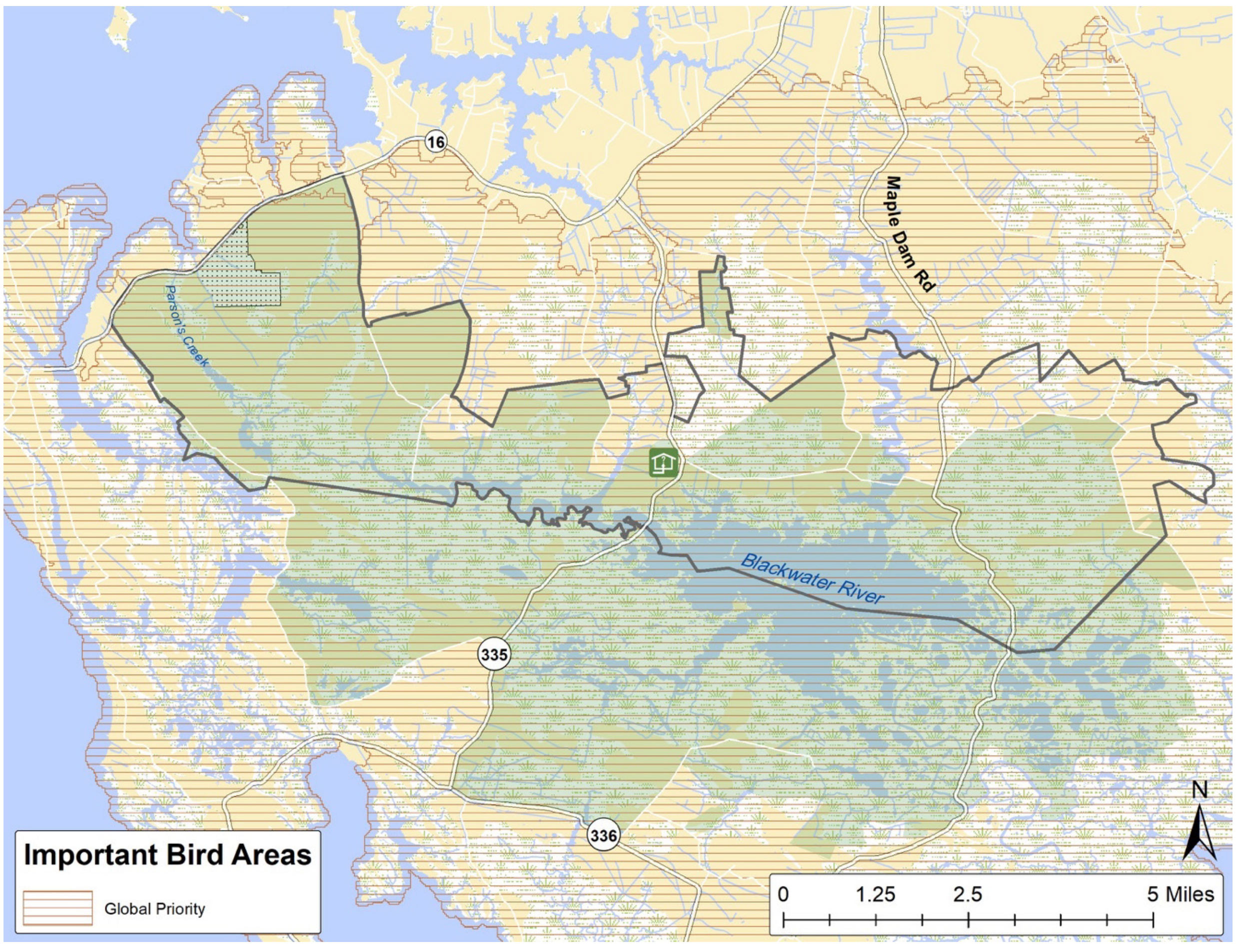


Figure 2-16. Important Bird Areas within Harriet Tubman Underground Railroad National Historical Park and the surrounding region (Data source: National Audubon Society).

Due to its association with Blackwater National Wildlife Refuge and its abundant wetland resources, the park is one of the most significant areas to waterfowl in Maryland; 24 species of ducks, 5 species of geese, and 3 species of swans are likely to nest or migrate through Harriet Tubman Underground Railroad National Historical Park. Each year since 1955, the U.S. Fish and Wildlife Service and the Maryland Department of Natural Resources have counted ducks, geese, and swans during aerial winter surveys (USFWS 2017). Peak populations have varied annually (Figure 2-17) with an overall declining trend in abundances across waterfowl groups (Figure 2-17). The area is included in the North American Waterfowl Management Plan (NAWMP) established in 1986 to conserve waterfowl and migratory birds in North America. High priority species within the NAWMP include the redhead, canvasback and wood duck, and the black duck, mallard, northern pintail, and blue-winged teal are designated as priority species. In addition to these species the area also supports Southern James Bay Canada goose, Atlantic brant, greater and lesser scaup, ring-necked duck, American widgeon, and common eider, which are all designated as Species of Management Concern for the region.

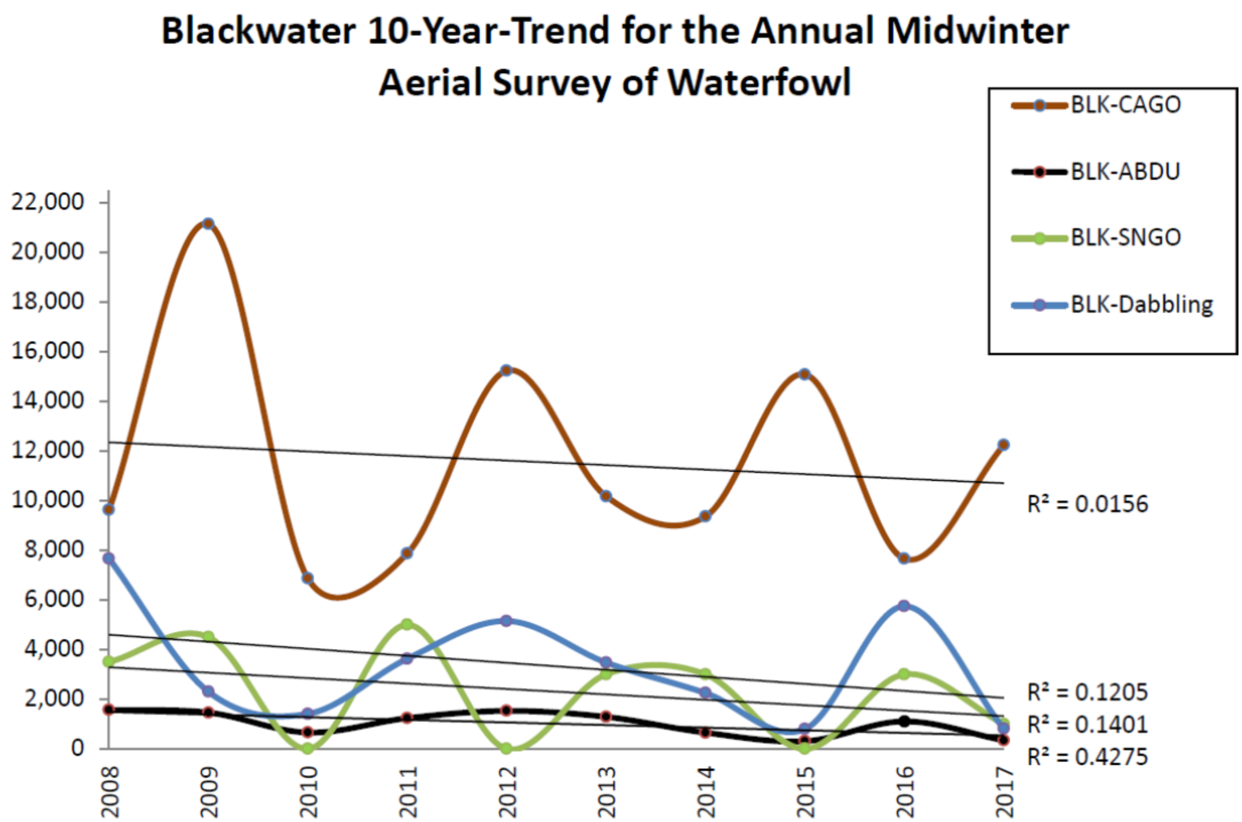


Figure 2-17. Annual abundances and 10-year trend for Canada geese (CAGO), snow geese (SNGO), American black ducks (ABDU), and total dabbling ducks at Blackwater National Wildlife Refuge. Aerial waterfowl surveys are conducted annually in the winter and overlap partially with Harriet Tubman Underground Railroad National Historical Park (Figure from USFWS 2017).

Blackwater National Wildlife Refuge, and by association, Harriet Tubman Underground Railroad National Historical Park, supports 85 species of nesting songbirds in forested wetlands (USFWS 2015). An eastern bluebird box program fledged 147 birds each year (USFWS 2006). Forest interior dwelling species (FIDS) of birds are a diverse group of species that require large and mature forest areas to maintain viable populations. Such areas have declined since European settlement with a concomitant decline in FIDS. Harriet Tubman Underground Railroad National Historical Park supports much of the remaining large contiguous tracts of forested lands on the Delmarva Peninsula such that 22 species of forest interior birds are potentially breeding at Blackwater National Wildlife Refuge and therefore within the park.

Brown thrasher photographed within Blackwater National Wildlife Refuge and most likely within Harriet Tubman Underground Railroad National Historical Park. Photo by Beverly Middleton.

Rare, Threatened, and Endangered Species

Harriet Tubman Underground Railroad National Historical Park contains areas within its boundaries that are considered critically significant for biodiversity conservation by Maryland's Biodiversity Conservation Network (BIONET) (Figure 2-18). BIONET prioritizes areas for terrestrial and freshwater biodiversity conservation, focusing on globally and state rare species and habitats, Animals of Greatest Conservation Concern, Watch List of plants, animal assemblages, hotspots of rare species, intact watersheds, and wildlife corridors. Areas around the Blackwater River and Parson's Creek are ranked Tier 1 (critically significant). Lowland areas in the western part of the park, including the Jacob Jackson parcel, are ranked as Tier 2 (extremely significant), and most other areas are ranked Tier 3 (highly significant). The immediate areas (3 km buffer) surrounding the park are also ranked significant (Tier 5) to critically significant (Figure 2-19).

Forests within the park provide habitat for the largest nesting population of American bald eagles along the Atlantic coast north of Florida. The park also supports the largest protected population of Delmarva fox squirrels in the U.S., and peregrine falcons are a common site. All three of these species were once considered endangered but have recovered enough to be taken off of the endangered species list. The only federally listed species is the northern long-eared bat (*Myotis septentrionalis*).

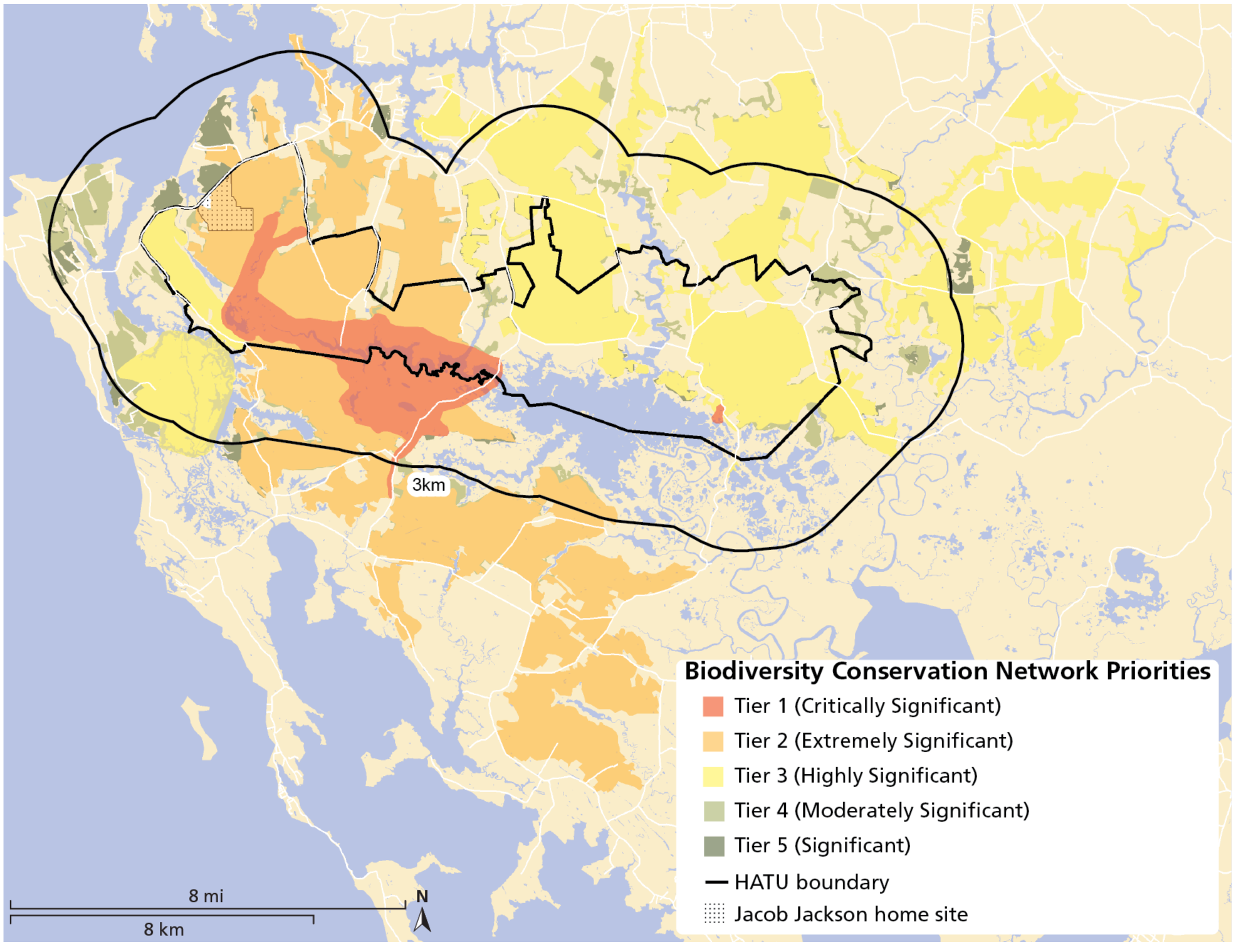


Figure 2-18. Biodiversity Conservation Network significant areas within a 3-km buffer of Harriet Tubman Underground Railroad National Historical Park (Data source: Biodiversity Conservation Network (BioNet)).

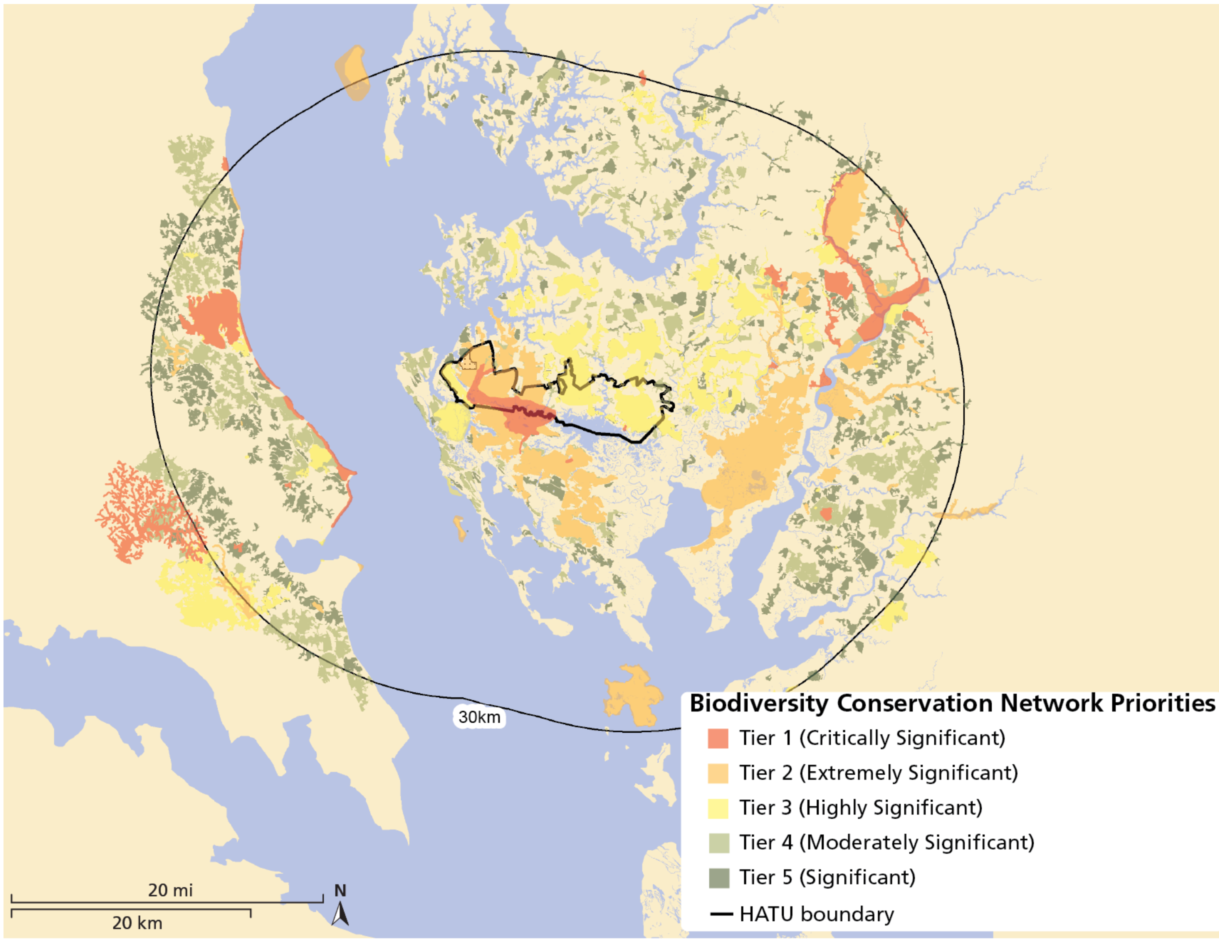
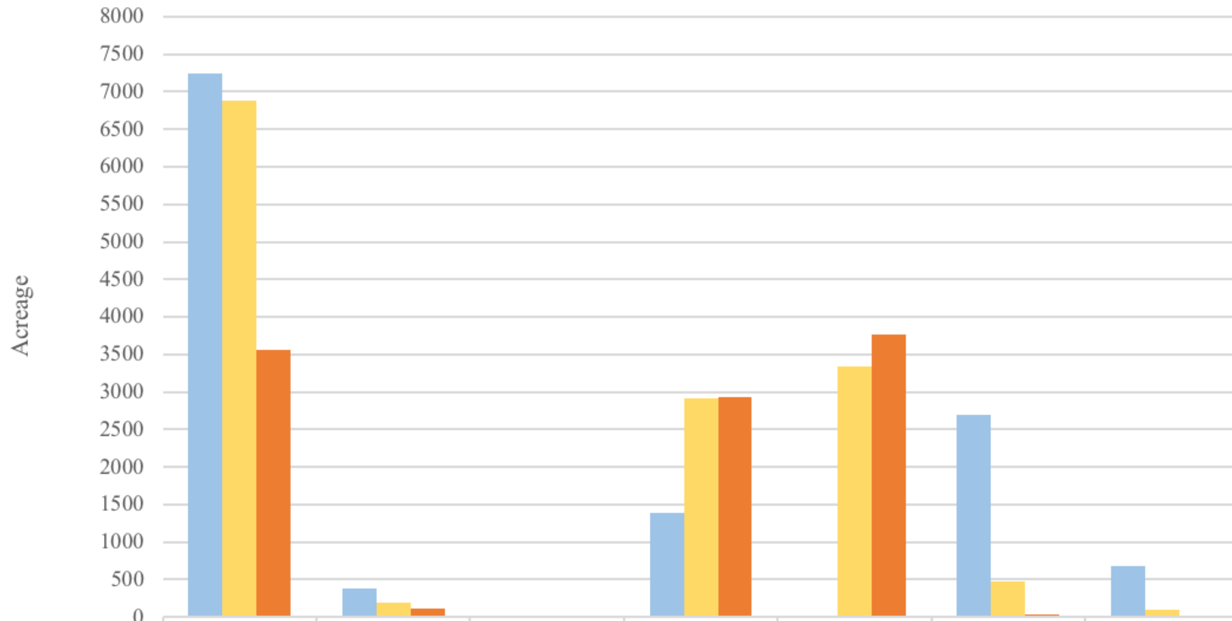


Figure 2-19. Biodiversity Conservation Network significant areas within a 30-km buffer around Harriet Tubman Underground Railroad National Historical Park (Data source: Biodiversity Conservation Network (BioNet)).

2.3.3. Resource Issues Overview

Sea Level Rise

Sea level rise is a major resource issue facing Harriet Tubman Underground Railroad National Historical Park. The Sea Level Affecting Marshes (SLAMM) modelling completed for the Blackwater NWR, Harriet Tubman Underground Railroad National Historical Park, and the surrounding region indicate major projected land cover conversions occurring over the next century (Figure 2-20). The most dramatic of these conversions will occur within the park's water cover category, with almost 2,200 acres of land converted to open water by 2050, and 8,900 acres (200% increase) converted by 2100. The southern portion of the park will be mostly inundated by the end of the century (Figure 2-21).



	Freshwater Swamp	Inland Freshwater Marsh	Tidal Freshwater Marsh	Transitional Salt Marsh	Regularly Flooded Marsh	Irregularly Flooded Marsh (Brackish)	Tidal Swamp
HATU Current	7249	384	16	1384	19	2701	677
HATU 2050	6885	198	15	2922	3336	482	92
HATU 2100	3557	107	15	2932	3759	30	16

HATU Current HATU 2050 HATU 2100

Figure 2-20. Current and projected changes in wetlands at Harriet Tubman Underground Railroad National Historical Park (HATU) over the next century using the Sea Level Affecting Marshes Model (SLAMM) (Data source: Maryland Department of Natural Resources 2011).

Given this large amount of open water inundation, the future condition of wetland resources in the park is of significant concern. Although some classes of wetlands are projected to increase in extent (e.g., transitional salt marsh and regularly flooded marsh) owing to landward migration, the park is projected to experience a net loss of wetlands, driven by the loss of irregularly flooded marsh early in the century (2,219 acres by 2050) and the loss of freshwater swamp later in the century, an estimated 3,328 acres from 2050 to 2100 (Figure 2-21).

Among the park's habitat types most affected by sea level rise are undeveloped dry land, inland freshwater marsh, freshwater and tidal swamps, and irregularly flooded brackish marshes. Undeveloped dry land is projected to lose over one-third of its land cover by 2050 and over 70% by 2100. Freshwater swamp is projected to experience a 50% loss, most of which is expected to occur in the later part of the century. Projections indicate inland freshwater marsh will have already lost almost 50% (approximately 185 acres) of its total acreage to transitional salt marsh and regularly flooded marsh areas by 2050. Tidal swamps are projected to lose 86% (585 acres) of their total acreage to regularly flooded marsh and tidal flat areas by 2050 and 97% by 2100. Over 2,200 acres of irregularly flooded marshes are projected to convert to regularly flooded marsh areas, tidal flats and open water by 2050, increasing to 2,672 – a 99% loss of its current extent – by 2100.

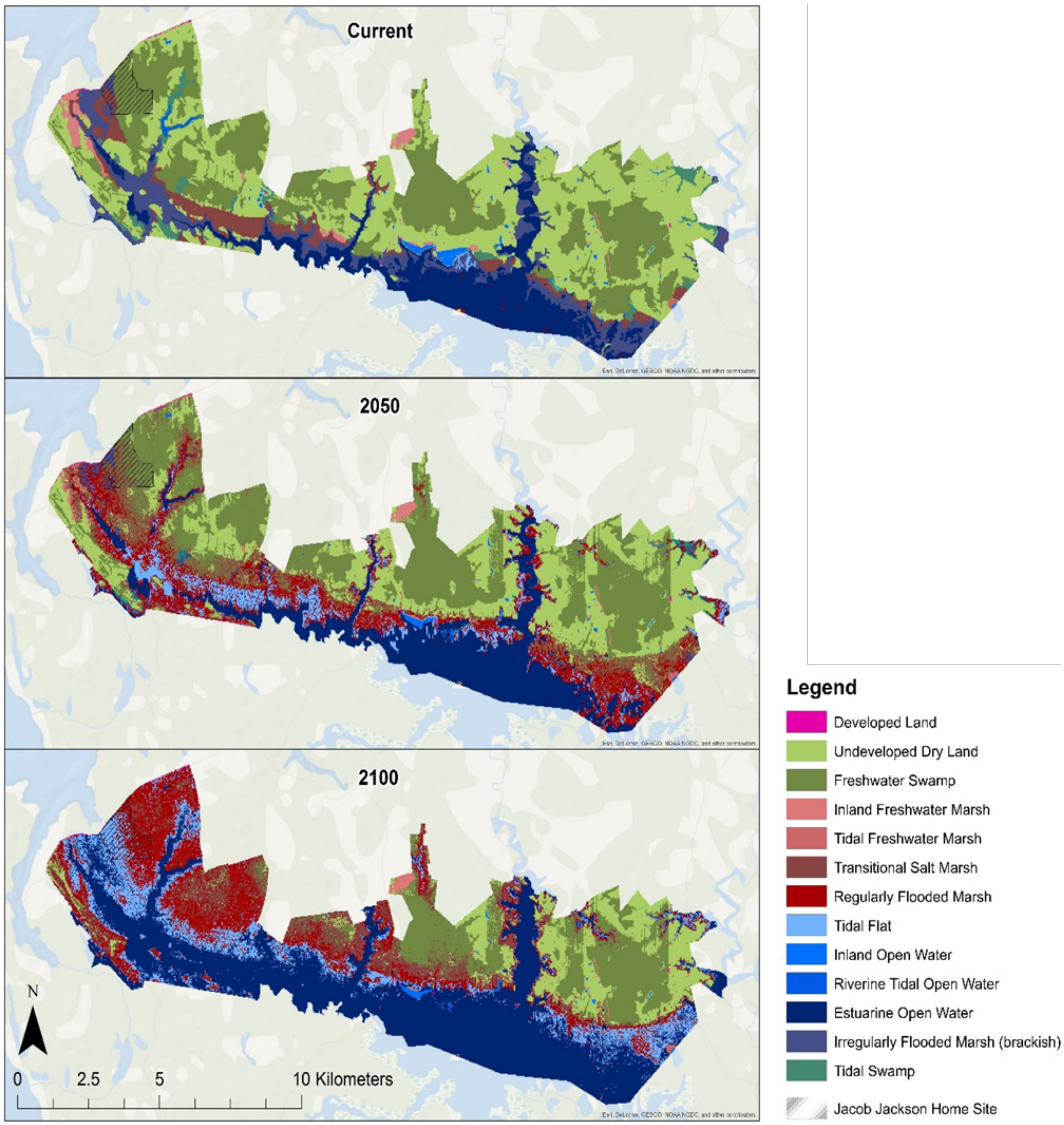


Figure 2-21. Predicted change in elevation relative to sea level in 2050 and 2100 compared to current elevations modeled for areas within Harriet Tubman Underground Railroad National Historical Park. Predictions are based on the Sea Level Affecting Marshes Model (Data source: Maryland Department of Natural Resources 2011).

Accounting for all gains and losses, the SLAMM modeling projects that the park will lose 16% of its wetlands by the end of the century, resulting in a condition score of 84%. The park's upland dry areas will likely be even harder hit, losing 71% of its current land cover by 2100. Combining both wetland and upland dry areas, Harriet Tubman Underground Railroad is projected to experience an

8,900-acre loss of vegetated land cover to open water by 2100, equating to 40% of its vegetated cover. Approximately 10% will already be lost by 2050.

Sea-level rise projections at the Jacob Jackson Home Site reflect those of the greater Harriet Tubman Underground Railroad area. Undeveloped dry land is projected to increase by 1 acre (8%) by 2050, and then decrease by 84% over the course of the following 50 years, losing approximately 10 of the original 12 acres by 2100. Freshwater swamp is projected to lose 35% (approximately 130 acres) of its cover by 2050, and nearly 100% by 2100, with just less than a half an acre projected to remain by the end of the century. Projections show that the majority of freshwater swamp will be lost to transitional salt marsh, regularly flooded marsh, and eventually, tidal flat over the course of the next century. (Figure 2-22). Irregularly flooded marsh is projected to lose 5 of its 43 acres (nearly 12%) by 2050, with the remaining 38 acres completely lost by 2100, converted mostly to regularly flooded marsh and tidal flats. Overall, the Jacob Jackson Home Site is projected to lose 80% of its total current uplands and 47% of its total current wetlands by the end of the century (Figure 2-22).

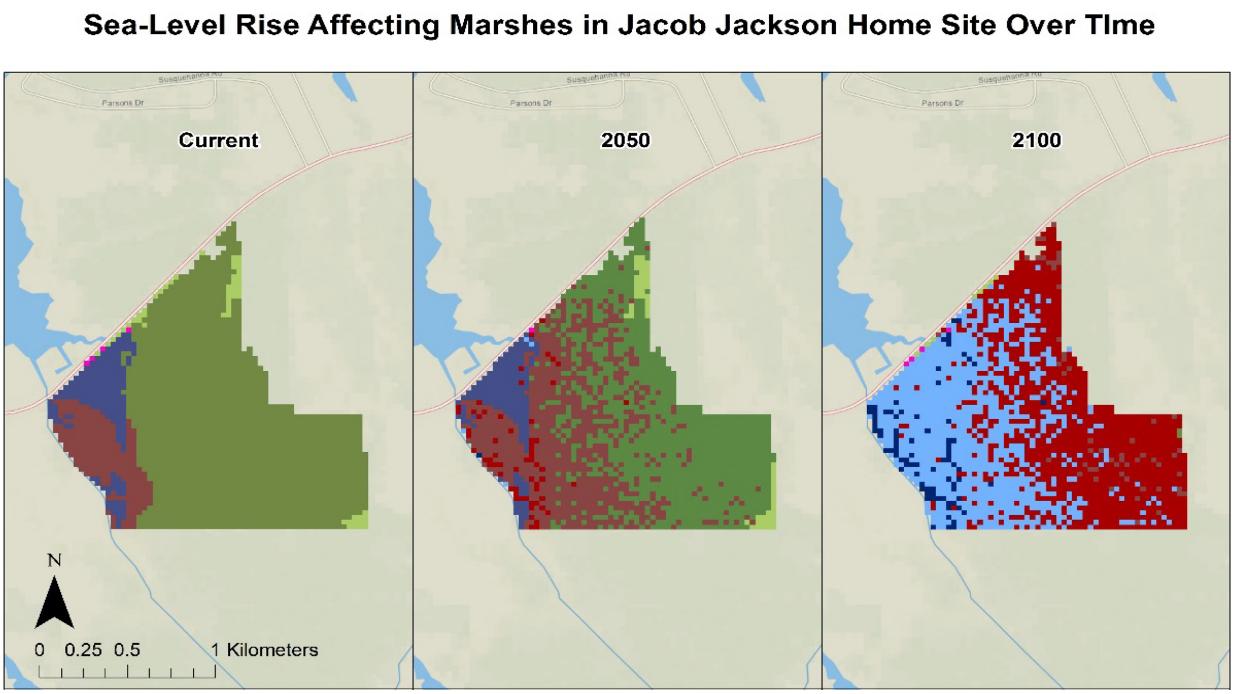


Figure 2-22. Projected locations of land cover changes due to sea level rise at the Jacob Jackson Home Site within Harriet Tubman Underground Railroad National Historical Park over the next century using the Sea Level Affecting Marshes Model (SLAMM). Legend matches that of Figure 2-21 (Data source: Maryland Department of Natural Resources 2011).

The loss of wetlands is indicative of declining and degrading wetland habitat throughout the region. The rate of sea-level rise has increased over recent decades at hotspots along the eastern coast (Valle-Levinson et al. 2017). Wetland loss can be attributed to many factors, including rising sea levels, land use conversion, increases in human population, urban sprawl, and the spread of invasive species (USFWS 2006, Kirwan & Megonigal 2013). Since 1933, Blackwater National Wildlife Refuge has lost over 7,000 acres of wetlands to modified hydrology, rising sea levels, subsiding land, saltwater intrusion, and damaging herbivory by wildlife (USFWS 2006). With sea levels rising at a rate of 3.0 mm/year, this trend of wetland loss is likely to continue over the next century (USFWS 2006).

Development

Development within the watershed of the park can be a major influence on park resources. Development threatens the quality of air, water, soundscapes, viewsheds, and night skies. Water quality is directly impacted by land use within a watershed, such as the Little Blackwater River (Fleming et al. 2011; Figure 2-23). The degradation of night skies has significant impacts on the park's ecological resources, as higher light levels during the night impact wildlife habitat quality, species interactions, and migration patterns. Additionally, both light and noise pollution can distract visitors from their appreciation of the park's natural resources and the purpose of its cultural areas.

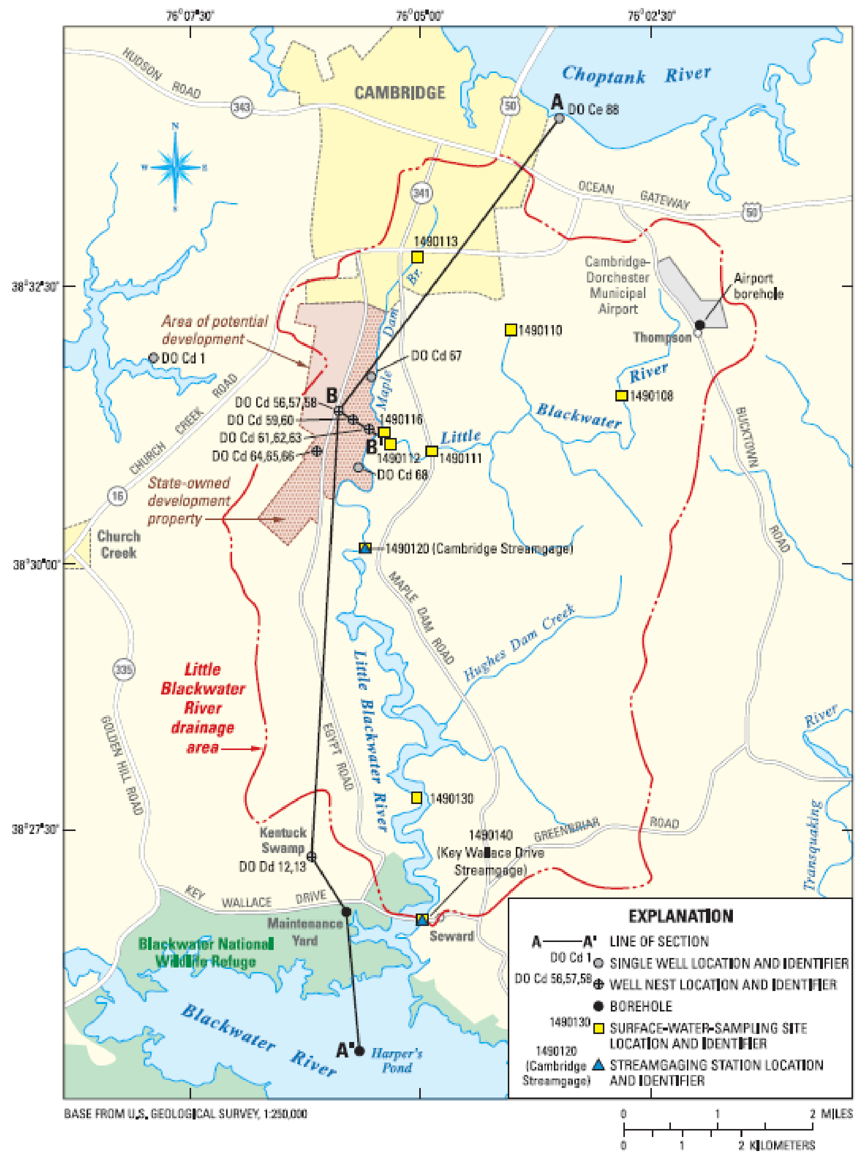


Figure 2-23. Potential development (brown shaded area) within the Little Blackwater River watershed (red outline). (Image source: Fleming et al. 2011).

Invasive Species

Biological invasions pose a significant threat to the natural resources of national parks and has been correlated with the number of visitors to parks (Allen et al. 2009). Invasions in national parks have also been correlated with climate change in the eastern US (Fisichelli et al. 2014). Approximately 70% of documented invasive species in parks are plants, although fish diversity is also significantly threatened by invasive aquatic wildlife (Lawrence et al. 2011).

No comprehensive inventory exists for Harriet Tubman Underground Railroad National Historical Park to provide insights into how many non-native species are present compared to native species. However, the common reed (*Phragmites australis*) and nutria (*Myocaster coypus*) are two prevalent threats to wetland resources. Phragmites has the ability to maintain monocultures and expand quickly to the detriment of native species diversity (Kettenring et al. 2015). Nutria was introduced to Maryland in 1943 near Blackwater National Wildlife Refuge (Pepper et al. 2017). This semi-aquatic rodent disturbs the structure of channels and leads to marsh erosion and loss (Haramis and Colona 1999). This species is intensively managed in the area (Pepper et al. 2017) and therefore does not currently pose a threat to the integrity of the marshes.

The common reed (*Phragmites australis*) threatens wetland resources in Harriet Tubman Underground Railroad National Historical Park. Photo: Todd Lookingbill, September 2016.

2.4. Resource Stewardship

2.4.1. Management Directives and Planning Guidance

No natural resource monitoring programs are currently in place at Harriet Tubman Underground Railroad National Historical Park since its establishment in 2013. Although the park realizes that its natural resources of the park are an important part in the interpretation of Harriet Tubman's life and work, it is principally focused on its historic and cultural value.

The foundation document for the park has not been published, but a draft includes a list of fundamental resources and values. Major natural resources identified include the working landscapes that the park embodies, which were as important to Harriet Tubman's life as they are to the citizens of Dorchester County today. Viewscapes and dark night skies are critically important as natural and cultural resources, as they both guided freedom-seekers in the past and enhance the experience of visitors to the park today. Fresh and brackish marshes and loblolly pine - oak hickory forests provide food web support for a diversity of wildlife. In particular, the 480-acre National Park Service-owned Jacob Jackson property, nearby Stewart's Canal, and Blackwater National Wildlife Refuge represent the powerful interplay between the cultural and natural resources of the area, and they provide terrific opportunities for preserving valuable resources, while enhancing discovery and teaching the public about history and ecology.

Future directives include the assessment of the impact of sea level rise, saltwater intrusion, and sinking land on all cultural and natural resources; partnering with the State of Maryland and the Blackwater National Wildlife Refuge to purchase land for natural resource conservation; development of a night sky / sound baseline database; an analysis of visitor use and its effects on cultural and natural resources; and expanding educational initiatives to offer water tours as well as opportunities to experience dark night skies.

2.4.2. Status of Supporting Science

The National Park Service's Inventory and Monitoring (I&M) Program was established in 1998 to observe natural resources within 270 parks aggregated into 32 ecoregional networks throughout the country (Fancy et al. 2008). Harriet Tubman Underground Railroad National Historical Park falls geographically within the Northeast Coastal and Barrier Network (NCBN), which stretches from Virginia to Massachusetts. Network staff catalogue data, perform data analysis, synthesis, and monitoring, and advise park planners on how to best protect resources.

The I&M Program designated 12 core inventories that describe the conditions of water, landforms, climate, wildlife distribution, and park resources unique to each park. Through continued monitoring of "Vital Signs," regional staff track physical, chemical, and biological processes of ecosystems that represent overall park health. The NCBN tracks 18 Vital Sign indicators that are divided into five categories: estuarine eutrophication, salt marsh change, geomorphic change, visitor use and impact, and landscape change (Stevens et al. 2005). At this time, Harriet Tubman Underground Railroad National Historical Park is not one of the eight parks in the NCBN at which these monitoring protocols are implemented.

Blackwater National Wildlife Refuge has a natural resources monitoring program in place, although some programs (e.g., forest inventory and forest interior dwelling birds) had to be ended owing to the lack of funding. A monitoring program is not in place at Harriet Tubman Underground Railroad National Historical Park. Without long-term monitoring to track national resource conditions, especially within the Jacob Jackson parcel, the park will lack information that could benefit its management decision-making process.

3. Study Scoping and Design

3.1. Preliminary Scoping

Preliminary scoping of the Harriet Tubman Underground Railroad National Historical Park Natural Resource Condition Assessment (NRCA) began in September 2016 with a kick-off meeting of the park's superintendent, staff from the Harriet Tubman Underground Railroad State Park, Northeast Region National Park Service personnel, and ecologists from the University of Richmond and the University of Maryland Center for Environmental Science. The historical background and geographic layout of the park were discussed at the meeting, as were its natural and cultural resources, stressors to those resources, and current and future management goals. A preliminary list of all of the park's natural resources was made to provide a starting point for determining which indicators would be studied in the NRCA.

Participants in the Harriet Tubman Underground Railroad National Historical Park Natural Resource Condition Assessment during a field visit at the park. Photo: Todd Lookingbill, September 2016.

Collection of data and background information on the park began after the kick-off. Data for park resources were organized into an electronic library primarily comprised of management reports, scientific papers and reports, electronic data files, geospatial data (GIS), and aerial imagery. Much of the data and information was obtained from the National Park Service Air Resources Division, the

US Fish and Wildlife Service (USFWS) at Blackwater National Wildlife Refuge, the USFWS Chesapeake Bay Field Office, and the US Geological Survey. Other important sources of data came from National Park Service Northeast Region - Olmsted Center for Landscape Preservation (historic landscape), and National Park Service - Natural Sounds and Night Skies Division (historic landscape). Additional expertise was provided by faculty at the California University of Pennsylvania (Delmarva fox squirrels) and the University of Maryland Center for Environmental Science at the Appalachian Laboratory (bats), biologists at Maryland Department of Natural Resources (deer), National Capital Region Inventory & Monitoring Program personnel (forest structure), and Northeast Temperate Network National Park Service staff (forest structure).

This initial scoping of available data and information assisted in choosing the final indicators and metrics. These were determined at a meeting in November, 2016, and were followed up with a lessons-learned meeting in November 2017 and a meeting in December 2017 to specifically address the wetland indicator. Owing to turn-over in park superintendents, two meetings with the interim and current superintendents in May 2017 and August 2018 summarized the NRCA process and provided feedback from the park. Discussions with Blackwater National Wildlife Refuge management and NPS staff at local and regional offices were critical in deciding on the indicators and reference conditions. Efforts were made to integrate indicators from the NPS I&M Vital Signs framework when possible. Collaboration with park natural resource staff was essential to the success of this assessment.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

Indicators form the basis of this condition assessment. The NPS Inventory and Monitoring (I&M) program has previously developed a number of ecological monitoring indicators grouped as 'vital signs' to represent key physical, chemical, and biological elements and processes of park ecosystems that are representative of the overall health or condition of park resources. The I&M vital signs are:

1) Air and Climate
2) Water
3) Biological Integrity
4) Landscapes
5) Human Use
6) Geology and Soil

For the purpose of calculating natural resource condition at Harriet Tubman Underground Railroad National Historical Park, the first four of these vital sign categories were used, though general features of 'human use' and 'geology and soil' are discussed throughout the report. For each vital sign category, three to six indicators were evaluated with one to five metrics as part of the assessment.

Detailed information on indicator relevance, metrics used, methods, reference condition, current condition, and trend are provided for each indicator in Chapter 4. Each indicator section also contains an assessment of level of confidence and data gaps for that indicator, which is given as a qualitative rating (i.e., high, moderate, low) based on best professional judgment. Indicators were not treated differently in the final park assessment based on differences in their confidence ratings.

3.2.2. Reporting Areas

The focus of the reporting area for the NRCA was the Harriet Tubman Underground Railroad National Historical Park legislative boundary (Figure 3-1). Much of the area within the park boundary is owned by the US Fish and Wildlife Service with smaller parcels owned by the National Park Service and the State of Maryland. Ownership did not factor in to any analyses; however, we highlighted specific results for the NPS-owned Jacob Jackson Home Site when available. All data used for the final assessment of park condition were collected from within the park, with the exception of air quality data, which were taken from the closest air monitoring stations, and eagle and deer data, which were based on surveys that crossed the park boundary and could not be easily be separated into data collected inside and outside the park boundary.

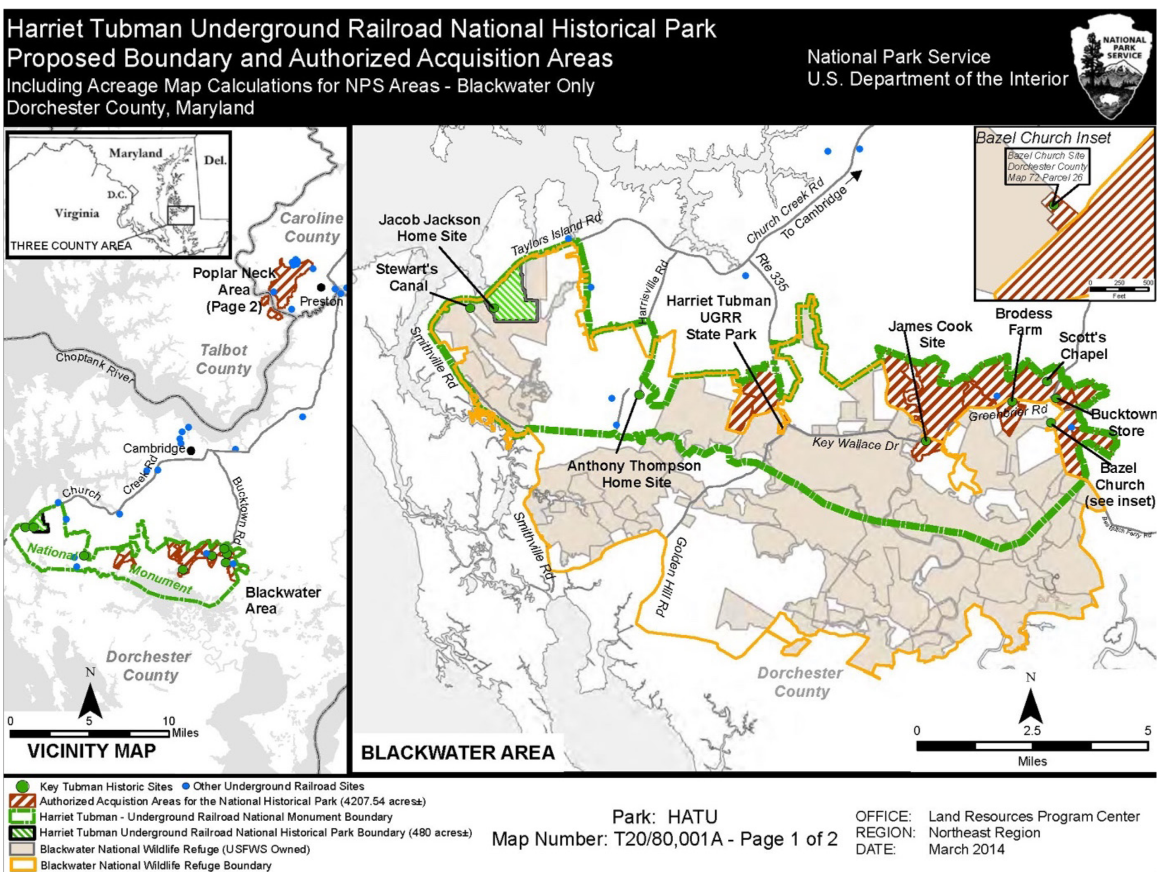


Figure 3-1. Map of Harriet Tubman Underground Railroad National Historical Park (Data source: NPS 2018).

3.2.3. General Approach and Methods

A total of 4 vital signs, 20 indicators, and 30 metrics were reviewed in this assessment (Figure 3-2). The approach for assessing resource condition within the park required establishment of a reference condition for each metric. In ideal situations, reference conditions were derived from scientific literature. However, where sufficient peer-reviewed data of reference conditions were not available, thresholds were determined based on best professional judgment in cooperation with NPS and USFWS staff. More detailed information about reference conditions and the confidence in condition assessments for each indicator can be found in the "Reference Condition" sections in Chapter 4.

Figure 3-2. Vital signs (second column) and indicators (third column) for Harriet Tubman Underground Railroad National Historical Park (HATU) used in its Natural Resource Condition Assessment (NRCA). Most indicators were assessed with one metric. Exceptions are ozone (two metrics), dissolved oxygen (two metrics), forest structure (five metrics), land cover (two metrics), wetlands (two metrics), and historic landscape (three metrics).

The methods used to calculate metric scores varied. These methods are described in detail in the "Data and Methods" sections of Chapter 4. In all cases, metric scores were compared to threshold values to calculate a percent attainment. When more than one metric was used to assess an indicator, the mean percent attainment of all metric scores was taken as the overall indicator score. Likewise, the individual indicator scores were averaged to determine the overall condition score for each vital sign category, and then for the park itself. Indicators, vital signs, and overall condition scores are presented in Chapter 4 and Chapter 5.

Metrics were assigned a qualitative rating corresponding to the quantitative score based on recommended NPS guidance (Table 3-1, 3-2): Significant concern (0-33% reference condition attainment), Moderate concern (34-66% reference condition attainment), and Good condition (67-100% reference condition attainment). Key findings and recommendations were summarized for each vital sign category in Chapter 5 after discussion with NPS staff.

Table 3-1. Indicator symbols used to indicate condition, trend, and confidence in the assessment.

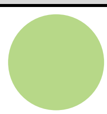
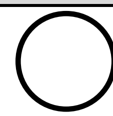
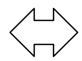
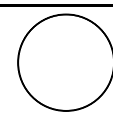
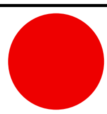
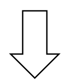
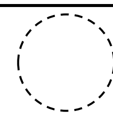
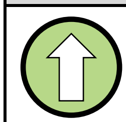
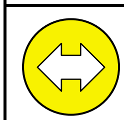
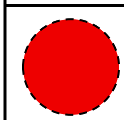
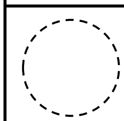
Condition Icon	Condition Icon Definition	Trend Icon	Trend Icon Definition	Confidence Icon	Confidence Icon Definition
	Resource is in Good Condition		Condition is Improving		High
	Resource warrants Moderate Concern		Condition is Unchanging		Medium
	Resource warrants Significant Concern		Condition is Deteriorating		Low

Table 3-2. Example indicator symbols and descriptions of how to interpret them in WCS tables.

Symbol Example	Verbal Description
	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.
	Current condition is unknown or indeterminate due to inadequate data, lack of reference value(s) for comparative purposes, and/or insufficient expert knowledge to reach a more specific condition determination; trend in condition is unknown or not applicable; low confidence in the assessment.

4. Natural Resource Conditions

4.1. Air Quality

Harriet Tubman Underground Railroad National Historical Park is located near and downwind from major industrial and urban areas. As amended in 1977 in the Clean Air Act, the U.S. Congress set a national goal of remedying and preventing any future impairment of visibility in any Class I, II, and III federal areas where that impairment is caused by manmade pollution. Despite improvements in air quality under the Clean Air Act over the past few decades and its Class II designation, Harriet Tubman Underground Railroad National Historical Park's visibility and air resources are still degraded relative to estimated natural or pre-industrial background conditions.

Four indicators were used to assess air quality within Harriet Tubman Underground Railroad National Historical Park: wet sulfur deposition, wet nitrogen deposition, visibility, and ground level ozone (4th highest 8-hour concentration and maximum 3-month 12-hour W126). Data used for this assessment were provided by the National Park Service Air Resource Division collated from a variety of national programs (Table 4-1).

Table 4-1. Indicators, sources, and data collection sites for data used in assessment of air quality resources within Harriet Tubman Underground Railroad National Historical Park. Site values interpolated using 5-year averages from nearby monitoring sites.

Indicator	Agency	Site	Source
Sulfur Deposition	NADP/NTN	Harriet Tubman Underground Railroad National Historical Park; Assateague Island National Seashore	http://nadp.sws.uiuc.edu
Nitrogen Deposition	NADP/NTN	Harriet Tubman Underground Railroad National Historical Park; Assateague Island National Seashore	http://nadp.sws.uiuc.edu
Visibility	NPS Air Resource Division	Harriet Tubman Underground Railroad National Historical Park; Assateague Island National Seashore	https://nature.nps.gov/air/maps/airatlas
Ozone	EPA CASTNET	Harriet Tubman Underground Railroad National Historical Park; Assateague Island National Seashore	http://epa.gov/castnet/javaweb/index.html

Air quality data were compared to reference condition values sourced from the National Park Service Natural Resource Program Center – Air Resource Division (National Park Service ARD 2011a). Current condition was determined by comparing the latest five years of data available for each indicator with reference conditions to obtain a percent attainment of reference conditions (Table 4-2). Data were not available from the park to assess trends. For trend analysis, data were sourced from Assateague Island National Seashore, a nearby park and monitoring station located approximately 100 km (60 miles) from Harriet Tubman Underground Railroad National Historical Park. Data are available from this park dating to the 2005-2009 five-year period.

Table 4-2. Air quality reference conditions used to assess air resource condition of Harriet Tubman Underground Railroad National Historical Park.

Air quality indicator	Number of sites	Period of observation	Reference conditions	Percent attainment applied
Wet sulfur deposition (kg/ha/yr)	1	2011-2015	< 1; 1-3; > 3	• < 1 = 100% • 1-3 = 0-100% scaled linearly • > 3 = 0%
Wet nitrogen deposition (kg/ha/yr)	1	2011-2015	< 1; 1-3; > 3	• <1 = 100% • 1-3 = 0-100% scaled linearly • >3 = 0%
Visibility (dv)	1	2011-2015	<2; 2-8; > 8	• <2 = 100% • 2-8= 0-100% scaled linearly • > 8 = 0%
Ozone (ppb)	1	2011-2015	< 60; 60-70; >70	• < 60 = 100% • 60-70= 0-100% scaled linearly • >70 = 0%
Ozone (W126; ppm-hrs)	1	2011-2015	< 7; 7-13; >13	• < 7 = 100% • 7-13= 0-100% scaled linearly • >13 = 0%

Air quality at Harriet Tubman Underground Railroad National Historical Park scored as Significant Concern (16%). All indicators were scored as Significant Concern (Table 4-3).

Table 4-3. Summary of air quality condition assessment at Harriet Tubman Underground Railroad National Historical Park.

Air quality indicator	Metric	Percent attainment	Condition	Overall condition
Wet sulfur deposition	Wet sulfur deposition (kg/ha/yr)	25%	Significant Concern	Significant Concern
Wet nitrogen deposition	Wet nitrogen deposition (kg/ha/yr)	0%	Significant Concern	Significant Concern
Visibility	Visibility (dv)	0%	Significant Concern	Significant Concern
Ozone	Ozone (ppb)	19%	Significant Concern	Significant Concern
	Ozone (W126; ppm-hrs)	35%	Significant Concern	Significant Concern

4.1.1. Total Wet Sulfur Deposition

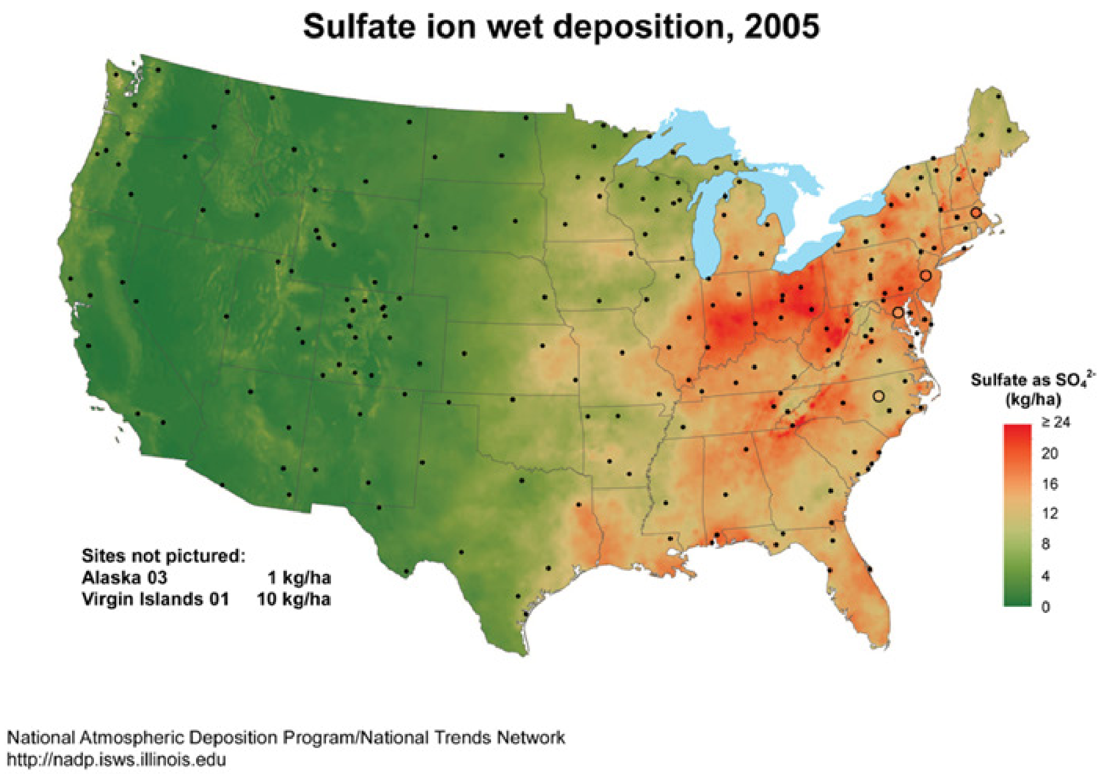
Description

Deposition is the process by which airborne particles are deposited onto the earth's surface (Porter and Morris 2007). Although deposition can occur via multiple pathways and for a variety of natural and anthropogenic pollutants, this assessment only considers deposition for sulfur and nitrogen from precipitation (wet deposition).

Wet deposition of sulfur can be a significant stressor for park ecosystems due to acidification of lakes, streams, soils, and soil water. Acidification of freshwater aquatic systems causes decreases in pH and acid neutralizing capacity, which, in turn, negatively affects sensitive aquatic biota, overall biodiversity, and ecosystem health (Driscoll et al. 2011). Acidification of soils depletes nutrients and can cause damage to susceptible vegetation including reduced growth, canopy dieback, and increased susceptibility to cold (Sullivan 2017).

Due to the high mobility of airborne sulfur-containing particles and prevailing westerly winds, the eastern portion of the U.S. experiences particularly high sulfur deposition rates. The largest source of sulfate emissions is energy generation from electric utilities (60%), and 41% of all sulfate emissions originate in the seven Midwest states centered on the Ohio Valley (Driscoll et al. 2001). Once airborne, sulfate particles can be transported distances greater than 500 km (311 mi) (Driscoll et al. 2001).

Sulfate emissions in the US have varied significantly over the last century. The earlier portion of the century was characterized by a drastic increase of sulfate emissions, from 9 million metric tons in 1900 to a high of 28.8 million metric tons in 1973 (Driscoll et al. 2001). After 1973 and the enactment of the Clean Air Act, emissions decreased to 5 million metric tons by 2012 (Sullivan 2017). The greatest improvements in total sulfur deposition are centered in the most affected eastern portion of the U.S. (Figure 4-1).



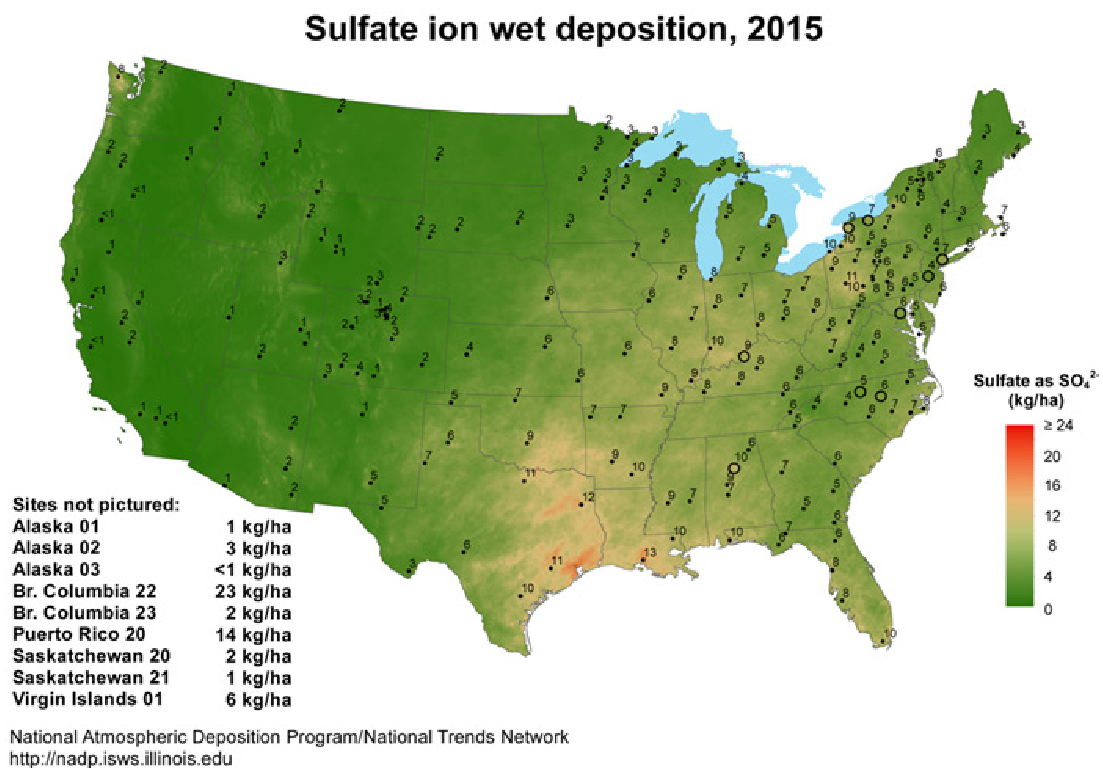


Figure 4-1. Total annual sulfate ion wet deposition for the conterminous United States in 2005 (top) and 2015 (bottom) (Data source: National Atmospheric Deposition Program 2018).

The median decrease in total sulfur deposition for the parks in the Mid-Atlantic region was 6.3 kg/ha/yr for the three-year averages from 2000-2002 to 2010-2012 (Sullivan 2017). Although these trends suggest significant improvements, many parks continue to experience deposition levels well above those expected from natural sources alone (Driscoll et al. 2001).

Data and Methods

Wet sulfur deposition is not measured within the park boundary but is interpolated from nearby stations by kriging, a statistical interpolation process. The closest monitoring site to Harriet Tubman Underground Railroad National Historical Park is in Worcester, MD, about 100 km (62 mi) from the park (NPS ARD 2012). Because Harriet Tubman Underground Railroad National Historical Park was only recently established, only one data point has been interpolated by the NPS ARD, representing 2011-2015. These data were used to assess current condition.

For the assessment of trend, five-year average values dating back to the 2005-2009 window were analyzed (https://www.nature.nps.gov/air/data/products/parks/index.cfm). These historical trend data were not available specifically for the park. Data from nearby Assateague Island National Seashore (NADP/NTN site #MD18) were assumed to provide a similar estimate of trend for total wet sulfur deposition.

Reference Conditions/Values

Total background sulfur deposition from natural sources in the eastern U.S. is 0.5 kg/ha/yr, which equates to a wet deposition of approximately 0.25 kg/ha/yr (Porter and Morris 2007; NPS ARD 2010a). NPS ARD has established wet sulfur deposition guidelines of <1 kg/ha/yr indicating Good Condition, 1-3 kg/ha/yr indicating Moderate Concern, and >3 kg/ha/ yr indicating Significant Concern. For this assessment, multiple thresholds were used: ≥3 kg/ha/yr was considered to be of Significant Concern (score of 0%), and deposition rates ≤ 1 kg/ha/year were considered to be Good Condition (attainment score of 100%). Attainment scores were scaled linearly from 0 to 100% for deposition rates between the reference points of 3 kg/ha/yr and 1 kg/ha/yr.

Condition and Trend

The 2011-2015 average annual sulfur wet deposition rate for the park was 2.5 kg/ha/yr. This represents a current condition of 25% attainment for the park based on comparison to the reference conditions. Factors such as elevation, land slope, the presence of lakes and streams, and the abundance of acid-sensitive tree species all increase a park's ecosystem sensitivity to acid deposition. Harriet Tubman Underground Railroad National Historical Park's geography and low-elevation, paired with its geology, topography, and vegetation communities, result in it being less susceptible or sensitive to acidification effects compared to other parks (Sullivan et al. 2011b). Total wet sulfur deposition in the region has decreased. For example, Assateague Island National Seashore decreased from a value of 5.1 kg/ha/yr for 2005-2009 to 2.6 kg/ha/yr for 2011-2015 (Figure 4-2).

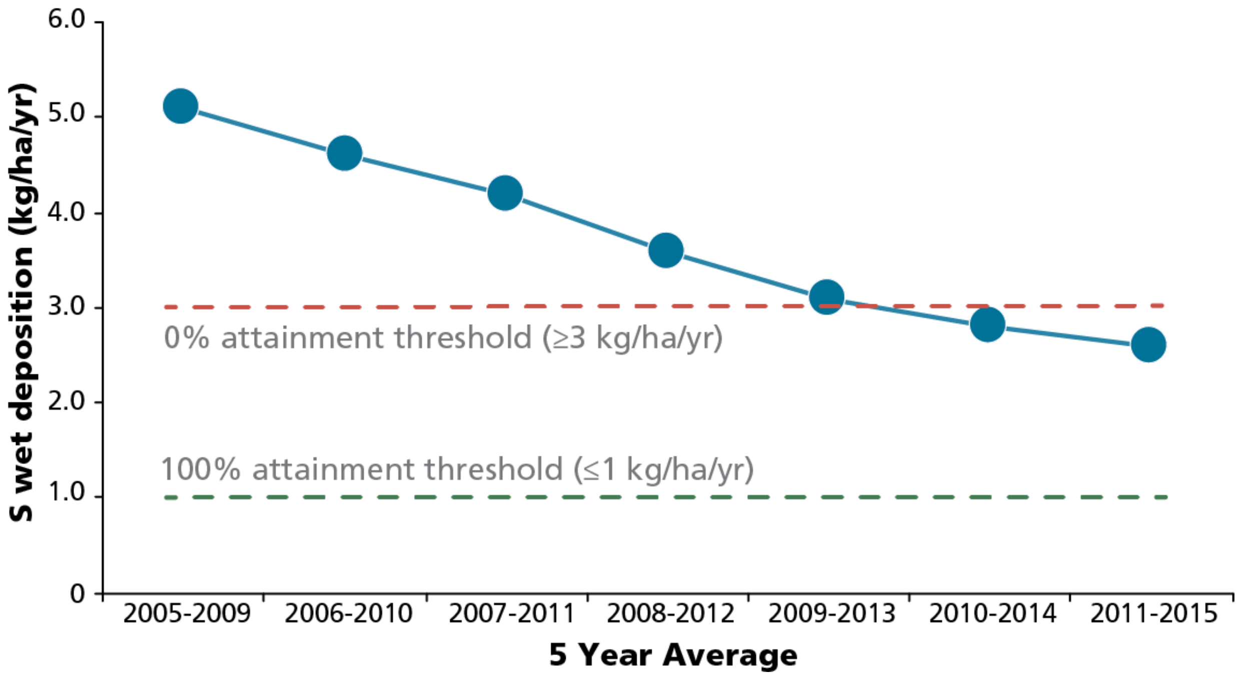


Figure 4-2. Five-year average values of total sulfur wet deposition (kg/ha/yr) for Assateague Island National Seashore (https://www.nature.nps.gov/air/data/products/parks/index.cfm) (Data source: National Atmospheric Deposition Program 2018).

Level of Confidence and Data Gaps

Many of the closest NADP/NTN monitoring stations within the region are located far from the parks, requiring considerable interpolation to derive park-based estimates. The distance between monitoring stations and the parks is problematic because wind patterns and localized meteorology may affect pollutant deposition. The closest monitoring site to Harriet Tubman Underground Railroad National Historical Park is in Worcester, MD (site #MD 18), about 100 km (62 mi) from the park. Since Harriet Tubman Underground Railroad National Historical Park is located on the coast, there are often local wind and meteorological patterns that can affect the deposition. Despite these factors, estimates derived for Harriet Tubman Underground Railroad National Historical Park match closely those derived for nearby Assateague Island National Seashore. In addition, the methods used by NPS ARD to generate these estimates are rigorous and well-documented. The overall confidence in the assessment of this indicator is high.

Source(s) of Expertise

- Holly Salazer, NPS Northeast Region Air Resources Coordinator

4.1.2. Wet Nitrogen Deposition

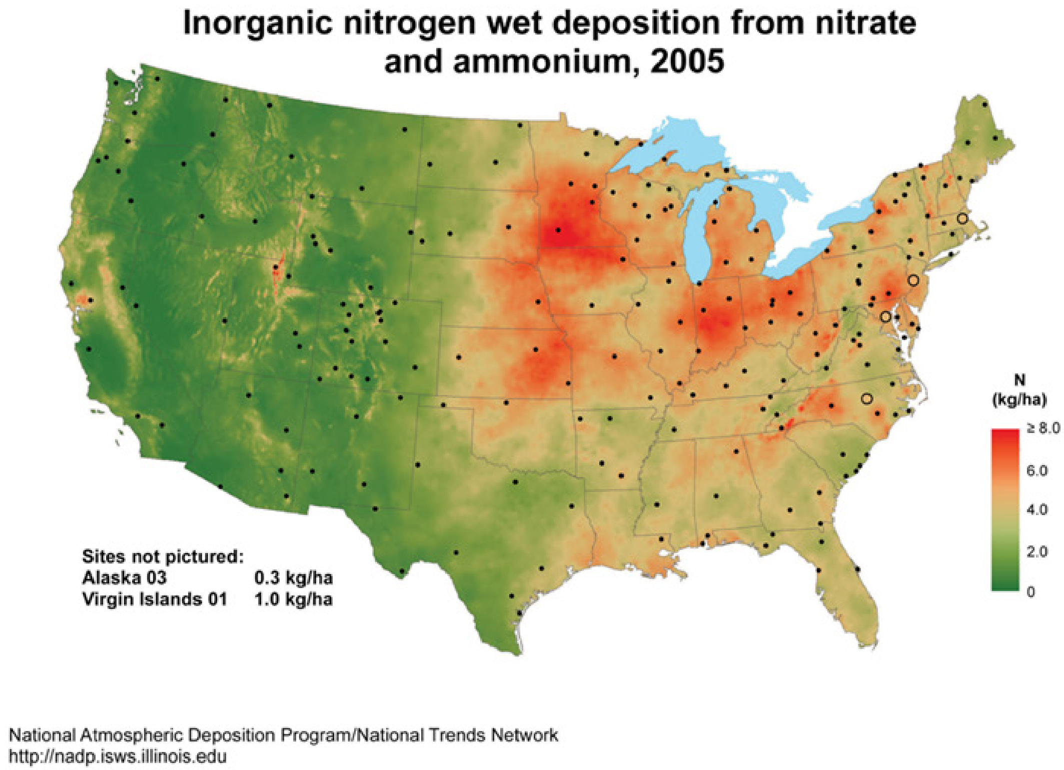
Description

Deposition is the process by which airborne particles are deposited onto the earth's surface (Porter and Morris 2007). Although deposition can occur via multiple pathways and for a variety of natural and anthropogenic pollutants, this assessment only considers deposition for sulfur and nitrogen from precipitation (wet deposition).

Wet deposition of nitrogen can be a significant stressor for park ecosystems due to acidification of lakes, streams, soils, and soil water. Acidification of freshwater aquatic systems causes decreases in pH and acid neutralizing capacity, which, in turn, negatively affects sensitive aquatic biota, overall biodiversity, and ecosystem health (Driscoll et al. 2011). Acidification of soils depletes nutrients and can cause damage to susceptible vegetation including reduced growth, canopy dieback, and increased susceptibility to cold (Sullivan 2017). Nutrient enrichment is another environmental stressor caused by nitrogen deposition. The excess nitrogen available as a nutrient in the ecosystem can result in changes in species composition for plant, lichen, and algal communities (Sullivan 2017). Some species are better able to take advantage of the excess nitrogen, leading to an abundance of opportunistic species at the cost of ecosystem diversity (Driscoll et al. 2011). Excessive nitrogen deposition also can lead to eutrophication in aquatic systems.

Nitrate emissions, like sulfate emissions, have undergone significant decreases since the Clean Air Act regulations of 1970, though the magnitude of improvements have not been as dramatic as for sulfate. Emissions dipped from a high of 31 million metric tons in 1970 to 11 million metric tons in 2012 (Sullivan 2017). Historically, anthropogenic nitrate emissions derive mostly from power plants and motor vehicles. However, recent increases in hydraulic fracturing for the development of oil and gas resources are also an important factor (Sullivan 2017). Agricultural sources also contribute to continuing high levels of nitrogen deposition.

The geographic distribution of nitrate emissions is centered on the Midwest, much like sulfates, and nitrates are also subject to the prevailing westerly winds, leading to elevated nitrogen deposition in the eastern portion of the U.S. (Driscoll et al. 2001). The greatest improvements in total nitrogen deposition are therefore centered in the most affected eastern portion of the U.S. (Figure 4-3). The median decrease in total nitrogen deposition for the parks in the Mid-Atlantic region was 3.9 kg/ha/yr for the three-year averages from 2000-2002 to 2010-2012 (Sullivan 2017).



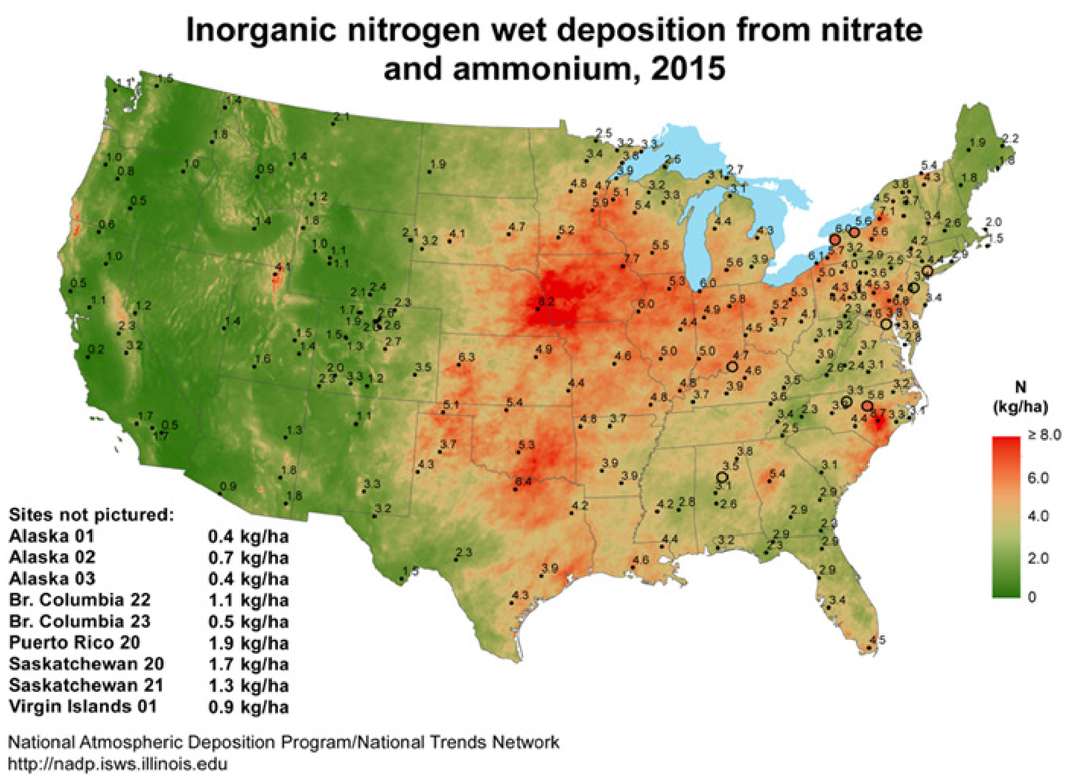


Figure 4-3. Total annual nitrogen wet deposition for the conterminous United States in 2005 (top) and 2015 (bottom) (Data source: National Atmospheric Deposition Program 2018).

Data and Methods

Data used for the park assessment were based on concentrations interpolated from the closest nearby stations by kringing, a statistical interpolation process. These concentrations were multiplied by annual average precipitation (30-year average derived from 1971-2000 provided in Daly et al. 2002) to estimate the total annual amount of nitrogen deposited. Because Harriet Tubman Underground Railroad National Historical Park was only recently established, only one data point has been interpolated by the NPS ARD, representing 2011-2015. These data were used to assess current condition.

For the assessment of trend, five-year average values dating back to the 2005-2009 window were analyzed (https://www.nature.nps.gov/air/data/products/parks/index.cfm). These historical trend data were not available specifically for the park. Data from nearby Assateague Island National Seashore (NADP/NTN site #MD18) were assumed to provide a similar estimate of trend for total wet nitrogen deposition.

Reference Conditions/Values

Background levels of nitrogen deposited (both wet and dry) by natural sources in the eastern U.S. have been estimated at 0.5 kg/ha/yr, which equates to a wet deposition of approximately 0.25 kg/ha/yr (Porter and Morris 2007; NPS ARD 2011a,b). NPS ARD has established wet nitrogen deposition guidelines as <1 kg/ha/yr indicating Good Condition, 1-3 kg/ha/yr indicating Moderate Concern, and >3 kg/ha/yr indicating Significant Concern (NPS ARD 2011a,b). While there is no evidence of ecosystem harm at deposition rates less than 1 kg/ha/yr, sensitive ecosystems show responses to wet nitrogen deposition rates as low as 1.5 kg/ha/yr (Fenn et al. 2003). For this assessment, multiple thresholds were used; ≥3 kg/ha/yr was considered to be of Significant Concern (score of 0%), and deposition rates ≤ 1 kg/ha/year were considered Good Condition (attainment score of 100%). Attainment scores were scaled linearly from 0 to 100% for deposition rates between the reference points of 3 kg/ha/yr and 1 kg/ha/yr.

Condition and Trend

Based on the threshold value of 3 kg/ha/yr, the 2011-2015 value of total nitrogen wet deposition in the park (3.9 kg/ha/yr) indicates a rating of Significant Concern and yields a current attainment score of 0%. Total nitrogen wet deposition in the region has decreased. For example, nitrogen deposition at Assateague Island National Seashore decreased from a value of 4 kg/ha/yr for 2005-2009 to 3.4 kg/ha/yr for 2011-2015 (Figure 4-4). This reflects an improving trend consistent with U.S.-wide reductions in emissions over the past decades (Driscoll et al. 2001) is consistent with decreasing trends in most parks in the eastern U.S. (NPS ARD 2010a). Additional reductions in nitrogen wet deposition are still needed to reduce negative impacts on natural resource condition (Porter and Johnson 2007).

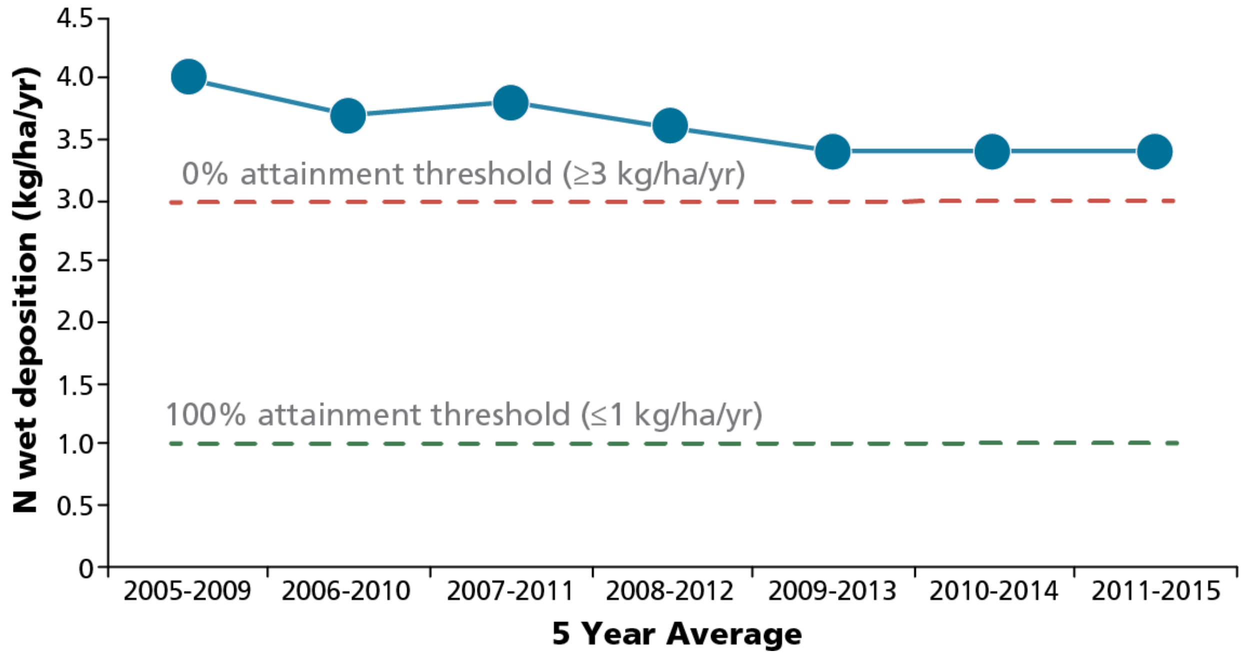


Figure 4-4. Five-year average values in total nitrogen wet deposition (kg/ha/yr) for Assateague Island National Seashore (https://www.nature.nps.gov/air/data/products/parks/index.cfm) (Data source: National Atmospheric Deposition Program 2018).

Level of Confidence and Data Gaps

Many of the parks in the region, including Harriet Tubman Underground Railroad National Historical Park, are miles from the closest NADP/National Trends Network (NTN) monitoring stations, requiring considerable interpolation to derive park-based estimates (Figure 4.4). The distance between monitoring stations and the park is problematic because variability in wind patterns and localized meteorology may significantly affect pollutant deposition. The closest monitoring site to Harriet Tubman Underground Railroad National Historical Park is in Worcester, MD (site #MD 18), about 100 km (62 mi) from the park. Despite these factors, estimates derived for Harriet Tubman Underground Railroad National Historical Park match closely those derived for nearby Assateague Island National Seashore. In addition, the methods used by NPS ARD to generate these estimates are rigorous and well-documented. The overall confidence in the assessment of this indicator is high.

Source(s) of Expertise

- Holly Salazer, NPS Northeast Region Air Resources Coordinator

4.1.3. Visibility

Description

Improving visibility in national parks and wilderness areas is of special concern to NPS, for example to protect the scenic vistas enjoyed by visitors (Loomis and Garnand 1986, NPS 1986). Particles less than 2.5 microns in diameter (PM 2.5) are emitted as smoke from power plants, gasoline and diesel engines, wood combustion, steel mills, forest fires, and chemical reactions (U.S. EPA 2006). These particles can have significant health impacts on humans and can negatively affect visibility (U.S. EPA 2004b, Cheung et al. 2005).

Nationally, visibility is relatively low in the eastern U.S. (Figure 4-5) (NPS ARD 2010a). Although the presence of organic matter, soot, nitrates, and soil dust all impair visibility, the major cause of reduced visibility in the eastern U.S. is sulfate particles formed from coal combustion (National Research Council 1993).

The Clean Air Act includes reduced visibility as an indicator of broader air quality degradation linked to human activities (U.S. EPA 2004a). The Clean Air Act visibility goal requires improvement for visibility on the 20% haziest days and no degradation on the 20% clearest days in Class I parks. Improving visibility in Class I parks also has the benefit of improving visibility in surrounding areas, including Class II parks.

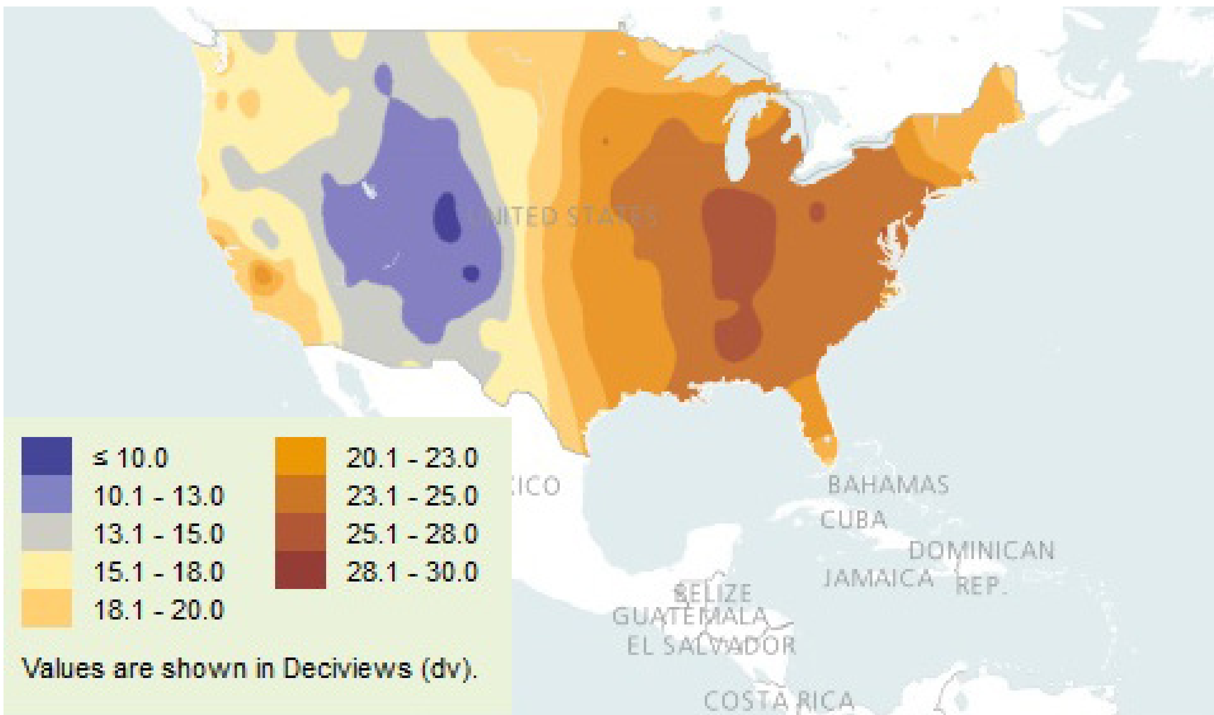


Figure 4-5. National patterns in haziest day haze index (dv) for the United States, 1999-2008 (Image source: NPS Air Resources Division 2010a).

<u>Data and Methods</u>

Data used for the park assessment were statistically interpolated by NPS ARD from the closest nearby Interagency Monitoring of Protected Visual Environments (IMPROVE) haze monitoring stations to the central point within Harriet Tubman Underground Railroad National Historical Park (NPS ARD 2012). The haze index, measured in deciviews (dv), indicates the difference between current group 50 visibility (the mean value of the 40th – 60th percentile data) and the natural group 50 visibility (estimated visibility in the absence of human-caused visibility impairment) (U.S. EPA 2003; NPS ARD 2011c). Because Harriet Tubman Underground Railroad National Historical Park was only recently established, only one data point has been interpolated representing the 2011 to 2015 time period. These data were used to assess current condition.

For assessment of trend, data were not available specifically for the park. It was assumed that estimated visibility from nearby Assateague Island National Seashore would provide similar estimates for visibility. Five-year average values dating back to the 2005 to 2009 window were analyzed to evaluate trend (https://www.nature.nps.gov/air/data/products/parks/index.cfm).

Reference Conditions/Values

Based on NPS ARD guidelines, a calculated haze index where the visibility is ≥8 dv above a natural visibility condition was considered to be of Significant Concern, with a 0% attainment score. Concentrations ≤ 2 dv above a natural visibility condition were considered to be in Good Condition, with a 100% attainment score (NPS ARD 2010a). Concentrations between 2-8 dv above a natural visibility condition were scaled linearly from 0 to 100% between these two reference points.

Condition and Trend

The park's 2011-2015 value of 9.4 dv indicates a condition of Significant Concern based on comparisons to the source threshold of 8 dv. This value represents a current condition of 0% attainment for the park. The trend in the five-year average values of haze index (dv) based on the Assateague Island National Seashore data indicates improving conditions for the region in recent years (Figure 4-6). Another recent assessment of 10-year trends in visibility within 163 NPS units throughout the country found that 12 park units showed significant improvement, 5 significant decline, and the remaining 146 showed no trend (NPS ARD 2010).

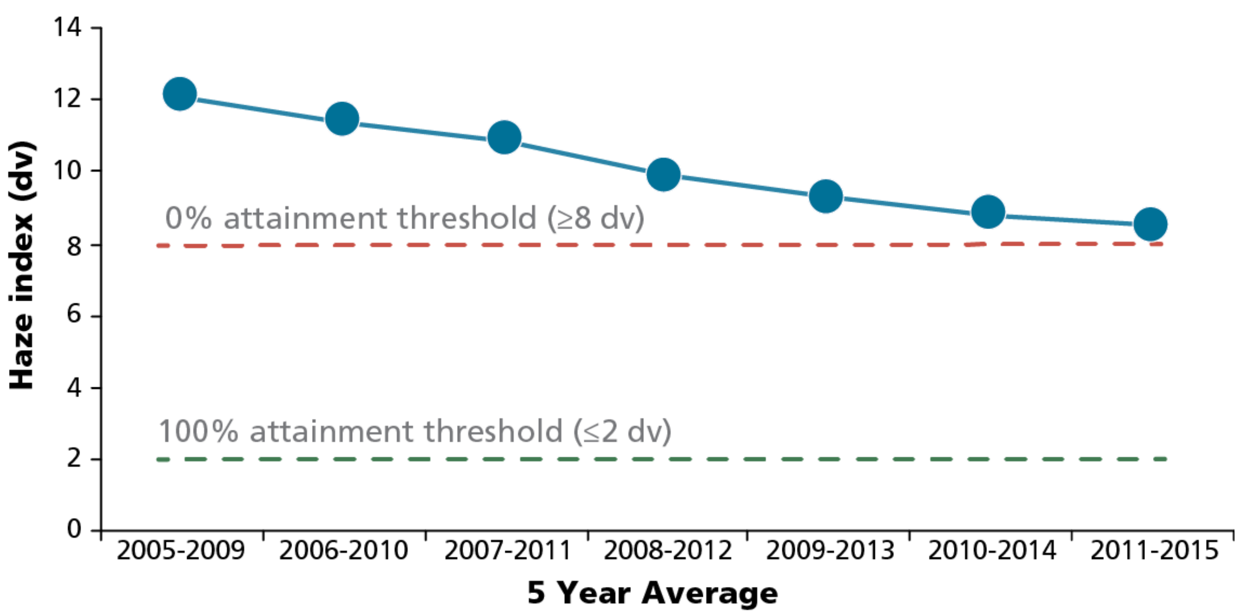


Figure 4-6. Five-year average values of haze index (dv) for Assateague Island National Seashore (https://www.nature.nps.gov/air/data/products/parks/index.cfm) (Data source: NPS Air Resources Division).

Level of Confidence and Data Gaps

Air quality data for Harriet Tubman Underground Railroad National Historical Park are not collected directly onsite but are spatially interpolated from monitoring stations located outside the park, the closest of which is in Worcester, MD (site #MD 18), about 100 km (62 mi) from the park. However, the interpolation process is distance-weighted such that the closest monitoring sites have the highest weight on the estimated value and only the 12 closest monitor sites are used to generate the estimated value. Additional considerations in evaluating potential error introduced by the interpolation process include generally high local variability in wind and meteorological conditions of coastal areas. Historical data also are not yet available for the park and small spatial errors are likely associated with the assessment of trend, which is derived from a different park. Nevertheless, given the overall agreement of the assessment results with regional air quality patterns and the strict NPS protocols used to derive the estimates, the confidence in the assessment is high.

Source(s) of Expertise

- Holly Salazer, NPS Northeast Region Air Resources Coordinator

4.1.4. Ozone

Description

Ozone, a secondary atmospheric pollutant, is not directly emitted but formed by a sunlight-driven chemical reaction on nitrous oxides and volatile organic compounds that are emitted largely from burning fossil fuels (Haagen-Smit and Fox 1956). Ozone in the troposphere can cause a number of health-related issues for humans, such as lung inflammation and reduced lung function, both of which can result in hospitalization (Lippmann 1991). Ozone concentrations of 120 ppb can be harmful to human lungs, even with short exposures during heavy exertion, such as jogging; similar issues can occur from prolonged exposure to ozone concentrations of 80 ppb (McKee et al. 1996). Nationally, the distribution of tropospheric ozone is relatively high in the Mid-Atlantic U.S. (Figure 4-7) (NPS ARD 2010a).

While trends in peak ozone levels (greater than or equal to 100 ppb) during the growing season have mirrored the decrease in sulfur and nitrogen deposition over the past 40 years, Moderate ozone concentrations in rural areas have become more widespread (Sullivan 2017). In fact, ozone concentrations have increased in the non-urban western U.S. by about 5 ppb between the late 1980s and the mid-2000s (Sullivan 2017). In 2010, the US Environmental Protection Agency proposed strengthening the primary (human health) standard to a value in the range of 60-70 ppb and establishing a separate secondary (welfare) standard to protect vegetation, based on an ecologically relevant indicator, the W126.

Some plant species are more sensitive to ozone than humans. Elevated ozone exposure levels can damage plant leaves, especially when soil moisture levels are Moderate to high. Under these conditions, plants have their stomata open, allowing gas exchange for photosynthesis, but also allowing ozone to enter. In a study of 28 plant species exposed to ozone for 3–6 weeks, foliar impacts, including premature defoliation were reported in all species at ozone concentrations between 60-90 ppb (Kline et al. 2008). As a consequence, a wide variety of vegetation at Harriet Tubman Underground Railroad National Historical Park may be vulnerable to elevated ozone concentrations (Lovett et al. 2009).

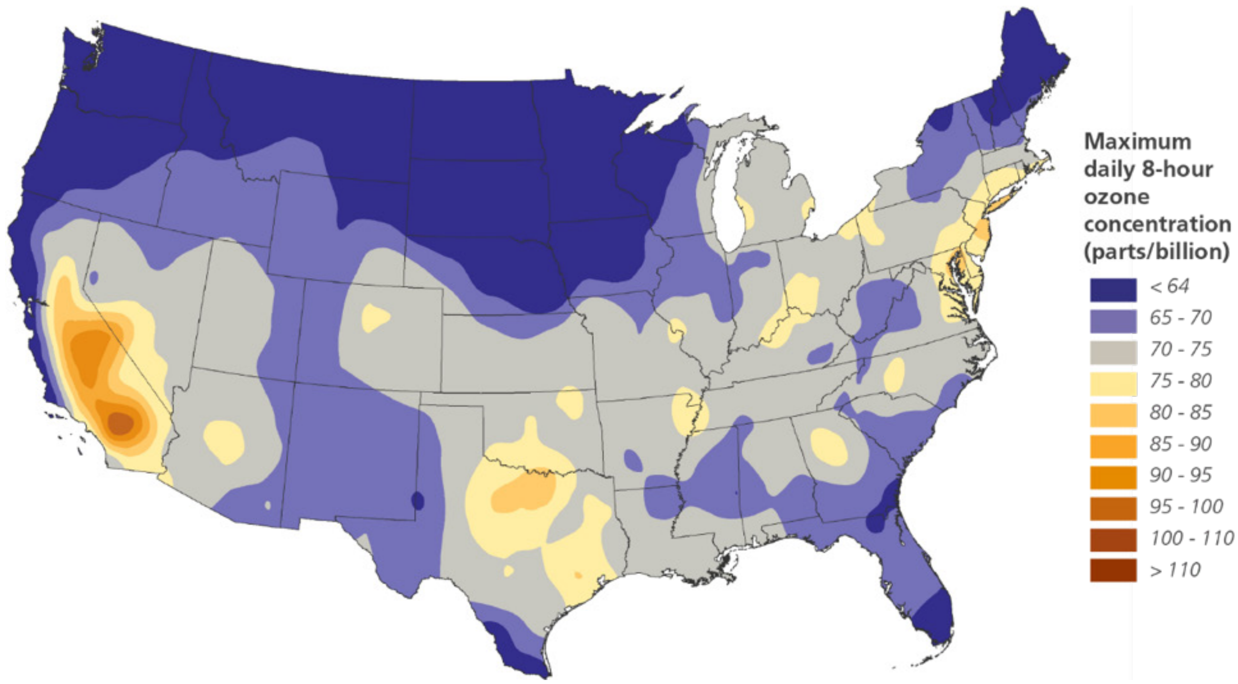


Figure 4-7. Air Atlas 2005-2009 displaying the fourth highest annual value of the maximum daily 8-hour ozone concentration in parts per billion in the continental US (http://www.nature.nps.gov/air/maps/AirAtlas/ozone.cfm) (Data source: NPS Air Resources Division).

Data and Methods

Ozone levels were estimated from the Clean Air Status and Trends Network (CASTNET) (http://epa.gov/castnet). Ozone is not measured within the park boundary but is interpolated from nearby stations by kriging, a statistical interpolation process. The closest monitoring site to Harriet Tubman Underground Railroad National Historical Park is in Worcester, MD, about 100 km (62 mi) from the park. Both the annual fourth-highest daily maximum 8-hour concentration (averaged over five years) and the plant-exposure indicator, W126, were used to assess ozone condition within the park. Data were provided by NPS ARD. These annual values are aggregated by NPS ARD to provide average values for 5-year intervals. The 5-year average for 2011-2015 was assessed against the threshold (ozone standards) to assess current condition.

For assessment of trend, data were not available specifically for the park. It was assumed that estimated ozone levels from nearby Assateague Island National Seashore (AQS Monitor ID: 240471001) would also reflect conditions within Harriet Tubman Underground Railroad National Historical Park. Five-year average values dating back to the 2005 to 2009 window were analyzed to evaluate trend (https://www.nature.nps.gov/air/data/products/parks/index.cfm).

Reference Conditions/Values

Tropospheric ozone is regulated under the Clean Air Act, and the U.S. EPA is required to set standard concentrations for ozone (U.S. EPA 2004a). In 1997, the ozone standard was set by the National Ambient Air Quality Standards (NAAQS) as 80 ppb for the 3-year average annual 4th highest daily maximum 8-hour ozone concentrations (U.S. EPA 2006). This standard has subsequently been lowered to 70 ppb (NAAQS 2008), with a current proposal for further reduction to an acceptable range of 60-70 ppb (NAAQS 2010). For this assessment, multiple threshold concentrations were used: concentrations >75 ppb were assigned an attainment score of 0%, and concentrations <60 ppb (set as 80% of the standard concentration limit) were assigned an attainment score of 100% (NPS ARD 2010a). For concentrations between 60-75 ppb, attainment scores were scaled linearly from 0 to 100% between these two reference points.

National Park Service ARD also looks at the W126 ozone metric as a more biologically relevant measure to assess the risk for ozone-induced foliar damage to sensitive plants. The W126 metric preferentially weights the higher ozone concentrations most likely to affect plants and sums all of the weighted concentrations during daylight hours. The highest 3-month period that occurs during the growing season is reported. Values less than 7 parts per million-hour (ppm-hr) are considered safe for sensitive plants (or 100% attainment and values greater than 13 ppm-hr warrant Significant Concern (or 0% attainment) (NPS ARD 2011c). For values between 7-13 ppm-hr, attainment scores were scaled linearly from 0 to 100% between these two reference points.

Condition and Trend

Harriet Tubman Underground Railroad National Historical Park's 2011-2015 ozone values indicate a significant level of concern. The NPS Air Quality estimate (five-year average) of the interpolated 4th highest daily maximum 8-hour ozone concentration from 2011 to 2015 was 71.9 ppb. Based on comparison to the threshold of 75.0 ppb, this value represents a current attainment score of 19% for the park. The 5-year average of the maximum 3-month 12-hour W126 between 2011 and 2015 for the park was 10.9 ppm-hr, which resulted in 35% reference condition attainment of reference condition. Averaging these two attainment values yields an overall condition score of 27%.

The reported trends for these two metrics are consistent with regional trends of declining tropospheric ozone concentrations (NPS ARD 2010a). For nearby Assateague Island National Seashore, the annual 4th highest daily maximum 8-hour ozone concentration decreased from 75.7 ppb in 2005-2009 to 72.2 ppb in 2011-2015 (Figure 4-8). The maximum 3-month 12-hour W126 ozone concentration exhibited a similar decrease during that time period (Figure 4-9). These improving conditions are consistent with national trends (Figure 4-10).

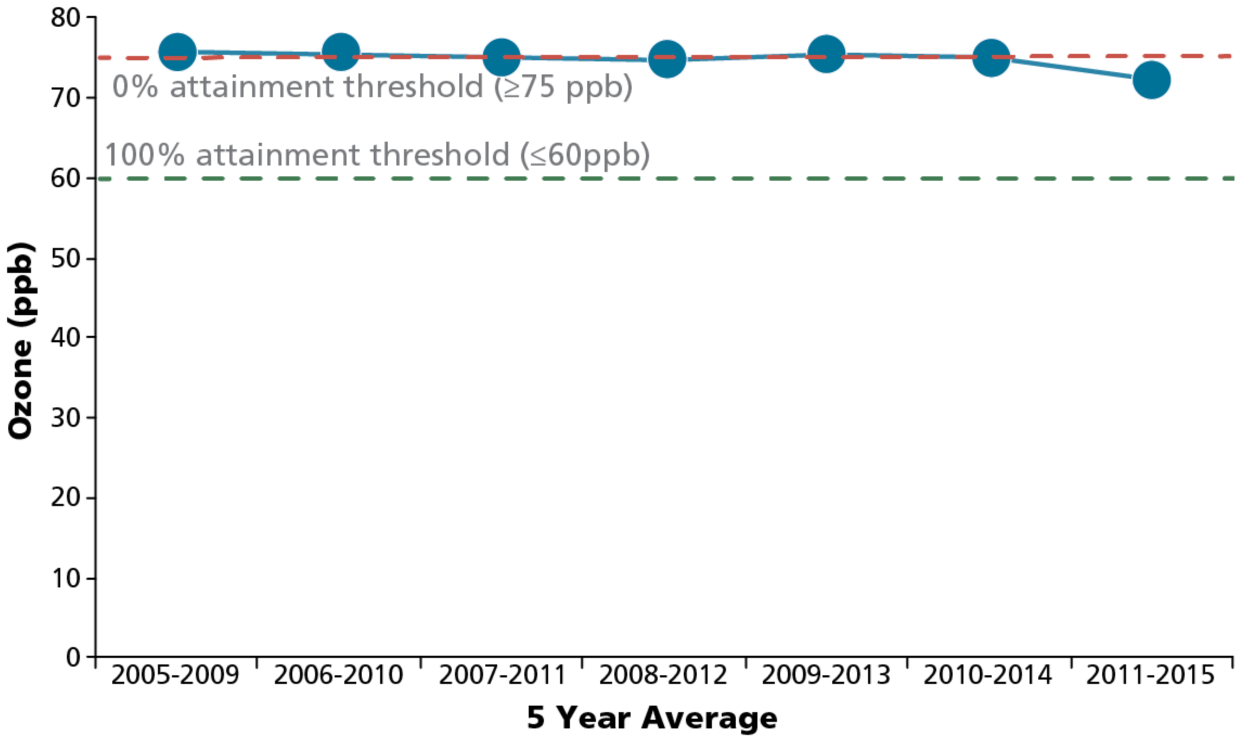


Figure 4-8. Five-year average values of annual 4th highest 8-hour concentration of ozone for Assateague Island National Seashore (https://www.nature.nps.gov/air/data/products/parks/index.cfm) (Data source: NPS Air Resources Division).

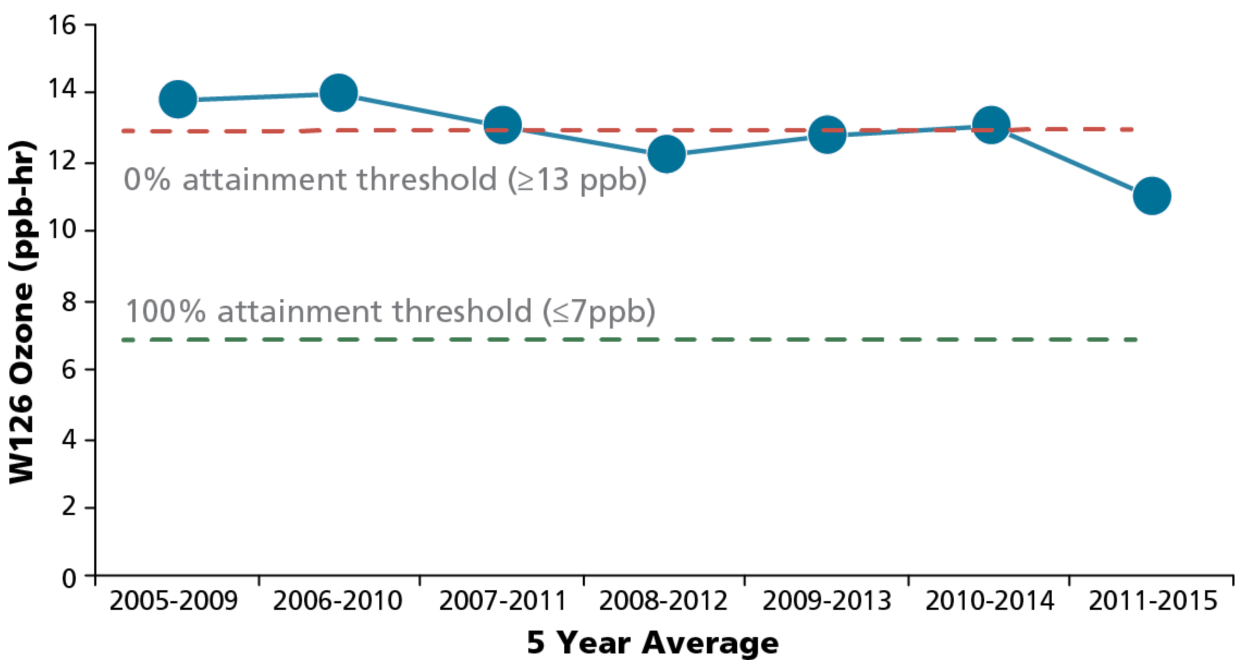


Figure 4-9. Five-year average values of annual 3-month maximum 12hr W126 ozone concentration for Assateague Island National Seashore (https://www.nature.nps.gov/air/data/products/parks/index.cfm) (Data source: NPS Air Resources Division).

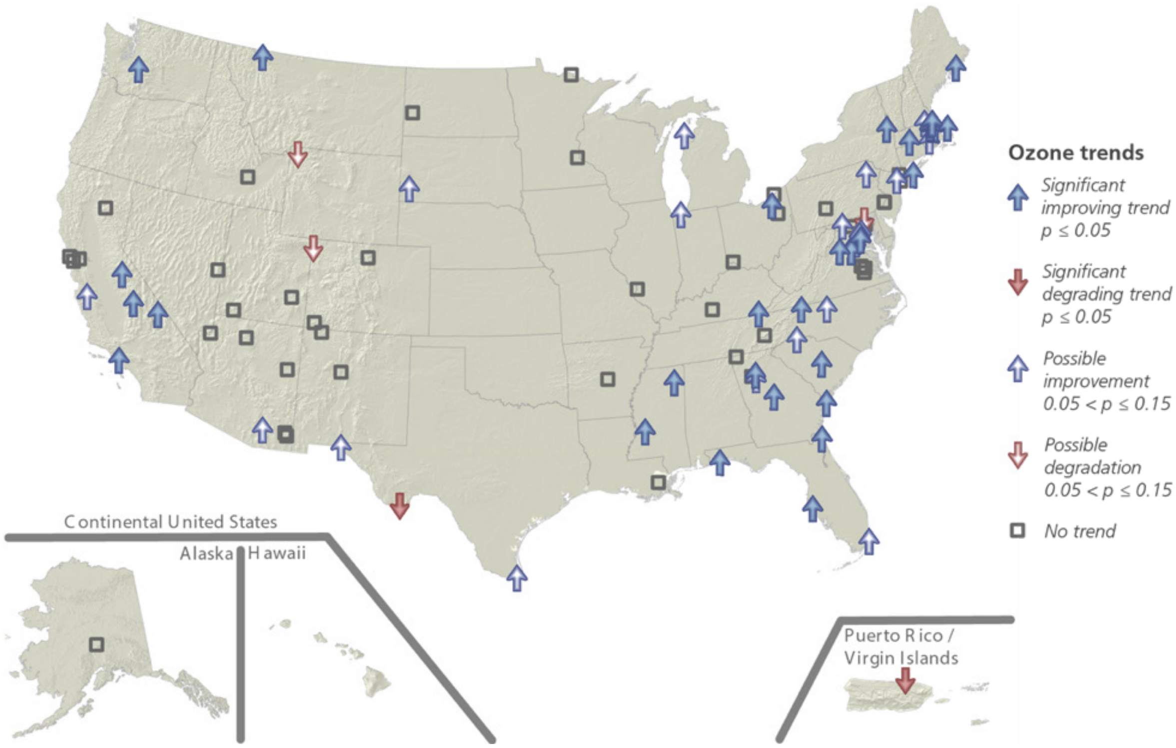


Figure 4-10. Trends in ozone concentrations from 1999-2008 for U.S. national parks (Data source: NPS Air Resources Division).

Level of Confidence and Data Gaps

Air quality data for Harriet Tubman Underground Railroad National Historical Park are not collected directly onsite but are spatially interpolated from monitoring stations located outside the park. Considerations in evaluating potential error introduced by the interpolation process include generally high local variability in wind and meteorological conditions of coastal areas. Historical data also are not yet available for the park and small spatial errors are likely associated with the assessment of trend, which is derived from a different park. However, given the agreement with national and regional air quality patterns and the strict NPS protocols used to derive the estimates, the confidence in the assessment is high. Although the data used for this assessment represent 5-year average values, which were compared to thresholds that were based on NAAQS 3-year average concentrations, there is no reason to believe this difference would bias the results.

Source(s) of Expertise

- Holly Salazer, NPS Northeast Region Air Resources Coordinator

4.2. Water Resources

Harriet Tubman Underground Railroad National Historical Park hosts a good portion of Blackwater Wildlife Refuge, and it is diverse in water features. Parson's Creek and the Blackwater River bisect both the refuge and park from west to east. Button's Creek and the Little Blackwater River enter the Blackwater River system from the north. Abundant water creates flowing as well as stagnant water in the form of freshwater and brackish streams, rivers, bays, marshes, and swamps.

Marshland near Parson’s Creek within Harriet Tubman Underground Railroad National Historical Park. Photo credit: National Park Service

Historically, Blackwater River and Parson’s Creek were not connected. Parson's Creek was channelized between 1850 and 1865 to facilitate the removal of timber. This channel was called Stewart's Canal after the landowner, and it is an important cultural feature of the park, as both Harriet Tubman and her father worked to build the canal. Further damage to marshes caused by nutria herbivory and accompanying salt water intrusion allowed a connection between Parson’s Creek and the headwaters of Blackwater River, such that the river is now tidally influenced from both ends. This breach was first noticed in 1989. A weir was installed in 2007 to reduce the salt water intrusion and restore the headwaters of the Blackwater River to freshwater conditions (Bessler and Whitbeck 2012).

The tides are asynchronous at the opposite ends of Blackwater River. A 4-hour tidal delay between the two connections to the Chesapeake Bay creates a pumping action that increases the salinity of the Blackwater River and surrounding wetlands. According to salinity tests, the freshest water is consistently found near the mouth of Buttons Creek at water quality monitoring station Site E (Figure 4-11). Most of Blackwater River is brackish, but salinity decreases towards the headwaters of the Blackwater River (Sites C and D in Figure 4-11).

Stewart's Canal, a channelized portion of Parson's Creek within Harriet Tubman Underground Railroad National Historical Park that facilitated the removal of timber in the mid-1800s. Photo credit: National Park Service.

Blackwater Wildlife Refuge established a long-term water quality monitoring program as a critical component in its Resource Inventory and Monitoring Program and to achieve the goals put forth in its Comprehensive Conservation Plan (US Fish and Wildlife Service 2006). Eight water quality monitoring stations are located within the Harriet Tubman Underground Railroad National Historical Park boundary (Figure 4-11) and are used here in the assessment. Measurements are made irrespective of storm events and tide level, although tide level is noted. Considering that flow of water can be a significant factor in driving physical and chemical characteristics of a water body, variability within the data is likely to be high.

In addition, benthic macroinvertebrate sampling was conducted in 2003 and 2006/2007 by two studies (Berger/EA Joint Venture 2004, Guy et al. 2010). Nine of the twelve sites are located within the Harriet Tubman Underground Railroad National Historical Park (Figure 4-12). The purpose of the short-term studies was to identify benthic invertebrate communities associated with different marsh habitats (including a recently failed marsh; Berger/EA Joint Venture 2004) and to assess the potential impacts of development in the upper reaches of the Little Blackwater River on downstream water toxicity and quality (Guy et al. 2010).

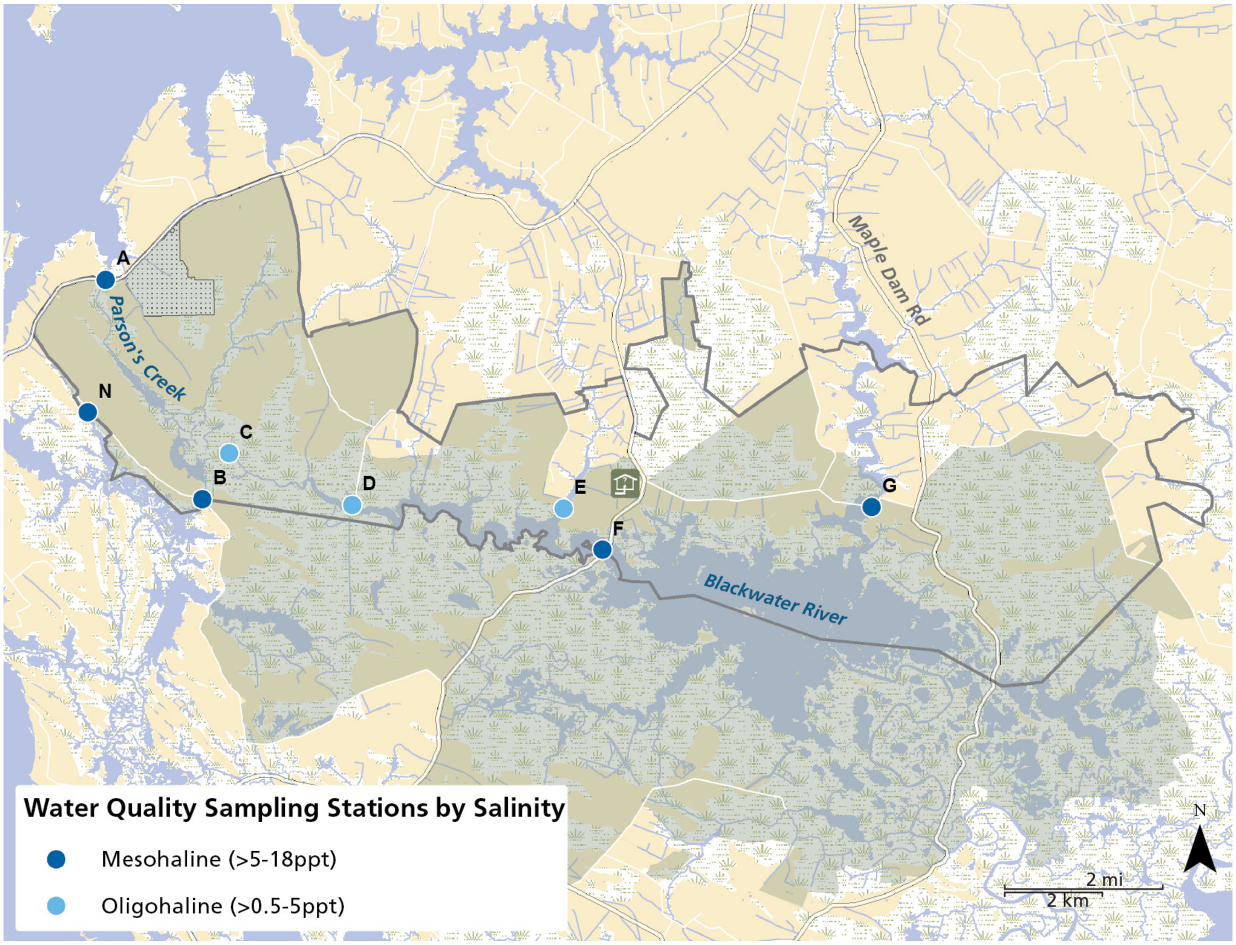


Figure 4-11. Water resources at Harriet Tubman Underground Railroad National Historical Park. The park boundary is outlined in gray with Blackwater National Wildlife Refuge highlighted in green. The Jacob Jackson parcel, owned by the National Park Service, is outlined as the stippled polygon in the northwest of the park. Long-term water quality monitoring stations A-G and N are visited twice per month throughout the year, with Site A water quality most relevant to the National Park Service-owned land. Salinity factors into the assessment of water clarity, nitrogen, phosphorus and chlorophyll *a* and is shown here as a categorization of the general salinity regime (map) and variation in salinity across seasons from 2010 to 2016 (inset). Above 5 ppt, a site is considered mesohaline and below 5 ppt, oligohaline. Sites F and G frequently fluctuate between oligohaline and mesohaline conditions and are just above the 5 ppt threshold for average salinity (Data source: Matt Whitbeck, Blackwater NWR 2017).

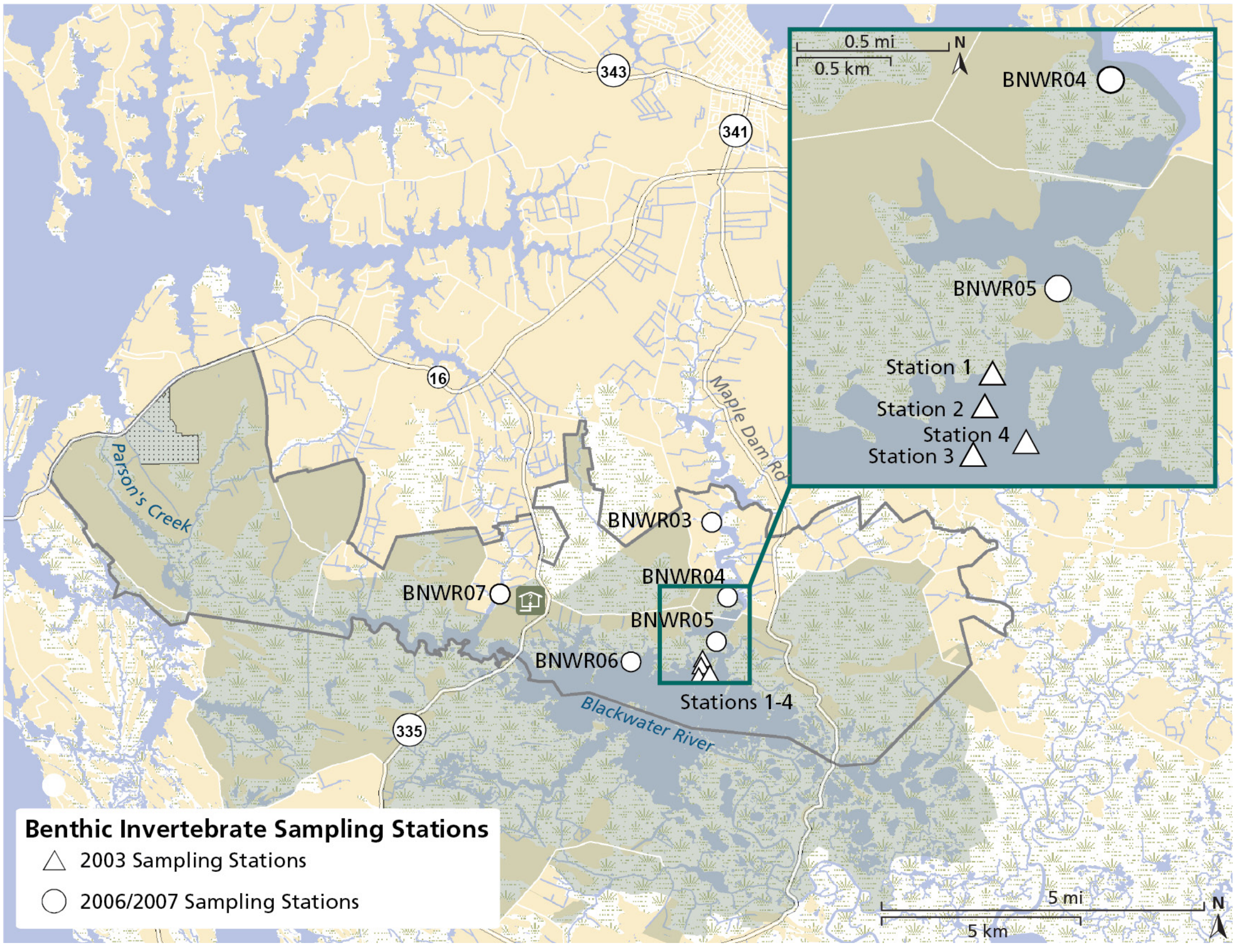


Figure 4-12. Benthic invertebrate sampling conducted across two studies in 2003 (Berger/EA Joint Venture 2004) and in 2006/2007 (Guy et al. 2010). Nine of the twelve sampling sites were located within Harriet Tubman Underground Railroad National Historical Park, outlined in gray. Blackwater National Wildlife Refuge is shaded green (Data source: Matt Whitbeck, Blackwater NWR 2017).

This Natural Resources Condition Assessment uses data collected from seven water quality sites monitored from 2010 to 2016 to assess six indicators – dissolved oxygen, water clarity, temperature, nitrogen, phosphorus and chlorophyll a - and from 9 sites to determine an index of benthic index of biotic integrity (Table 4-4).

Table 4-4. Water resources data provided by agencies and specific sources included in the assessment of Harriet Tubman Underground Railroad National Historical Park.

Indicator	Agency	Source
Dissolved oxygen	US Fish and Wildlife Service	Blackwater Wildlife Refuge
Water clarity	US Fish and Wildlife Service	Blackwater Wildlife Refuge
Temperature	US Fish and Wildlife Service	Blackwater Wildlife Refuge
Nitrogen	US Fish and Wildlife Service	Blackwater Wildlife Refuge

Table 4-4 (continued). Water resources data provided by agencies and specific sources included in the assessment of Harriet Tubman Underground Railroad National Historical Park.

Indicator	Agency	Source
Phosphorus	US Fish and Wildlife Service	Blackwater Wildlife Refuge
Chlorophyll a	US Fish and Wildlife Service	Blackwater Wildlife Refuge
Benthic Index of Biotic Integrity	US Army Corps of Engineers, US Fish and Wildlife Service	Berger/EA Join Venture 2004, Guy et al. 2010

Reference conditions were used for each of the seven indicators (Table 4-5), to determine percent attainment of each indicator when compared to the reference.

Table 4-5. Data availability and reference conditions used to assess condition of seven water resource indicators at Harriet Tubman Underground Railroad National Historical Park. Dissolved oxygen and temperature were assessed at two levels based on one reference condition that determined whether the habitat was adequate (100%) or not (0%). Water clarity, total nitrogen, total phosphorus, and chlorophyll a were assessed at six levels (0-5) based on a gradient of habitat conditions (EcoCheck 2011). The benthic index of biotic integrity was assessed at five levels (1-5) based on comparing several metrics calculated at a sample site to a minimally impacted site (Weisberg et al. 1997, Norris and Sanders 2009). Percent attainment among the categories was scaled linearly from 0% (level 0 for water quality and level 1 for benthic index of biotic integrity) and 100% (level 5). Chlorophyll *a* was assessed specifically for spring and summer months because the reference conditions for this indicator vary by season. All other indicators did not incorporate seasonality in the assessment of reference condition attainment, and none accounted for tidal flow or storm events.

Water resources indicator	Number of sites	Number of samples	Period of observation	Reference condition
Dissolved oxygen	8	814	2010-2016	• > 5.0 mg/L • < 3 consecutive samples in a year that fail the reference condition
Water clarity	8	489	2010-2016	• 5: ≥ 120 cm for oligohaline, ≥ 180 cm for mesohaline • 4: ≥ 70 cm - < 120 cm for oligohaline, ≥ 100 cm - < 180 cm for mesohaline • 3: ≥ 40 cm - < 70 cm for oligohaline, ≥ 70 cm - < 100 cm for mesohaline • 2: ≥ 30 cm - < 40 cm for oligohaline, ≥ 50 cm - < 70 cm for mesohaline • 1: ≥ 20 cm - < 30 cm for oligohaline, ≥ 30 cm - < 50 cm for mesohaline • 0: < 20 cm for oligohaline, < 30 cm for mesohaline
Temperature	8	933	2010-2016	<32.2 °C
Total nitrogen	2	197	2012-2016	• 5: ≤ 0.6 mg/L for oligohaline, ≤ 0.5 mg/L for mesohaline • 4: > 0.6 mg/L - ≤ 0.9 mg/L for oligohaline, > 0.5 mg/L - ≤ 0.6 mg/L for mesohaline • 3: > 0.9 mg/L - ≤ 1.3 mg/L for oligohaline, > 0.6 mg/L - ≤ 0.8 mg/L for mesohaline • 2: > 1.3 mg/L - ≤ 1.8 mg/L for oligohaline, > 0.8 mg/L - ≤ 1.0 mg/L for mesohaline • 1: > 1.8 mg/L - ≤ 2.8 mg/L for oligohaline, > 1.0 mg/L - ≤ 1.5 mg/L for mesohaline • 0: > 2.8 mg/L for oligohaline, > 1.5 mg/L for mesohaline

Table 4-5 (continued). Data availability and reference conditions used to assess condition of seven water resource indicators at Harriet Tubman Underground Railroad National Historical Park. Dissolved oxygen and temperature were assessed at two levels based on one reference condition that determined whether the habitat was adequate (100%) or not (0%). Water clarity, total nitrogen, total phosphorus, and chlorophyll a were assessed at six levels (0-5) based on a gradient of habitat conditions (EcoCheck 2011). The benthic index of biotic integrity was assessed at five levels (1-5) based on comparing several metrics calculated at a sample site to a minimally impacted site (Weisberg et al. 1997, Norris and Sanders 2009). Percent attainment among the categories was scaled linearly from 0% (level 0 for water quality and level 1 for benthic index of biotic integrity) and 100% (level 5). Chlorophyll *a* was assessed specifically for spring and summer months because the reference conditions for this indicator vary by season. All other indicators did not incorporate seasonality in the assessment of reference condition attainment, and none accounted for tidal flow or storm events.

Water resources indicator	Number of sites	Number of samples	Period of observation	Reference condition
Total phosphorus	2	197	2012-2016	• 5: ≤ 0.04 mg/L for oligohaline, ≤ 0.02 mg/L for mesohaline • 4: > 0.04 mg/L - ≤ 0.07 mg/L for oligohaline, > 0.02 mg/L - ≤ 0.04 mg/L for mesohaline • 3: > 0.07 mg/L - ≤ 0.10 mg/L for oligohaline, > 0.04 mg/L - ≤ 0.06 mg/L for mesohaline • 2: > 0.10 mg/L - ≤ 0.15 mg/L for oligohaline, > 0.06 mg/L - ≤ 0.08 mg/L for mesohaline • 1: > 0.15 mg/L - ≤ 0.28 mg/L for oligohaline, > 0.08 mg/L - ≤ 0.15 mg/L for mesohaline • 0: > 0.28 mg/L for oligohaline, > 0.15 mg/L for mesohaline
Chlorophyll a	2	48	2012-2016 (spring)	• 5: ≤ 1.5 µg/L for oligohaline, ≤ 2.09 µg/L for mesohaline • 4: > 1.5 µg/L - ≤ 20.9 µg/L for oligohaline, > 2.09 µg/L - ≤ 6.2 µg/L for mesohaline • 3: > 20.9 µg/L - ≤ 27.7 µg/L for oligohaline, > 6.2 µg/L - ≤ 11.1 µg/L for mesohaline • 2: > 27.7 µg/L - ≤ 39.4 µg/L for oligohaline, > 11.1 µg/L - ≤ 19.1 µg/L for mesohaline • 1: > 39.4 µg/L - ≤ 62.3 µg/L for oligohaline, > 19.1 µg/L - ≤ 49.8 µg/L for mesohaline • 0: > 62.3 mg/L for oligohaline, > 49.8 mg/L for mesohaline

Table 4-5 (continued). Data availability and reference conditions used to assess condition of seven water resource indicators at Harriet Tubman Underground Railroad National Historical Park. Dissolved oxygen and temperature were assessed at two levels based on one reference condition that determined whether the habitat was adequate (100%) or not (0%). Water clarity, total nitrogen, total phosphorus, and chlorophyll a were assessed at six levels (0-5) based on a gradient of habitat conditions (EcoCheck 2011). The benthic index of biotic integrity was assessed at five levels (1-5) based on comparing several metrics calculated at a sample site to a minimally impacted site (Weisberg et al. 1997, Norris and Sanders 2009). Percent attainment among the categories was scaled linearly from 0% (level 0 for water quality and level 1 for benthic index of biotic integrity) and 100% (level 5). Chlorophyll *a* was assessed specifically for spring and summer months because the reference conditions for this indicator vary by season. All other indicators did not incorporate seasonality in the assessment of reference condition attainment, and none accounted for tidal flow or storm events.

Water resources indicator	Number of sites	Number of samples	Period of observation	Reference condition
Chlorophyll a (continued)	2	48	2012-2016 (summer)	• 5: ≤ 3.0 µg/L for oligohaline, ≤ 1.7 µg/L for mesohaline • 4: > 3.0 µg/L - ≤ 9.5 µg/L for oligohaline, > 1.7 µg/L - ≤ 7.7 µg/L for mesohaline • 3: > 9.5 µg/L - ≤ 16.4 µg/L for oligohaline, > 7.7 µg/L - ≤ 11.0 µg/L for mesohaline • 2: > 16.4 µg/L - ≤ 29.9 µg/L for oligohaline, > 11.0 µg/L - ≤ 15.8 µg/L for mesohaline • 1: > 29.9 µg/L - ≤ 76.8 µg/L for oligohaline, > 15.8 µg/L - ≤ 35.8 µg/L for mesohaline • 0: > 76.8 mg/L for oligohaline, > 35.8 mg/L for mesohaline
Benthic Index of Biotic Integrity	9	13	2003, 2006-2007	1 - 5

Water resources at Harriet Tubman Underground Railroad National Historical Park scored as Moderate Concern (49%), although only one indicator – chlorophyll a – achieved this condition. All other indicators were either scored as Good Condition – dissolved oxygen and temperature – or Significant Concern – water clarity, nitrogen, phosphorus, and the benthic index of biotic integrity (Table 4-6).

Table 4-6. Summary of water resource condition assessment at Harriet Tubman Underground Railroad National Historical Park.

Water resources indicator	Metric	Percent attainment	Condition	Overall condition
Dissolved oxygen	Dissolved oxygen (mg/L)	77%	Good Condition	Moderate Concern
	# Hypoxic events	61%	Moderate Concern	Moderate Concern
Water clarity	Secchi depth (cm)	32%	Significant Concern	Moderate Concern
Temperature	Water temperature (°C)	100%	Good Condition	Moderate Concern
Total nitrogen	Total nitrogen (mg/L)	19%	Significant Concern	Moderate Concern
Total phosphorus	Total phosphorus (mg/L)	29%	Significant Concern	Moderate Concern
Chlorophyll a	Chlorophyll a (µg/L)	43%	Moderate Concern	Moderate Concern
Benthic Index of Biotic Integrity	BIBI score (1-5)	33%	Significant Concern	Moderate Concern

4.2.1. Dissolved Oxygen

Description

The concentration of dissolved oxygen (DO) in water is one of the most fundamental parameters of aquatic habitats (Wetzel 2001) and is often used to assess the health of aquatic environments. DO is produced by aquatic plant photosynthesis when sufficient light and nutrients are available. DO may also enter the water column through diffusion from air, wind cycling, and chemical oxidation (Figure 4-13; Horne and Goldman 1994). The supply of DO is counterbalanced by physical, chemical, and biological factors that determine the trophic status of a water body (Wetzel 2001).

The single most important factor that regulates DO is temperature because temperature affects the water's ability to hold DO and leads to the stratification of the water column. With stratification and little mixing by wind or turbulence, oxygen that diffuses into surface water cannot reach deeper layers. This may lead to a thermal-niche oxygen squeeze that causes organisms, such as striped bass in the Chesapeake Bay, to seek suitable habitat elsewhere (Kraus et al. 2015).

Already low DO levels can be further depleted by decomposition of organic matter and biological activity in general. Organic matter, such as dead algae from algal blooms and other plant and animal matter, sinks to the bottom of the environment, where it decomposes. The microbial decomposition process consumes DO, leaving less available to higher aquatic organisms, which also consume DO in the process of cellular respiration.

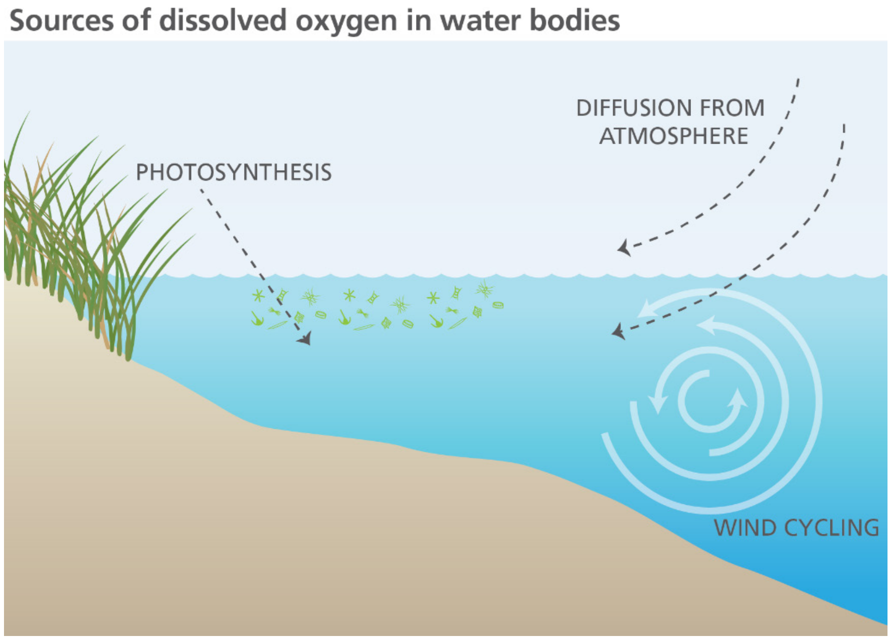


Figure 4-13. Sources of dissolved oxygen in water bodies (Adapted from Fondriest Environmental, Inc.).

<u>Data and Methods</u>

Data were collected two times per month between 2010 and 2016 from eight field sites at Harriet Tubman Underground Railroad National Historical Park (Figure 4-12). For each sampling event, a calibrated YSI 85 water quality probe was used to obtain a dissolved oxygen measurement. Measurements were averaged for each sampling site and each year to determine average condition in space and time, realizing that DO fluctuates throughout the day (higher during the day when plants photosynthesize and produce oxygen and lower during the night when plants respire) and during the year as temperatures change. To understand variation among seasons, DO was averaged for each season at each site.

<u>Reference Conditions/Values</u>

The reference condition of 5.0 mg/L DO (EcoCheck 2011) was used for all measurements. A passing score of 100 was assigned if a measurement was equal to or greater than the reference condition, and a failing score of 0 was assigned if a measurement was less than the reference. Each measurement was scored individually by comparing to the reference condition. Passing scores were counted for each of 8 sampling stations and the entire park to obtain a percent score for each location. 67 percent and above of passing scores was considered Good, between 34 and 66 percent Moderate Concern, and below 33 percent Significant Concern.

DO levels that are below the reference level for more than two consecutive time periods are a concern because they suggest hypoxia that persists for a longer time period. One hypoxia event in a year was considered a failing score for that year. The percent of passing scores were calculated for each site and averaged to obtain a percent score for the park. Similar to above, 67 percent was considered Good condition, between 34 and 66 percent Moderate Concern, and 33 percent and below is Significant Concern.

Condition and Trend

The condition of DO at Harriet Tubman Underground Railroad National Historical Park is scored as Good, with an average DO of 7.4 mg/L and a percent reference condition attainment of 77%, which is similar to scores reported by Eco Health for the nearby Choptank River (https://ecoreportcard.org/report-cards/chesapeake-bay/health/). All water monitoring sites within Harriet Tubman achieved the reference condition (Table 4-7), although the DO levels at sites C and N were often below 5 mg/L. Thus, the average condition at sites C and N was assessed as Moderate Concern (Figure 4-14).

Table 4-7. Average DO and average score from 2010 to 2016 for eight sampling sites within Harriet Tubman Underground Railroad National Historical Park.

Location	DO (g/mL)	Percent attainment	Score
A	8.27	82.98%	Good Condition
B	7.17	73.64%	Good Condition
C	5.98	58.62%	Moderate Concern
D	6.65	74.58%	Good Condition
E	7.27	77.97%	Good Condition
F	8.87	97.10%	Good Condition
G	9.42	94.96%	Good Condition
N	5.83	54.55%	Moderate Concern
Average	7.43	76.80%	Good Condition

The condition of hypoxia at Harriet Tubman Underground Railroad National Historical Park is scored as Moderate Concern with 61 percent attainment. We observed 17 occurrences when sites remained hypoxic for more than two consecutive samples (Table 4-8). Hypoxic periods sometimes started as early as May and could last into November.

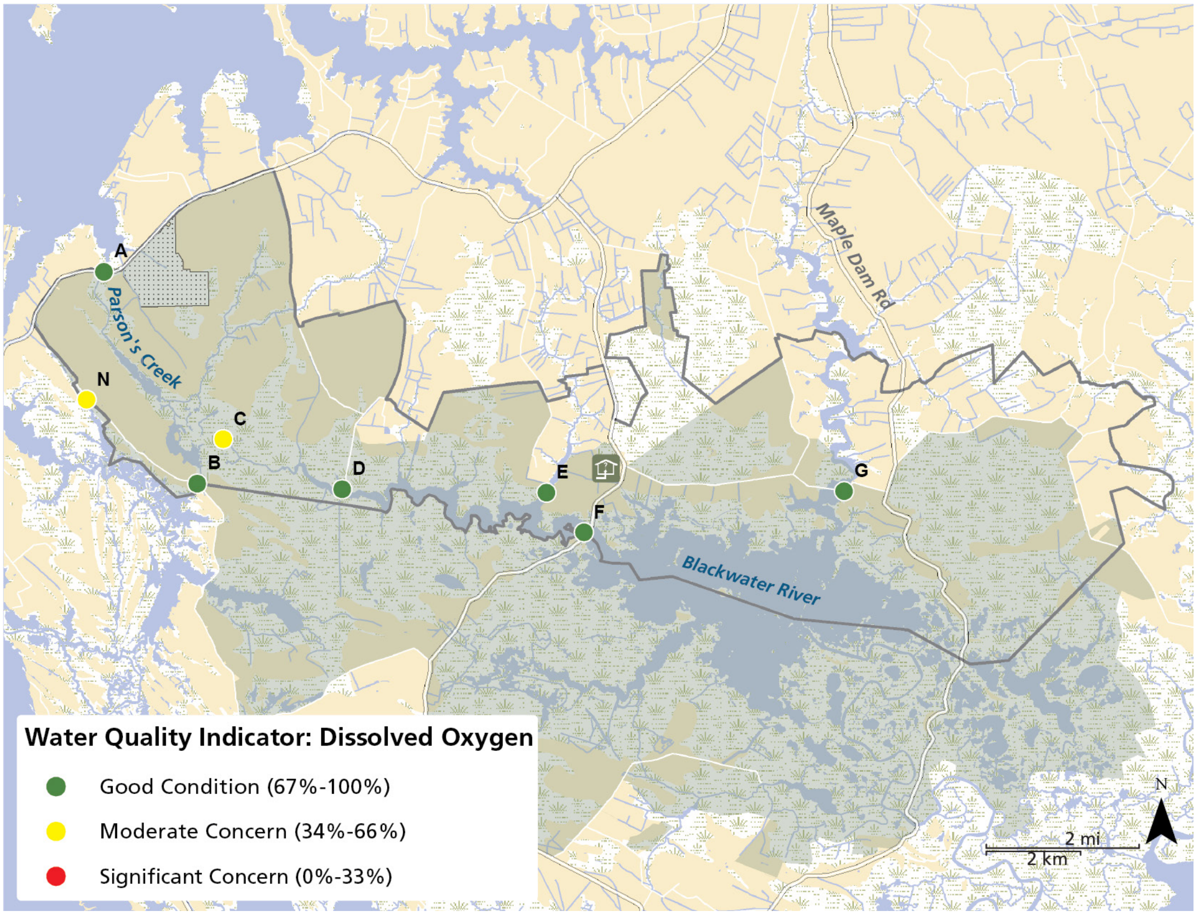


Figure 4-14. Attainment of the dissolved oxygen reference condition from 2010 to 2016 for eight sampling sites within Harriet Tubman Underground Railroad National Historical Park outlined in gray. Blackwater National Wildlife Refuge is shaded green (Data source: Matt Whitbeck, Blackwater NWR 2017).

Table 4-8. Months in which DO levels failed the reference condition of 5.0 mg/L DO for more than two consecutive measurements in 2010 to 2016 at 8 monitoring sites located within Harriet Tubman Underground Railroad National Historical Park.

Site	2010	2011	2013	2014	2015	2016	Percent attainment
A	May-Aug[a]	Aug-Sep[a]	–[b]	–[b]	–[b]	–[b]	67%
B	Jul-Sep[a]	May-Oct[a]	Sep-Oct	–[b]	–[c]	–[c]	25%
C	Jun-Aug[a]	Jul-Sep[a]	Jun-Aug	May-Jul	–[b]	–[b]	33%
D	–[b]	Aug-Sep[a]	Jun-Aug	–[b]	–[b]	–[b]	67%
E	–[b]	Jul-Sep[a]	Jun-Jul	–[b]	–[b]	–[b]	67%

[a] Months where there were at least two failed DO measurements (DO < 5.0 mg/L) (also with a red background).

[b] Years that did not have two failed DO measurements (DO < 5.0 mg/L) (also with a green background).

[c] Years that did not have two failed DO measurements (DO < 5.0 mg/L), but also where sites B and N had been discontinued for 2015 and 2016 (also with a white background).

Table 4-8 (continued). Months in which DO levels failed the reference condition of 5.0 mg/L DO for more than two consecutive measurements in 2010 to 2016 at 8 monitoring sites located within Harriet Tubman Underground Railroad National Historical Park.

Site	2010	2011	2013	2014	2015	2016	Percent attainment
F	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	100%
G	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]	100%
N	May-Sep[a]	May-Sep[a]	May-Nov[a]	Oct-Nov[a]	–[c]	–[c]	0%

[a] Months where there were at least two failed DO measurements (DO < 5.0 mg/L) (also with a red background).

[b] Years that did not have two failed DO measurements (DO < 5.0 mg/L) (also with a green background).

[c] Years that did not have two failed DO measurements (DO < 5.0 mg/L), but where sites B and N were discontinued (also with a white background).

Sites B, C and N are particularly problematic (Significant Concern) with 0 to 33 percent attainment, and sites A, D, E, F, and G are in Good condition with 67-100 percent attainment (Figure 4-15).

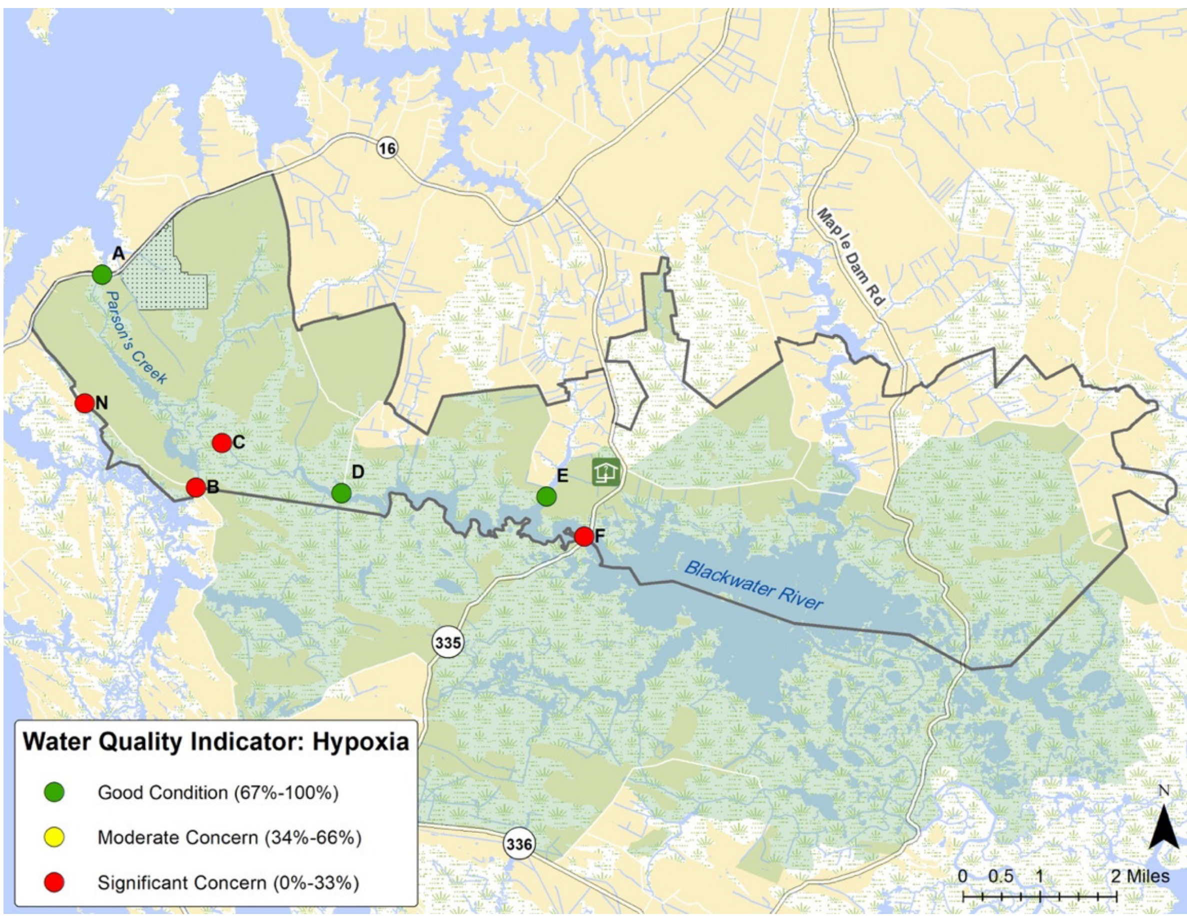


Figure 4-15. Attainment of the hypoxia reference condition from 2010 to 2016 for eight sampling sites within Harriet Tubman Underground Railroad National Historical Park outlined in gray. Blackwater National Wildlife Refuge is shaded green (Data source: Matt Whitbeck, Blackwater NWR 2017).

Overall, the condition of an adequate supply of oxygen is scored as Good with an average attainment of 69 percent based on a DO score (77 percent) and a hypoxia score (61 percent).

DO concentration varies across seasons, with summer months generally scored lowest; sites C and N scored as Significant Concern and sites F and G scored as Good (Table 4-9). The spring, summer, and fall seasons generally scored Good with a few exceptions – sites B and N scored Moderate Concern and Significant Concern in the fall, respectively, and site N scored Moderate Concern in the spring.

Table 4-9. Percent attainment of dissolved oxygen reference condition at each of 8 monitoring sites within Harriet Tubman Underground Railroad National Historical Park in four seasons (fall, winter, spring, and summer).

Site	Fall	Winter	Spring	Summer
A	89.74% [a]	100.00% [a]	94.44% [a]	47.06% [b]
B	59.26% [b]	100.00% [a]	83.33% [a]	45.45% [b]
C	70.00% [a]	100.00% [a]	81.25% [a]	30.77% [c]
D	70.00% [a]	100.00% [a]	88.24% [a]	61.54% [b]
E	90.00% [a]	100.00% [a]	94.12% [a]	57.69% [b]
F	100.00% [a]	100.00% [a]	100.00% [a]	88.24% [a]
G	100.00 [a]	100.00% [a]	100.00% [a]	80.00% [a]
N	29.63% [c]	96.00% [a]	63.89% [b]	22.73% [c]
Average	76.08%	99.50%	88.16%	54.18%

[a] Good condition (also with a green background).

[b] Condition warrants moderate concern (also with a yellow background).

[c] Condition warrants significant concern (also with a red background).

The trend in DO concentration is improving from an average of 6.8 mg/L in 2010 across all sites to an average of 8.6 mg/L across all sites in 2016 (Figure 4-16). Periods of persistent hypoxia (more than two consecutive measurements below 5.0 mg/L DO) declined across all sites, especially in 2015 and 2016 (Table 4-8).

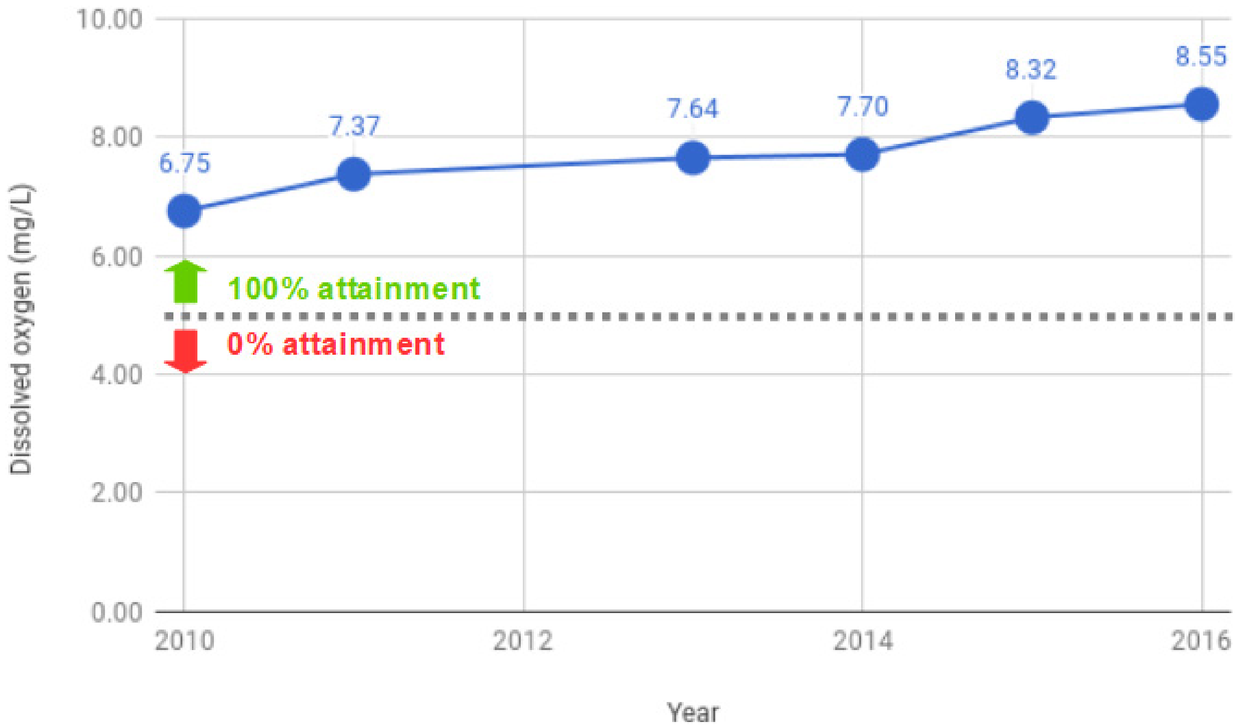


Figure 4-16. Average annual DO concentration from 2010 to 2016 from eight sampling sites at Harriet Tubman Underground Railroad National Historical Park (Data source: Matt Whitbeck, Blackwater NWR 2017).

Level of Confidence and Data Gaps

Confidence in the assessment is high because dissolved oxygen measurements were conducted for six years across eight sites within the park boundary. Methods followed stringent QA/QC procedures instituted by Blackwater Wildlife Refuge. Site A, which received one of the highest scores among the 8 sampling locations, is located in Stewart's Canal just outside the National Park Service's Jacob Jackson parcel and is the best representation of dissolved oxygen conditions in flowing waters at Jacob Jackson.

Source(s) of Expertise

- Matt Whitbeck, Supervisory Wildlife Biologist at Chesapeake Marshlands National Wildlife Refuge Complex.

4.2.2. Water Clarity

Description

Water clarity describes how well light penetrates water. It is important to ecosystem health because it can limit the growth and survival of submersed aquatic vegetation (Dennison 1987). Aquatic vegetation provides food and oxygen for heterotrophic organisms and is therefore necessary for their survival and growth.

Water clarity is decreased by factors that block sunlight, such as suspended sediments from runoff and phytoplankton growth. In some areas, such as the Blackwater River at Harriet Tubman

Underground Railroad National Historical Park, humic substances derived from organic soils color the water dark, which absorbs blue light and produces black or brown water systems (EcoCheck 2011).

Data and Methods

Data were collected by Blackwater National Wildlife Refuge two times per month between April and October from 2010 to 2016. Data are available from eight field sites at Harriet Tubman Underground Railroad National Historical Park, although additional sampling locations exist outside park boundaries (Figure 4-12). A 20-cm Secchi disc was lowered into the water at each site, and the depth at which the disc became no longer visible was recorded. Salinity at each field site during each sampling event was also recorded to classify the salinity regime, which determines the reference condition.

Reference Conditions/Values

Each Secchi depth observation was compared against a set of reference conditions and assigned a score from 0 to 5 (Ecocheck 2011). A score of 0 indicates low water clarity and 0% attainment of the reference condition. A score of 5 indicates high water clarity and 100% attainment of the reference condition. Reference conditions differed for sites with different salinity regimes (Table 4-10) because salinity affects the aggregation of suspended particles in estuarine waters (Schlesinger 1997, Håkanson 2006, Harvey et al. 2015). Thus, mesohaline sites have greater Secchi depths than oligohaline sites. Oligohaline sites have a salinity between 0.5 and 5 ppt and 100% of the reference condition attained when Secchi depth reaches 120 cm. Mesohaline sites have a salinity between 5 and 18 ppt and attain 100% of the reference condition at 180 cm Secchi depth.

Table 4-10. Reference condition in centimeters at Secchi depth and corresponding score based on the salinity regime of a sample site (EcoCheck 2011).

Oligohaline	Mesohaline	Score
≥ 120	≥ 180	5
≥ 70 - < 120	≥ 100 - < 180	4
≥ 40 - < 70	≥ 70 - < 100	3
≥ 30 - < 40	≥ 50 - < 70	2
≥ 20 - < 30	≥ 30 - < 50	1
< 20	< 30	0

Each Secchi depth measurement was scored individually before being aggregated into an average score for each year or site. Site scores were averaged to develop an overall park score. Percent attainment was calculated by dividing the average score for each year or site by 5 and multiplying by 100.

Condition and Trend

Water clarity at Harriet Tubman Underground Railroad National Historical Park was scored as Significant Concern. The average Secchi depth in the park was 43 cm with an average percent reference condition attainment of 32%. All sites within the park were scored as Moderate or Significant Concern (Table 4-11, Figure 4-17), with Site A near the National Park Service's Jacob Jackson parcel attaining the highest score (51%).

Table 4-11. Average Secchi depth and average score from 2010 to 2016 for eight sampling sites within Harriet Tubman Underground Railroad National Historical Park, for mesohaline sites (A, B, F, G, and N), and for oligohaline sites (C, D, and E).

Site	Average Secchi depth	Score	Percent attainment
A	77.25	2.57	51.40%
B	53.87	1.90	38.00%
C	39.19	1.95	39.00%
D	38.89	2.00	40.00%
E	29.35	1.04	20.80%
F	33.68	1.20	24.00%
G	30.16	0.91	18.20%
N	44.50	1.20	24.00%
Average	43.47	1.61	32.20%
Average Mesohaline	48.74	1.56	31.20%
Average Oligohaline	35.81	1.66	33.20%

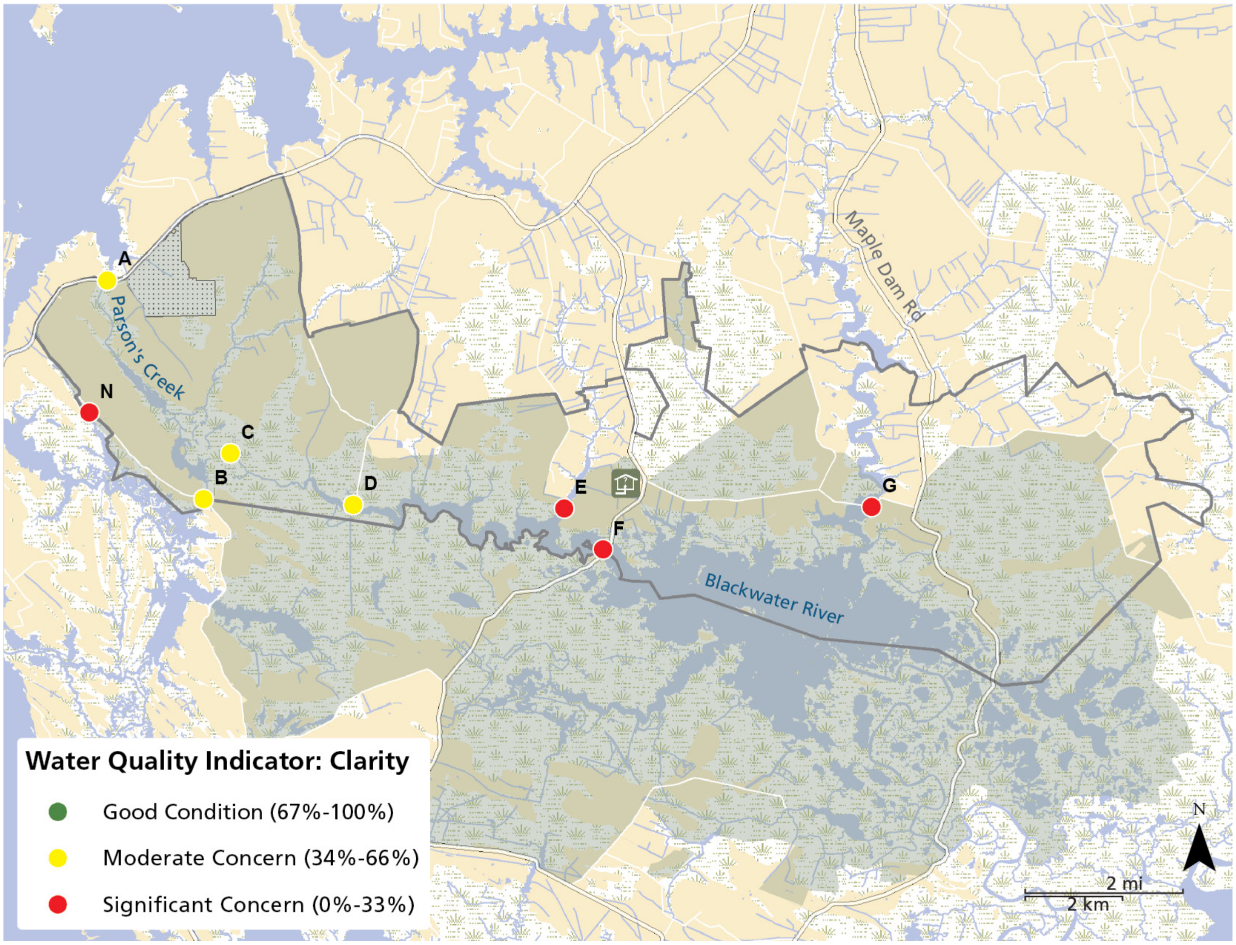


Figure 4-17. Attainment of the Secchi depth reference condition from 2010 to 2016 for eight sampling sites (green = 66% or more of reference value attained, yellow = 33-65% of reference value attained, red = <33% of reference value attained) within Harriet Tubman Underground Railroad National Historical Park outlined in gray. Blackwater National Wildlife Refuge is shaded in green (Data source: Matt Whitbeck, Blackwater NWR 2017).

The trend in water quality assessed by Secchi depth is decreasing from an average of 49 cm in 2010 to 39 cm in 2016 (Figure 4-18). For mesohaline sites, the average Secchi depth was 49 cm, below the reference condition of 180 cm. For oligohaline sites, the average depth was 36 cm, below the reference condition of 120 cm (Figure 4-19, Figure 4-20).

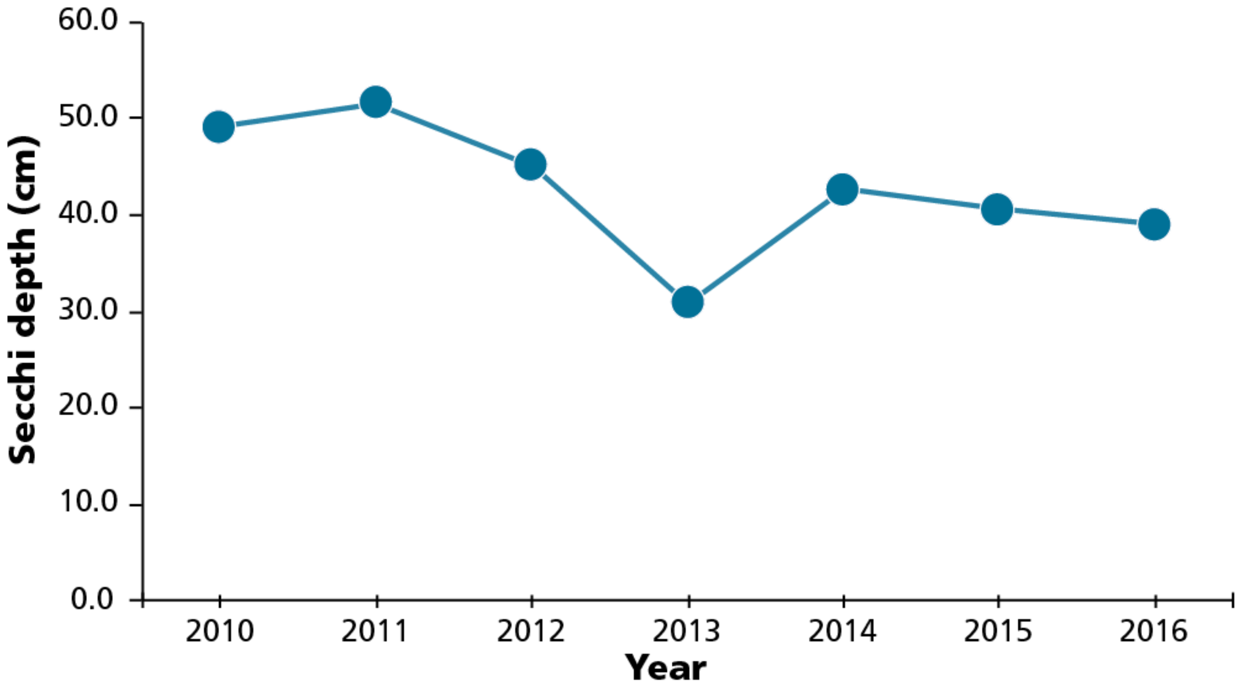


Figure 4-18. Annual average Secchi depth from 2010 to 2016 from eight sampling sites at Harriet Tubman Underground Railroad National Historical Park (Data source: Matt Whitbeck, Blackwater NWR 2017).

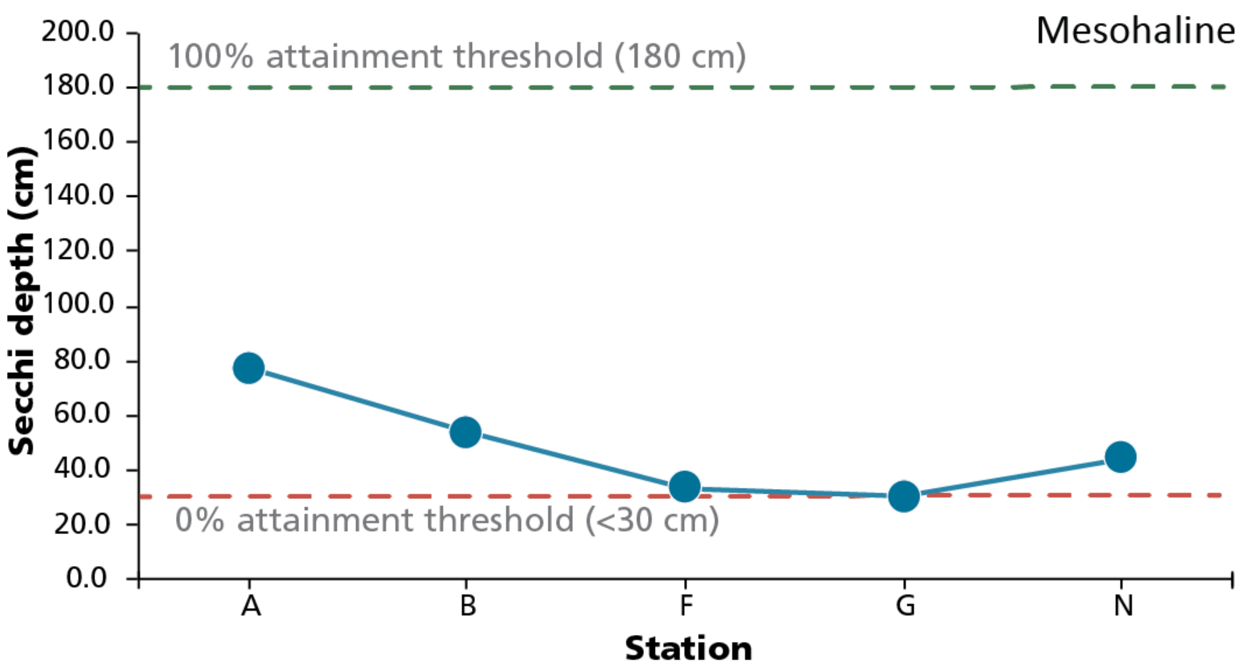


Figure 4-19. Average Secchi depth from 2010 to 2016 from five mesohaline sampling sites at Harriet Tubman Underground Railroad National Historical Park. A site above the green line had 100% average attainment of the reference condition. A site below the red line had 0% average attainment of the reference condition (Data source: Matt Whitbeck, Blackwater NWR 2017).

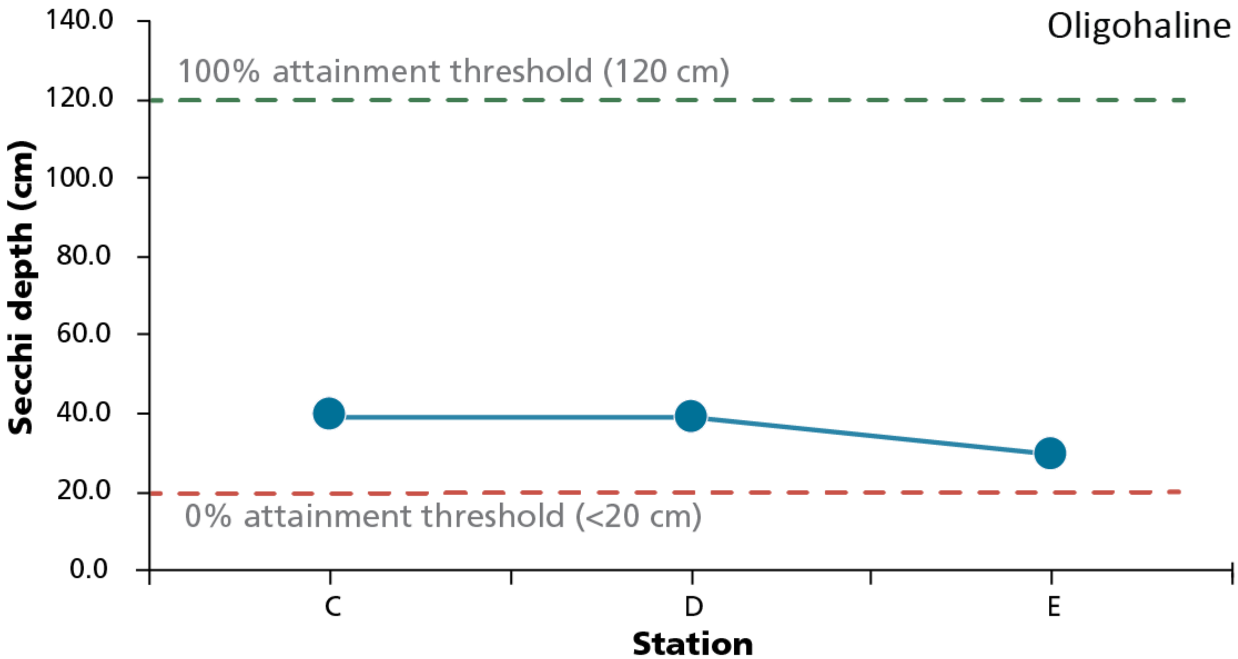


Figure 4-20. Average Secchi depth from 2010 to 2016 from three oligohaline sampling sites at Harriet Tubman Underground Railroad National Historical Park. A site above the green line had 100% average attainment of the reference condition. A site below the red line had 0% average attainment of the reference condition (Data source: Matt Whitbeck, Blackwater NWR 2017).

Level of Confidence and Data Gaps

Confidence in the assessment is high because eight sites were sampled across seven years with multiple samples per month. The reference values do not fully take into account the black water condition that is prevalent within the Blackwater River. Thus, low water clarity may reflect the natural color of the water rather than be an indicator of water quality. To offset this uncertainty, reference conditions based on submersed aquatic vegetation (SAV) thresholds were used (EcoCheck 2011). SAV-based reference conditions are more easily achieved and better reflect the shallow-water habitat at Harriet Tubman Underground Railroad National Historical Park.

Source(s) of Expertise

- Matt Whitbeck, Supervisory Wildlife Biologist at Chesapeake Marshlands National Wildlife Refuge Complex

4.2.3. Temperature

Description

Water temperature acts to regulate biological activity and rate of chemical reactions, which generally increase with temperature (Horne and Goldman, 1994). The thermal tolerance of an organism's enzymes determines the conditions in which a species can survive. In an environment that is too warm, enzymes stop working and organisms die. Temperature also affects the amount of dissolved oxygen available, and it influences the susceptibility of organisms to parasites, disease, and pollution. Causes of temperature changes in the water include weather conditions, shade or the lack thereof, and discharges into the water from urban sources or groundwater inflows.

Data and Methods

Data were collected two times per month between 2010 and 2016 from eight field sites at Harriet Tubman Underground Railroad National Historical Park (Figure 4-12). For each sampling event, a temperature probe (YSI 85) was used to obtain a water temperature measurement from each site.

Reference Conditions/Values

A reference condition of ≤ 32.2°C temperature was used for this assessment, which is the water quality standard for Class I and Class II warm waters (U.S. Environmental Protection Agency 1988). A passing score of 100 was assigned if a measurement was equal to or less than the reference condition, and a failing score of 0 was assigned if a measurement was greater than the reference. The percentage of passing results was used as the percent attainment and translated to a condition score. The scores for each individual site were averaged to calculate a score for each site, which were averaged to find an overall score for the park.

Condition and Trend

The condition of water temperature at Harriet Tubman Underground Railroad National Historical Park is good. Of 933 measurements across the 8 sites, five measurements failed to pass the reference condition. These included one measurement at site A in 2016, three measurements at site B in 2010, 2012, and 2013, and one measurement at site N in 2013. This equates to 97.6-100% attainment across sites and 99.5% attainment for Harriet Tubman Underground Railroad National Historical Park overall (Figure 4-21).

The trend in temperature is unchanging over the 7-year monitoring period (Figure 4-22).

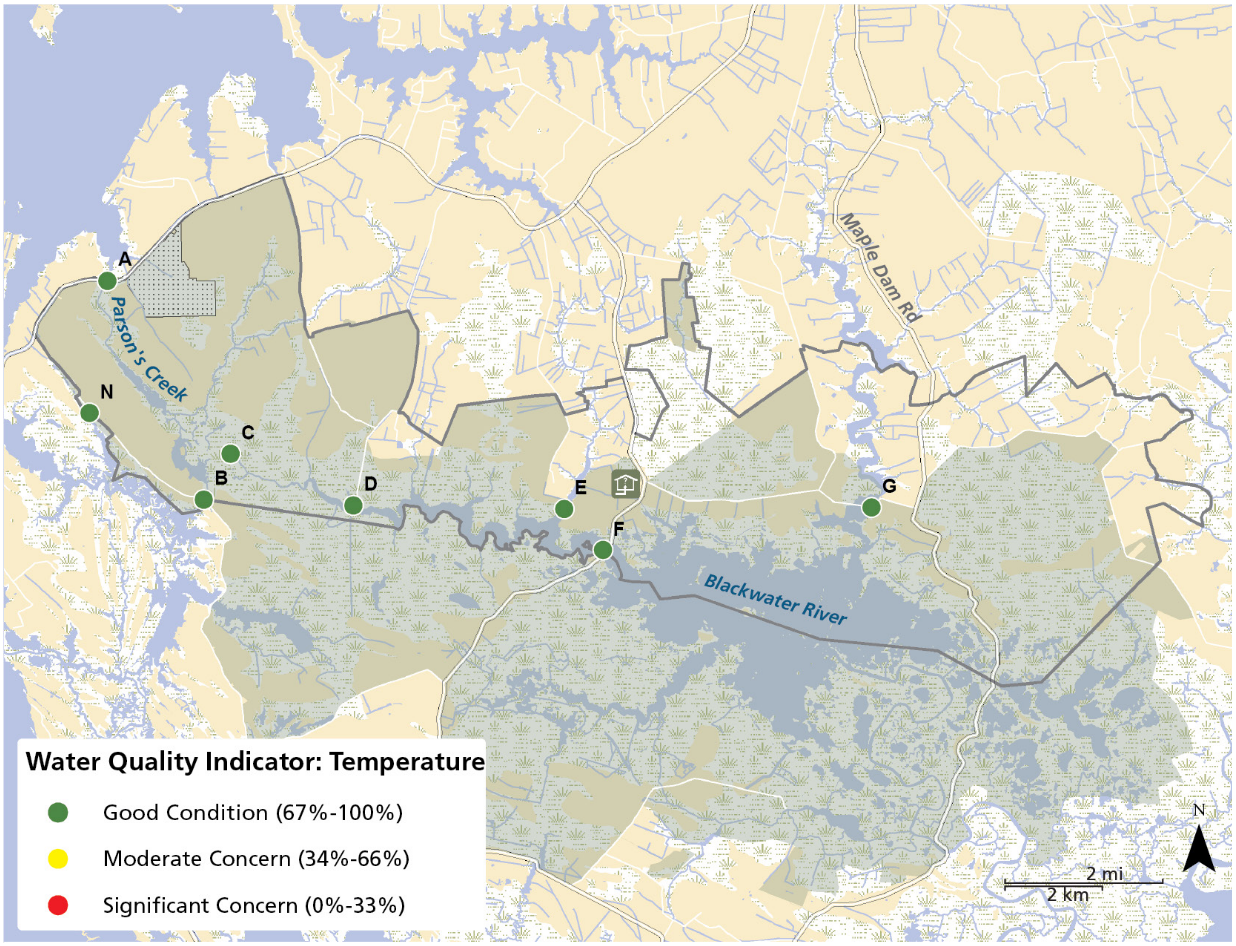


Figure 4-21. Attainment of the temperature reference condition from 2010 to 2016 for eight sampling sites (green = 66% or more of reference value attained, yellow = 33-65% of reference value attained, red = <33% of reference value attained) within Harriet Tubman Underground Railroad National Historical Park outlined in gray. Blackwater National Wildlife Refuge is shaded in green (Data source: Matt Whitbeck, Blackwater NWR 2017).

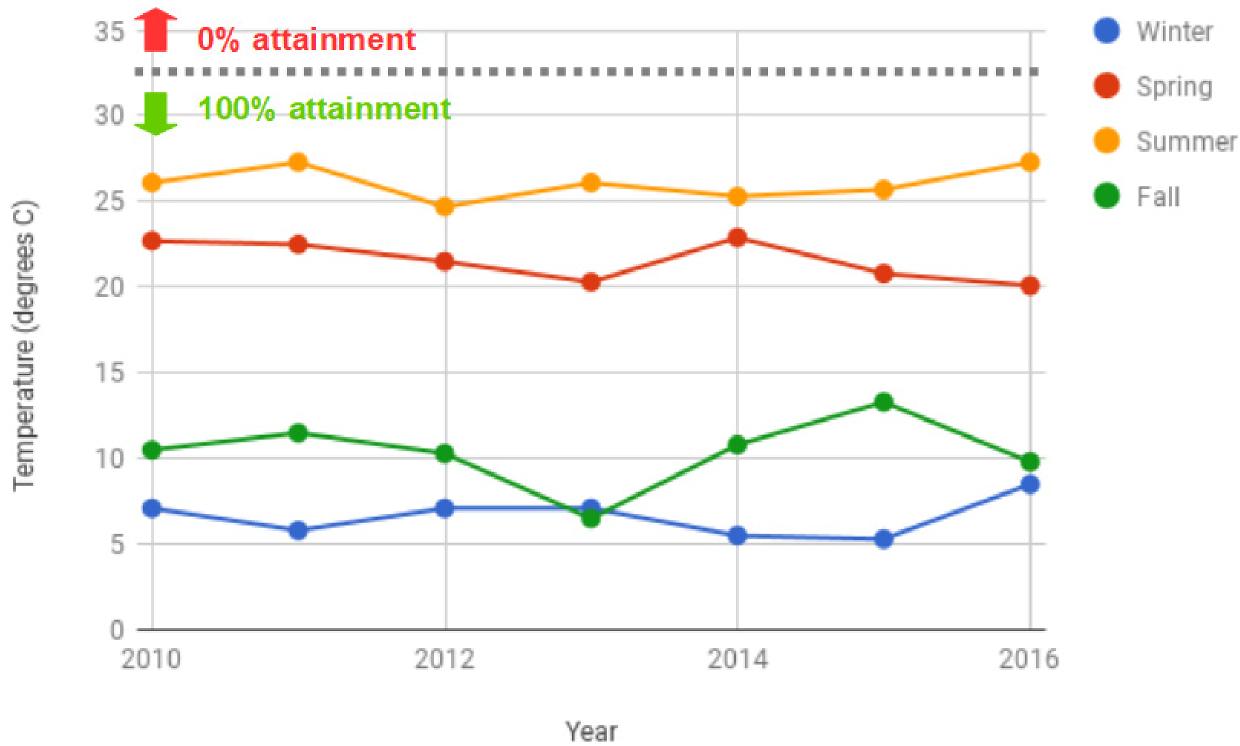


Figure 4-22. Annual temperature from 2010 to 2016 from eight sampling sites at Harriet Tubman Underground Railroad National Historical Park (Data source: Matt Whitbeck, Blackwater NWR 2017).

Level of Confidence and Data Gaps

Confidence in the assessment is high because temperature measurements were conducted for seven years across eight sites within the Harriet Tubman Underground Railroad National Historical Park boundary. Although only 5 out of 933 measurements failed the reference condition, it is unclear how long these conditions lasted or how widespread they were.

Source(s) of Expertise

- Matt Whitbeck, Supervisory Wildlife Biologist at Chesapeake Marshlands National Wildlife Refuge Complex

4.2.4. Total Nitrogen

Description

Nitrogen is an essential nutrient that is needed in relatively large quantities by living cells. Nitrogen exists in aquatic ecosystems as nitrogen gas, nitrate, ammonia, nitrite, and urea. Nitrate is the most common form and moves easily through soil into water. Organisms use it to build proteins, so it is necessary for growth and influences the variety, abundance, and nutritional value of plants and animals present in an ecosystem.

The amount of nitrogen in a waterbody is influenced by surrounding land use. Nitrogen concentrations can be raised above a healthy level by fertilizer runoff from agricultural fields, runoff from roads, and waste discharge (Horne and Goldman 1994). Excess nitrogen promotes algae overgrowth, leading to algae blooms. They cause additional water quality problems, such as decreased dissolved oxygen concentration and decreased water clarity (EcoCheck 2011).

Data and Methods

Data were collected by Blackwater National Wildlife Refuge two times per month between 2012 and 2016 from two field sites, F and G, within Harriet Tubman Underground Railroad National Historical Park (Figure 4-12). For each sampling event, a water sample was taken from one meter below the water surface and sent to an analytical lab to determine the concentration of total nitrogen. Salinity measurements, used to determine reference conditions, were also collected at each site to determine the salinity regime at the time and location of sampling (EcoCheck 2011).

Reference Conditions/Values

Each total nitrogen measurement was compared against a set of reference conditions and assigned a score from 0 to 5 (EcoCheck 2011). A score of 0 indicates a high total nitrogen concentration and 0% attainment of the reference condition. A score of 5 indicates a low total nitrogen concentration and 100% attainment of the reference condition. The reference condition is different between sites with different salinity regimes. For oligohaline sites, the reference condition is ≤ 0.6 mg/L of total nitrogen for 100% attainment of the reference condition. For mesohaline sites, the reference is ≤ 0.5 mg/L for 100% attainment (Table 4-12) (EcoCheck 2011).

Table 4-12. Reference condition in mg/L of nitrogen and corresponding score based on the salinity regime of a sample site (EcoCheck 2011).

Oligohaline	Mesohaline	Score
≤ 0.6	≤ 0.5	5
> 0.6 - ≤ 0.9	> 0.5 - ≤ 0.6	4
> 0.9 - ≤ 1.3	> 0.6 - ≤ 0.8	3
> 1.3 - ≤ 1.8	> 0.8 - ≤ 1.0	2
> 1.8 - ≤ 2.8	> 1.0 - ≤ 1.5	1
> 2.8	> 1.5	0

The total nitrogen scores at each individual site were averaged for the entire sampling period (2012-2016) and for the four seasons (fall, winter, spring, and summer) separately to develop a score for each site. The scores for the two sites were averaged to find an overall total nitrogen score for the park. To calculate percent of reference condition attained, scores were divided by 5 and multiplied by 100.

Condition and Trend

The condition of total nitrogen at Harriet Tubman Underground Railroad National Historical Park was scored as Significant Concern. The average total nitrogen concentration was 1.92 mg/L, with 19% average reference condition attainment (Table 4-13). Neither site achieved the reference condition (Figure 4-23).

Table 4-13. Average total nitrogen concentration in mg/L and score from 2012 to 2016 for two sampling sites within Harriet Tubman Underground Railroad National Historical Park.

Location	Nitrogen	Score	Percent score
F	1.68	1.16	23.23%
G	2.17	0.69	13.88%
Average	1.92	0.93	18.55%

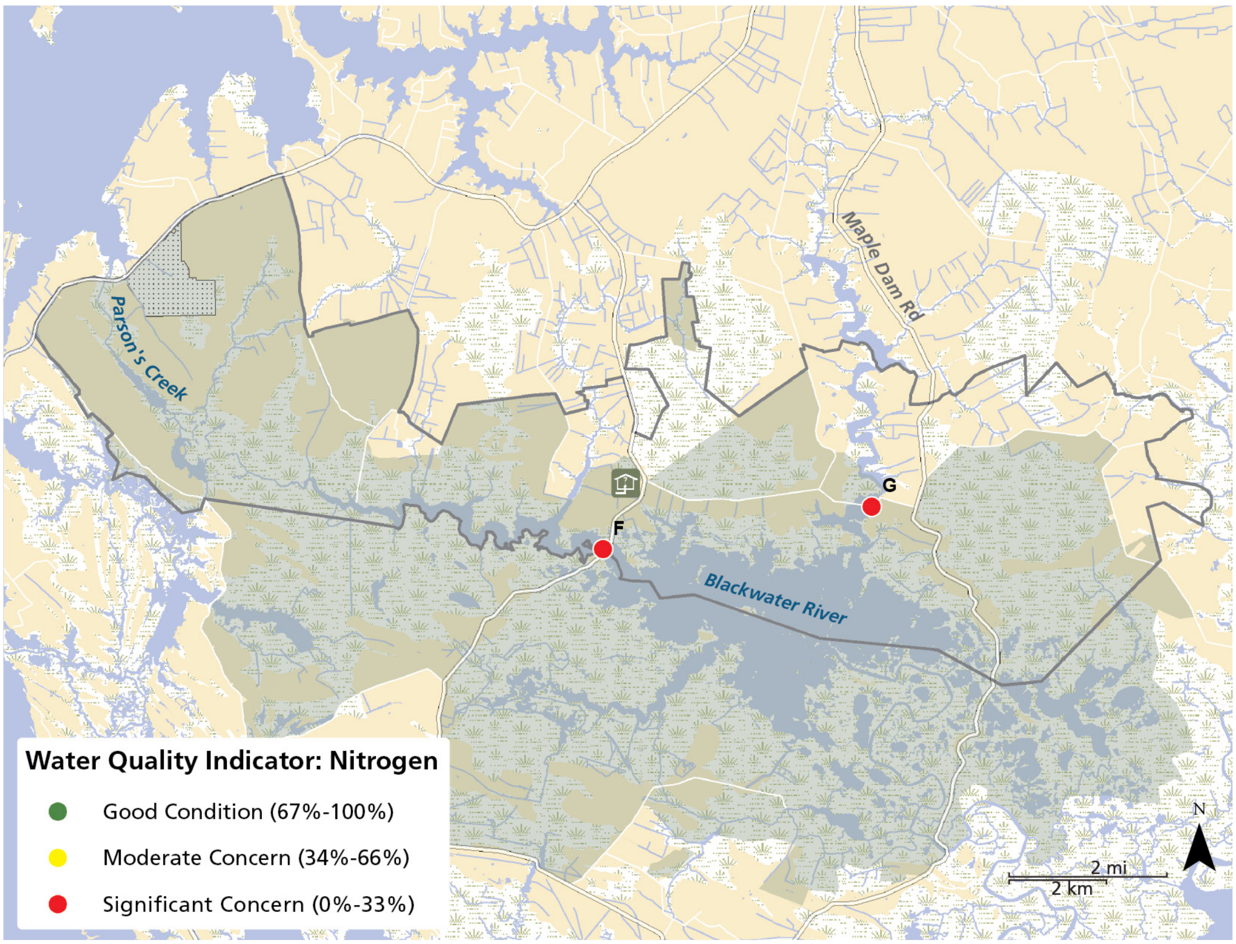


Figure 4-23. Attainment of the total nitrogen reference condition from 2012 to 2016 for two sampling sites (green = 66% or more of reference value attained, yellow = 33-65% of reference value attained, red = <33% of reference value attained) within Harriet Tubman Underground Railroad National Historical Park outlined in gray. Blackwater National Wildlife Refuge is shaded green (Data source: Matt Whitbeck, Blackwater NWR 2017).

Percent attainment of the total nitrogen reference condition was also consistently low (Significant Concern) when data were separated by the four seasons, with total nitrogen concentration in the summer and fall months higher, and therefore attainment values lower, between June and November (Table 4-14).

Table 4-14. Percent attainment of total nitrogen reference condition for the four seasons at sites F and G at Harriet Tubman Underground Railroad National Historical Park. All sample periods scored with conditions that warrant significant concern (cells also with a red background). No sites scored with good condition or warranting moderate concern.

Location	Fall N	Winter N	Spring N	Summer N
F	20.71%	30.53%	32.73%	14.00%
G	9.29%	29.47%	22.73%	1.38%

No trend in total nitrogen concentration can be observed through time (Figure 4-24).

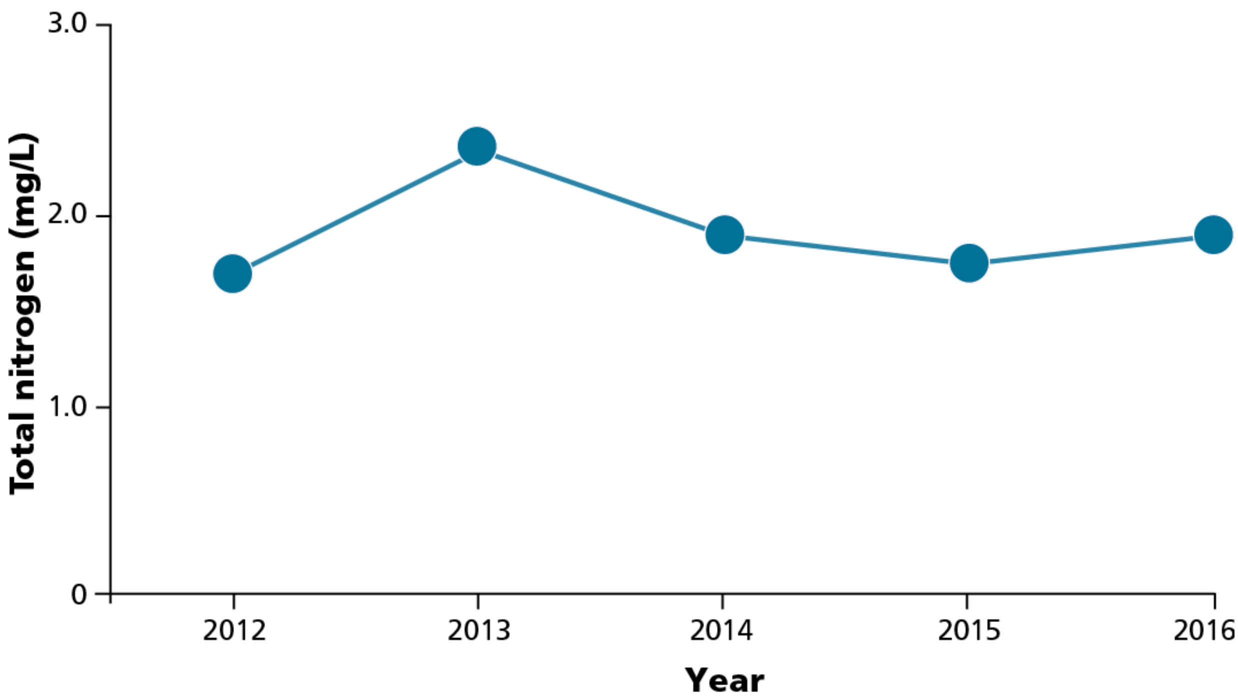


Figure 4-24. Annual average nitrogen concentration from 2012 to 2016 from two sampling sites at Harriet Tubman Underground Railroad National Historical Park (Data source: Matt Whitbeck, Blackwater NWR 2017).

Level of Confidence and Data Gaps

Confidence in the assessment is moderate. Although total nitrogen measurements were conducted for five years, the spatial resolution of the sampling locations is poor, with only two sites representing the entire park. Neither of the two sites are close to the National Park Service's owned Jacob Jackson parcel. In addition, total nitrogen concentrations may be sensitive to tides and storm events such that the assessment may be influenced by when samples were taken.

Source(s) of Expertise

- Matt Whitbeck, Supervisory Wildlife Biologist at Chesapeake Marshlands National Wildlife Refuge Complex

4.2.5. Total Phosphorus

Description

Phosphorus is an essential nutrient present in low concentrations in many aquatic ecosystems. It is more easily retained by soil and roots more easily than nitrogen. Phosphorus exists in organic and inorganic forms, as particulate matter or dissolved. However, it is only biologically available to phytoplankton as soluble phosphate. The amount of phosphorus in a waterbody can be influenced by surrounding land use. Phosphorus concentrations can be raised naturally by erosion or anthropogenically by domestic, agricultural, and industrial waste discharge (Horne and Goldman 1994). Excess phosphorus promotes algae overgrowth, leading to algae blooms, which cause a decrease in dissolved oxygen concentration and water clarity (EcoCheck 2011).

Data and Methods

Data were collected by Blackwater National Wildlife Refuge two times per month between 2012 and 2016 from two field sites, F and G, within Harriet Tubman Underground Railroad National Historical Park (Figure 4-12). For each sampling event, a water sample was taken from one meter below the water surface and sent to an analytical lab to determine the concentration of total phosphorus. Salinity measurements were also collected at each site to determine the reference condition, which is influenced by the salinity regime at the time and location of sampling (EcoCheck 2011).

Reference Conditions/Values

Each total phosphorus measurement was compared against a set of reference conditions and assigned a score from 0 to 5 (EcoCheck 2011). A score of 0 indicates a high phosphorus concentration and 0% attainment of the reference condition. A score of 5 indicates a low total phosphorus concentration and 100% attainment of the reference condition. The reference condition is different between sites with different salinity regimes. For oligohaline sites, the reference condition is ≤ 0.04 mg/L for 100% attainment of the reference condition. For mesohaline sites, the reference is ≤ 0.02 mg/L for 100% attainment (Table 4-15) (EcoCheck 2011).

Table 4-15. Reference condition in mg/L of total phosphorus and corresponding score based on the salinity regime of a sample site (EcoCheck 2011).

Oligohaline	Mesohaline	Score
≤ 0.04	≤ 0.02	5
> 0.04 - ≤ 0.07	> 0.02 - ≤ 0.04	4
> 0.07 - ≤ 0.10	> 0.04 - ≤ 0.06	3
> 0.10 - ≤ 0.15	> 0.06 - ≤ 0.08	2
> 0.15 - ≤ 0.28	> 0.08 - ≤ 0.15	1
> 0.28	> 0.15	0

The scores at each individual site were averaged to determine a score for each site for the entire sampling period (2012-2016) and for the four seasons (fall, winter, spring, and summer) separately.

The scores for the two sites were averaged across sites for an overall park score. Scores were divided by 5 and multiplied by 100 to calculate percent attainment of the reference condition.

Condition and Trend

The condition of total phosphorus at Harriet Tubman Underground Railroad National Historical Park was scored as Significant Concern. The average phosphorus concentration was 0.16 g/L, with 29% average attainment of the reference condition (Table 4-16). Neither site achieved the reference condition (Figure 4-25).

Table 4-16. Average phosphorus concentration in mg/L and average score from 2012 to 2016 for sampling sites F and G within Harriet Tubman Underground Railroad National Historical Park.

Location	Phosphorus	Score	Percent score
F	0.11	2.08	41.62%
G	0.21	0.80	15.92%
Average	0.16	1.44	28.77%

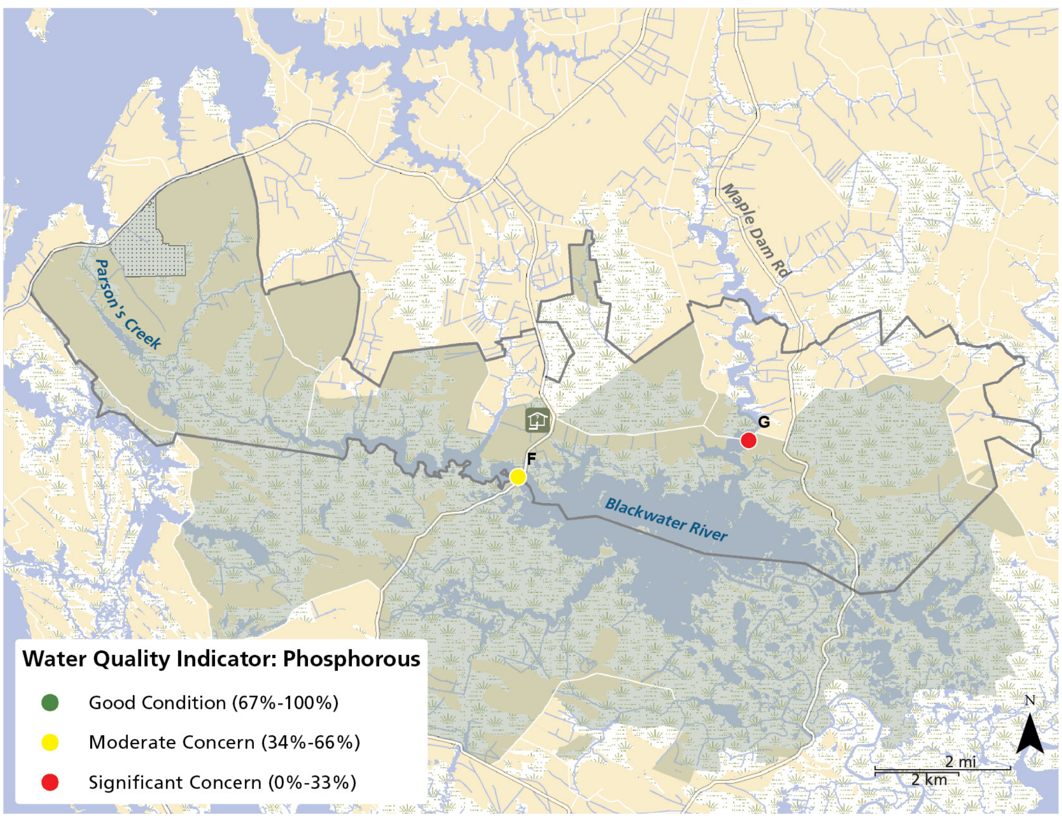


Figure 4-25. Attainment of the phosphorus reference condition from 2012 to 2016 for two sampling sites (green = 66% or more of reference value attained, yellow = 33-65% of reference value attained, red = <33% of reference value attained) within Harriet Tubman Underground Railroad National Historical Park in gray. Blackwater National Wildlife Refuge is shaded green (Data source: Matt Whitbeck, Blackwater NWR 2017).

Percent attainment of the total phosphorus reference condition was scored as Moderate Concern for fall, winter, and spring at site F; it was scored as Significant Concern for site G throughout the year, as well as for site F during the summer months (Table 4-17).

Table 4-17. Percent attainment of total phosphorus reference condition for the four seasons at sites F and G at Harriet Tubman Underground Railroad National Historical Park. Cells in red are scored as Significant Concern and yellow as Moderate Concern. No conditions scored as Good.

Location	Fall P	Winter P	Spring P	Summer P
F	45.00% [a]	53.68% [a]	48.18% [a]	26.00% [b]
G	14.29% [b]	26.32% [b]	21.82% [b]	6.21% [b]

[a] Condition warrants moderate concern (also with a yellow background).

[b] Condition warrants significant concern (also with a red background).

The trend is unchanging across the five-year time frame of the measurements (Figure 4-26).

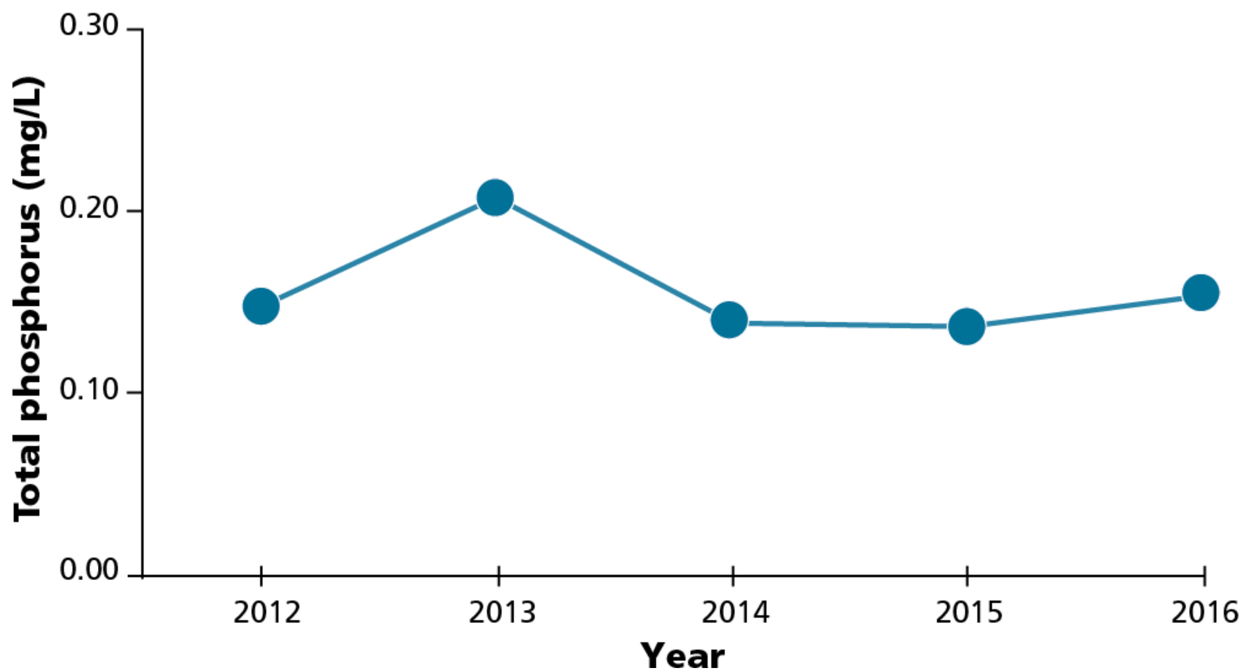


Figure 4-26. Annual phosphorus concentration from 2012 to 2016 from two sampling sites at Harriet Tubman Underground Railroad National Historical Park (Data source: Matt Whitbeck, Blackwater NWR 2017).

Level of Confidence and Data Gaps

Confidence in the assessment is moderate. Although phosphorus measurements were conducted for five years, the spatial resolution of the sampling locations is poor, with only two sites representing the entire park. In addition, total phosphorus concentrations may be sensitive to tides and storm events, which may influence the assessment of the indicator.

Source(s) of Expertise

- Matt Whitbeck, Supervisory Wildlife Biologist at Chesapeake Marshlands National Wildlife Refuge Complex

4.2.6. Chlorophyll a

Description

Chlorophyll *a* (chl *a*) is the primary photosynthetic pigment prevalent in phytoplankton (Wetzel 2001), which are free-floating algae that inhabit the water column of lakes, estuaries, and oceans (Horne and Goldman 1994). When present in high amounts, phytoplankton reduce water clarity, preventing sunlight penetration and vascular plant growth. The quantification of chl *a* is used as a rapid and economical measure of phytoplankton biomass. High temperature, high light, and nutrient enrichment support growth of phytoplankton, indicated by greater amounts of chl *a*. When chl *a* is low, water clarity is higher and the ecosystem is healthier, hence its use as an indicator in ecosystem assessments (EcoCheck 2011).

Data and Methods

Data were collected four times per month. Because phytoplankton in temperate regions grow in pulses of blooms (Horne and Goldman 1994), data were compiled only for the spring and summer months from 2012 to 2016 as recommended by EcoCheck (2011). Spring months were March, April, and May. Summer months were July, August, and September. Chl *a* data were collected from a subset of all water quality sampling stations at Blackwater National Wildife Refuge and only two sites, F and G, reside within the boundaries of Harriet Tubman Underground Railroad National Historical Park (Figure 4-27). At each site, a water sample was collected and pushed through a filter that captured chlorophyll pigment molecules. The filter was later analyzed in a lab using spectrophotometry. Salinity at each field site during each sampling event was also recorded to classify the salinity regime, which determines the reference condition.

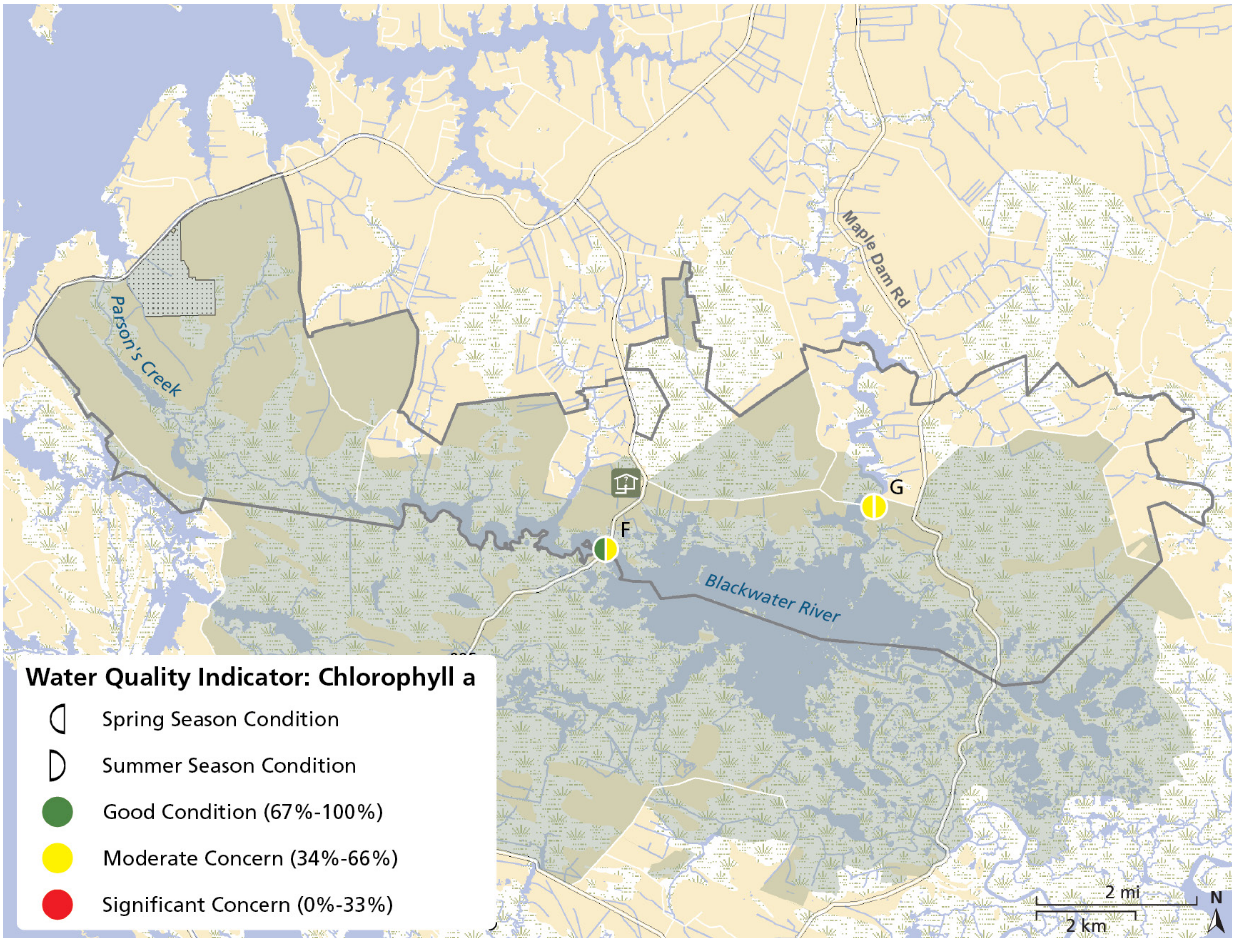


Figure 4-27. Attainment of the chlorophyll *a* reference condition from 2012 to 2016 for two sampling sites (green = 66% or more of reference value attained, yellow = 33-65% of reference value attained, red = <33% of reference value attained) within Harriet Tubman Underground Railroad National Historical Park outlined in gray. The left half of each circle represents spring attainment, while the right half represents summer attainment. Blackwater National Wildlife Refuge is shaded green (Data source: Matt Whitbeck, Blackwater NWR 2017).

Reference Conditions/Values

Each chl *a* concentration was compared against a set of reference conditions and assigned a score from 0 to 5 (EcoCheck 2011). A score of 0 indicates a high chl *a* concentration and 0% attainment of the reference condition. A score of 5 indicates a low chl *a* concentration and 100% attainment of the reference condition. The reference condition is different between spring and summer months and between sites with different salinity regimes. Oligohaline conditions were more common during spring months. In the spring, the reference condition is 1.5 µg/L for oligohaline sites and 2.09 µg/L for mesohaline sites. Mesohaline conditions were more common during summer months. In the summer, the reference condition is 3.0 µg/L for oligohaline sites and 1.7 µg/L for mesohaline sites (Table 4-18).

Table 4-18. Reference conditions in µg/L of chlorophyll *a* and corresponding score based on the salinity regime of a sample site and season (EcoCheck 2011).

Oligohaline spring	Oligohaline summer	Mesohaline spring	Mesohaline summer	Score
≤ 1.50	≤ 3.00	≤ 2.09	≤ 1.70	5
> 1.50 - ≤ 20.90	> 3.00 - ≤ 9.50	> 2.09 - ≤ 6.20	> 1.70 - ≤ 7.70	4
> 20.90 - ≤ 27.70	> 9.50 - ≤ 16.40	> 6.20 - ≤ 11.10	> 7.70 - ≤ 11.00	3
> 27.70 - ≤ 39.40	> 16.40 - ≤ 29.90	> 11.10 - ≤ 19.10	> 11.00 - ≤ 15.80	2
> 39.40 - ≤ 62.30	> 29.90 - ≤ 76.80	> 19.10 - ≤ 49.80	> 15.80 - ≤ 35.80	1
> 62.30	> 76.80	> 49.80	> 35.80	0

Each individual chl *a* measurement was scored based on the season and salinity regime at the time of sampling. Scores were then averaged by season or site, then averaged across sites to receive an overall park score. Site and park scores were converted to percent attainment of reference condition by dividing the score by five and multiplying by 100.

<u>Condition and Trend</u>

The condition of chl *a* at Harriet Tubman Underground Railroad National Historical Park was scored as Moderate Concern (43%). The average spring chl a concentration in the park was 24 µg/L (56%), and the average summer concentration was 40 µg/L (32%; Table 4-19, Figure 4-27).

Table 4-19. Average chlorophyll a concentration in µg/L and average score during the spring and summer from 2012 to 2016 for two sampling sites within Harriet Tubman Underground Railroad National Historical Park.

Location	Spring chl *a*	Score	Percent score	Summer chl *a*	Score	Percent score
F	18.02	3.46	69.17	24.95	1.96	39.17
G	30.47	2.12	42.50	55.51	1.25	25.00
Average	24.25	2.79	55.83	40.23	1.60	32.08

The trend in chl *a* concentration was decreasing between 2012 and 2016 during both the spring and summer months, with 2012 concentrations nearly halved by 2016 (Figure 4-28, Figure 4-29).

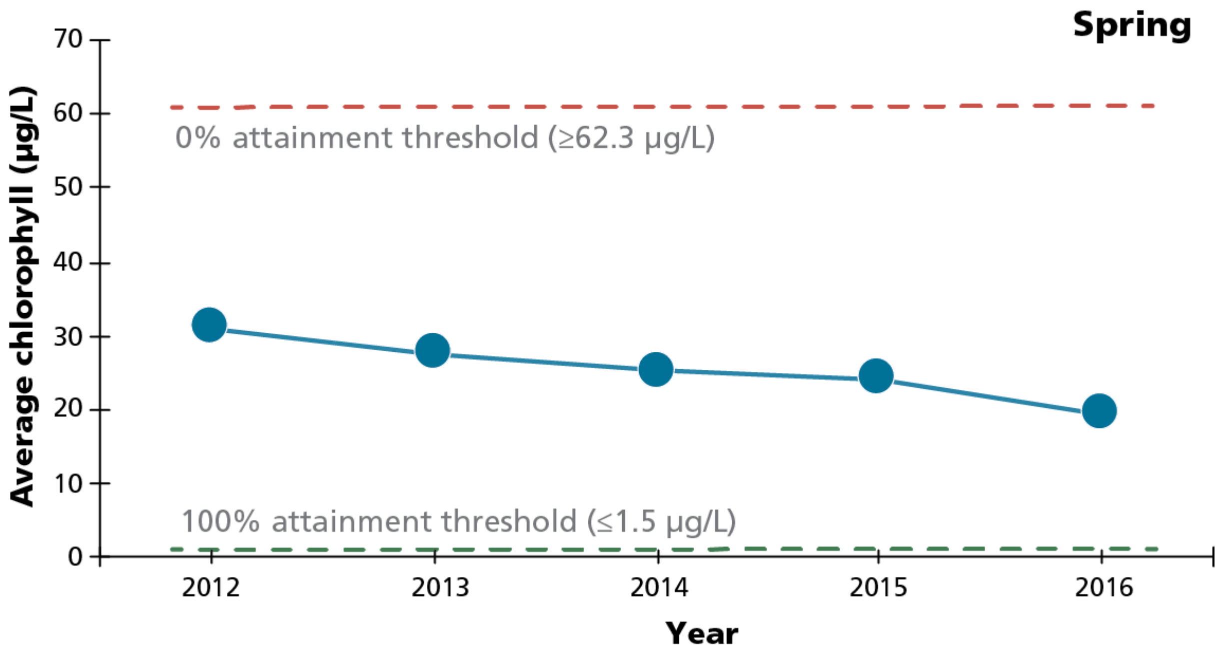


Figure 4-28. Annual average chlorophyll *a* concentration during the spring from 2012 to 2016 for two sampling sites at Harriet Tubman Underground Railroad National Historical Park. A point above the red line indicates 0% average attainment of the oligohaline reference condition. A point below the green line indicates 100% average attainment of the reference condition (Data source: Matt Whitbeck, Blackwater NWR 2017).

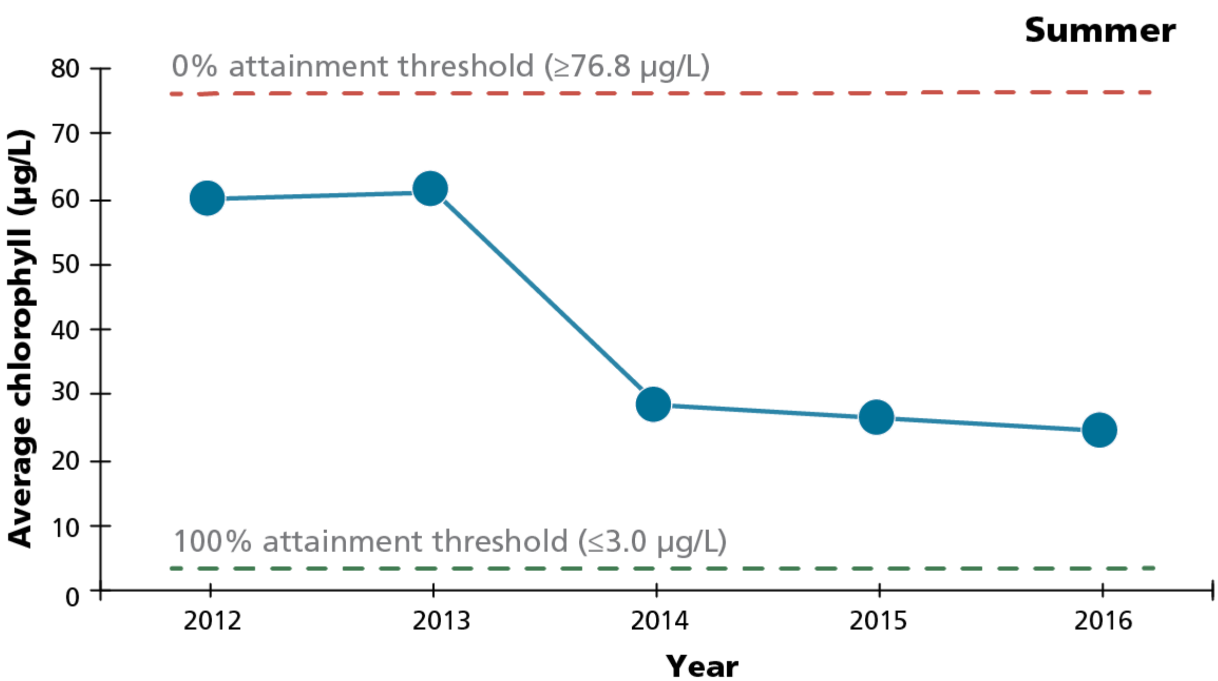


Figure 4-29. Annual average chlorophyll a concentration during the summer from 2012 to 2016 for two sampling sites at Harriet Tubman Underground Railroad National Historical Park. A point above the red line indicates 0% average attainment of the mesohaline reference condition. A point below the green line indicates 100% average attainment of the reference condition (Data source: Matt Whitbeck, Blackwater NWR 2017).

Data Gaps and Level of Confidence
Confidence in the assessment is moderate. Although chl *a* measurements were conducted for five years, the spatial resolution of the sampling locations is poor, with only two sites in the mesohaline areas representing the entire park. Methods followed stringent QA/QC procedures instituted by Blackwater Wildlife Refuge.

Source(s) of Expertise
- Matt Whitbeck, Supervisory Wildlife Biologist at Chesapeake Marshlands National Wildlife Refuge Complex

4.2.7. Benthic Index of Biotic Integrity

Description
Benthic macroinvertebrates are one of the most important components of estuarine food webs because they link primary producers, such as phytoplankton, with larger organisms, such as fish (Odum et al. 1984) and birds (Sherfy and Kirkpatrick 2003, Szalay and Resh 1997), both of which are economically important groups of species in the Blackwater area. Benthic macroinvertebrates are abundant and short-lived, which allows their populations to respond rapidly to changes in water chemistry. Therefore, coupled with their relative ease of sampling, benthic macroinvertebrates are often excellent indicators of aquatic ecosystem health.

The Benthic Index of Biotic Integrity (B-IBI) realizes the critical role that benthic macroinvertebrates play within aquatic ecosystems and characterizes ecosystem condition using a variety of metrics that are relevant for different habitats. B-IBIs are used widely but are particularly well-developed in Maryland through the Maryland Department of Natural Resources' Maryland Biological Stream Survey (Southerland et al. 2008). It provides a validated mechanism that integrates several ecosystem health metrics into one score that measures condition of an aquatic waterbody.

Data and Methods
Data are available from two studies conducted by Berger/EA Joint Venture (2004) for the U. S. Army Corps of Engineers and by Guy et al. (2010) for the U. S. Fish and Wildlife Service. In all, 15 samples were collected using petite ponar grabs ($0.023m^2$). Laboratory methods followed standard procedures for benthic monitoring (Llansó et al. 2005). Samples were sieved through a 500-micron screen and preserved in a buffered 10% formaldehyde solution stained with rose bengal. Organisms in each sample were separated in the lab and identified to the lowest practical taxonomic level.

Five benthic samples were collected on September 25 and 26, 2003 (Berger/EA Joint Venture 2004) as a reconnaissance effort. Each sample represented different habitats at Blackwater National Wildlife Refuge consisting of vegetated emergent marsh (Station 1), recently failed marsh that is now unvegetated (Station 2), open water with a weak current (Station 3), defined channel with a strong current (Station 4), and mineral substrate with a strong current (Station 5). Stations 1-4 were clustered together at the mouth of the Little Blackwater River, whereas Station 5 was located 3 miles south of the other stations and outside the Harriet Tubman Underground Railroad National Historical Park boundary (Figure 4-12).

As part of a sediment toxicity study conducted in 2006 and 2007 to determine whether a development in the upper reaches of the Little Blackwater River was impacting water quality within Blackwater Wildlife Refuge (Guy et al. 2010), benthic invertebrates were sampled at 7 stations each year. Five of these stations were located with the Harriet Tubman Underground Railroad National Historical Park boundary along the lower reaches of the Little Blackwater River and within Buttons Creek (Figure 4-12).

Both studies followed published methods for calculating a Benthic Index of Biotic Integrity for non-vegetated and vegetated substrate (Versar 2002). Calculated metrics included total species abundance, percent abundance of pollution-sensitive taxa, percent abundance of carnivores and omnivores, and tolerance.

Reference Conditions/Values

B-IBI scores range from 1-5 and are calculated by comparing a metric calculated at a sampling location to a minimally impacted site (Weisberg et al. 1997, Norris and Sanders 2009). The B-IBI is habitat specific for salinity and sediment type. For the samples collected, oligohaline and low mesohaline salinity ranges were used (Weisberg et al. 1997). Threshold values are described in Weisberg et al. (1997) and Alden et al. (2002).

The final score averages the individual scores for each metric per sample to determine whether a site is degraded or not. The sample scores for 2006 and 2007 were averaged to determine a single score. A score of 5 indicates 100% attainment, a score of 3 indicates 50% attainment, and a score of 1 indicates 0% attainment. The range of B-IBI scores from 1 to 5 were scaled linearly from 0-100% attainment (Percent attainment = Score x 25 – 25; Figure 4-30).

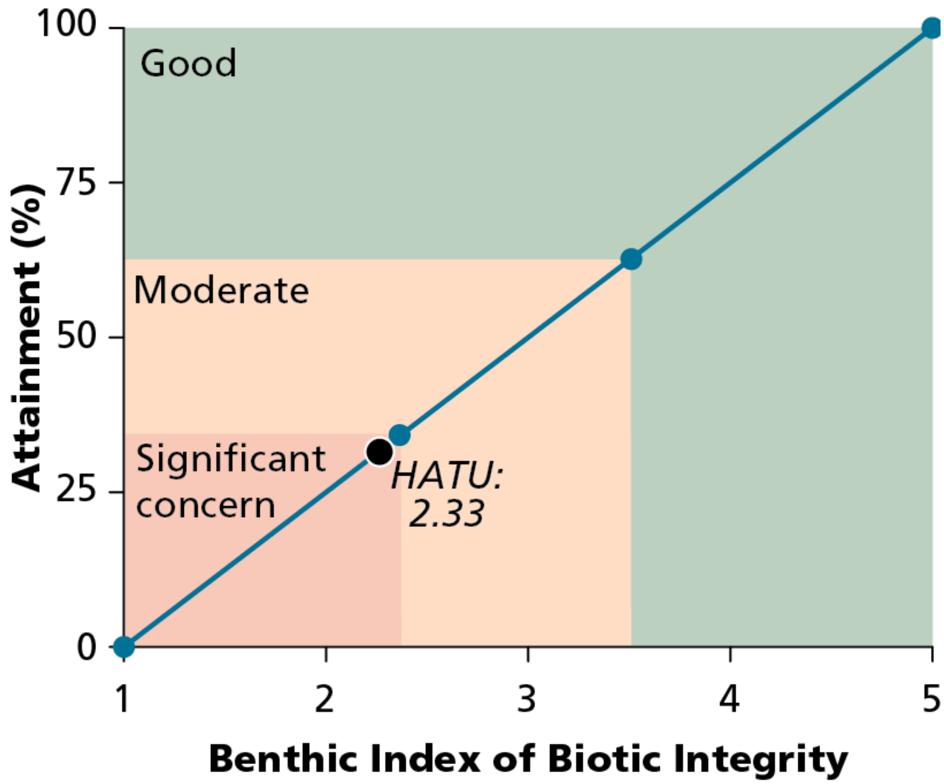


Figure 4-30. Percent attainment categories applied to the benthic index of biotic integrity (B-IBI). The B-IBI score at Harriet Tubman Underground Railroad National Historical Park was degraded with a median score of 2.33, which corresponds to 33% of reference condition attained and a condition of 'Significant Concern'.

Condition and Trend

The condition of benthic macroinvertebrates at Harriet Tubman Underground Railroad National Historical Park was scored as Significant Concern. The median score across all sites was 2.33, with 33% reference condition attainment (Table 4-20, Figure 4-31). Trend through time could not be assessed with the data.

Table 4-20. Calculated metrics, scores of the metrics when compared to a reference condition, and percent attainment of the reference condition for nine sample locations at Harriet Tubman Underground Railroad National Historical Park. Data are derived from Berger/EA Joint Venture (2004) and Guy et al. (2010). Green indicates Good Condition score (≥66%) for a metric, yellow indicates Moderate Concern (≥33% but < 66%), and red indicates Significant Concern (<33%). N/A – not applicable because metric was not evaluated. Bolded values are summary scores across metrics, across years for each location, and the percent score for each location.

Parameter	Site BNWR3		Site BNWR4		Site BNWR5		Site BNWR6		Site BNWR7		Station 1	Station 2	Station 3	Station 4
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2003	2003	2003	2003
Abundance (#/m^2)	1614.00 [a]	0.00 [c]	318.00 [b]	0.00 [c]	182.00 [b]	0.00 [c]	1159.00 [b]	276.00 [c]	1182.00 [a]	0.00 [c]	989.00 [a]	1634.00 [a]	1247.00 [a]	903.00 [a]
Biomass (g/m^2)	N/A	N/A	N/A	N/A	N/A	N/A	0.02 [c]	0.02 [c]	N/A	N/A	N/A	N/A	N/A	N/A
Pollution-indicative (%)	98.59 [c]	0.00 [c]	92.90 [b]	0.00 [c]	100.00 [c]	0.00 [c]	84.31 [c]	83.33 [c]	5.77 [a]	0.00 [c]	39.10 [b]	84.20 [b]	85.70 [b]	100.00 [c]
Pollution-sensitive (%)	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]	0.00 [c]
Carnivore & Omnivore (%)	73.24 [a]	0.00 [c]	21.40 [b]	0.00 [c]	75.00 [a]	0.00 [c]	N/A	N/A	23.10 [b]	0.00 [c]	21.70 [b]	84.20 [a]	85.70 [a]	100.00 [a]
Tanypodinae / Chironomidae	1.92 [a]	0.00 [c]	0.00 [a]	0.00 [c]	33.30 [b]	0.00 [c]	N/A	N/A	9.09 [a]	0.00 [c]	N/A	N/A	N/A	N/A
Tolerance	9.80 [c]	0.00 [c]	8.77 [b]	0.00 [c]	9.63 [c]	0.00 [c]	N/A	N/A	7.80 [b]	0.00 [c]	9.00 [b]	9.80 [c]	9.70 [c]	9.80 [c]
Score per sample	**3.00**	**1.00**	**3.00**	**1.00**	**2.33**	**1.00**	**1.50**	**1.00**	**3.67**	**1.00**	**3.00**	**3.00**	**3.00**	**2.60**
Score across years	**2.00**		**2.00**		**1.67**		**1.25**		**2.33**		**3.00**	**3.00**	**3.00**	**2.60**
Percent attainment	**25.00**		**25.00**		**16.67**		**6.25**		**33.33**		**50.00**	**50.00**	**50.00**	**40.00**

[a] Good condition (also with a green background).

[b] Condition warrants moderate concern (also with a yellow background).

[c] Condition warrants significant concern (also with a red background).

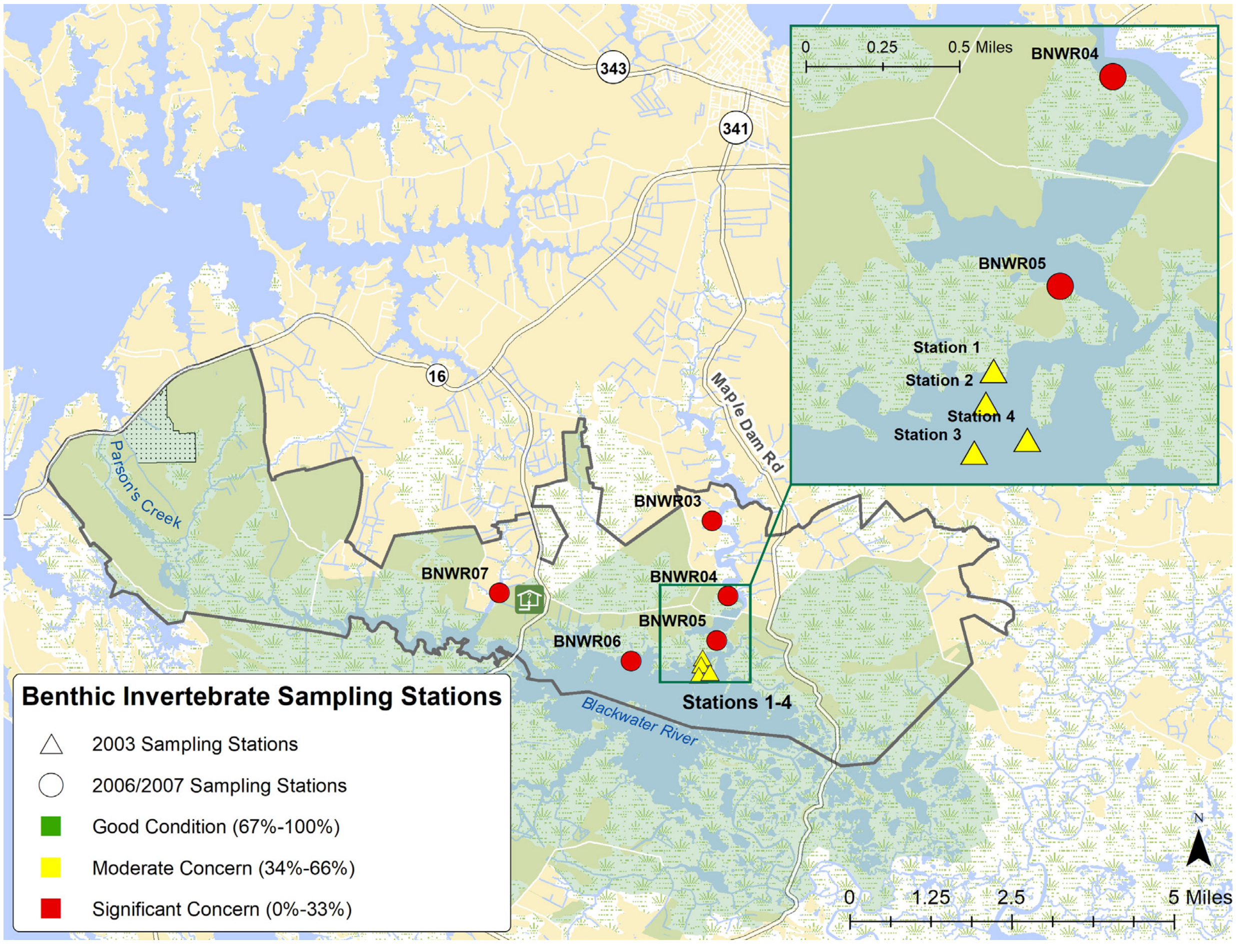


Figure 4-31. Attainment of the reference condition at 9 sample sites (green ≥ 66% or more of reference value attained, yellow = 34-66% of reference value attained, red ≤ 33% of reference value attained) within Harriet Tubman Underground Railroad National Historical Park (Data source: Matt Whitbeck, Blackwater NWR 2017).

Level of Confidence and Data Gaps

Confidence in the assessment is low. Nine samples with no spatial replicates were collected across two studies (Berger/EA Joint Venture 2004, Guy et al. 2010). Data from samples collected in 2003 and 2006 are comparable; however, 2007 scores are significantly different from 2006 scores even though the same locations were sampled, highlighting high temporal variability. Thus, higher spatial and temporal replication, as well as a greater spatial breadth of sampling is needed to gain confidence in the benthic macroinvertebrate assessment.

Source(s) of Expertise

- Robert Hilderbrand, University of Maryland Center for Environmental Science Appalachian Labz

4.3. Biological Integrity

Harriet Tubman Underground Railroad National Historical Park supports a diversity of important natural resources that require joint management with the cultural resources that the park is known for. Forests, such as the historically-important Jacob Jackson tract, provide a habitat template for a productive and diverse food web. However, pests, diseases, climate change, and an overabundance of sika (*Cervus nippon*) and whitetail deer (*Odocoileus virginianus*) threaten the structure and function of forests. Delmarva fox squirrel (*Sciurus niger cinereus*), an iconic tree-dwelling species of the region, is a species of management concern that was removed from the endangered species list in 2010 owing to its population recovery on the Delmarva peninsula. Delmarva fox squirrel population abundance declines when forests are harvested for timber; thus, this species requires mature and late-successional forests. Similarly, bald eagles (*Haliaeetus leucocephalus*) are an iconic species that are now abundant in and around the park after suffering severe population declines owing to the chemical DDT. Populations have recovered to the extent that the species was removed from the threatened and endangered species list in 2007.

Hardwood forest at Blackwater Wildlife Refuge, which overlaps significantly with Harriet Tubman Underground Railroad National Historical Park. Photo credit: United States Fish and Wildlife Service

In addition, the park supports a diversity of forest interior-dwelling birds that require a healthy forest structure to complete their life cycle. Bat species are also diverse in the park and use forests for roosting and nearby wetlands for foraging; however, bats have been in decline nationwide due to disease.

The six indicators that were used to assess the condition of Harriet Tubman Underground Railroad National Historical Park's biological integrity include forest structure, Delmarva fox squirrel abundance, bald eagle abundance, diversity of bats, diversity of forest interior birds, and deer density (Table 4-21). Delmarva fox squirrels and bald eagles represent species of management concern, while the diversity of forest interior birds and bats provide indicators of the food web support that the park provides. The structure of the forests represents the underlying habitat template, whereas population densities of sika and white-tailed deer represent a threat to the forest structure. Data used to determine the condition of indicators were sourced from data compiled by Blackwater Wildlife Refuge, which overlaps significantly with Harriet Tubman Underground Railroad National Historical Park. The managers, scientists, and citizens who have collected these data have devoted significant time and effort to obtaining, managing, and summarizing the information used in this report.

Table 4-21. Indicators and sources of data used in the assessment of biotic resources within Harriet Tubman Underground Railroad National Historical Park.

Biological integrity indicator	Agency	Source
Forest structure	US Fish and Wildlife	Forest inventory data and documentation
Deer	US Fish and Wildlife	Survey data (Haus and Bowman 2018)
Delmarva fox squirrels	• US Fish and Wildlife • California University of Pennsylvania	• GIS data • Benchmark monitoring • Trapping data
Bald eagles	US Fish and Wildlife	Mid-winter count data
Forest interior birds	US Fish and Wildlife	Bird survey data
Bats	US Fish and Wildlife	Resident bat inventory data and report

Reference conditions were used for each of the six indicators (Table 4-22) to determine percent attainment of each indicator when compared to the reference (Table 4-23).

Table 4-22. Biological integrity reference conditions used to assess biological resource condition of Harriet Tubman Underground Railroad National Historical Park.

Biological integrity indicator	Metric	Number of sites	Period of observation	Reference conditions
Forest structure	Structural stage	72	2009-2014	• ≥ 25% of plots in late-successional forest = 100% • < 25% of stands in mature and late-successional forest = 0%
	Coarse woody debris	73	2009-2014	% plots with ≥10 m^3/hectare coarse woody debris
	Snags	73	2009-2014	• ≥ 10% standing trees are snags = 100% • <10% standing trees are snags = 0%
	Tree regeneration	73	2009-2014	% plots with ≥1 seedling
	Tree condition	73	2009-2014	• ≤10% plots foliage problems from disease or pests = 100 • >50% plots with foliage problems = 0%
Deer density	deer/km2	11	2017	• ≤8 deer/km^2 = 100% • >8 deer/km^2 = 0%
Delmarva fox squirrel	Occupancy	9	1990, 2003, 1991-2011, 1996-2017	% forest fragments occupied
Bald eagle	# of individuals	14	1980-2017	≥114 eagles = 100%; < 114 eagles = 0%
Forest interior birds	# of area sensitive species present	43	1996-2000, 2006	presence of ≥1 highly area sensitive species or ≥4 area-senstitive species = 100%, otherwise 0%
Bats	# of species present	18	2015-2016	% expected bat species (8 species)

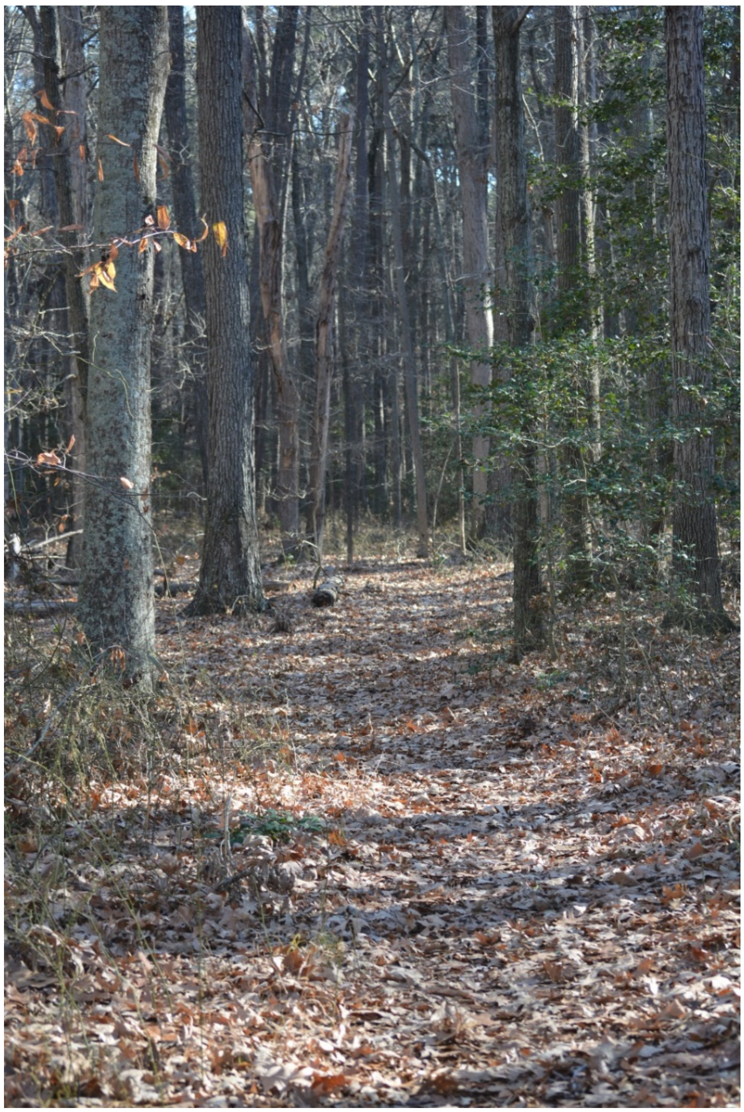
Table 4-23. Summary of biological integrity condition assessment at Harriet Tubman Underground Railroad National Historical Park.

Biological integrity indicator	Metric	Percent attainment	Condition	Overall condition
Forest structure	Structural stage	100%	Good	Moderate Concern
	Coarse woody debris	33%	Significant concern	Moderate Concern
	Snags	0%	Significant concern	Moderate Concern
	Tree regeneration	64%	Moderate concern	Moderate Concern
	Tree condition	49%	Moderate concern	Moderate Concern
Deer density	deer/km2	0%	Significant Concern	Moderate Concern
Delmarva fox squirrel	Occupancy	100%	Good	Moderate Concern
Bald eagle	# of individuals	90%	Good	Moderate Concern
Forest interior birds	# of area sensitive species present	100%	Good	Moderate Concern
Bats	# of species present	63%	Moderate Concern	Moderate Concern

4.3.1. Forest Structure

Description

Forests in the eastern United States provide habitat for a diverse flora and fauna. Their high diversity and productivity generates significant economic benefits through a supply of forest products (Miller et al. 2016) and recreational opportunities, such as birding, hiking, and hunting. Therefore, maintaining healthy forests that can support diverse ecosystem benefits and services is often an important management goal for landowners such as the National Park Service. Specifically, Harriet Tubman Underground Railroad National Historical Park encompasses 5,125 acres of forest that support thriving populations of Delmarva fox squirrels, eagles, bats, forest interior dwelling birds, and deer, among other flora and fauna.



Forest trail within Blackwater National Wildlife Refuge, whose forests overlap significantly with Harriet Tubman Underground Railroad National Historical Park. Photo credit: United States Fish and Wildlife Service.

Here, we assess forest structure within Harriet Tubman Underground Railroad National Historical Park to determine current forest condition. Harriet Tubman, in her life and work as slave and free woman, travelled through the forests of the area, including the forests owned by Jacob Jackson north of Parson's Creek. Woodlands provided physical and spiritual retreats for Harriet Tubman and the slaves she freed, as well as wood and food for survival and sustenance. Thus, assessing forest structure and function provides a glimpse of a dominant natural feature Harriet Tubman would have been intimately familiar with.

Forest structure takes many forms. A few of the biological components for which we have data include:

1. Structural stage – Forest structural stage influences the maintenance of biological diversity and is assessed by comparing the structural stage of forest plots relative to a distribution that supports biological diversity. Forest structure is calculated from tree size of canopy trees. This metric provides an indicator of habitat availability for species that are dependent on specific structural stages. For example, Delmarva fox squirrels (*Sciurus niger cinereus*), an important ecological component of the area, are tree-dwelling and therefore prefer late-successional stands, whereas a species competing with the Delmarva fox squirrel – Eastern gray squirrels (*Sciurus carolinensis*) – thrive in early successional stands.
2. Coarse woody debris – Dead wood that has fallen to the forest floor is called coarse woody debris and is an important structural feature that provides habitat for a diverse food web including fungi, arthropods, herptiles, small mammals and birds (DeGraaf and Rudis 1986, Petranka et al. 1994). Thus, volume of fallen down wood, as it is continuously broken down into smaller pieces, provides a useful metric for assessing wildlife habitat on the forest floor.
3. Snags – Dead wood that is still standing is called snags. Similar to coarse woody debris, snags provide important habitat for wildlife, particularly cavity-nesting birds (Zarnowitz and Manuwal 1985, Schreiber and deCalesta 1992). Density and size of snags, therefore, is an important metric for assessing habitat availability, with larger snags being the most valuable.
4. Tree regeneration – Forests need to produce seedlings (regenerate) for long-term sustainability and to determine future canopy structure and composition. Regeneration can be impacted by a variety of factors, such as climate change and air pollution, but, most notably, by deer browsing (Rooney 2001, Cote et al. 2004). Tree regeneration is determined by counting the number of seedlings (>15 cm) by species and size class.
5. Tree condition – Observations of canopy foliage condition provides an indicator of problems or decline that canopy trees may be experiencing in the region. Pests and pathogens are often to blame for decline but damage may also come from fire, competitive suppression, water, human induced, animal (e.g., beaver), or weather. Tree condition is observed qualitatively for each individual tree in a stand as the percent of the tree canopy that is damaged.

<u>Data and Methods</u>

Blackwater National Wildlife Refuge established and sampled 90 continuous forest inventory (CFI) plots (Figure 4-32) from 2009 to 2014 to monitor changes in habitat conditions. Seventy-three of the plots were located within the boundaries of Harriet Tubman Underground Railroad National Historical Park. The CFI particularly emphasized factors that impact Delmarva fox squirrels and forest interior dwelling songbirds such as forest maturity and factors that provide habitat, such as coarse woody debris and snags. In Fall 2012, the refuge lost the forester leading the effort. The first round of inventories was completed, but a new round was not initiated.

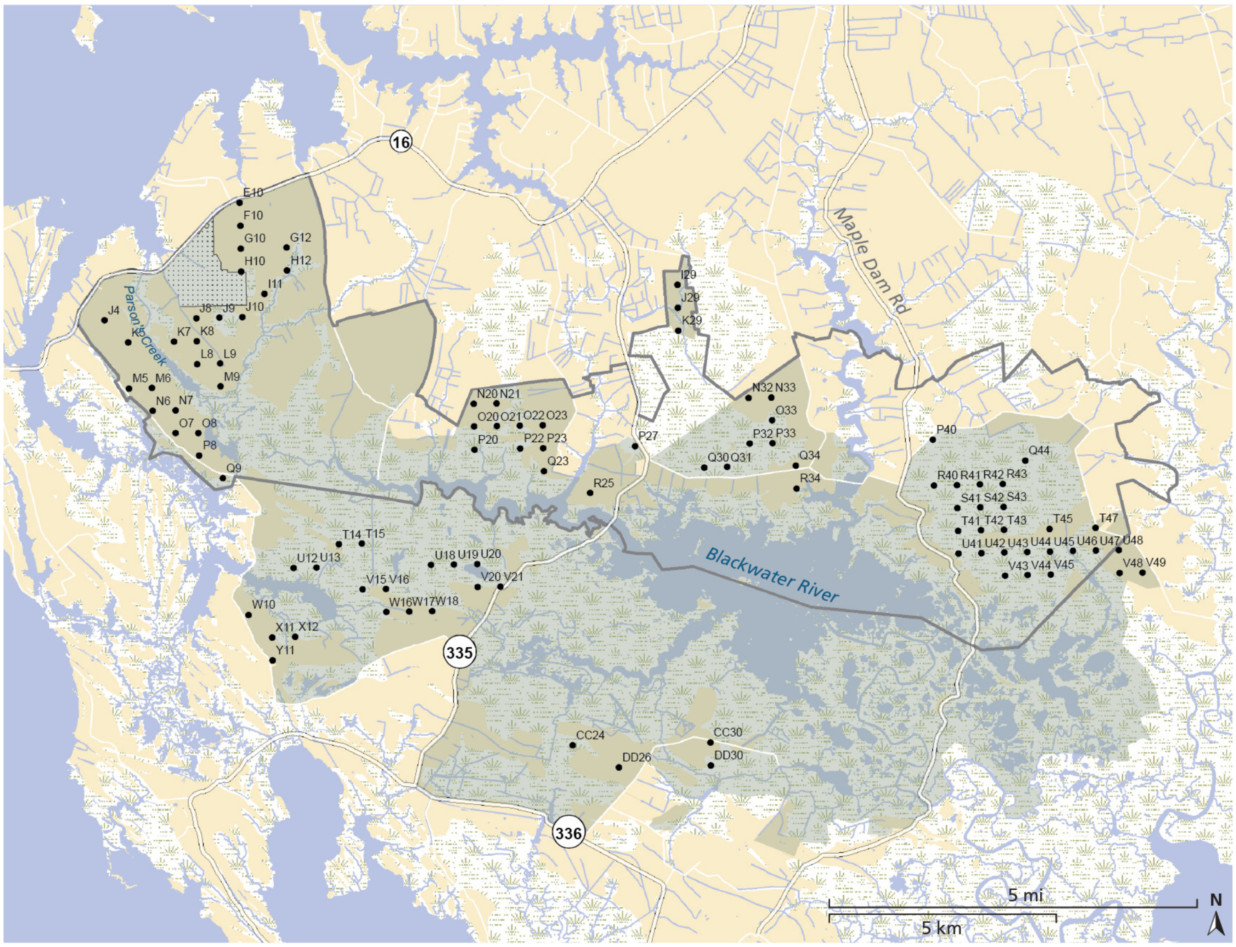


Figure 4-32. Location of 90 continuous forest inventory (CFI) plots within the boundaries of Harriet Tubman Underground Railroad National Historical Park (purple area) and outside the park. Only plots inside of the park were used for scoring forest condition.

Within each plot, overstory, pulpwood, shrubs, regeneration, and ground flora variables were collected. Data included: microsite variability, stand origin, harvest history, general stand structure, and forest type. Height, age, and growth within the last ten years were recorded on a dominant tree within each plot. Down woody debris, seasonal flooding, and damage were also measured. From the center of the plot, azimuth, species, cavities, decay, distance from center, damage, crown class, and merchantable height were recorded. Data on shrubs within a 12 feet radius of the plot center were collected as were data on ground flora in a 5.27-foot radius, 23.55 feet both North and South of the plot center. Pictures were taken in each cardinal direction from plot center for a subsample of plots. Data were checked for quality control / quality assurance.

To calculate forest structural stage, Northeast Temperate Network Standard Operating Procedures for "Analyzing and Reporting Ecological Integrity" were used. Plots were classified as early successional, mature, and late successional based on relative basal area of live canopy trees. Size classes were 10-25.9 cm diameter at breast height (diameter at breast high) for pole, 26-45.9 cm diameter at breast high for mature, and ≥ 46 cm diameter at breast high for large trees. Basal area for each canopy tree was calculated from diameter at breast high, summed for each size class in each plot, and divided by total basal area for the plot to determine relative basal area for each size class. Plots were considered early successional when ≥ 67 percent basal area was in pole and mature sizes with more basal area in pole sizes. Mature stage plots were those with ≥ 67 percent basal area in pole and mature sizes but with more basal area in mature than pole sizes, or ≥ 67 percent basal area in mature plus large sizes with more basal area in mature than large sizes. Finally, late-successional stage was defined as ≥ 67 percent basal area in mature plus large sizes with more basal area in large than mature sizes.

For coarse woody debris, plots were divided in forest types dominated by pine or pine/oak and by hardwoods (oak/sweetgum). Down wood that was measured in ft^3 within 1/25th acre plots was converted to coarse woody debris reported as m^3 per hectare.

When snags were encountered in plot inventories, they were recorded and compared to the abundance of all standing trees (dead and alive) within the park to determine percent of standing trees that are snags.

Tree regeneration was measured by counting and measuring all seedlings less than 4.5 feet tall in 1/100 acre plots.

Tree condition was measured for each overstory tree (>10" diameter at breast high for pine and >12" diameter at breast high for hardwood) within each 1/5 acre plot. Damage was assessed by categorizing any observed damage into weather, animal, disease, human induced, water, insect, suppression/stagnation, and fire damage classes.

Reference Condition

Following Tierney et al. (2016), structural stage was assessed as Good when ≥ 25 percent of all forested plots were late-successional, Moderate Concern when < 25 percent of all plots were late-successional, and Significant Concern when < 25 percent of all forested plots mature and late-successional. Percent attained was calculated as the percent of plots characterized as mature and late-successional.

Reference conditions for coarse woody debris ideally compare volume of dead down wood to volume of live woody debris (e.g., Tierney et al. 2016); however, height of live trees was not measured and so this approach could not be used. Instead, we follow Acadia National Park's score card approach that does not rely on live tree volume (Tierney et al. 2016). Pine and pine/oak forest received a score of Good when coarse woody debris was >25 m^3/hectare, Moderate Concern when coarse woody debris was between 10 and 25 m3/hectare, and Significant Concern when coarse woody debris was <10 m^3/hectare. For hardwood-dominated plots, a score of Good was applied when coarse woody debris was >80 m^3/hectare, Moderate Concern when coarse woody debris was between 50 and 80 m^3/hectare, and Significant Concern when coarse woody debris was <50 m^3/hectare. Percent of reference condition attained was calculated as the percent of plots that scored Good or Moderate Concern.

Following Tierney et al. 2016, snag abundance was scored as Good when ≥ 10 percent standing trees are snags and ≥ 10 percent medium-large trees are snags. Snag abundance was considered Medium Concern when < 10 percent of standing trees are snags or < 10 percent of medium large trees are snags, and Significant Concern when < 5 medium to large snags were encountered per hectare.

Typically, a stocking index is used to evaluate tree regeneration; however, the methods used in the forest inventory (Johnson's Modified Regeneration Index) at Black Water Wildlife Refuge are not compatible with any known methods. Instead, presence of at least one seedling in a 1/100 acre plot is considered evidence of regeneration and percent regeneration is calculated across all plots. Regeneration is scored linearly with Good = 67-100 percent of plots showing signs of regeneration, Moderate Concern = 34-66 percent regeneration, and Significant Concern = 0-33%.

Following Tierney et al. 2016, tree condition is scored as Good when <10 percent of trees have foliage problems from insects and disease, Moderate Concern when 10-50 percent have a foliage problem, and Significant Concern when >50 percent of trees have a foliage problem.

Current Condition and Trend

Forest structure attained 57 percent of the reference condition averaged across five metrics that describe forest structure (Table 4-24). This equates to a score of Moderate Concern. Trend in forest structure could not be assessed because each plot was only measured once in time.

Table 4-24. Summary of forest structure scores of Harriet Tubman Underground Railroad National Historical Park.

Metric	Percent attainment	Condition
Structural stage	100%	Good
Coarse woody debris	33%	Significant Concern
Snags	0%	Significant Concern
Regeneration	49%	Moderate Concern
Tree condition	64%	Moderate Concern
Average	49%	Moderate Concern

Structural stage

Out of 72 plots that were considered forested (≥ 60 percent tree cover; Northeast Temperate Network guidelines, SOP 17, version 3.11), 10 percent (n=7) were early successional, 55 percent (n=40) supported mature forest, and 35 percent (n=25) were late-successional (Figure 4-33). Thus, structural stage is scored as Good (> 25% late successional) with a combined mature and late successional score of 90 percent attained. However, out of 935 trees measured, only three trees were measured as medium-large trees, suggesting that old growth is virtually non-existent.

Coarse woody debris

Coarse woody debris was measured as down wood in 1/25 acre plots on wood with >4" diameter. Twenty-two out of 73 plots within the park had no down wood. Using Acadia National Park's scorecard approach from the NE Temperate Network Long-Term Forest Monitoring Protocol (Tierney et al. 2016), coarse woody debris was scored in plots that were assigned to pine-oak forests (n=59) and to northern hardwood forests (n=14). Of 73 plots monitored for forest structure within Harriet Tubman Underground Railroad National Historical Park, 15 percent (11 plots) were assigned a Good score, 18 percent (13 out of 73 plots) were assigned a Moderate Concern score, and 67 percent (49 plots) were assigned a score of Significant Concern (Figure 4-34). The overall score for coarse woody debris for the park is Significant Concern with only 33 percent of plots above the Significant Concern level for coarse woody debris.

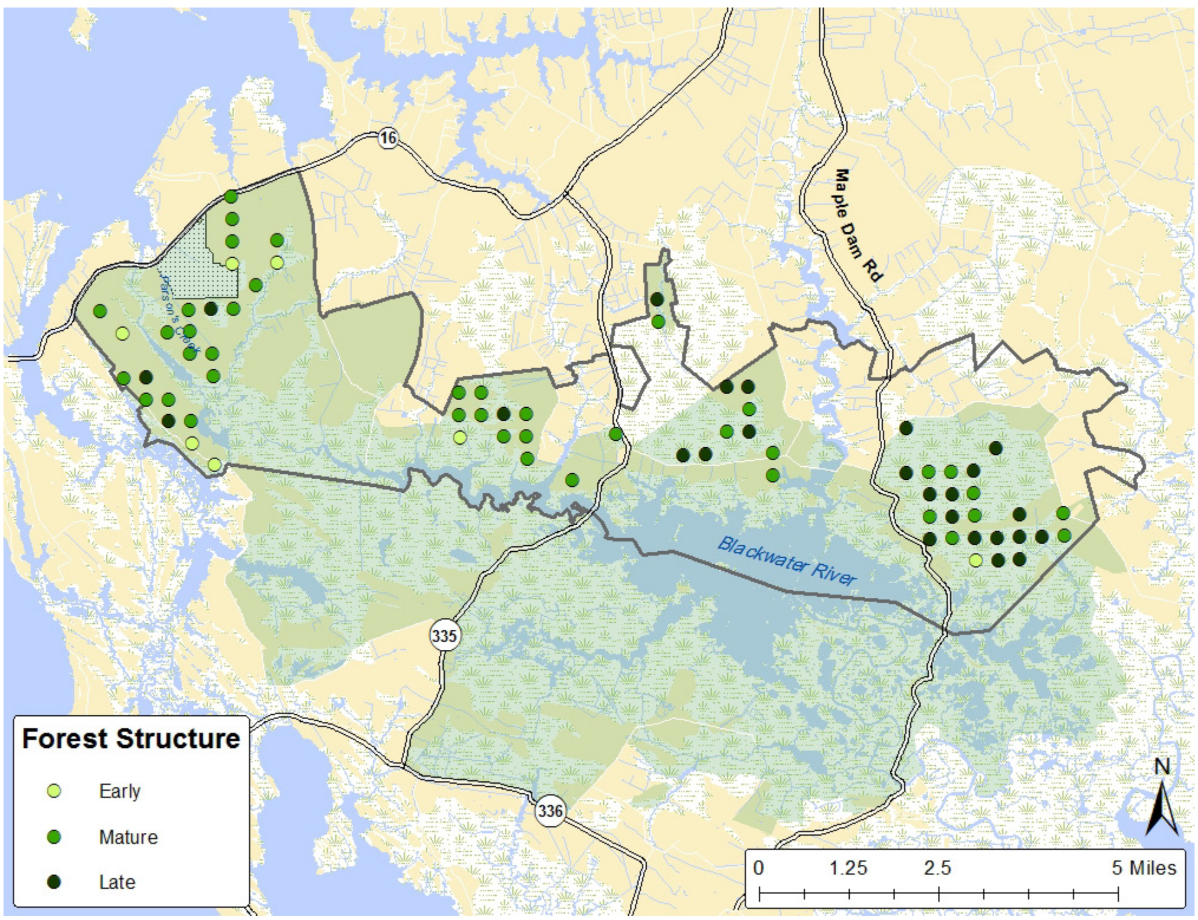


Figure 4-33. Forest structure within 72 plots characterized as forested within Harriet Tubman Underground Railroad National Historical Park outlined in gray. Blackwater National Wildlife Refuge is shaded green and the stippled area shows the forested Jacob Jackson tract. The assessment of forest structure applies the Standard Operating Procedures of the Northeast Temperate Network. Basal area was calculated from diameter at breast height measurements, summed for each of three size categories and then classified as early, mature, and late-successional.

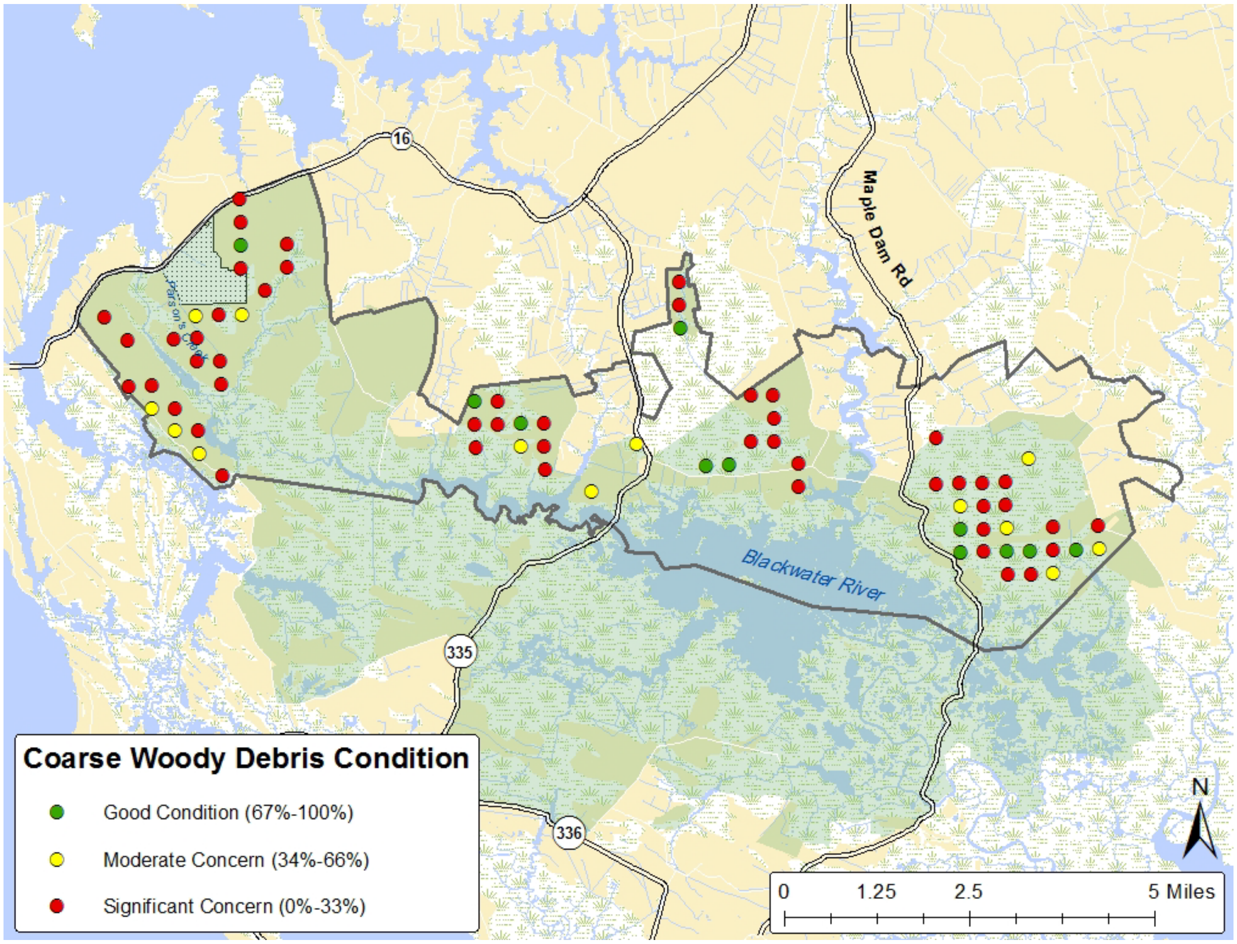


Figure 4-34. Coarse woody debris scores for 73 plots within Harriet Tubman Underground Railroad National Historical Park outlined in gray. Blackwater National Wildlife Refuge is shaded green. Fifty-nine plots were dominated by pine and pine/mixed hardwoods. These plots received a score of Good when coarse woody debris was >25 m^3/hectare, Moderate Concern when coarse woody debris was between 10 and 25 m^3/hectare, and Significant Concern when coarse woody debris was <10 m^3/hectare. For hardwood-dominated plots (oak/sweetgum), a score of Good was applied when coarse woody debris was >80 m^3/hectare, Moderate Concern when coarse woody debris was between 50 and 80 m^3/hectare, and Significant Concern when coarse woody debris was <50 m^3/hectare.

Snags

Because no snags within the park boundary were medium-large (>30 cm diameter at breast high), and only 4.7 percent (44 out of 935) of standing trees were snags, zero percent of the reference condition was attained, and snag abundance is therefore scored as Significant Concern.

Regeneration

Among 73 plots, 51 percent (n=37 plots) showed no regeneration and 49 percent (n=36 plots) showed at least some regeneration (at least one tree less than 1ft recorded) (Figure 4-35). Thus, regeneration is scored at 49 percent and Moderate Concern.

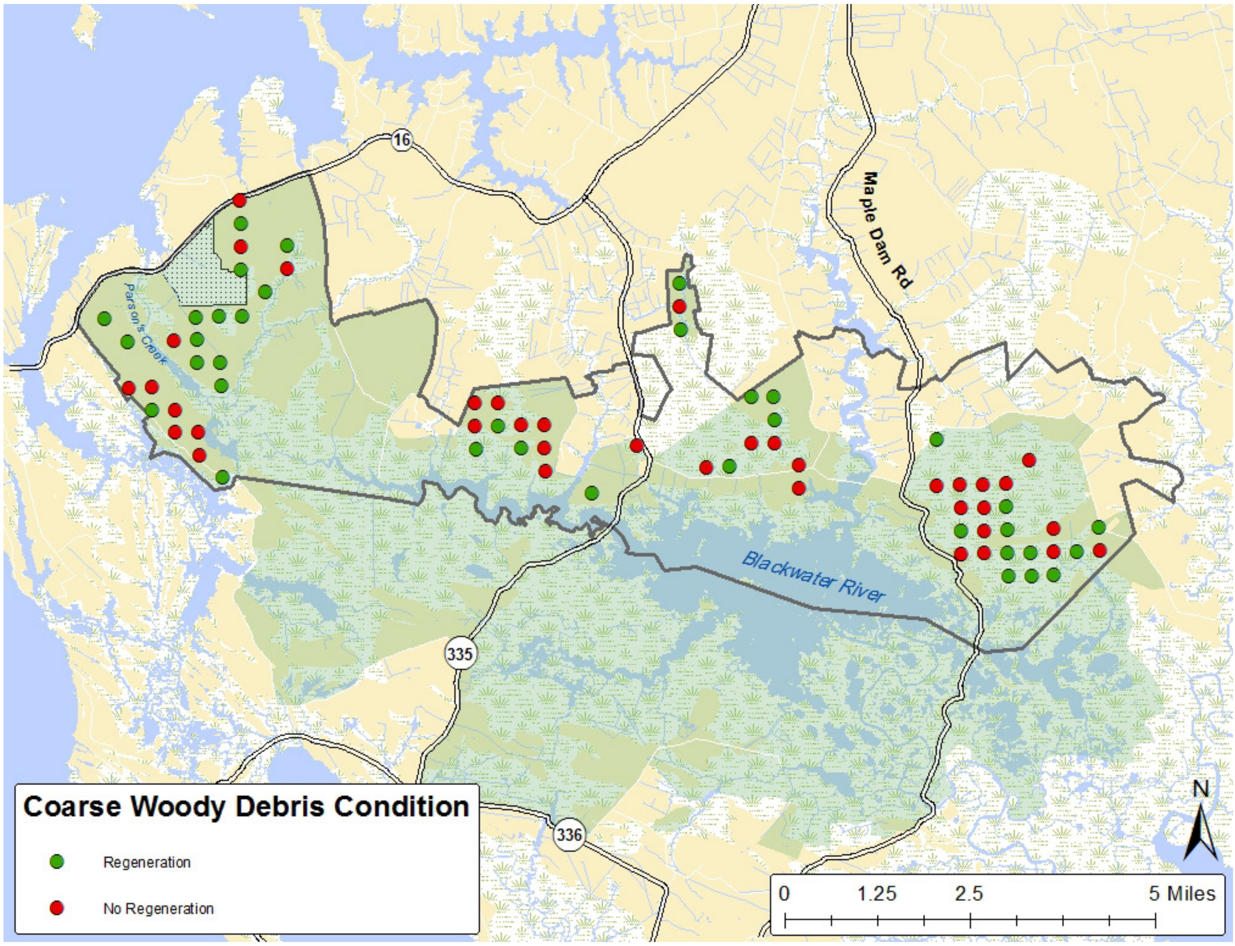


Figure 4-35. Regeneration in each forested plot at Harriet Tubman Underground Railroad National Historical Park outlined in gray. Blackwater National Wildlife Refuge shaded green. Regeneration was observed in a plot when at least one tree seedling was present within a 1/100 acre plot.

Tree condition

Nine percent (n=82 trees) of 891 live trees had some form of disease, and 4.5 percent (n=40 trees) had some form of insect damage (Figure 4-36). Overall, 13.5% of all trees showed foliage damage from disease or insects, thus scoring as Moderate Concern for the park with 64 percent reference condition attained. Invasive pests or pathogens of high concern were not noted.

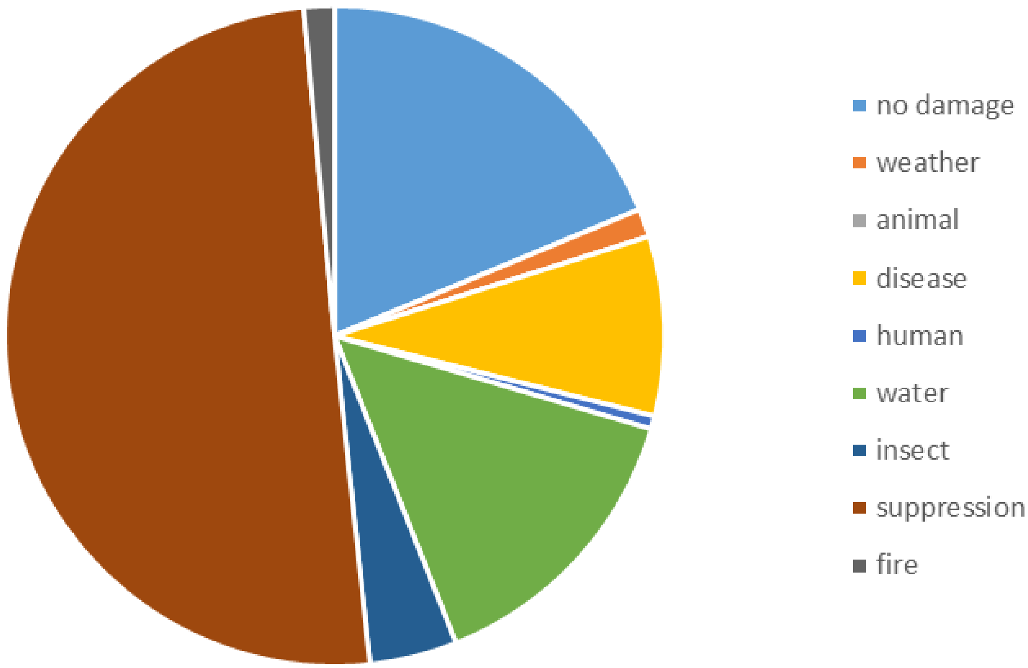


Figure 4-36. Percent of trees that are not damaged or show signs of damage from weather, animal, disease, human induced, water, insects, competitive suppression, or fire at Harriet Tubman Underground Railroad National Historical Park.

Data Gaps and Level of Confidence

Confidence in the scoring of forest structure is medium. Although data are based on a forest inventory that was designed for Blackwater Wildlife Refuge by a trained forester, each of the inventory plots was only measured once. Therefore, a score for each plot is based on one sample in time only and trend cannot be assessed. In addition, the forest inventory did not encompass the Jacob Jackson tract, which is an important forested area of the park that was experimentally harvested and is currently undergoing succession (Carol Bocetti, personal communication). Although vegetation data of the harvesting experiment were collected, they could not be accessed, and are therefore a significant data gap. Although standard operating procedures for other parks were used as guidelines, confidence in the reference conditions is medium as reference conditions can be park specific or are a moving target as climate change continues to change environmental conditions.

Source(s) of Expertise

- Kathryn Miller, Northeast Temperate Network, National Park Service
- Elizabeth Matthews, National Capital Region Network, National Park Service
- Matt Whitbeck, Blackwater Wildlife Refuge, US Fish and Wildlife Service
- John Paul Schmidt, National Capital Region, National Park Service

4.3.2. Deer Density

<u>Description</u>

High population numbers of deer are recognized to have a large impact on the regeneration of woody tree species and the richness and abundance of herbaceous species (McShea et al. 1997, Côté et al. 2004, Nuttle et al. 2014, Habeck and Schultz 2015). Because deer overbrowsing alters plant community structure, breeding bird abundances and species richness also tend to decline with increasing deer densities (deCalesta 1994, McShea and Rappole 1997, Tymkiw et al. 2013).

Deer densities in eastern deciduous forests increased rapidly during the latter half of the 20th century (Porter 1992, Kroll 1994) and may now be at historically high levels (McCabe and McCabe 1997). Pre-settlement estimates of deer densities in the eastern United States range between 3.1 and 4.2 deer/km^2 (McCabe and McCabe 1997). Today, deer densities exceeding continent-scale pre-settlement estimates are common (Côté et al. 2004), especially in eastern North America (Abrams and Johnson 2012, Bressette et al. 2012). Densities of 20 deer/km^2 are now common, including in national parks (Bates 2016).

Harriet Tubman Underground Railroad Historical Park is home to two deer species – white-tailed deer (*Odocoileus virginianus*) and Sika deer (*Cervus nippon*) with the latter the most abundant. Sika deer are native to eastern Asia but became established during the early 1900's when released by Clement Henry on James Island (US Fish and Wildlife Service 2006). Sika deer hunting is popular at Blackwater National Wildlife Refuge, such that the deer herd is managed at abundances that are conducive to a good hunting experience. Similarly, white-tailed deer populations are maintained throughout the state of Maryland to support recreational hunting.

Sika deer at Blackwater National Wildlife Refuge. Photo credit US Fish and Wildlife Service.

Data and Methods

Trends in deer population abundances have been recorded at Blackwater National Wildlife Refuge since 1998 through hunter check stations during refuge hunts. Because only a few roads access the refuge, hunter check stations effectively document the number of deer killed during a hunting season. Each deer is sexed, aged, and weighed. Using these data, deer populations can be reconstructed and used to assess trends, but not density, in time.

Because population reconstruction from hunter data does not estimate deer density, survey transects were established (Figure 4-37) along 39.1 km of roadways in September 2017 at Blackwater National Wildlife Refuge. Approximately only half of the roadway length sampled was located within the boundary of Harriet Tubman Underground Railroad National Historical Park; yet, all data were used in the assessment to represent the Blackwater area in general. Transects were divided into west and east transects to ensure that the entire transect route could be surveyed in one night during peak deer activity. Each route was sampled five times.

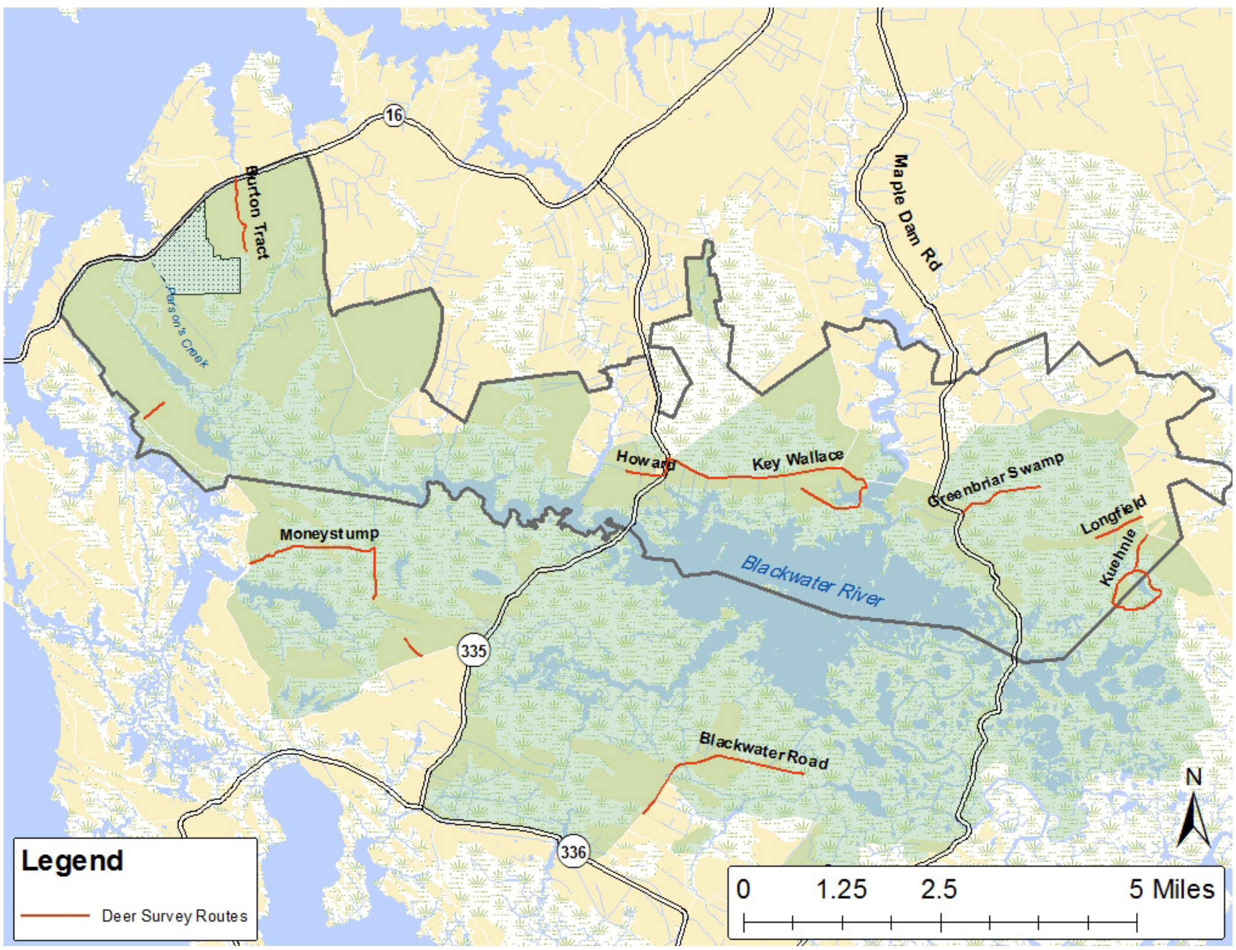


Figure 4-37. Location of two surveyed transects (east route and west route) within Blackwater National Wildlife Refuge (Data source: Haus and Bowman 2018).

Using a handheld FLIR unit to detect deer, and a range finder to measure distance, deer density was estimated using distance sampling approaches (Buckland et al. 1993).

Thermal heat signatures captured at Blackwater National Wildlife Refuge using a handheld FLIR unit (Image source: US Fish and Wildlife Service).

<u>Reference Condition</u>

Plant and song bird species richness and abundance are reduced when deer density approaches eight deer per square km (Horsley et al. 2003), although some biotic communities show signs of stress at lower deer densities (deCalesta 1997). Tilghman (1989) recommends deer densities of 7 deer/km^2 to prevent regeneration failure of Pennsylvania forests, although in a recent study (Russell et al. 2017), seedling abundance already decreased at 5.8 deer/km^2. Deer densities of 10-17 deer/km^2 decreased regeneration of understory species whereas deer densities of 3-6 deer/km^2 appeared to support a healthy community structure (Healy 1997). Given this prior research, the threshold level for deer density at Harriet Tubman Underground Railroad National Historical Park was established at 8.0 deer/km^2. Above this deer density threshold, deer density was scored at 0% attainment and below the threshold, deer density was scored at 100%.

Current Conditions and Trend

Overall deer density (sika and white-tailed deer) on Blackwater National Wildlife Refuge is estimated to be 26.9 ± 2.1 deer/km^2 (Haus and Bowman 2018). The east survey route detected 28.4 deer/km^2 whereas the west survey route detected 25.5 deer/km^2. Deer density in forested habitat was estimated at 25.28 ± 3.46 deer/km^2, whereas habitat dominated by agriculture supported 17.55 ± 4.29 deer/km^2. Using motion-triggered cameras on private property directly to the east of Blackwater National Wildlife Refuge, Dougherty and Bowman (2012) estimated a sika deer density of 33 deer/km^2. These densities are within the range of deer densities reported for other national parks in the region (Bates 2016).

Given the high deer densities documented within the refuge and the immediate Blackwater region, current condition of deer population density at Harriet Tubman Underground Railroad National Historical Park is assessed as very degraded, with 0% attainment.

Although deer density was only estimated once in 2017, population estimates from hunter check station data show that deer densities have remained stable at a high level in recent years (Figure 4-38).

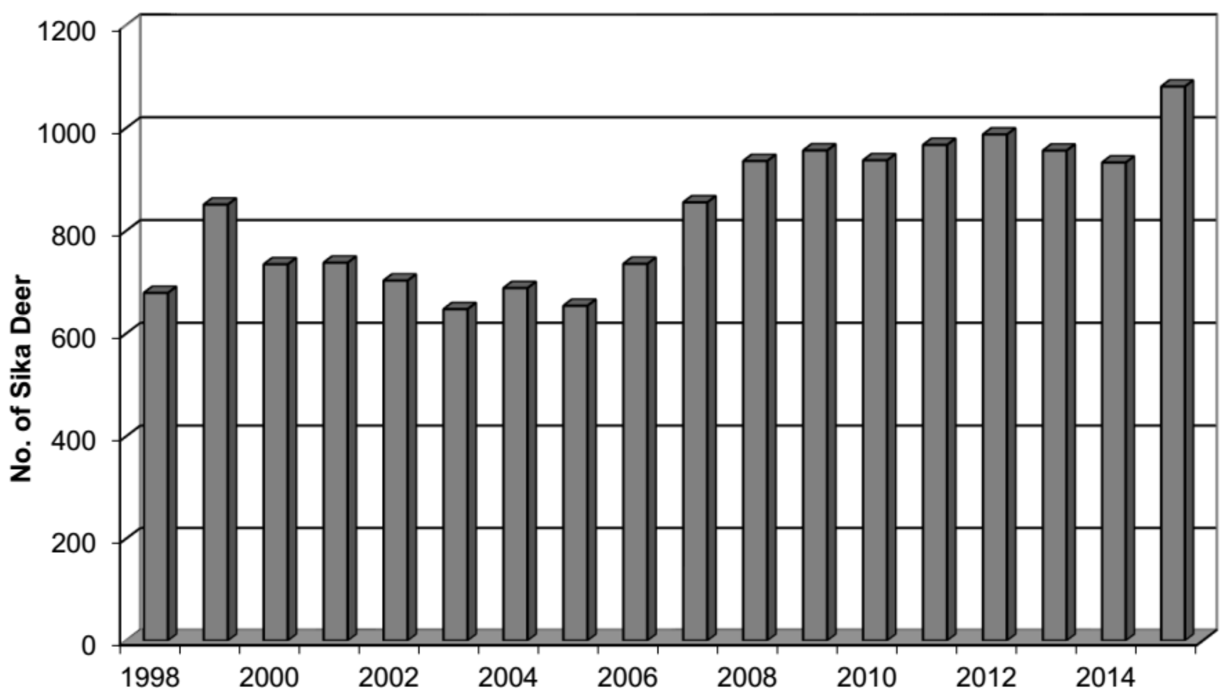


Figure 4-38. Sika deer abundance estimates for Blackwater National Wildlife Refuge using the Downing Reconstruction Model (Figure source: Brian Eyler, Maryland Department of Natural Resources).

Data Gaps and Level of Confidence

Deer density was estimated only once in 2017; however, population estimates from hunter check stations can provide insights into how deer densities have fluctuated through time (Figure 4-40). Although density estimates from transect surveys are preferred, the combination of 2017 transect density data with population estimates through time provide a high level of confidence in the assessment of deer density at Harriet Tubman Underground Railroad National Historical Park. In fact, when extrapolated across the hunt area, the 2017 transect data provides comparable estimates of deer abundance (1,137 deer) to estimates from herd reconstruction models from harvest data (1,100 deer) (Haus and Bowman 2018).

<u>Source(s) of Expertise</u>

- Brian Eyler, Deer Program Leader, Maryland Department of Natural Resources
- Matt Whitbeck, Natural Resources Manager, US Fish and Wildlife Service

4.3.3. Delmarva Fox Squirrel

<u>Description</u>
Considered to be a conservation success story in the United States, the Delmarva fox squirrel (*Sciurus niger cinereusis*) is an important indicator for the health of the Harriet Tubman Underground Railroad National Park forest ecosystem. The Delmarva fox squirrel is a large charismatic tree squirrel that is a subspecies of the eastern fox squirrel (*Sciurus niger*). This species is the largest of all the tree squirrels, growing up to 30 inches – with approximately half the length found in the tail – and weighing up to 3 pounds. Eastern and Delmarva fox squirrels require mature forest stands characterized by closed canopy and an open understory. Typically, the composition of the woodlot is a mix of loblolly pine and mast-producing hardwoods such as oak, hickory, walnut, and beech. Squirrels commonly forage in farm fields found near mature forest stands and generally avoid suburban and more urban landscapes (Taylor and Flyger, 1974; Dueser et al., 1988).

Delmarva fox squirrel relaxing in a tree at Blackwater National Wildlife Refuge. Photo credit: M. Simon, Maryland Environmental Service.

The Delmarva fox squirrel historically occurred on the Delmarva Peninsula and southeastern Pennsylvania; however, in the mid-1900s, as a result of habitat loss and fragmentation and overhunting, the distribution contracted to less than 10% of its historical range (Taylor and Flyger, 1974). Thus, in 1967 the Delmarva fox squirrel was federally listed as endangered (USFWS 2012). Soon after listing, conservation efforts, led by federal and state biologists and academic scientists, ensued. These efforts included banning legal hunting for the species and translocations of individuals to unoccupied forests. However, suitable forest habitat throughout the species' former range remained scarce even after hunting ceased and required young forests to mature over several decades, as well as changing timber harvest management practices.

Delmarva fox squirrel within the understory of a forest within Blackwater National Wildlife Refuge. The species typically prefers a closed canopy but an open understory. Photo credit: Betty Whetzel.

Although state wildlife areas and federal refuges were selected for translocation sites, the majority of the sites occurred on private property with landowner agreement (Figure 4-41; Keller and Therres, 2017). In 2015, after 48 years of being on the endangered species list, the Delmarva fox squirrel was officially delisted (USFWS 2015a). The population is now believed to consist of approximately 20,000 individuals which inhabit 28% of the Delmarva Peninsula (USFWS2015a). However, although the population has rebounded significantly, the species is still under threat as a result of its small geographic distribution, its limited number of populations, and changes in climate which may result in less productive and more variable habitat (Hilderbrand et al., 2007). Habitat may not be currently limiting existing populations, but continued vigilance in managing and preserving the habitat is required for sustainability.

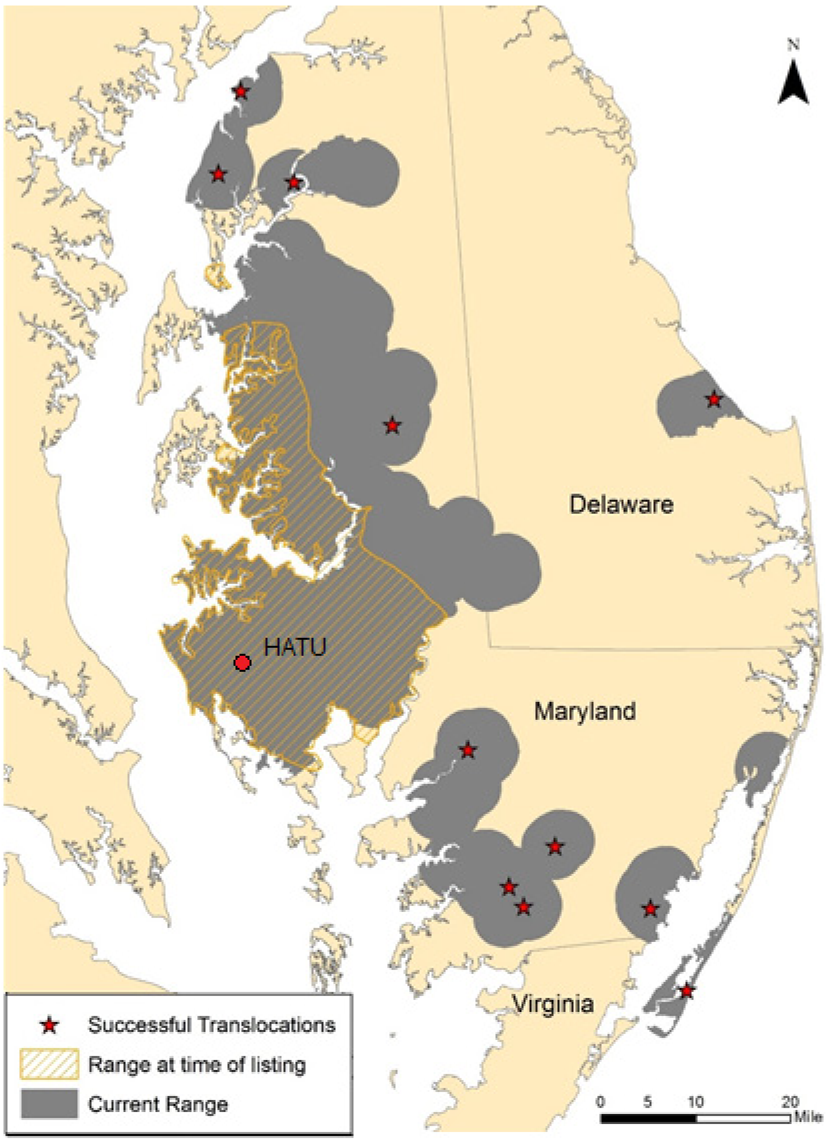


Figure 4-39. Changes in the range of the Delmarva fox squirrel from 1993 to 2015, including successful translocation sites (stars) and the location of Harriet Tubman Underground Railroad National Historical Park (circle), which was not a translocation site. At the time of listing in 1967, the range of the Delmarva fox squirrel was much reduced (Figure source: Cherry Keller, USFWS).

Harriet Tubman Underground Railroad National Historical Park includes approximately 25,000 acres of federal, state, and private lands in Dorchester County. Blackwater National Wildlife Refuge is a significant part of the park and is known to host the largest natural population of the Delmarva fox squirrel (USFWS 2015a). As a native species to the park and a very charismatic creature, many visitors are interested in seeing the Delmarva fox squirrel on the hiking trails and roadsides throughout the Park. This species is of great importance to the area and the park because of its role as an indicator of ecosystem health, its significance as a conservation success story, and its role of drawing visitors into natural areas. It stands to reason that Harriet Tubman encountered Delmarva fox squirrels during her work and travels in the area and so the species may be viewed not only as a natural resource but also as a cultural resource.

<u>Data and Methods</u>

To understand the distribution of the Delmarva fox squirrel, sightings and other records of Delmarva fox squirrels' presence have been recorded in a GIS database by the US Fish and Wildlife Service throughout the Delmarva Peninsula, including areas within Harriet Tubman Underground Railroad National Historical Park. In addition, intensive monitoring in the 1990's of several benchmark sites throughout the region sought to record population trends through time using mark-recapture estimates. One of these benchmark sites (60-acre tract "Egypt") is located within park boundaries (Figure 4-40).

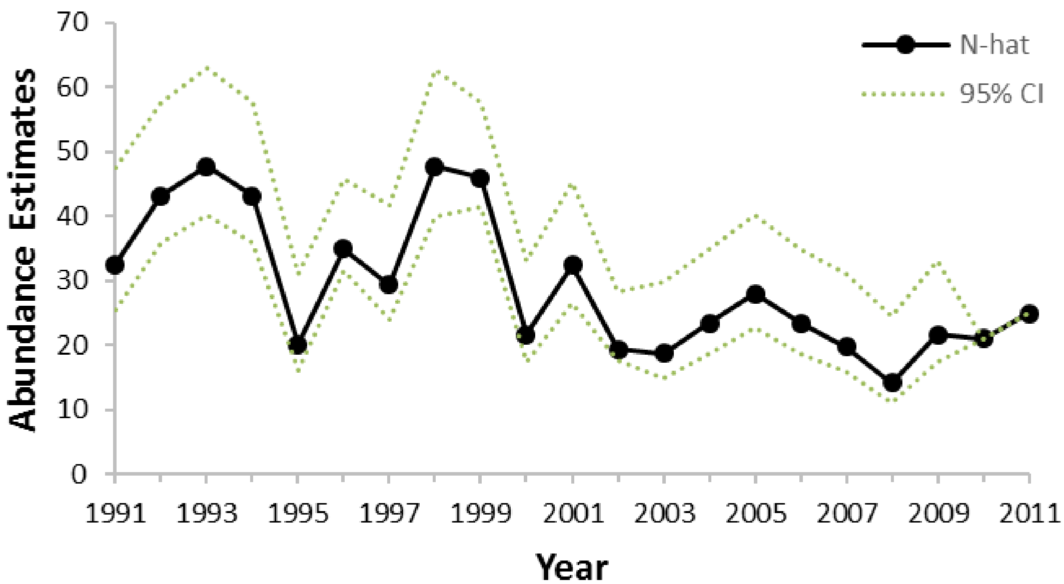


Figure 4-40. Population abundance estimates (N-hat) and confidence intervals for benchmark site Egypt, a 60-acre forest tract west of the Little Blackwater River within Harriet Tubman Underground Railroad National Historical Park. The population trend shows a decline because adjacent fields were cultivated as corn in the 1990s and later converted to wetland. Hence, Delmarva fox squirrel densities were artificially high during the early half of monitoring owing to squirrels feeding on corn. When the food source was removed, the population declined to more normal levels. Monitoring was discontinued in 2011. Owing to these issues, these data are not used except for illustrative purposes.

Benchmark site monitoring provides detailed information on population fluctuations about a few very small areas. Because this approach is limited in geographical extent, it was generally abandoned for camera surveys that could be conducted over larger areas. In 2004, a camera survey of Blackwater Wildlife Refuge was conducted (Morris 2006), providing points of known occupancy.

The refuge is now developing a monitoring program using cameras and occupancy modeling to track general population changes across the refuge (Whitbeck, personal communication 2018).

Delmarva fox squirrels are 'home bodies' and generally stay within an approximately 40-acre (16 hectare) home range (USFWS 2012, p.11), and populations are considered separate if they are more than 3.6 km (2.2 miles) apart (Hilderbrand et al. 2007). This high site fidelity enables the occupancy approach that assumes that, if a Delmarva fox squirrel is sighted in an area, the area is occupied by the species. Sightings can then be compared to habitat suitability models or habitat maps using forested polygons or LiDAR modeling. Morris (2006) developed a habitat model based on camera surveys that identified canopy height, canopy closure and the diameter at breast high of trees to be significant predictors of Delmarva fox squirrel presence as detected by cameras. These data were also used to test the LiDAR habitat model for Delmarva fox squirrels (USFWS 2012, p. 65-74).

Delmarva fox squirrel captured using camera sampling at Blackwater National Wildlife Refuge. Photo credit: Anne Gauzens.

Dr. Carol Bocetti (California University of Pennsylvania) has conducted trapping surveys (Figure 4-41) since 1996 within the National Park Service-owned Jacob Jackson parcel to test how a timber harvest in 1998-1999 affects Delmarva fox squirrel and gray squirrel (*Sciurus carolinensis*) populations. Squirrels were captured using cage traps baited with corn. Individuals captured were sexed, their approximate age was determined (e.g., juvenile, sub-adult, adult), and then they were tagged. Sampling events generally were conducted during consecutive days, although rain events would cause sampling to be delayed. The number of consecutive sampling days varied depending upon the data collector, the season, and the number of individuals captured.

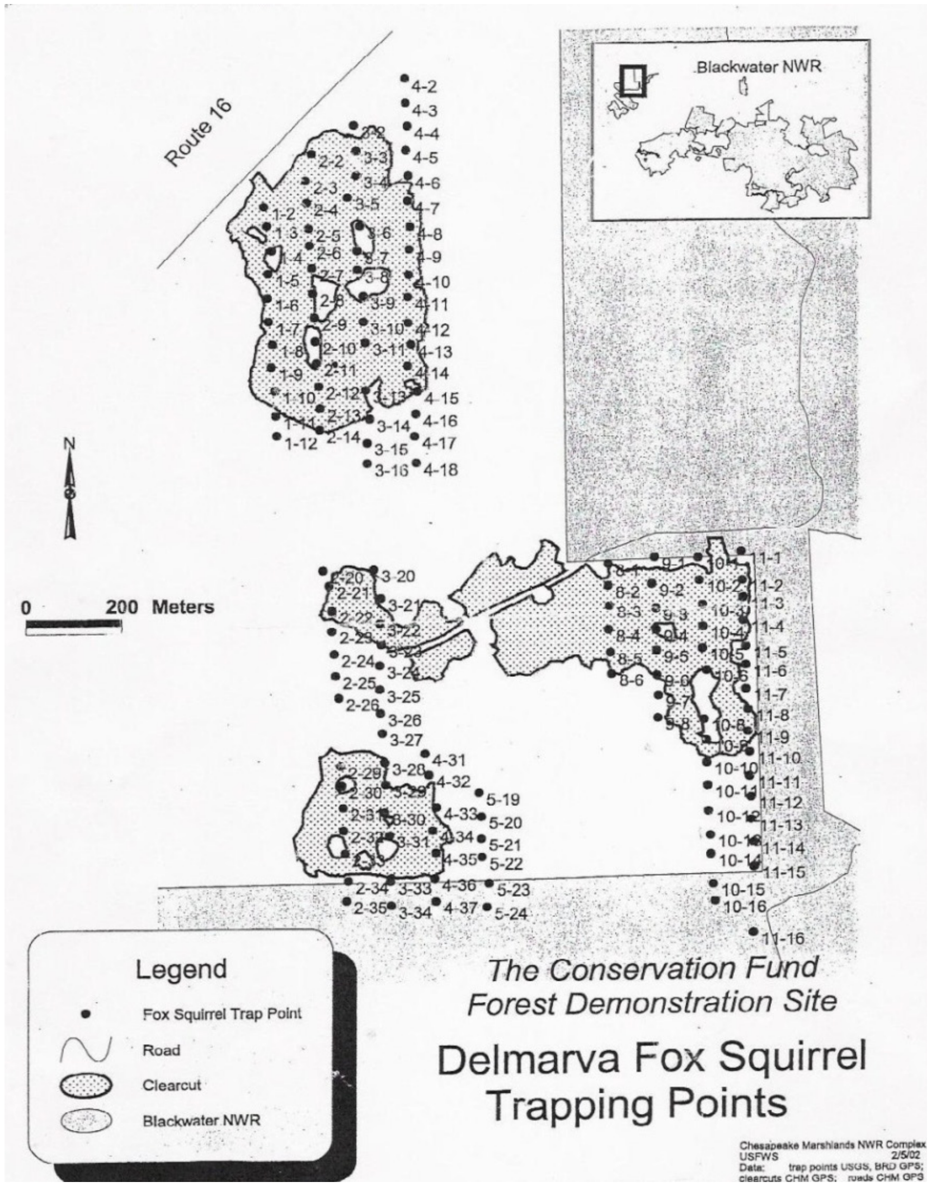


Figure 4-41. Delmarva fox squirrel trapping locations within the National Park Service-owned Jacob Jackson parcel of Harriet Tubman Underground Railroad National Historical Park. Trapping locations span clear-cut areas and forested areas. The Conservation Fund owned the property before the National Park Service purchase.

Reference Condition

Forested polygons were outlined by the Maryland Department of Natural Resources in the 1990's to provide a baseline for occupied forested areas. This baseline can be used as a reference to compare to current occupancy. In addition, LiDAR (Light Detection and Ranging) technology can identify mature forests that are suitable for Delmarva fox squirrels. Point data of occupancy can be overlaid onto the habitat suitability maps to determine degree of occupancy. Saturation (100% of forest patches occupied) was scored as 100% and scaled linearly below that.

Trapping data at the Jacob Jackson home site provide long-term population data rather than absolute density estimates, with the intent of monitoring population trends over time. Increasing abundance estimates suggests an actively reproducing population, no change suggests a stable but potentially aging population, and declining abundances indicate mortality with little recruitment. The reference condition was abundance (per 1000 trap hours) before timber harvest. Above this level was considered 100% attainment. Abundances below pre-harvest levels were scaled linearly.

Current Conditions and Trend

Delmarva fox squirrel occupancy data shows that fox squirrels occupy each delineated forest polygon (Figure 4-42), suggesting that the habitat is saturated (100%) with Harriet Tubman Underground Railroad.

LiDAR-defined suitable habitat for Delmarva fox squirrels (Figure 4-43) shows that not all of the forest was mature in 2003 when the LiDAR data were collected. Younger stands occur in the western portions of the park, which could have matured into suitable forest in the last 15 years. However, similar to the 1990 forest delineation, the 2003 habitat map suggests that most forest habitats (and some non-forest habitat) are occupied by Delmarva fox squirrels, again indicating that the habitat is saturated. Thus, across the two habitat maps, occupancy is scored as 100%.

Trapping data at the Jacob Jackson Home site shows that Delmarva fox squirrel populations increased initially after timber harvest in late 1998 (Figure 4-44) because clear-cut areas could easily be navigated by squirrels. However, abundances declined ten years after harvest as forests regenerated in previously clear-cut areas and closed the understory. Gray squirrel abundances increased during the same time, increasing competition for food resources.

The condition of Delmarva fox squirrels is scored as Good (100%) based on habitat occupancy and long-term trapping. The trend is considered stable in areas that support mature forest and improving in areas that are at various levels of regeneration such as the Jacob Jackson home site.

Data Gaps and Level of Confidence

Confidence in the assessment is high. Long-term trapping data provide trend data for the Jacob Jackson parcel, whereas occupancy modeling shows that the Delmarva fox squirrel is widespread within Harriet Tubman Underground Railroad National Historical Park. No significant data gaps are identified.

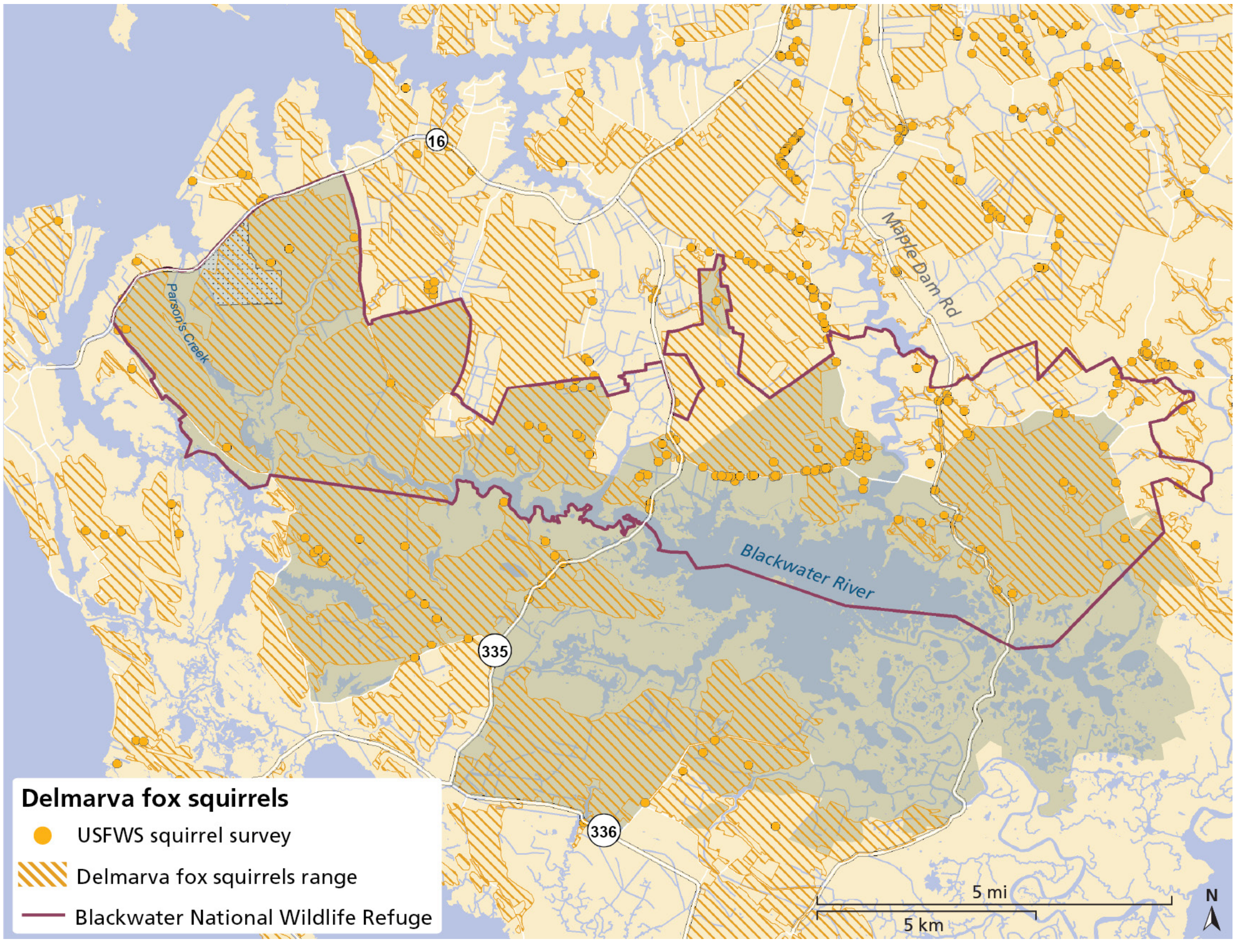


Figure 4-42. Occupied forest polygons outlining forested areas where Delmarva fox squirrels were considered to occur by the Maryland Department of Natural Resources in the 1990's (orange diagonal lines) and locations where Delmarva fox squirrels have been seen or recorded on cameras (orange dots). Occupancy data can only determine if an individual is present. No data does not mean that individuals are absent. The park boundary is outlined in purple (Data source: Cherry Keller, USFWS Chesapeake Bay Field Office 2017).

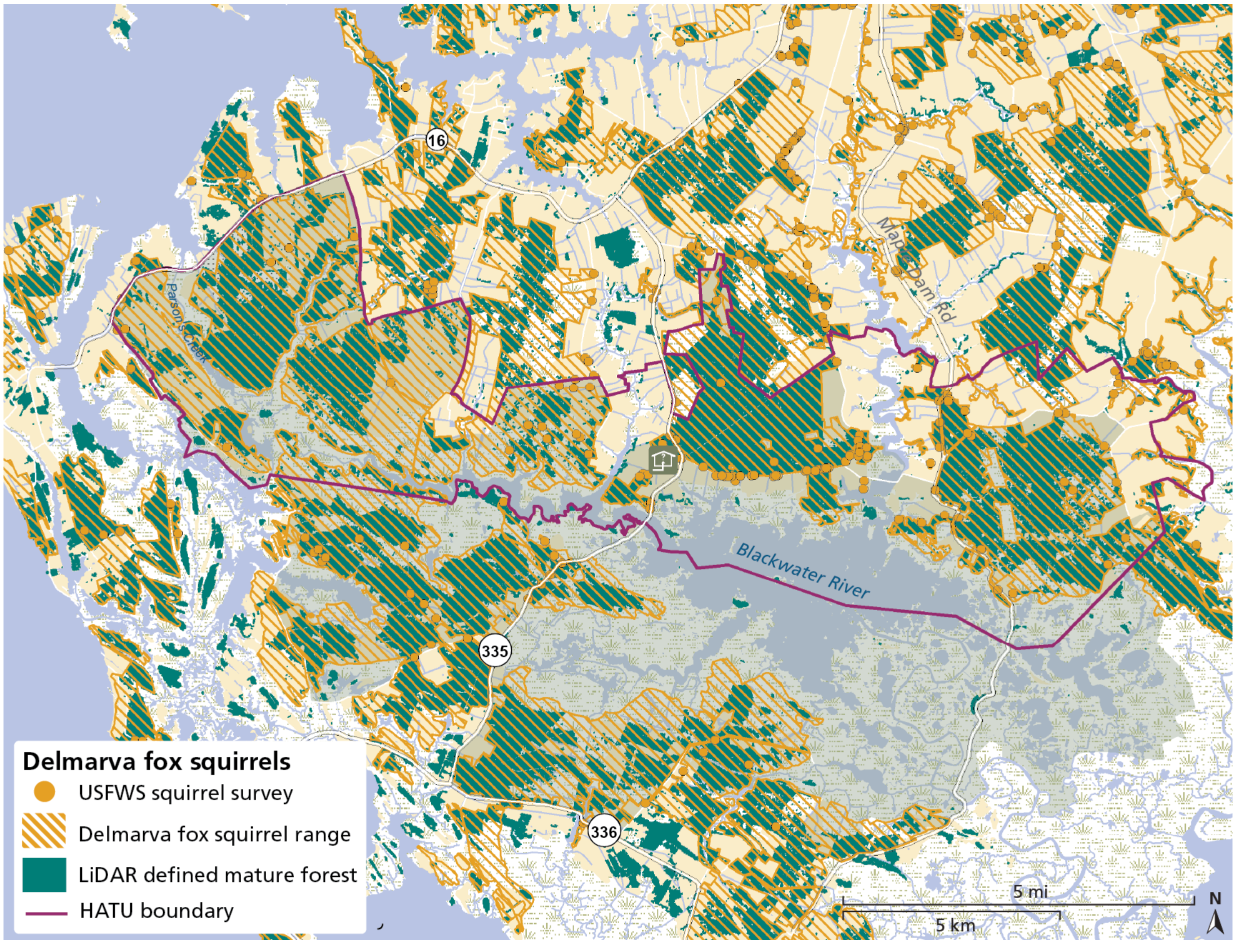


Figure 4-43. LiDAR-defined mature forest stands within and surrounding Harriet Tubman Underground Railroad National Historical Park. Occupancy data can only determine if an individual is present. No data does not mean that individuals are absent. The park boundary is outlined in purple (Data source: Cherry Keller, USFWS Chesapeake Bay Field Office 2017).

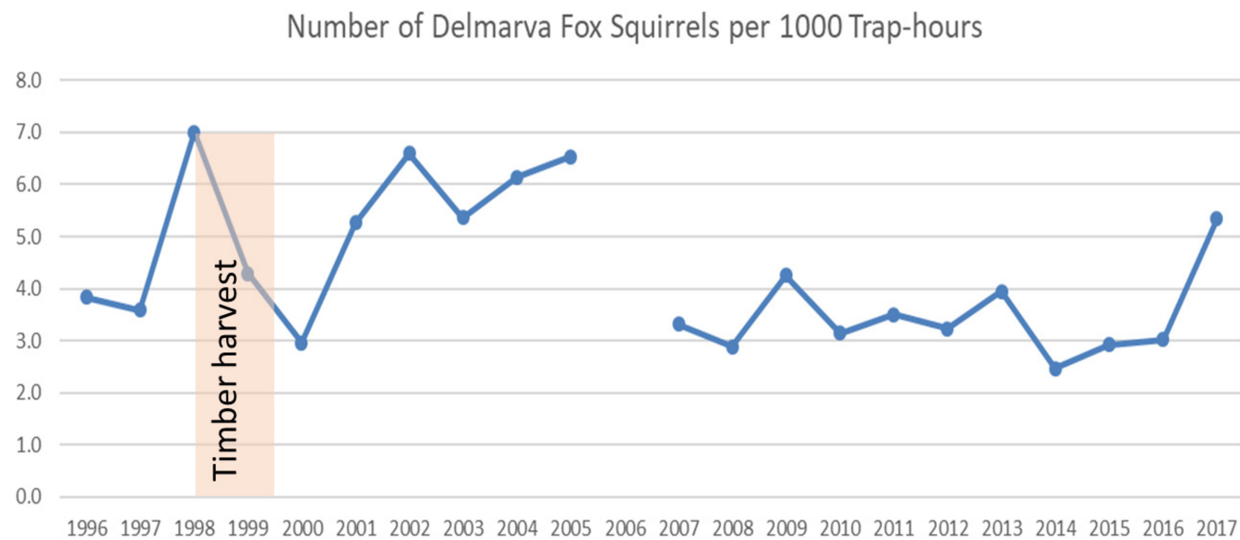


Figure 4-44. Abundance of Delmarva fox squirrels observed in traps from 1996 to 2017 at the Jacob Jackson Home site within Harriet Tubman Underground Railroad National Historical Park. Timber harvest occurred in late 1998. IUE is Individuals per Unit Effort (measured in 1000 trap-hours). No trapping was done in 2006. Data from Dr. Carol Bocetti.

Sources of Expertise

- Cherry Keller, US Fish and Wildlife Service
- Carol Bocetti, California University of Pennsylvania

4.3.4. Bald Eagle

Description

The bald eagle (*Haliaeetus leucocephalus*) was chosen as the emblem of the United States of America on June 20, 1782, six years after the thirteen colonies declared independence from Great Britain. Although abundant before and during Harriet Tubman's life, bald eagles became close to extinction in the late 20th century in the contiguous United States owing predominantly to the pesticide DDT, but also to habitat loss and hunting. DDT interferes with a bird's calcium metabolism and therefore causes egg shells to thin (Brown 1976). Consequently, eggs are too brittle for an egg to hatch successfully.

A bald eagle within Harriet Tubman Underground Railroad National Historical Park. Photo by Betty Whetzel.

By the 1950's only 412 nesting pairs were counted in the 48 contiguous states of the United States (Grier 1982). The bald eagle was declared an endangered species in 1967, which prohibited hunting. Once DDT was banned in 1972, populations recovered (Grier 1982) to the extent that the species was removed from the list of endangered species on July 12, 1995 and transferred to the list of threatened species. It was removed from the List of Endangered and Threatened Wildlife in the Lower 48 States on June 28, 2007.

Author Maude M. Grant (1880-1930) wrote:

> *It is said the eagle was used as a national emblem because, at one of the first battles of the Revolution (which occurred early in the morning) the noise of the struggle awoke the sleeping eagles on the heights and they flew from their nests and circled about over the heads of the fighting men, all the while giving vent to their raucous cries. "They are shrieking for Freedom," said the patriots.*
>
> *Thus the eagle, full of the boundless spirit of freedom, living above the valleys, strong and powerful in his might, has become the national emblem of a country that offers freedom in word and thought and an opportunity for a full and free expansion into the boundless space of the future.*

Bald eagles were undoubtedly familiar to Harriet Tubman when she lived and worked as a slave the first 29 years of her life, and later as a free woman working as an Underground Railroad conductor, helping others to freedom. The bald eagle is therefore a particularly poignant natural feature at Harriet Tubman Underground Railroad National Historical Park given the park's historical context as well as the bald eagle's own struggle for survival.

Blackwater National Wildlife Refuge, and by extension Harriet Tubman Underground Railroad National Historical Park, is known to be the most important wintering location for bald eagles north of Florida on the Atlantic Coast. The area produces abundant food and nesting habitat that support the highest nesting density of eagles in Maryland and in the mid-Atlantic region (USFWS 2006).

Data and Methods

The National Wildlife Federation initiated nationwide eagle counts in 1979 in an effort to monitor bald eagle populations after the ban of DDT as a pesticide. Since then, bald eagle midwinter surveys have been conducted in January in the conterminous United States (Eakle et al. 2015). As part of this effort, nesting and overwintering eagles have been counted each year since 1980 at Blackwater National Wildlife Refuge. This assessment uses mid-winter count data collected at 14 survey stations (Figure 4-45). Only non-roost counts of eagles are used in this assessment.

Reference Conditions

The reference condition for eagles is the number of eagles counted during the mid-winter survey at Blackwater National Wildlife Refuge during the year of delisting – 114 eagles counted in 2007. A passing score of 100 was assigned if a count was equal to or greater than the reference condition, and a failing score of 0 was assigned if a count was less than the reference condition.

Condition and Trend

The condition of eagles at Harriet Tubman Underground Railroad National Historical Park is good, with an average of 167 individuals counted annually between 2008 and 2017, corresponding to an average 90% attainment of the reference condition since the eagles were delisted. The eagle population fluctuates each year, with a low of 107 eagles counted in 2009 and a high of 232 eagles, more than double the reference condition, in 2016 (Table 4-25).

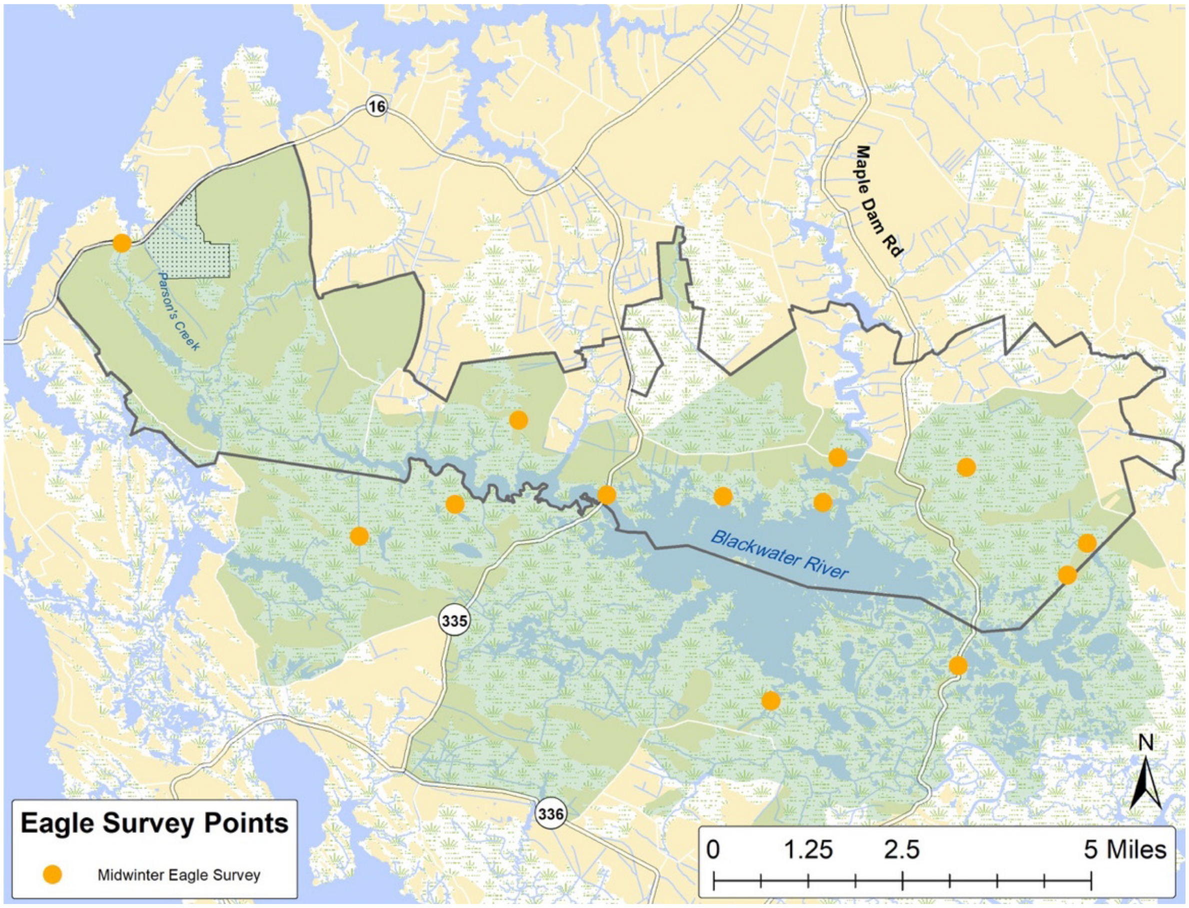


Figure 4-45. Eagle midwinter survey points for Blackwater National Wildlife Refuge. Although some survey points fall outside the Harriet Tubman Underground Railroad National Historical Park boundary, all sites are used in the assessment (Data source: Matt Whitbeck, Blackwater NWR 2017).

Table 4-25. Number of eagles counted annually and percent score from 2008 to 2017 in Harriet Tubman Underground Railroad National Historical Park.

Year	Non-roost counts	Percent attainment
2008	145	100%
2009	107	0%
2010	173	100%
2011	189	100%
2012	168	100%
2013	158	100%
2014	154	100%
2015	207	100%
2016	232	100%
2017	138	100%
Average	**167**	**90%**

Since 1980, the number of eagles counted in the park has generally increased (Figure 4-46).

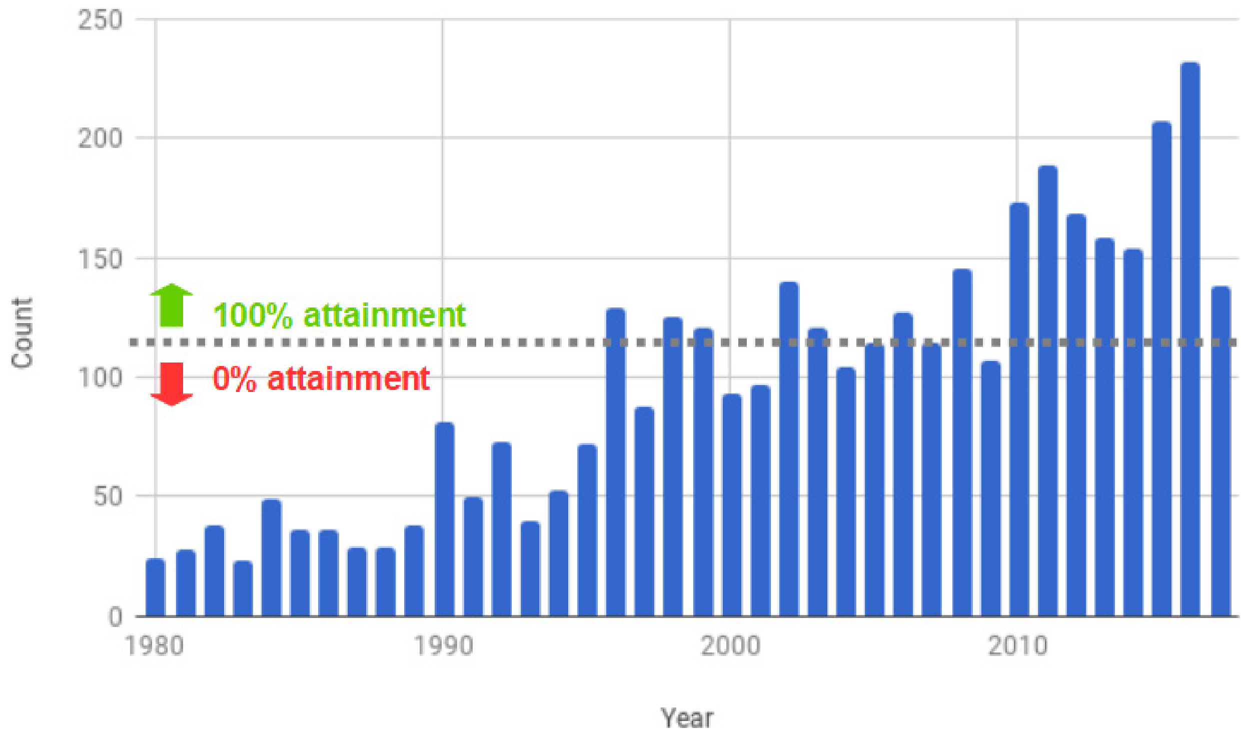


Figure 4-46. Annual non-roost count of eagles in Harriet Tubman Underground Railroad National Historical Park since 1980. The reference condition (dotted line) is the number of eagles counted in 2007, the year of delisting.

Level of Confidence and Data Gaps

Confidence in the assessment is high. Data were collected spanning 37 years and scored spanning the last 10 years since bald eagles were taken off of the threatened and endangered species list in 2007.

Source(s) of Expertise

- Matt Whitbeck, Supervisory Wildlife Biologist at Chesapeake Marshlands National Wildlife Refuge Complex.
- Sheila Colwell, Biologist, National Park Service

4.3.5. Forest Interior Birds

Relevance and Context

Bird communities are often used as general indicators of ecosystem structure, function, and composition (Johnson and Patil 2007). Changes in composition of the community can provide subtle or unexpected cues of environmental degradation (Johnson and Patil 2007). Birds integrate information about the health of food webs, as they consume a broad range of foods including plants, insects, earthworms and small animals (Jones et al. 2000). Many fruit-eating birds help disperse seeds by consuming them and depositing them in new places and nectar-feeding birds play a critical role in pollination (Jones et al. 2000).

Forest Interior Dwelling Species (FIDS) are particularly useful indicators of the health of forest ecosystems, as they require large areas of continuous mature forest cover and their habitat requirements correspond with those of many other species (Jones et al. 2000). FIDS are especially sensitive to the effects of disturbances (Canterbury et al. 2000). The Chesapeake Bay region experienced a 63% decline in neotropical migrants (many of which are FIDS) between the years of 1980 and 1989 (Jones et al. 2000). In addition to the overall decrease in forest habitat in recent decades, the resulting smaller forest patches often consist of younger trees and more edge environment. This increases the threat of nest predation, human disturbance, and invasion by exotic flora (Jones et al. 2000). Harriet Tubman Underground Railroad National Historical Park and Blackwater National Wildlife Refuge contain much of the large remaining tracts of forest on the Delmarva Peninsula and provide valuable refuge for the region's resident and migratory bird populations.

Blue grosbeak at Blackwater National Wildlife Refuge. Photo by Sanjib Bhattacharyya.

Data and Methods

Data for the assessment of current condition were comprised of an avian survey conducted in Blackwater National Wildlife Refuge in 2006. Additional surveys conducted in 1996-2000 were used to assess any trends. Data from 2000-2006 or from 2006 to present were not available. Each survey consisted of 104 survey points distributed at 500-m intervals in forest habitat. Species were detected using three- to ten-minute counts from 5:00 am to 10:00 am during a sampling window from late May to mid-July (Carowan et al.). Forty-three of the points were located within the boundary of Harriet Tubman Underground Railroad National Historical Park (Figure 4-47). Data from the 43 survey points were used to establish annual lists of the FIDs present in the park. These lists were then compared to the list of FIDS expected in the Mid-Atlantic Coastal Plain as provided by the Chesapeake Bay Critical Area Commission's report (Jones et al. 2000).

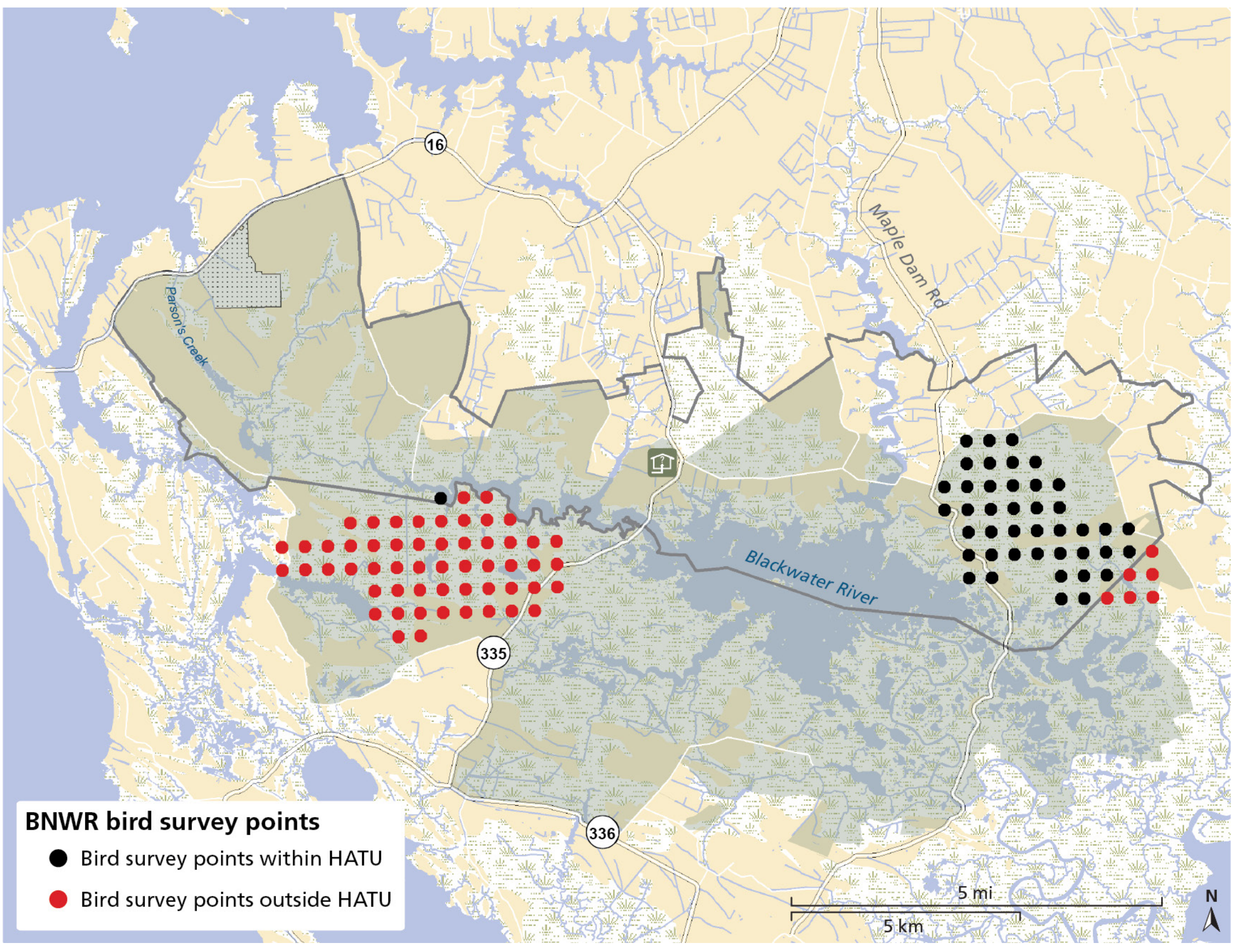


Figure 4-47. Survey points from 1996-2000 and 2006 inventory of Forest Interior Dwelling Species (FIDS) at Blackwater National Wildlife Refuge. Data points in black are located within Harriet Tubman Underground Railroad National Historical Park and are used in the assessment (Data source: Matt Whitbeck, Blackwater NWR 2017).

Reference Condition

Twenty-five FIDS breed in the Chesapeake Bay Critical Area, according to the Critical Area Commission's report (Table 4-26) (Jones et al. 2000). These species can be divided into two categories: highly area-sensitive species and area sensitive species. Three species have been identified as unlikely to be breeding in Blackwater National Wildlife Refuge and removed from the list: cerulean warbler, veery and black throated green warbler (Carowan 2006). Twelve of the remaining 22 species are highly area-sensitive species and are very susceptible to forest loss, fragmentation, and habitat degradation (Jones et al. 2000). The remaining ten species are considered area-sensitive but can withstand higher levels of habitat degradation and fragmentation.

Table 4-26. Twenty-two forest interior dwelling species identified as possibly nesting in Harriet Tubman Underground Railroad Historical Park (Jones et al. 2000).

Scientific name	Common name	Sensitivity
Buteo lineatus	Red-shouldered hawk	Highly Area Sensitive
Buteo platypterus	Broad-winged hawk	Highly Area Sensitive
Certhia americana	Brown creeper	Highly Area Sensitive
Helmitheros vermivorus	Worm-eating warbler	Highly Area Sensitive
Limnothlypis swainsonii	Swainson's warbler	Highly Area Sensitive
Mniotilta varia	Black-and-white warbler	Highly Area Sensitive
Oporornis formosus	Kentucky warbler	Highly Area Sensitive
Seiurus aurocapillus	Ovenbird	Highly Area Sensitive
Seiurus motacilla	Louisiana waterthrush	Highly Area Sensitive
Setophaga ruticilla	American redstart	Highly Area Sensitive
Strix varia	Barred owl	Highly Area Sensitive
Wilsonia citrina	Hooded warbler	Highly Area Sensitive
Caprimulgus vociferus	Whip-poor-will	Area Sensitive
Dryocopus pileatus	Pileated woodpecker	Area Sensitive
Empidonax virescens	Acadian flycatcher	Area Sensitive
Hylocichla mustelina	Wood thrush	Area Sensitive
Parula americana	Northern parula	Area Sensitive
Picoides villosus	Hairy woodpecker	Area Sensitive
Piranga olivacea	Scarlet tanager	Area Sensitive
Protonotaria citrea	Prothonotary warbler	Area Sensitive
Vireo flavifrons	Yellow-throated vireo	Area Sensitive
Vireo olivaceus	Red-eyed vireo	Area Sensitive

The Critical Area Commission guidelines state that the presence of one highly area sensitive FIDS species or four area-sensitive species is an indicator of high-quality FIDS habitat (Jones et al. 2000). The presence of six highly area-sensitive species indicates an exceptional habitat. The park was given a rating of 100% or 0% based on the presence of one highly area-sensitive species or at least four area-sensitive species in the 2006 survey. The trend in FIDS was evaluating by examining any changes in area-sensitive species dating back to 1996.

Current Condition and Trend

The 2006 bird survey contains observations of three highly area-sensitive FIDS (Table 4-27) and six area-sensitive species (Table 4-28). These observations exceeded the threshold, and the resource was considered in very Good Condition (100% attainment). Over the ten years of survey data, six of the 12 expected highly area-sensitive FIDs for the area and nine of the ten area-sensitive species were identified. The number of highly area-sensitive species identified each year ranged from two to four, and the number of area-sensitive species ranged from five to seven, suggesting that the trend is stable.

Table 4-27. Highly area-sensitive forest interior dwelling species observed in Harriet Tubman Underground Railroad Historical Park during 1996-2000 and 2006 survey (Whitbeck 2017).

Scientific name	Common name	1996	1997	1998	1999	2000	2006
Buteo lineatus	Red-shouldered hawk	0	0	0	0	0	1
Buteo platypterus	Broad-winged hawk	0	0	0	0	0	0
Certhia americana	Brown creeper	0	0	0	0	0	0
Helmitheros vermivorus	Worm-eating warbler	14	9	19	9	17	7
Limnothlypis swainsonii	Swainson's warbler	0	0	0	0	0	0
Mniotilta varia	Black-and-white warbler	0	0	1	0	0	0
Oporornis formosus	Kentucky warbler	5	0	0	1	0	0
Seiurus aurocapillus	Ovenbird	17	14	22	16	18	18
Seiurus motacilla	Louisiana waterthrush	0	0	0	2	0	0
Setophaga ruticilla	American redstart	0	0	0	0	0	0
Strix varia	Barred owl	0	0	0	0	0	0
Wilsonia citrina	Hooded warbler	0	0	0	0	0	0
Number of Highly Area Sensitive Species Observed		**3**	**2**	**3**	**4**	**2**	**3**

Table 4-28. Area-sensitive forest interior dwelling species observed in Harriet Tubman Underground Railroad Historical Park during 1996-2000 and 2006 survey (Whitbeck 2017).

Scientific name	Common name	1996	1997	1998	1999	2000	2006
Caprimulgus vociferus	Whip-poor-will	0	0	1	0	0	0
Dryocopus pileatus	Pileated woodpecker	15	14	2	6	13	8
Empidonax virescens	Acadian flycatcher	8	5	4	4	8	12
Hylocichla mustelina	Wood thrush	6	4	6	6	5	7
Parula americana	Northern parula	0	0	0	0	0	0
Picoides villosus	Hairy woodpecker	4	3	1	1	2	4
Piranga olivacea	Scarlet tanager	0	1	3	4	0	0
Protonotaria citrea	Prothonotary warbler	0	0	0	0	1	2
Vireo flavifrons	Yellow-throated vireo	0	1	0	0	0	0
Vireo olivaceus	Red-eyed vireo	26	7	16	13	17	17
Number of Area Sensitive Species Observed		**5**	**7**	**7**	**6**	**6**	**6**

Data Gaps and Level of Confidence

The condition assessment has a moderate level of confidence. While confidence in the bird survey conducted at Blackwater National Wildlife Refuge is high, the available data are over a decade old. Additionally, over half of the bird survey points from Blackwater National Wildlife were outside Harriet Tubman Underground Railroad Historical Park boundaries, and therefore were not considered for this report. In the broader region including all of Blackwater National Wildlife Refuge, 22 of the 25 expected FIDs were observed (Carowan 2006). The level of confidence in this indicator could be improved with more recent and regular bird surveys within Harriet Tubman Underground Railroad Historical Park.

Source(s) of Expertise

- Matt Whitbeck, Supervisory Wildlife Biologist, Chesapeake Marshlands NWR Complex.

4.3.6. Bats

Description

Bats play important ecological roles that are vital to the health of natural ecosystems and human economies. More than 1,300 bat species have been identified worldwide. Many of these species consume insects, including damaging agricultural pests. Others provide pollination services or disperse seeds. Bat droppings are valuable as natural fertilizer, which can be mined to provide significant economic benefits for landowners and local communities.

In recent years, however, bat populations have declined precipitously (Nagel and Gates 2017). Cave-dwelling bats are susceptible to white-nose syndrome, a disease caused by the fungus *Pseudogymnoascus destructans* (Zukal et al. 2014). Since discovery of the disease in 2006, millions of bats in North America have died (Blehert et al. 2009, Dzal et al. 2010, Brooks 2011). White-nose syndrome affects some bats more than others. Susceptible species include little brown bats (*Myotis lucifugus*), northern long-eared bats (*Myotis septentrionalis*), and tricolored bats (*Perimyotis subflavus*) (Dzal et al. 2010, Brooks 2011). Declines, however, are not just restricted to cave-dwellers; foliage-roosting bats are killed at wind-power facilities (Hayes 2013). The species most affected are hoary bats (*Lasiurus cinereus*), eastern red bats (*Lasiurus borealis*) and silver-haired bats (*Lasionycteris noctivagans*) (Johnson et al. 2003, Johnson 2005, Cryan and Barclay 2009, Cryan 2011).

Northern long-eared bat captured in 2016 at Moneystump Swamp at Blackwater National Wildlife Refuge. Photo credit: United States Fish and Wildlife Service.

Wetlands and riverine environments provide an abundance of insects. Wetland distribution and abundance therefore are important determinants in bat foraging activity (Ford et al. 2006). Bats also require roost sites found in forested and developed landscapes (Rhodes et al. 2006, Neubaum et al. 2007). Connectivity among roost and foraging sites have also proven important to allow bats to fulfill their needs without expending too much energy (Lookingbill et al. 2010). With its abundant wetlands, rivers, forests, and some human developments, Harriet Tubman Underground Railroad National Historical Park provides ample habitat for bats and is therefore an important resource for a variety of bat species.

<u>Data and Methods</u>

Blackwater National Wildlife Refuge conducted a bat survey for two years in 2015 and 2016 to develop a basic inventory of the refuge (Whitbeck 2017). The Resident Bat Inventory Protocol for Region 5 National Wildlife Refuges was used which created a grid of 30-acre cells, stratified the grid into northern, middle, and sourthern layers, and randomly sampled 3 cells from each layer per year, resulting in 18 survey points (Figure 4-48).

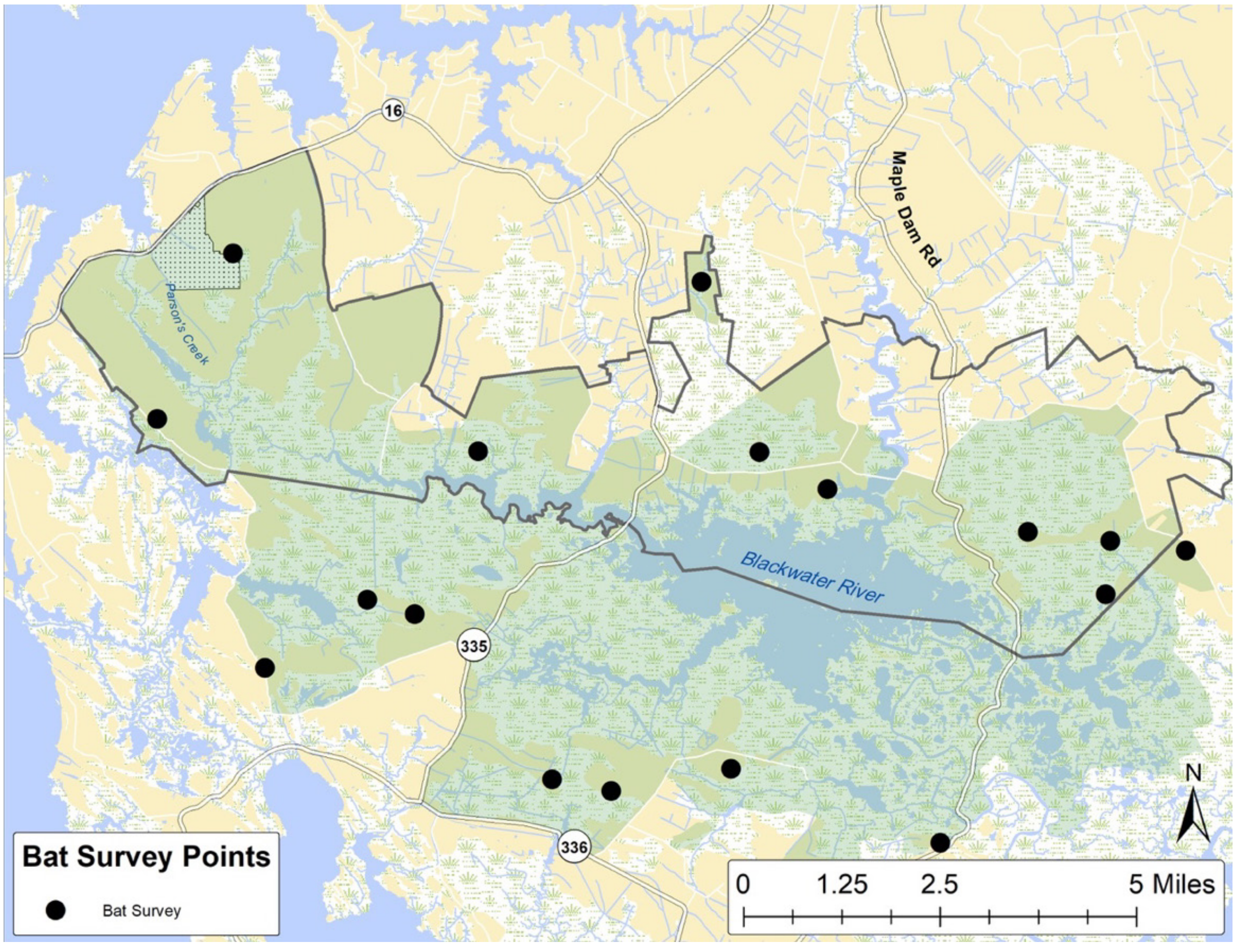
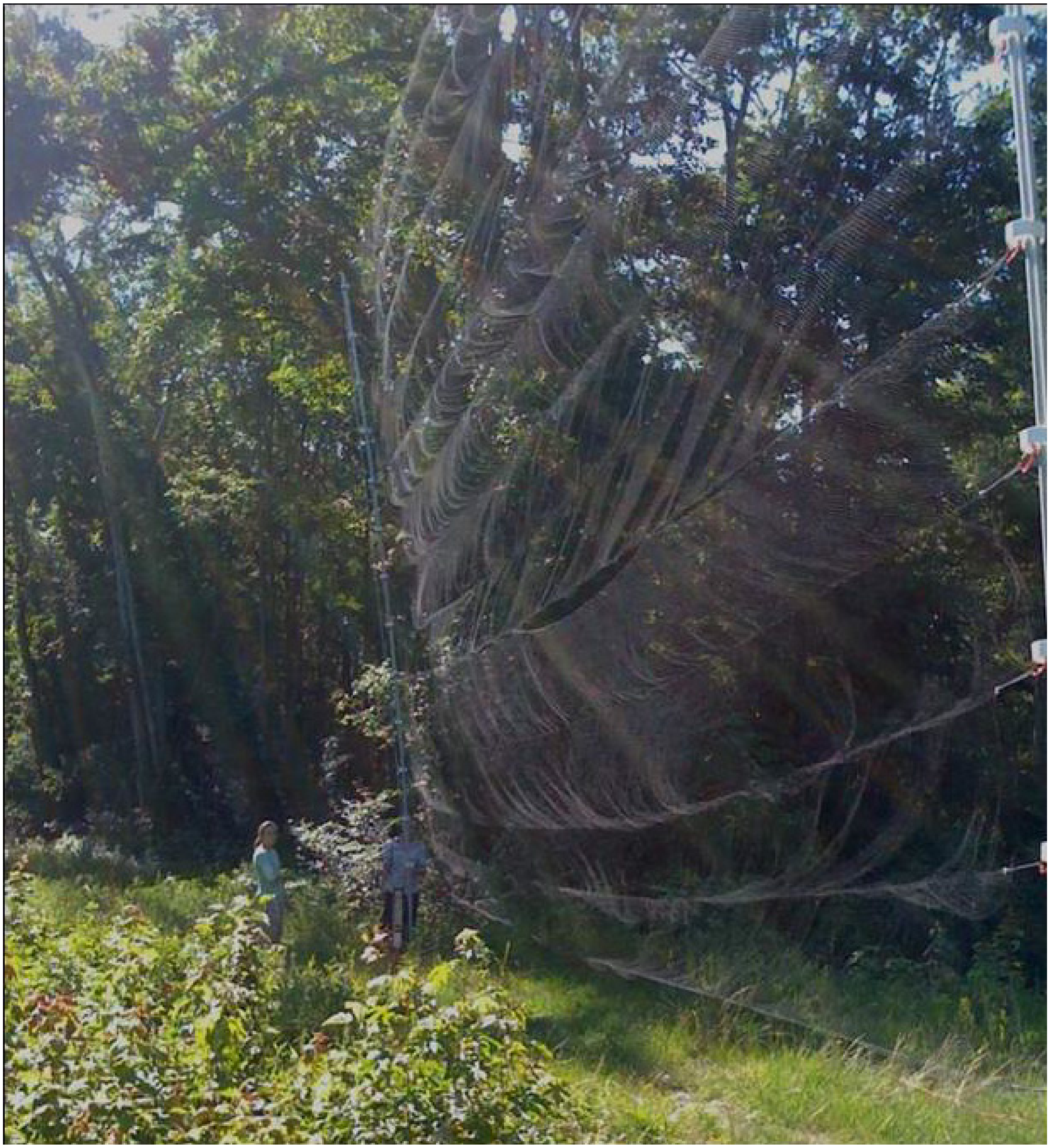


Figure 4-48. Sampling sites for bats at Harriet Tubman Underground Railroad National Historical Park and Blackwater National Wildlife Refuge (Data source: Matt Whitbeck, Blackwater NWR 2017).

Sampling was conducted during the maternity/volant period and during migration from May 15 to October 15 using acoustics and mist netting. Each site was sampled for acoustics for 6 days and using mist nets for 2 days. Sampling efforts was evenly distributed between maternity/volant period and migration period.



A mist net used at Blackwater National Wildlife Refuge to capture bats. Photo credit: United States Fish and Wildlife Service.

<u>Reference Condition</u>

A list of all bat species that could occur in Dorchester County was compiled by consulting range maps and experts. It includes the little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), tricolored bat (*Perimyotis subflavus*), big brown bat (*Eptesicus fuscus*), eastern red bat (*Lasiurus borealis*), hoary bat (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagans*), and evening bat (*Nycticeius humeralis*). In all Harriet Tubman Underground Railroad National

Historical Park is expected to support as many as 8 species. This level was used as the reference condition and condition assessed as percent of bat species observed compared to the expected species richness.

Current Condition and Trend
The condition of bats at Harriet Tubman Underground Railroad National Historical Park is Moderate Concern (63%). Within the Park boundary, the big brown bat, tri-colored bat, eastern red bat, hoary bat, and evening bat were observed in 2015 and 2016. Thus, 5 of the 8 expected bat species, or 63%, were present. The northern long-eared bat was also documented within Blackwater National Wildlife Refuge approximately 2 miles outside of the park boundary. No bat species were documented at the sample site close to the National Park Service-owned Jacob Jackson parcel.

The trend of bat populations is declining as white nose syndrome is killing bats throughout the region.

Data Gaps and Level of Confidence
Confidence in the assessment is moderate. Although the survey was thorough, using mist nets and acoustics, the sample sites were only sampled over a two-year period. Also, some bat species are difficult to capture with mist nets or identify using calls. Thus, with more effort, more bat species may be documented with the park boundary, which would change the condition assessment from Moderate Concern to Good Condition.

Source(s) of Expertise
- Ed Gates, University of Maryland Center for Environmental Science Appalachian Laboratory
- Elizabeth Stevenson, University of Maryland Center for Environmental Science Appalachian Laboratory
- Matt Whitbeck, Supervisory Wildlife Biologist at Chesapeake Marshlands National Wildlife Refuge Complex

4.4. Landscape Dynamics
As much or more than any other natural resource, Harriet Tubman Underground Railroad National Historical Park is defined by its landscape condition, including the rich historical context of the landscape. The site is characterized by vast expanses of marshes, fields, and forests that today remain much the same as when Tubman was alive. Forests comprise the historic land cover type in the region, and they are still dominant within the park. Land conversion from forest can have severe consequences to ecosystem services such as water filtering, and habitat destruction is one of the leading causes of local extirpations and extinctions of forest-dependent wildlife. Land development also creates more impervious surface cover, which can have a multiplicative effect on diminishing the integrity and health of forested landscapes.

This region of the Delmarva Peninsula has also been historically rich in wetland resources. Wetlands within Harriet Tubman Underground Railroad National Historical Park, Blackwater National Wildlife Refuge, and the surrounding region provide important stopover habitat and breeding, nesting, and wintering grounds for several species of waterfowl and migratory birds. They also provide essential nursery and breeding grounds for various species of fish and other aquatic wildlife. However, wetland resources of the park are under threat from sea level rise and the invasion of non-native plant species.

The historic setting of the mid-19th century was one of dark night skies, agrarian landscapes, and quiet spaces. These conditions are also conducive to the wildlife of the park today. Managing light pollution in Harriet Tubman Underground Railroad National Historical Park will be a challenge because of its close proximity to several large cities. The viewsheds and soundscape of the park may also be threatened by development and roads that are pervasive in the modern landscape.

Three categories of indicators were used to assess landscape dynamics in Harriet Tubman Underground Railroad National Historical Park: land cover, wetland extent, and the historic landscape (Table 4-24). Data came primarily from a 1-m resolution Chesapeake Conservancy Land Cover Dataset for Dorchester County based on 2013 LiDAR imagery, but also surface elevation tables (SET) established by Cahoon and Nemerson and a Digital Elevation Model (DEM) from the National Elevation Dataset (Table 4-29). Specific metrics analyzed for these indicators were as follows:

- percentage of landscape in forested land cover;
- percentage of landscape in impervious surface land cover;
- changes in surface elevation at three monitored sites;
- percentage of wetland projected to remain as sea levels rise;
- average luminance ratio of night skies;
- percentage of visible land from four historic vistas that is undeveloped; and
- percentage of landscape greater than 30 meters from any roads.

Reference conditions for each of the metrics were based largely on conditions that Harriet Tubman would have experienced during her lifetime (Table 4-30).

Table 4-29. Landscape dynamics data provided by agencies and specific sources included in the assessment of Harriet Tubman Underground Railroad National Historical Park.

Indicator	Agency	Source
Land Cover	Chesapeake Bay Program	High-Resolution Land Cover Dataset
Wetlands	• USGS • Maryland Department of Natural Resources	• Don Cahoon, David Nemeson • Sea Level Affecting Marshes Model
Historic landscape	• Chesapeake Bay Program • National Elevation Dataset • National Park Service	• High-Resolution Land Cover Dataset • Average Luminance Ratio Model • Digital Elevation Model • Map of Points of Interest

Table 4-30. Data availability and reference conditions used to assess condition of three landscape dynamics indicators at Harriet Tubman Underground Railroad National Historical Park.

Landscape dynamics indicator	Number of sites	Number of samples	Period of observation	Reference condition
Land cover	1	1	2013	• Forest land cover >59% = 100% • Forest land cover <30% = 0% • Forest percentages between 30–59% scaled linearly from 0–100% attainment
	1	1	2013	• Impervious surface land cover <2% = 100% • Impervious surface land cover >10% = 0% • Impervious cover between 2-10% scaled linearly from 100–0% attainment
Wetlands	3	3	2005-2008	• Accretion >3.52 mm/yr = 100% • Accretion <3.52 mm/yr accretion = 0%
	1	1	2009-2100	• Model projections of no future net wetland loss = 100% • Model projections of future net wetland loss = 0%
Historical landscape	1	1	2015	• Night sky ALR <0.33 = 100%, • Night sky ALR ≥2.00 = 0% • Night sky ALR between 0.33-2.00 scaled linearly from 100-0% attainment
	1	1	2013	Viewsheds scaled linearly from 0-100% attainment based on percent of historic viewshed that are undeveloped
	1	1	2013	Soundscape scaled linearly from 0-100% attainment based on percent of total park area outside 30m road buffer

Landscape dynamics at Harriet Tubman Underground Railroad National Historical Park scored as Moderate Concern (54%) (Table 4-31) based on 100 percent attainment of the land cover indicator, 0 percent attainment of the wetlands indicator, and 63 percent attainment of the historical landscape indicator.

Table 4-31. Summary of landscape dynamics condition assessment at Harriet Tubman Underground Railroad National Historical Park.

Landscape dynamics indicator	Metric	Percent attainment	Condition	Overall condition
Land cover	% of landscape in forested land cover	100%	Good Condition	Moderate Concern
	% of landscape in impervious land cover	100%	Good Condition	Moderate Concern
Wetlands	Accretion rate	0%	Significant Concern	Moderate Concern
	SLAMM projection of wetland loss	0%	Significant Concern	Moderate Concern
Historic landscape	Average luminance ratio of night skies	0%	Significant Concern	Moderate Concern
	% of undeveloped visible land from four historic vistas	97%	Good Condition	Moderate Concern
	% of landscape greater than 30 m from roads	92%	Good Condition	Moderate Concern

4.4.1. Land Cover

Description

Forests are the dominant land cover within the Chesapeake Bay watershed, covering approximately 24 million acres, or nearly 60% of the total land area (Sprague et al. 2006). Blackwater National Wildlife Refuge - a large portion of which overlaps with Harriet Tubman Underground Railroad National Historical Park - contains over 8,300 acres of forestland (Carowan et. al 2006), including some of the largest remaining intact tracts of forest left within Dorchester County (Carowan et. al 2006). Among their many ecosystem services, forests serve as buffers to harmful runoff and help protect water quality by filtering nutrients and sediments, capturing rainfall, and stabilizing soil and riverbanks (Millennium Ecosystem Assessment 2005). Additionally, forests provide approximately two-thirds of the water that replenishes groundwater supply and feeds our streams (Sprague et al. 2006).

Forests also support terrestrial wildlife species by providing cover, shelter, food, nesting habitat, and safe migration corridors. Tree canopies provide much-needed shade to rivers, streams, and other waterways, stabilizing water temperature for aquatic wildlife that depend upon cooler waters for spawning and survival. In addition to providing oxygen to humans and wildlife, trees also help store carbon from the atmosphere and trap nitrogen and other pollutants that may negatively affect the quality of our air and water. Economically, forests bring in billions of dollars annually to the Chesapeake Bay economy through timber, recreational, and tourism opportunities (Sprague et al. 2006).

Forests like the one pictured from the Jacob Jackson Home site within Harriet Tubman Underground Railroad National Historical Park provide important habitat for several species of wildlife, including the endangered Delmarva fox squirrel. Photo: Todd Lookingbill, September 2016.

Land conversion from forest can occur for a variety of purposes in the region, including agriculture and timber harvesting (Dale et al. 2000). From 1973 to 2000, the total amount of forest has decreased by 4.3% nationally (Sleeter et al. 2013) and 4.0% in the Eastern U.S. (Drummond and Loveland 2010) due primarily to increasing urban, suburban, and exurban development. Deforestation can lead to exotic species invasions (Vitousek et al. 1997), degraded and diminished water flows (Meyer and Turner 1992), and the spread of new diseases (Langlois et al. 2001). From 1990-2005, an estimated 100 acres of Chesapeake Bay forests were lost every day (Sprague et al. 2006). The consequences of this loss can be severe to forest-dependent wildlife, and habitat destruction is the leading cause of local species extinctions and declines in biodiversity (Wilson 1989).

Land development also creates more impervious surface cover, which can have a multiplicative effect on diminishing the integrity and health of forested landscapes. Impervious surfaces are materials such as roads, rooftops, and compacted soils that prevent water from infiltrating the soil. The amount of impervious surface cover on a landscape is strongly correlated with the amount of urban development, and this measure is frequently used as an indicator of the negative environmental impacts of human modifications of the landscape (Arnold and Gibbons 1996). Specific impacts include changes in water quantity and quality.

Impervious surfaces like this parking lot at the Harriet Tubman Underground Railroad National Historical Park visitor center limit the filtering of runoff by soil, resulting in increased levels of nutrients entering waterways. Photo: Todd Lookingbill, September 2016.

Impervious surfaces reduce the capacity of landscapes to slow, store, and filter water (Sprague et al. 2006). By preventing water from seeping into the ground, impervious surfaces increase the volume and velocity of storm water runoff entering a waterway (Brinson et al. 2013). This altered hydrology in urbanized watersheds can lead to increased peak flow rates and annual discharge volumes (Boggs and Sun 2011, Sprague et al. 2006). The velocity and flashy nature of this runoff as it moves across the surface of a landscape can cause erosion and flooding (Sprague et al. 2006, Arnold and Gibbons 2007).

Impervious surfaces also facilitate the conveyance of pollutants into waterways by preventing water from percolating into the soil where it would undergo natural pollutant processing (Arnold and Gibbons 1996). Moreover, there is less groundwater recharge in watersheds with high impervious cover, potentially resulting in reduced base flow conditions in streams. As a consequence, impervious surface cover has been found to have significant effects on macroinvertebrates and other sensitive aquatic and riparian species (Walsh et al. 2007).

These characteristic set of effects (including increased stream flashiness, increased nutrient loads, and decreased groundwater recharge) are referred to collectively as the “urban stream syndrome” (Walsh et al. 2005). Percent impervious surface, therefore, can provide a good approximation of watershed and aquatic habitat degradation, even within areas of relatively little development (Gergel et al. 2002).

Data and Methods

For this assessment, land cover was evaluated as the percent of forest and impervious surfaces on the landscape. Data were taken from the Chesapeake Conservancy High-Resolution Land Cover Dataset (Chesapeake Conservancy 2016). The land cover dataset is made up of 1-m raster pixels, each assigned a land type classification based on LiDAR from 2013 for Dorchester County (Chesapeake Conservancy 2016). For the purposes of this analysis, one of the classifications was considered forest: Tree Canopy (Class ID 3). Six of the classifications were aggregated as impervious surfaces: Structures (Class ID 7), Impervious Surfaces (Class ID 8), Impervious Roads (Class ID 9), Tree Canopy over Structures (Class ID 10), Tree Canopy over Impervious Surfaces (Class ID 11) and Tree Canopy over Roads (Class ID 12). The percent forest and percent imperviousness were derived by calculating the percent of pixels within the park boundary of each of these types, and excluded areas classified as Water (Class ID 1) and Wetlands (Class ID 2). These percentages were then compared to threshold values to assess current condition.

Trends for land cover and impervious surface were assessed using the National Land Cover Database (NLCD) for the years 2001 (Homer et al. 2007), 2006 (Fry et al. 2011), and 2011 (Homer et al. 2015). The NLCD dataset is designed for national and regional analyses only (Wickham et al. 2013) due to scale; therefore, analyses with these data are used for trend purposes only. The NLCD land cover data are provided at a resolution of 30-m pixels and use a 16-class land cover classification scheme (Homer et al. 2015). Forest land cover was defined as the combination of four of these classes – Deciduous Forest (Class ID 41), Evergreen Forest (Class ID 42), Mixed Forest (Class ID 43), and Woody Wetland (Class ID 95). Areas classified as Open Water (Class ID 11) and Emergent Herbaceous Wetlands (Class ID 95) were excluded for this analysis. Trend for impervious surface was assessed using NLCD's Percent Developed Imperviousness dataset for the years 2001 (Homer et al. 2007), 2006 (Fry et al. 2011), and 2011 (Homer et al. 2015). Cells in this 30-m raster are assigned values according to estimated percent imperviousness (0-100% impervious surface cover for each pixel).

Threshold

Simulation studies indicate the loss of forest ecological function occurs once the amount of forest in the landscape is reduced below 59% (Gardner et al. 1987, Turner et al. 2001). Landscapes with lower forest cover tend to lose the characteristic qualities of intact forest required of organisms such as forest-interior birds and forest-dwelling mammals. Small losses in forest within landscapes near this critical threshold result in large changes in average patch size, amount of interior forest, amount of edge habitat, and related metrics typically associated with forest fragmentation (Fahrig 2003). These same studies identified a second potential threshold value of 30% (Turner et al. 2001). Landscapes with less than 30% forest suffer from more serious concerns related to overall habitat loss. For this assessment, forest land cover percentages above 59% were assigned an attainment score of 100%; forest percentages below 30% were assigned an attainment score of 0%; and forest percentages between 30–59% were scaled linearly from 0–100% attainment.

Many studies have documented threshold type effects on water resources at relatively low impervious surface cover. For example, a study in Georgia showed significant increases in nutrients, including nitrate and sulfate, in watersheds with greater than 5% impervious surface cover (Schoonover and Lockaby 2006). In another study, Yang and colleagues (2010) reported significant changes in streamflow for watersheds with 3–5% impervious surface cover. In a Maryland study, impervious surface cover as low as 0.5–2% resulted in the decline of the majority (80%) of stream taxa, while 2–25% cover showed a decline in 100% of the taxa (King et al. 2011). Other studies have found declines in species diversity when 5-15% of the watershed is in impervious cover (Booth and Reinhelt 1993), including losses of sensitive aquatic invertebrates (Utz et al. 2009), fish taxa (Schueler 2000), and plant diversity (Taylor 1993).

Based on the range of documented impervious surface threshold values, this assessment assigned an attainment score of 100% for a landscape totaling less than 2% of its total area in impervious surface. A landscape with greater than 10% of its land cover in impervious service represented an attainment score of 0%. Percent impervious surface values between 2% and 10% were scored linearly from 0-100%.

The scores for percent forest and percent impervious surface were averaged to attain the overall score for land cover in Harriet Tubman Underground Railroad National Historical Park.

Current Condition and Trend

Using the Chesapeake Conservancy's 1-m land cover data from 2013, the Harriet Tubman Underground Railroad National Historical Park had a total forest cover of 72%, which represents 100% attainment (Figure 4-49). The density of forest decreases drastically for the 30-km area around the park, which has only 35.7% forest cover. Trend data for land cover within the park over the years 2001-2011 was relatively constant at 74% to 73% (Figure 4-50); therefore, the trend was assessed as stable.

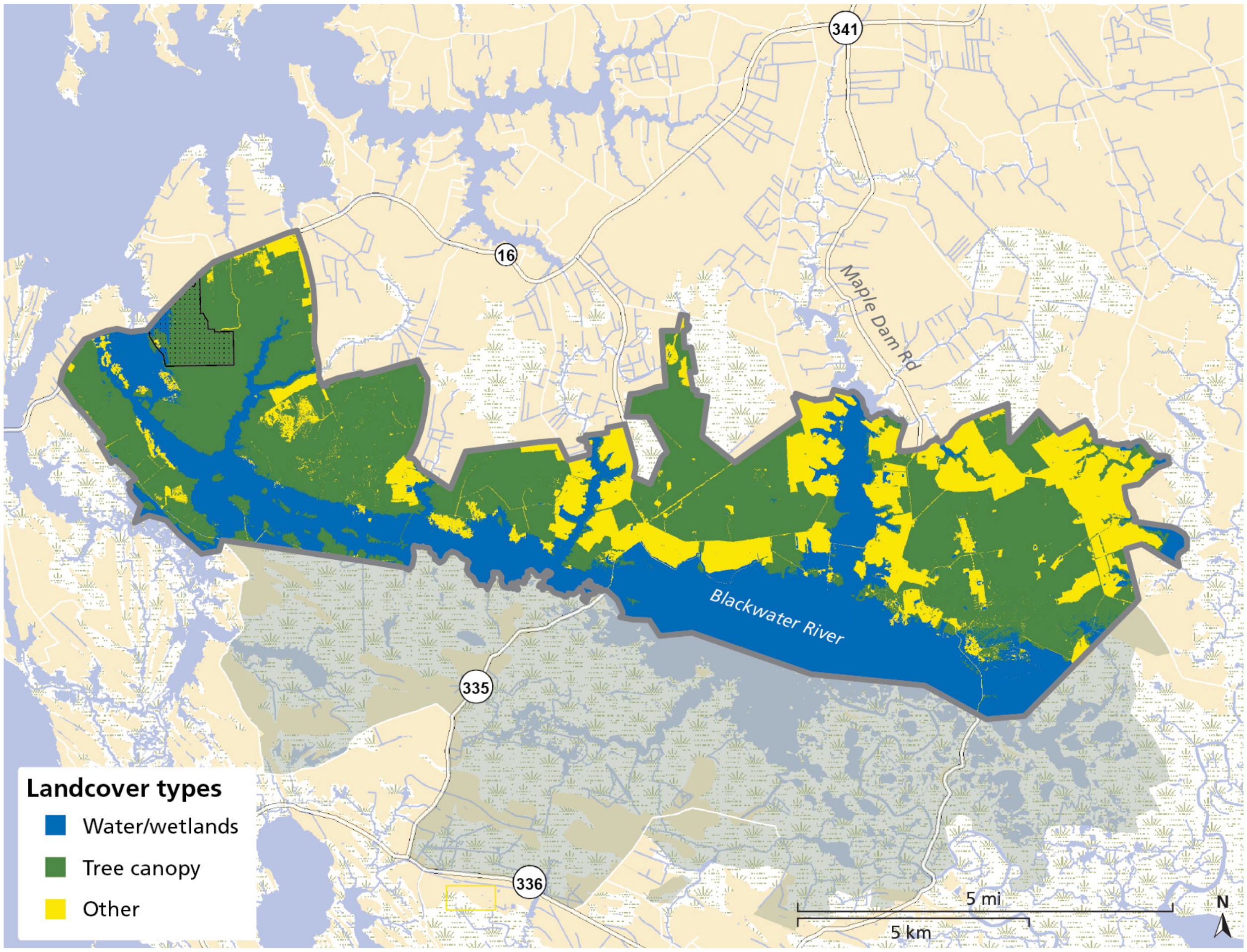


Figure 4-49. Percent forest in Harriet Tubman Underground Railroad National Historical Park. The Jacob Jackson Home site is outlined in black (Data source: Chesapeake Conservancy 2016).

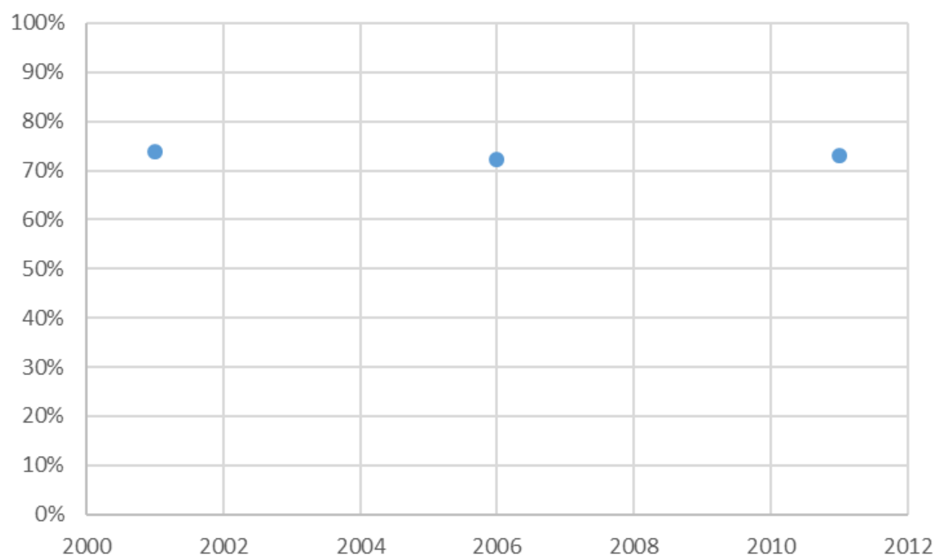


Figure 4-50. Forest land cover trends in Harriet Tubman Underground Railroad National Historical Park (Data source: National Landcover Data).

Impervious surface for the park was 1%, also achieving 100% attainment (Figure 4-51). Within the 30-km area surrounding the park, impervious surface was slightly greater at 2.1%. Over the years 2001-2011, NLCD data exhibited a stable trend for imperviousness within the park, with a total estimated impervious surface of 0.2% (Figure 4-52).

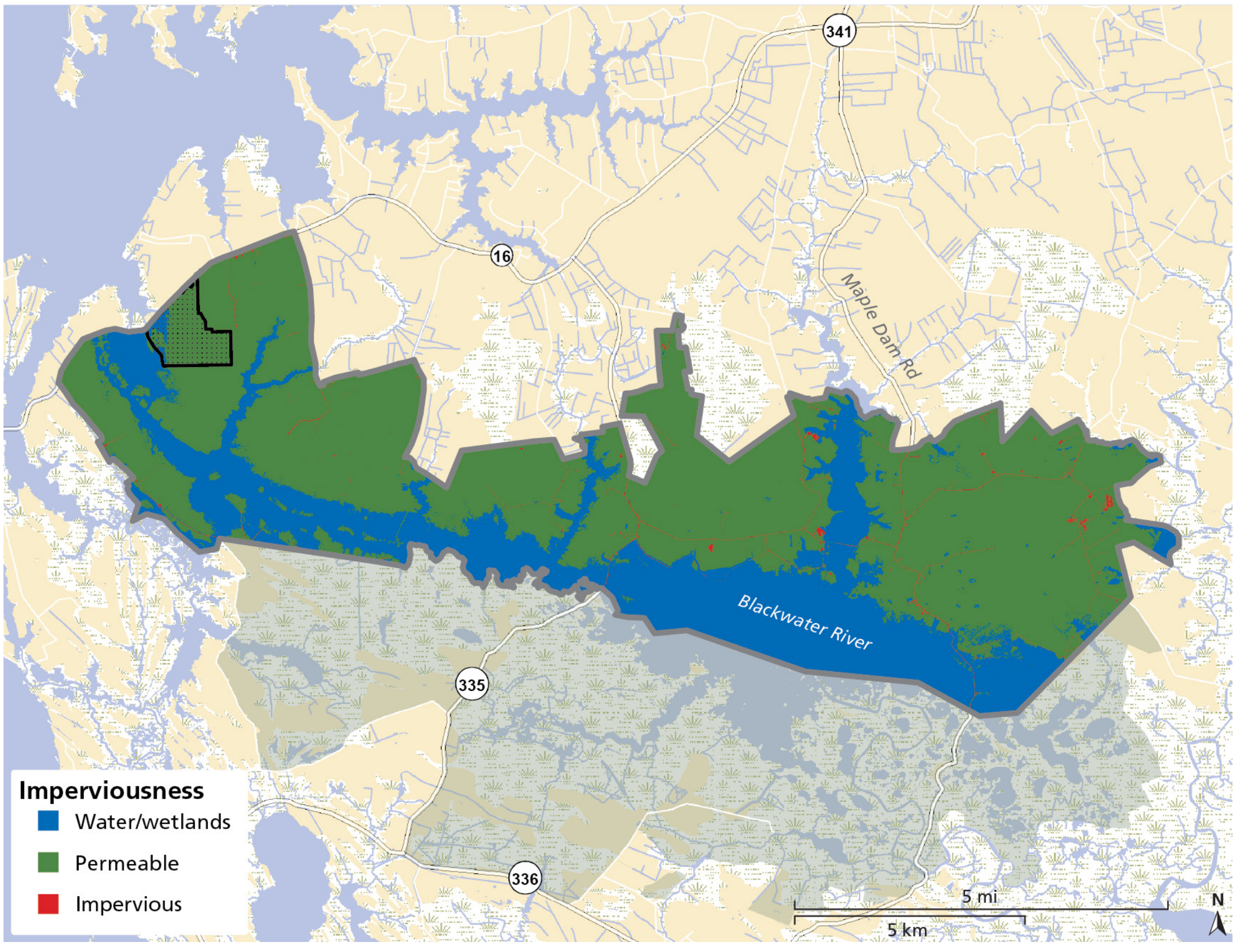


Figure 4-51. Percent imperviousness in Harriet Tubman Underground Railroad National Historical Park. The Jacob Jackson Home site is outlined in black (Data source: Chesapeake Conservancy 2016).

Averaging the 100% attainment score associated with high tree cover with the 100% attainment score associated with the low impervious surface cover yields an overall attainment score for the land cover indicator of 100%. Trend is assessed as stable.

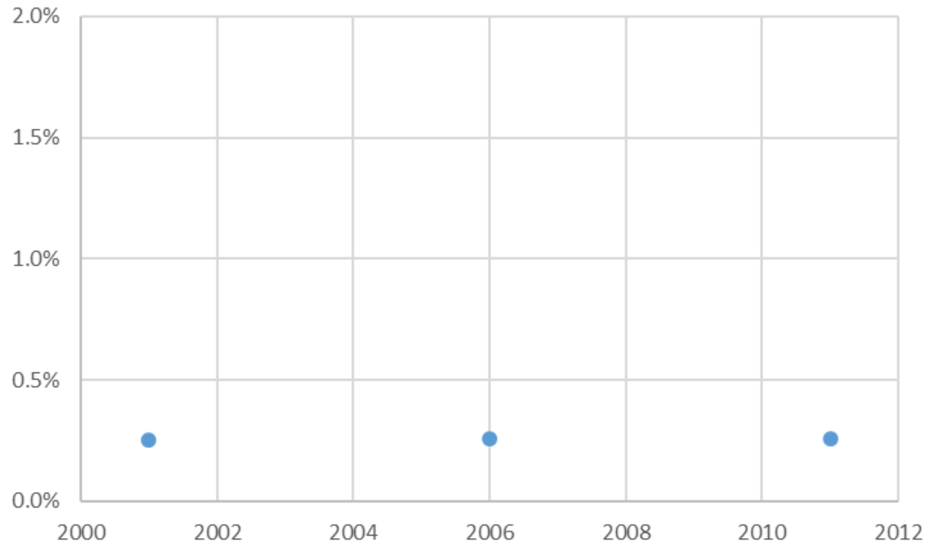


Figure 4-52. Imperviousness trends in Harriet Tubman Underground Railroad National Historical Park (Data source: National Landcover Data).

Data Gaps and Level of Confidence

Confidence in this indicator is assessed as moderate. Development of the Chesapeake Conservancy land cover dataset was done at a 1-m scale, providing 900 times the information content as the standard 30-m resolution National Land Cover Dataset (NLCD). Although the confidence in that classification is high, those data represent a single snapshot in time. The assessment of trend for this indicator relies on the lower resolution NLCD dataset. The classification of land cover in these data occurs at regional scales with overall accuracy of approximately 80% and less on the local scale (Wickham et al. 2013).

Despite the finding of no significant trend in overall forest loss, there are local changes that could impact the park. For example, the series of images in Figure 4-53 illustrate the clearing and regrowth of forest in and immediately to the east of the Jacob Jackson parcel from 1984 to 2016.

Source(s) of Expertise

- Jeff Allenby, Director of Conservation Technology, Chesapeake Conservancy

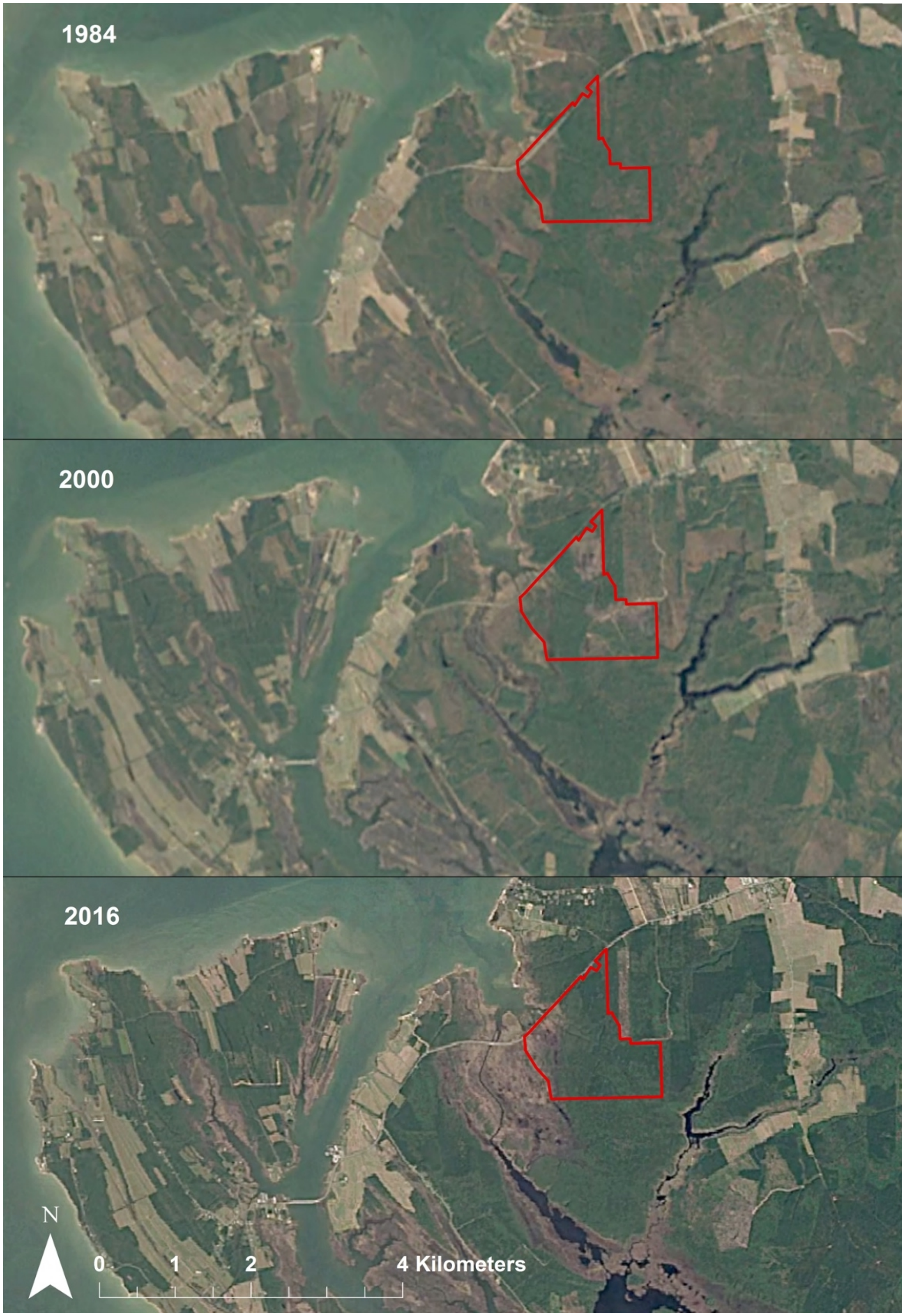
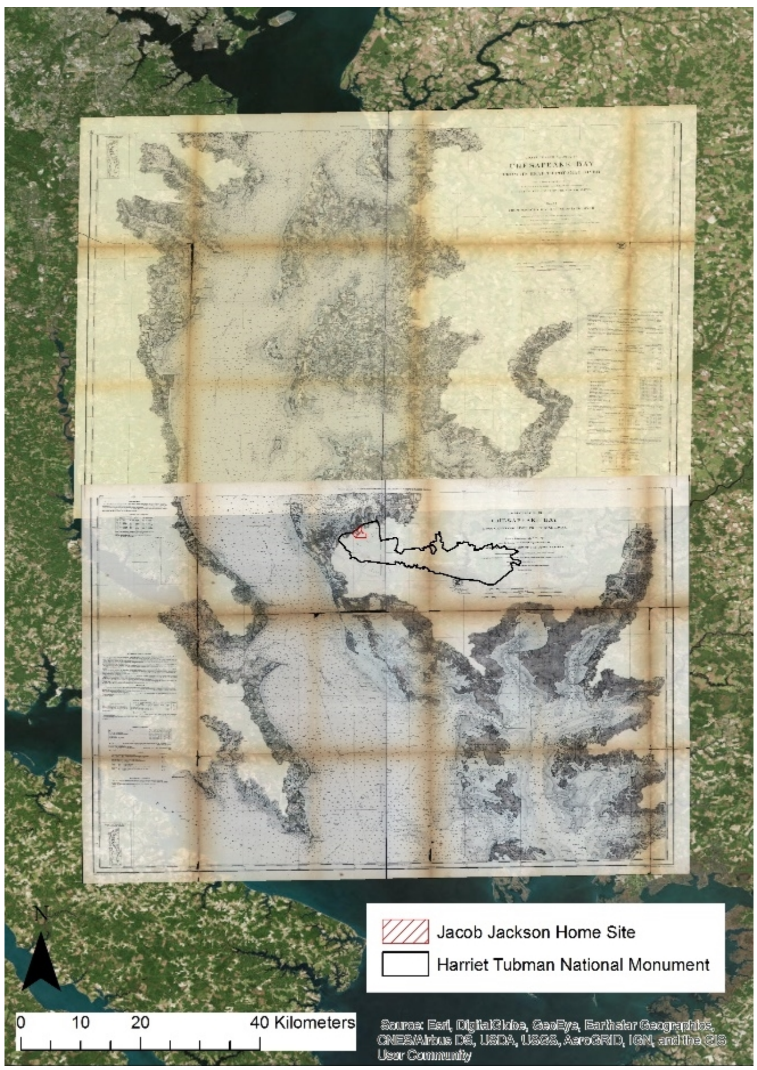


Figure 4-53. Local changes in forest cover for the Jacob Jackson parcel of Harriet Tubman Underground Railroad National Historical Park (Data source: Google Earth Engine).

4.4.2. Wetlands

<u>Description</u>

Wetlands are some of the most ecologically important and productive ecosystems in the world (Kirwan & Megonigal 2013). Comprising nearly 5.5% of the contiguous United States' total surface area (USFWS 2009), wetlands provide numerous ecological and economic services. They store carbon, trap sediments that pollute water clarity and quality, recycle nutrients from harmful runoff, provide important habitat for myriad wildlife species, and supply the nursery and harvesting grounds for fisheries and other aquaculture operations (Dahl 1990, USFWS 2006, Kirwan & Megonigal 2013). Wetlands also serve as a natural barrier for coastal regions, offering protection from detrimental storms and surges, flooding, and shoreline erosion (Kirwan & Megonigal 2013, Glick et al 2008).



Historical map of wetland resources of Chesapeake Bay and Harriet Tubman Underground Railroad National Historical Park (Data Source: Olmsted Center for Landscape Preservation).

Coastal watersheds claim 37% (41.1 million) of the contiguous United States' total wetland acreage (Dahl & Stedman 2013). The Chesapeake Bay watershed, specifically, is home to roughly 1.5 million acres of wetland habitat. While this figure reflects only 4% of the Bay watershed's total habitat cover, these wetlands play an instrumental role in providing clean water and critical habitat for a range of wildlife and plant species, including several federal- and state-listed rare, threatened, and endangered species (USFWS 2006).

Trees in Harriet Tubman Underground Railroad National Historical Park show die-off due to high saltwater intrusion, and effect of rising sea levels. Photo: Todd Lookingbill, September 2016.

The region of the Delmarva Peninsula surrounding Harriet Tubman Underground Railroad National Historical Park has historically been rich in wetland resources. Blackwater National Wildlife Refuge (NWR) contains over 21,000 acres of wetland habitat within its refuge boundary (USFWS 2006). In conjunction with the nearby Nanticoke Protection Area, which contains over 24,000 acres of wetlands, the combined wetland acreage of these two protected landscapes makes up one-third of Maryland's tidal wetland area (USFWS 2006). Specifically, Harriet Tubman Underground Railroad National Historical Park - 80% of which overlaps with Blackwater NWR – has over 12,000 acres of wetland habitat according to the Sea Level Affecting Marshes Model (SLAMM) for this area, equating to approximately half (48%) of its total land cover. Wetlands within Harriet Tubman Underground Railroad National Historical Park, Blackwater NWR, and the surrounding region provide important stopover habitat and breeding, nesting, and wintering grounds for several species of waterfowl and migratory birds. They also provide essential nursery and breeding grounds for various species of fish and other aquatic wildlife (USFWS 2006).

Die-off amongst trees and the invasion of *Phragmites* at Harriet Tubman Underground Railroad National Historical Park. Photo: Todd Lookingbill, September 2016.

Threats to the wetland resources of the park include sea level rise and the invasion of non-native plant species. The Chesapeake Bay is experiencing sea level rise at almost twice the global rate (Glick et al 2008, USFWS 2006). The Bay's growing population, paired with its low-lying topography and expansive coastline, make it one of the most vulnerable places to rising sea levels in the United States. Many lands along the Bay's coasts have already experienced a six-inch increase over the last century (Glick et al 2008). Rising sea levels are inundating these coastal shorelines and wetlands of the Chesapeake Bay, modifying the Bay's hydrology, flushing once fresh and brackish areas with high levels of salinity, and fragmenting important marsh habitat, thereby changing the composition of species that depend upon wetland habitats (Glick et al 2008, USFWS 2006). Increased storm events and encroaching development have accelerated shoreline erosion, resulting in the loss of beaches and increased sediment deposition in wetland areas (NWF 2008). The modification of these wetlands has increased the susceptibility of coastal areas to destructive storm surges and wave action (USFWS 2006). In Blackwater NWR and Harriet Tubman Underground Railroad National Historical Park, large patches of forests and tree stands, particularly those comprised of Loblolly pine (*Pinus taeda*), are experiencing high rates of die-off due to saltwater intrusion.

<u>Data and Methods</u>

The current condition of wetlands within Harriet Tubman Underground Railroad National Historical Park were assessed using surface elevation tables (SET) established by Cahoon and Nemerson (pers. communication) at two locations within the Harriet Tubman Underground Railroad National Historical Park boundary and one just outside the boundary (Figure 4-54). Each location received three deep rod SETs that were driven to refusal (12-24 m), 3 shallow benchmark SETs driven to the depth of the root zone, and 9 feldspar marker horizon plots (Cahoon pers. communication). Sites were established in 2005 and monitored for three years until 2008. Blackwater Wildlife Refuge hosts other SETs as part of a prescribed burn experiment (Cahoon et al. 2010). These data are not considered here because none of the SETs are located within the Harriet Tubman Underground Railroad National Historical Park boundary.

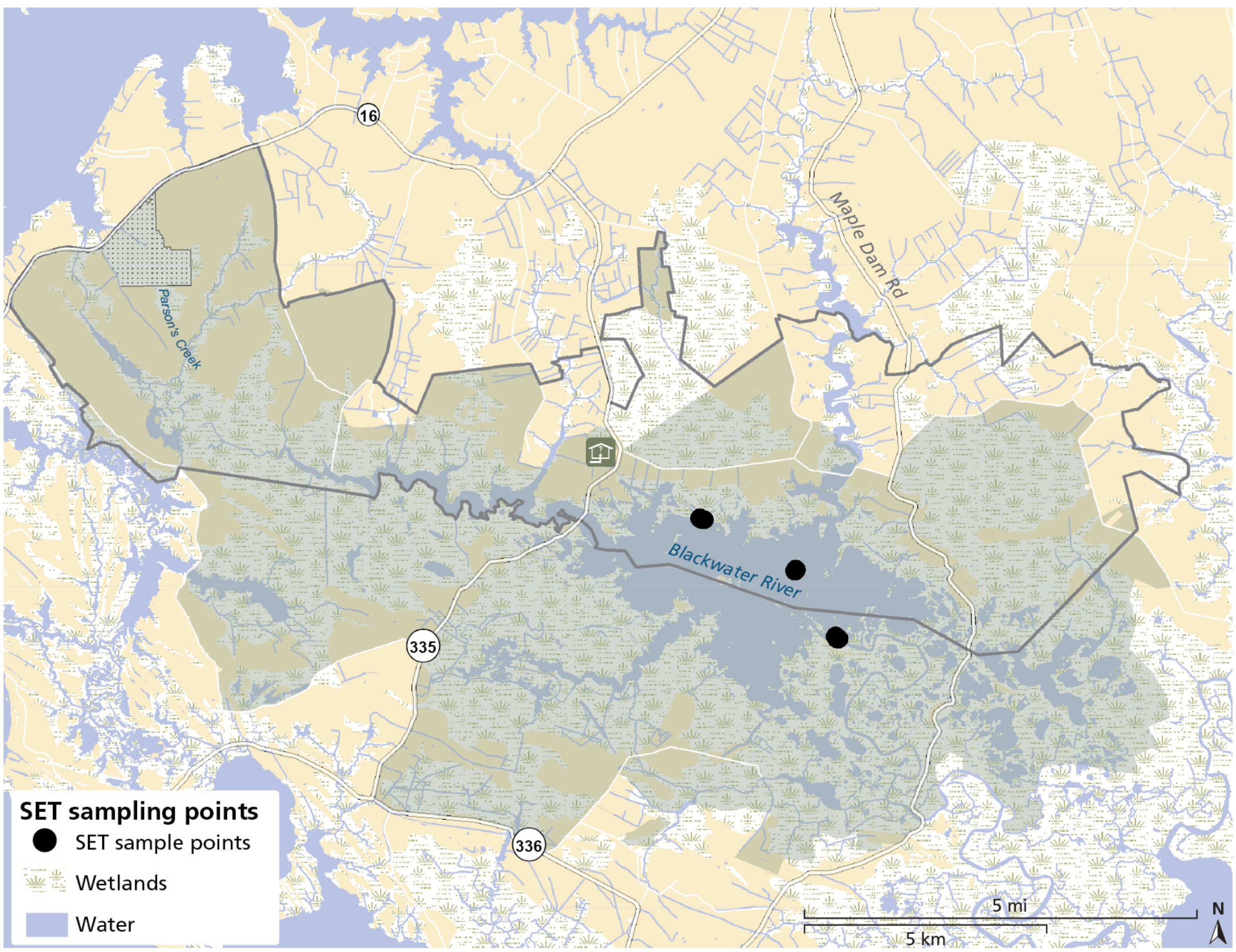


Figure 4-54. Location of three sites that each received three sets of deep rod and shallow sediment elevation tables. One site is outside the Harriet Tubman Underground Railroad National Historical Park boundary but is included to increase sample representation (Data source: Don Cahoon 2018).

To further illustrate the current state and potential future trends of wetlands within the park, spatial data from Maryland Department of Natural Resources' (DNR) Sea-Level Affecting Marshes Model (SLAMM) were accessed. SLAMM is a widely-used mathematical model that creates simulations of shoreline modification and wetland conversion processes that occur during long-term sea level rise. It produces scenarios for estimated changes in tidal marsh, shoreline, and wetland areas over time (DNR 2011). The Maryland DNR utilizes SLAMM datasets to create projections that display changes to marsh and wetland habitats specific to the Chesapeake Bay, as they change over time as a result of sea level rise. The DNR's SLAMM study uses land cover, hydrology, elevation, and sea level rise data; wetland accretion and erosion rates; and sediment accumulation information to predict the impact that rising sea levels will have on the wetlands of the Bay. The outputs of DNR's SLAMM study are scenarios that use a projected 1-meter (3.28 ft) rise in sea levels over the next 100 years (by 2100) (DNR 2011) to estimate impact on land cover within the Bay. Scenarios were run for the years 2050 and 2100 (Clough & Larson 2009) using current conditions (2010) as baseline data. The study area extracted from the DNR dataset included the entire Harriet Tubman Underground Railroad National Historical Park legislative boundary.

Threshold

Accretion of the wetland surface needs to be at least as high as sea level rise for wetlands to be sustainable in their current configuration as sea level rises. Sea level rise within the Chesapeake Bay region is estimated to be between 3.2 to 4.7 mm/yr depending on the location and period of record (Cronin 2013). Globally, 9-13 mm/yr sea level rise is projected globally in the 21st century (Cronin 2013 and references therein). In Cambridge, MD, on the Choptank River, relative sea level rise (accounting for sea level rise and land level changes) is 3.52 mm/yr (Cahoon et al. 2010). We use this local relative sea level rise rate as the threshold of accretion below which wetlands are not considered to be able to sustain themselves. A failing score of 0% was assigned if accretion was less than the reference condition of 3.52 mm/yr, and a passing score of 100% was assigned if accretion exceeded 3.52 mm/yr.

SLAMM model projections allowed us to calculate net loss or gain of wetland areas over the next 100 years. We consider a no net loss of wetlands to be the reference conditions, such that a net loss of wetlands is considered 0% attainment and a net gain of wetlands 100% attainment.

Current Condition and Trend

The marsh surface elevation trends based on 3-years of SET data were negative at all three locations (Table 4-32). Thus, these areas have not been keeping pace with sea-level rise during this period, and current condition was assigned a failing score of 0% attainment.

According to the Sea Level Affecting Marsh Model (SLAMM) that was constructed for Blackwater Wildlife Refuge and applied to Harriet Tubman Underground Railroad National Historical Park, the park is projected to experience a net loss of wetlands, driven by the loss of irregularly-flooded marsh early in the century (2,219 acres by 2050) and the loss of freshwater swamp later in the century, an estimated 3,328 acres from 2050 to 2100 (Figure 4-55). Accounting for all gains and losses, the SLAMM modeling projects that the park will lose 16% of its wetlands by the end of the century.

Considering no net loss as our reference condition, a loss of 16% wetland is scored at 0% reference condition attained.

Table 4-32. Marsh surface elevation change trends for three locations in Harriet Tubman Underground Railroad National Historical Park.

Location	Elevation trend	Percent attainment
Wildlife Drive	-0.8 mm/y	0%
1980's Created Island	-0.9 mm/y	0%
Reference area (Barbadoes)	-4.2 mm/y	0%

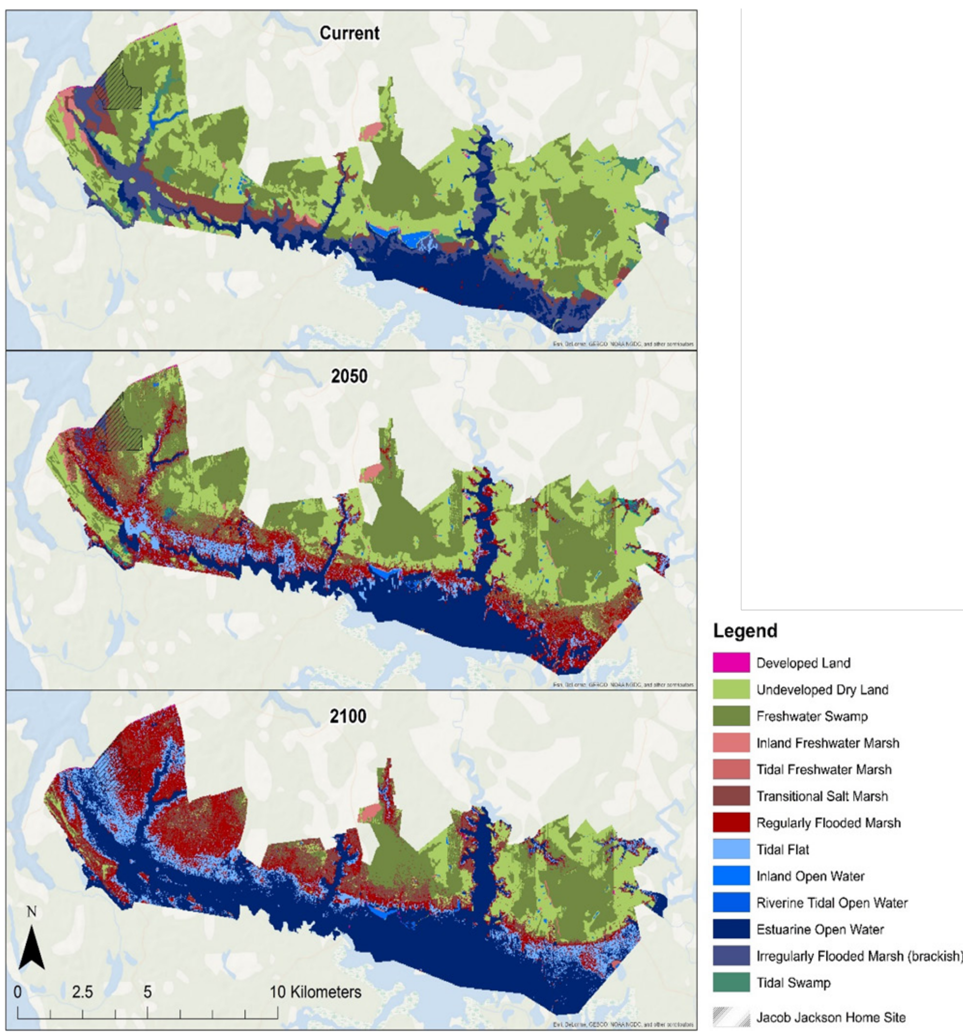


Figure 4-55. Projected locations of landcover changes due to sea level rise at Harriet Tubman Underground Railroad National Historical Park over the next century (Data source: SLAMM, Maryland Department of Natural Resources 2011).

Averaging the 0% attainment score associated with the observed negative accretion rates with the 0% attainment score associated with the SLAMM projections of future wetland loss yields an overall attainment score for the wetlands indicator of 0%.

Data Gaps and Level of Confidence

Confidence in the assessment of this indicator is high. The assessment is based on field data as well as model projections. Combined, these two approaches are powerful validations of each other. Model projections are consistent with observations of wetland loss due to sea level rise in recent decades. Trends in sea level rise, especially along the eastern seaboard and the Chesapeake Bay region, are well-documented in the scientific literature and are accelerating. Information and data specific to Blackwater NWR provide an even clearer picture of local trends due to the high geographic overlap between these two legislative boundaries.

The assessment of wetland resources at Harriet Tubman Underground Railroad National Historical Park is based on data collected within Blackwater Wildlife Refuge. Baseline data pertaining to the current presence and health of natural resources within the Harriet Tubman Underground Railroad National Historical Park park boundaries are, however, scarce. Data derived from any future incorporation into regional NPS natural resource monitoring would help elucidate and quantify additional threats, such as biological invasions, to the park's wetland resources.

Source(s) of Expertise

- Don Cahoon, US Geological Service
- David Nemerson, National Aquarium

4.4.3. Historic Landscape

Description

The historic landscape of the mid-19th century was one of dark night skies, agricultural fields, and quiet spaces. To appreciate the sense of place in honoring both Harriet Tubman's life and the Underground Railroad requires a certain fidelity to these historic conditions. The midnight sky and stars were tools that Harriet Tubman used to navigate and find sanctuary (Bradford, 1896). The agrarian landscape in which she grew up helped shape the woman that she would become. An important part of the visitor experience is being able to escape the light and noise pollution associated with modern society. The condition of the night skies, viewshed, and soundscape is also critically important to the natural resources of the park.

> *The midnight sky and the silent stars have been the witness to your devotion to freedom and your heroism." - Frederick Douglass*

The continental U.S. has some of the highest levels of artificial lighting in the world, and considering the growing population and increasing urbanization, light pollution is projected to continue to increase (Elvidge et zl. 2014, Falchi et al. 2016). The natural darkness associated with the night sky is an important natural, scientific, economic, and cultural resource value of our nation; yet, fewer than 10% of Americans are able to experience natural night sky conditions (15,000 stars and the

Milky Way visible) on a regular basis (Clarke 1999). Dark skies are valued in parks for their wildlife function, sense of wilderness, and astronomically for stargazing (Morning et al. 2015, NPS 2018).

Historic agrarian landscapes of Harriet Tubman Underground Railroad National Historical Park. Photo: Todd Lookingbill, September 2016.

Light pollution includes direct glare, sky glow, and temporary, unexpected fluctuations in lighting (Longcore and Rich 2004). Behavioral and population-level ecology are affected based on individual and species differences in orientation or disorientation to increased light availability, attraction or repulsion to light sources, lowered reproductive capacity, and hindered visual and audio intraspecies communication (Koen et al. 2018). These factors culminate in changes in community ecology, influencing competition, including resource partitioning and predation, ultimately favoring species that are most light tolerant (Longcore and Rich 2004). Light pollution has disparate effects on the environmental including impacts on salamander foraging, bird migration, and turtle breeding (Duriscoe 2001, Salmon 2003, Harder 2004). Mechanistically, the disruption of natural darkness can have ecological implications for wildlife mating, migration, sleep, foraging, orientation, and other aspects of their life cycle (Gaston et al. 2013), making light pollution a significant threat to overall biodiversity (Holker et al. 2010).

Managing light pollution in Harriet Tubman Underground Railroad National Historical Park will be a challenge because of its close proximity to several large cities. Washington DC, Baltimore, MD and Richmond, VA are within 100 miles of the park, while Newport News, Norfolk, and Virginia Beach are all just over 100 miles away. These urban areas produce substantial amounts of artificial light that are reflected into the atmosphere and decrease the night sky quality for hundreds of miles around. It is anticipated that night sky viewing within Harriet Tubman Underground Railroad National Historical Park will become increasingly more important as visitors seek out locations where better views of the night sky are available away from urban influences.

The daytime viewsheds are another important consideration in preserving and recreating the historical landscape. A self-guided tour of the park explores over 30 different sites that played a role in Tubman's life; including the Bucktown General Store, the Jacob Jackson Homesite, and the Bazzel Church. The integrity of these landscapes helps visitors appreciate Harriet Tubman's sacrifices as a lifelong humanitarian and civil rights activist. In general, wildlife and landscape viewing is an integral part of the national park experience and a major reason why visitors come to parks (Miller and Wright 1999). The importance of park vistas and associated scenery was captured in the National Park Service Organic Act (16 U.S.C. l) mission "to conserve the scenery and the natural and historic objects and the wild life therein."

A viewshed is defined as the area of land visible from a geographically specific vantage point. Mapping viewsheds characteristics is a first-step in landscape protection planning (La Rosa 2011). Calculating the percentage of a viewshed with undesirable properties provides a quantitative description of visual stress on a landscape. This information can be used in park internal planning activities and in building future partnerships with neighboring land owners. In addition to the historic and cultural value of maintaining the park as an agrarian landscape, the multiple studies indicate that recreational visitors tend to prefer more natural to developed landscapes (Kearney et al. 2008, Han 2010).

Similar to the concept of viewshed, a soundscape is defined by the total ambient acoustic environment audible from a given point on the landscape (Wrightson 2000). The overall decibel level and composition of an area's soundscape can have significant impacts on people, wildlife, and their environment (Truax and Barrett 2011). Natural soundscapes are valuable resources that influence and are a part of the ecological communities that national parks seek to preserve (Miller 2008). Examples of natural sound sources include wildlife, waterfalls, wind, and rain (Pijanowski et al. 2011). Properly functioning soundscapes are important for intraspecies communication, territory establishment, courting and mating, nurturing and protecting young, predation and predator avoidance, foraging behavior, effective use of habitat, and other biological responses (Shannon et al. 2016). Therefore, natural sounds are thought to provide valuable indicators of the health of an ecosystem (Gómez et al. 2018). Visitors also appreciate natural sounds in parks. A system-wide survey of park visitors revealed that nearly as many visitors come to national parks to enjoy the natural soundscape (91%) as come to view the scenery (93%; NPS 1995).

But the soundscape of a park is comprised of both natural, ambient sounds and human-made sounds. These anthropogenic noises can affect the cultural and historical ambience of the park. They also can impact wildlife. For example, changes in sound regime can displace animal species that are highly sensitive to noise or make them accustomed to noise and eventually not react to potentially harmful noise disturbances (Barber et al. 2009). An increasing human source of sound in American landscapes since the 19th century are modern roads (Laurance et al. 2014). Although roads are often sited to minimize other types of environmental disruptions, they have wide-ranging impacts to the natural soundscape of areas; including lands that are protected (TRBNRC 2005, Francis et al. 2017).

Roads provide a potentially harmful disturbance to the natural soundscape of Harriet Tubman Underground Railroad National Historical Park. Photo: Todd Lookingbill, September 2016.

<u>Methods and Data</u>

The historical landscape of Harriet Tubman Underground Railroad National Historical Park was assessed through consideration of the condition of its night skies, viewshed from four historical landmarks, and potential noise pollution from roads in the park.

The parameter used for evaluating night skies was the average anthropogenic sky luminance presented as a ratio of natural conditions (Average Luminance Ratio; ALR). This metric was calculated by measuring the total observed sky brightness (in nanolamberts - nL), subtracting the natural night sky average brightness (78 nL) to find the anthropogenic component, and calculating the ratio of anthropogenic to natural night sky brightness. The ALR measure is a robust metric that can be easily modeled, but provides a general and relatively coarse description of overall resource conditions (Moore et. al 2013). ALR is calculated using ground-based measurements and a GIS model when data are not available (Moore et. al 2013).

The viewshed was assessed from four significant landmarks within the park: the Visitor Center, Bucktown General Store, Jacob Jackson Homesite, and Bazzel Church (Figure 4-56). The percentage of the viewable land from the four vistas that was undeveloped was used to assess the park's viewsheds for desirability by visitors.

Figure 4-56. Location of historic vistas within Harriet Tubman Underground Railroad National Historical Park used for viewshed analysis (Data source: Maryland Department of Natural Resources, all photos by Todd Lookingbill, 2016).

The analysis was conducted using ESRI's Spatial Analyst Viewshed Tool in ArcGIS 10.1. Three input datasets were required; a digital elevation model (DEM), a land cover map, and the geographic coordinates of the four landmark points in which a person would be viewing the landscape. A DEM for the park was derived from the National Elevation Dataset (NED). Land cover data were taken from the Chesapeake Conservancy High-Resolution Land Cover Dataset (Chesapeake Conservancy 2016). The land cover dataset is made up of 1-m raster pixels, each assigned a land type classification. For the purposes of this analysis, the following classes were considered anthropogenic: Structures, Impervious Surfaces, Impervious Roads, Tree Canopy over Structures, Tree Canopy over Impervious Surfaces, and Tree Canopy over Impervious Roads. All other classes were considered natural land. The percent historic land cover was derived by calculating the percent of pixels of these natural types within the area viewable from the four vista points. In the interest of only examining the areas within the park, all outputs were clipped to the park boundary for the final analysis.

The soundscape was assessed using local Maryland roads to determine the percentage of the park that is exposed to road noise. According to a Caltran-11 Noise Study Report, a car can easily be heard driving on a road that is 30 meters away (Hendriks et al. 2013). To calculate the percentage of the park within the 30-meter threshold of roads, ESRI's Spatial Analyst Buffer Tool in ArcGIS 10.1 was used. The total area not affected by road noise (located outside of the 30-meter buffer) was divided by the total area of the park to calculate the percentage of the park exposed to road noise. In the interest of only examining the areas within the park, all outputs were clipped to the park boundary for the final analysis.

Reference Condition

Harriet Tubman Underground Railroad National Historical Park is categorized as a level 1, non-urban park with a night sky reference condition of less than 0.33 ALR (Moore et al. 2013). An ALR of 0.33-2.00 would be categorized as Moderate Concern, while greater than 2.00 ALR would be Significant Concern. For this assessment, multiple thresholds were used to assess night skies: ALR ≥ 2.00 was considered to be of Significant Concern (score of 0%), and ALR ≤ 0.33 was considered to be Good Condition (attainment score of 100%). Attainment scores were scaled linearly from 100% to 0% for ALR values between 0.33 and 2.00. Only one data point in time was available for the assessment, and trend was not calculated.

Percent attainment for the viewshed metric was calculated as the raw percent of viewable area that was in an undeveloped land class. Trend was not assessed for this indicator because the detailed land cover data used for the assessment were only available for 2016.

Percent attainment for the soundscape metric was calculated as the raw percent of park that was outside the 30-meter road buffer and therefore less disturbed by road noise. Trend was not assessed for this indicator because the detailed land cover data used for the assessment were only available for 2016.

Current Condition and Trend

The condition of night skies in the park is of Significant Concern (percent attainment = 0%) based on the mean value of 3.0 ALR and range of 2.5-3.6 ALR for the park. Ambient light pollution is higher in the western half of the park which is in closer proximity to urban sources of light (Figure 4-57). At this time, available data are insufficient to establish a trend.

The viewshed analysis was conducted assuming an observer height of two meters at each of the four vistas points. The Digital Elevation Model (DEM) was then used to account for terrain obstacles that may obscure what can be seen from each point. Atmospheric refraction and the curvature of the earth's surface were also accounted for in the model. Because the terrain is relatively flat, there were few obstructions in this simplified version of the model.

An approximate Digital Surface Model (DSM) was then created to account for additional obstructions to the viewsheds created by surrounding land cover. The DSM was constructed by increasing the height of each pixel of the DEM by an estimated height of the land cover corresponding to that pixel. Water, wetlands, low vegetation, barren, impervious surfaces, and impervious roads were all given a height of zero meters. Shrubland was estimated to increase the height of the surface by one meter. Structures were estimated to be eight meters high and all land cover classes with "Tree Canopy" in the title were assigned an additional height of 20 meters above the elevation provided in the DEM. The amount of land viewable from the four vistas decreased significantly in this revised viewshed layer (Figure 4-58).

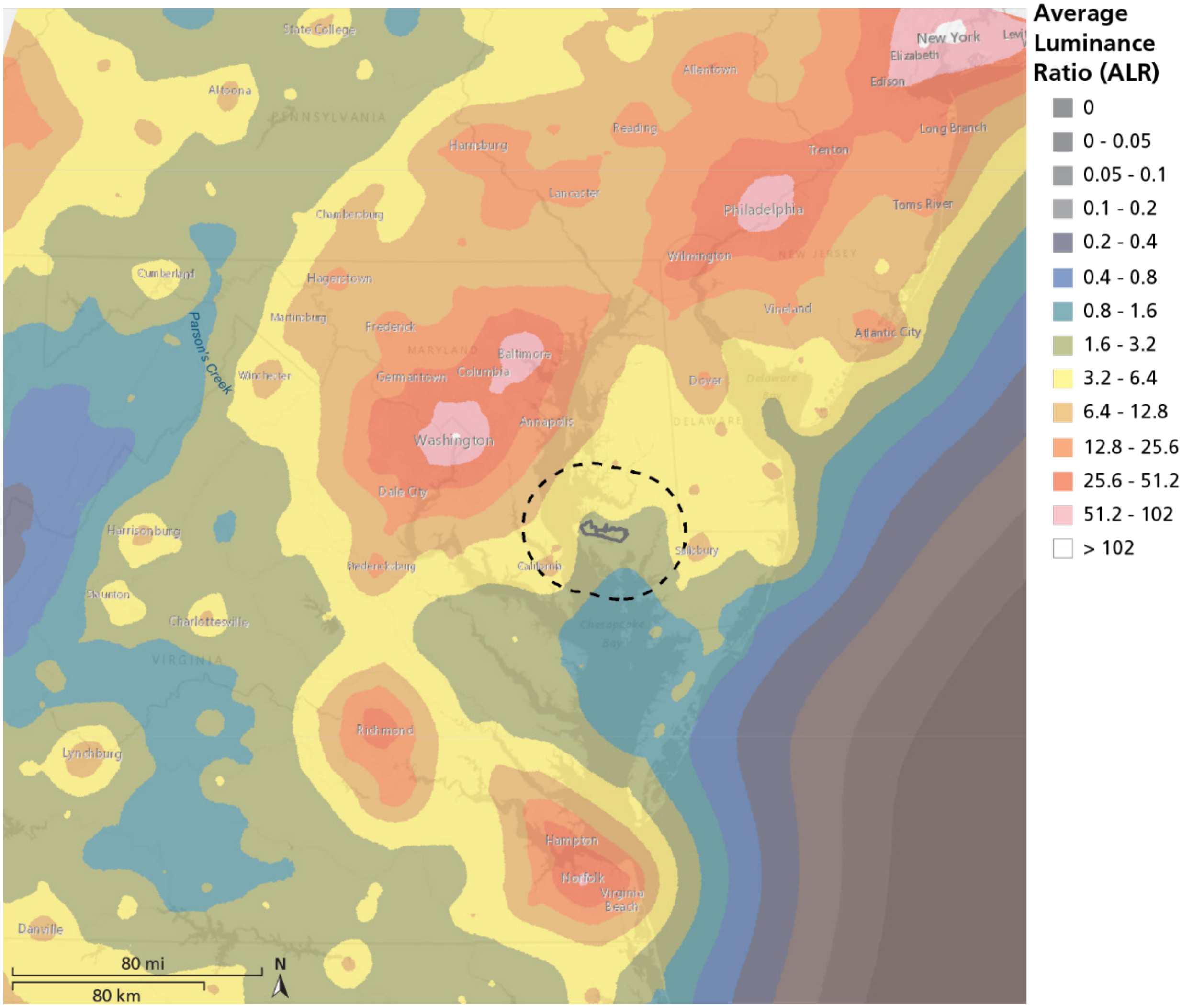


Figure 4-57. Map of average luminance ratio (ALR) within Harriet Tubman Underground Railroad National Historical Park and surrounding landscape (Data source: NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program).

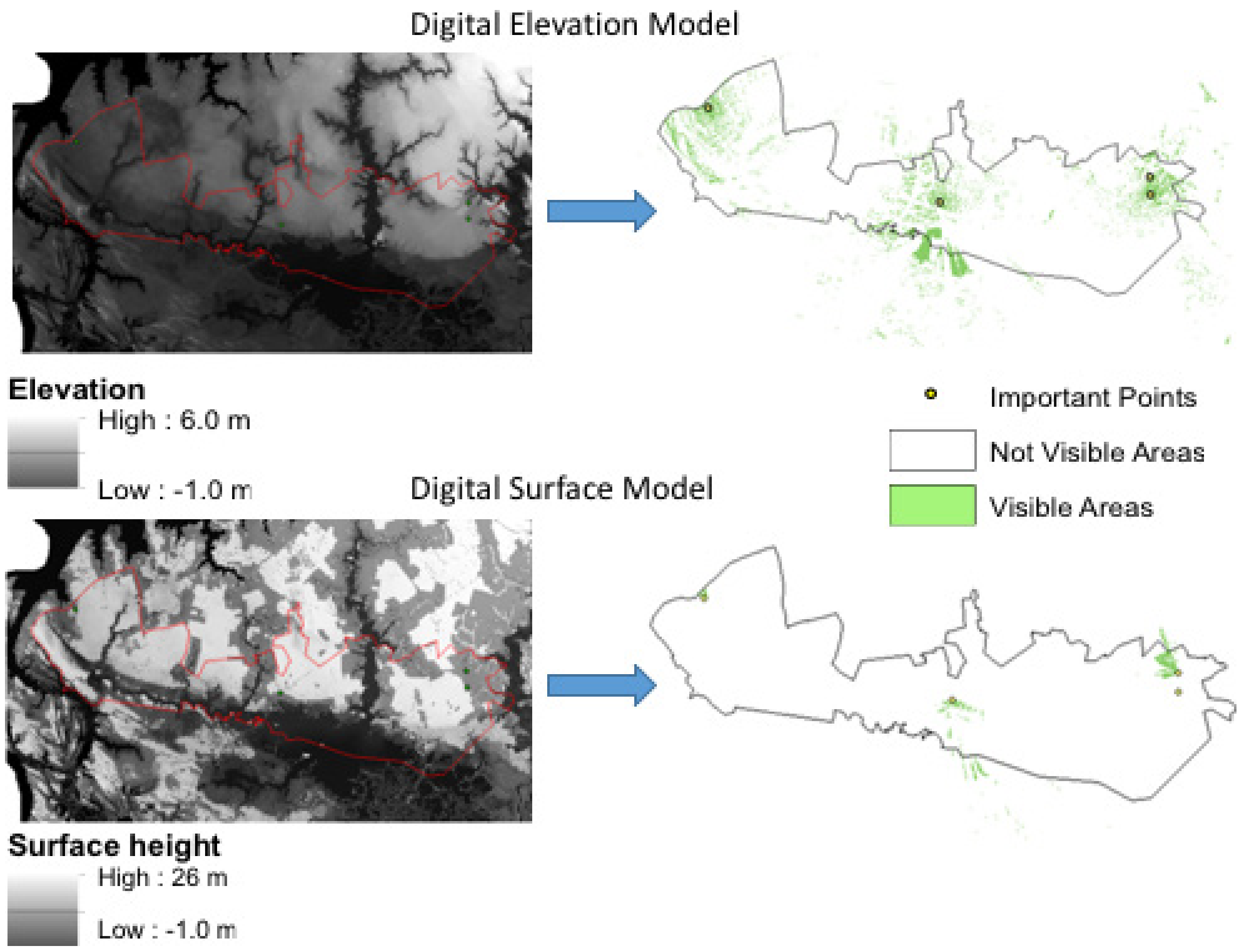


Figure 4-58. Viewshed model comparison from four historic vistas within Harriet Tubman Underground Railroad National Historical Park using a Digital Elevation Model and Digital Surface Model (DEM combined with land cover) (Data source: USGS National Elevation Dataset).

Using the DSM-based viewshed models, 264 acres (approximately 1% of the area contained with the legislative boundary) is visible from the four historic vistas analyzed (Figure 4-59). Of this viewable land, 74% is classified as low vegetation in the Chesapeake Conservancy (2016) land cover data (Figure 4-60). Twelve percent is characterized as wetlands and 6.8 percent is open water. A total of 3.7 percent is classified as tree canopy, which is primarily located around the Jacob Jackson Home site and Bazzel Church. The tree cover around these observation points results in the substantial reduction in the extent of visible area between the DEM and DSM-based models. In aggregate, only 3.3 percent of the area visible from the four vistas is classified as anthropogenic developed land, yielding a percent attainment score of 96.7%.

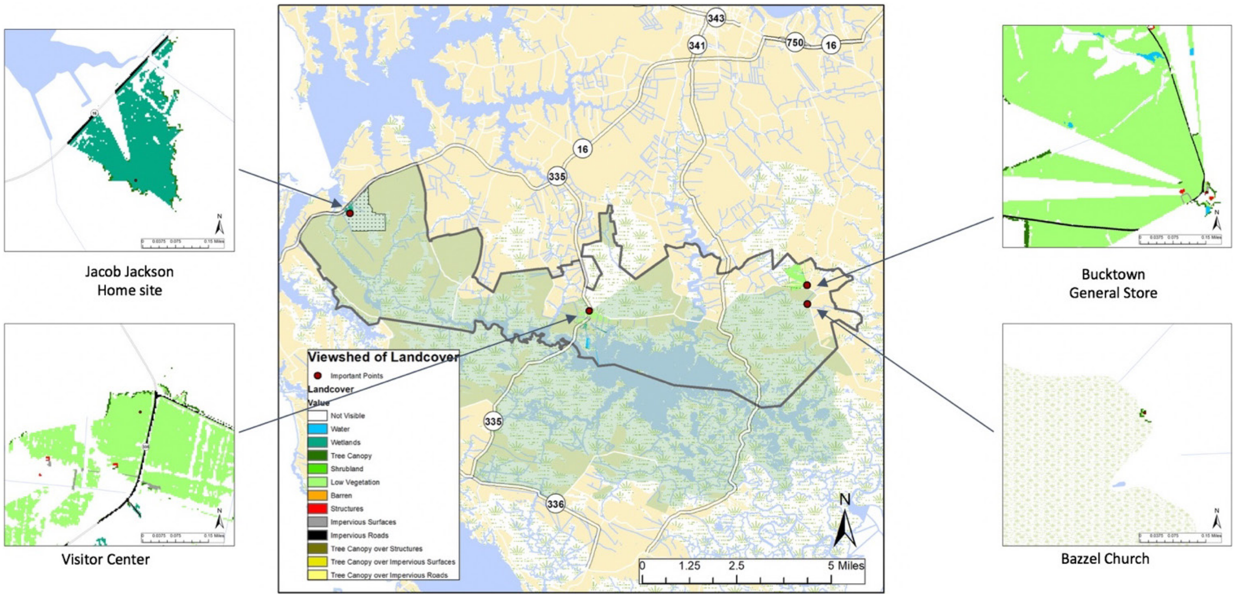


Figure 4-59. Viewshed model of the land cover that is visible from four historic vistas within the boundary of the Harriet Tubman Underground Railroad National Historical Park (Data source: Chesapeake Conservancy 2016).

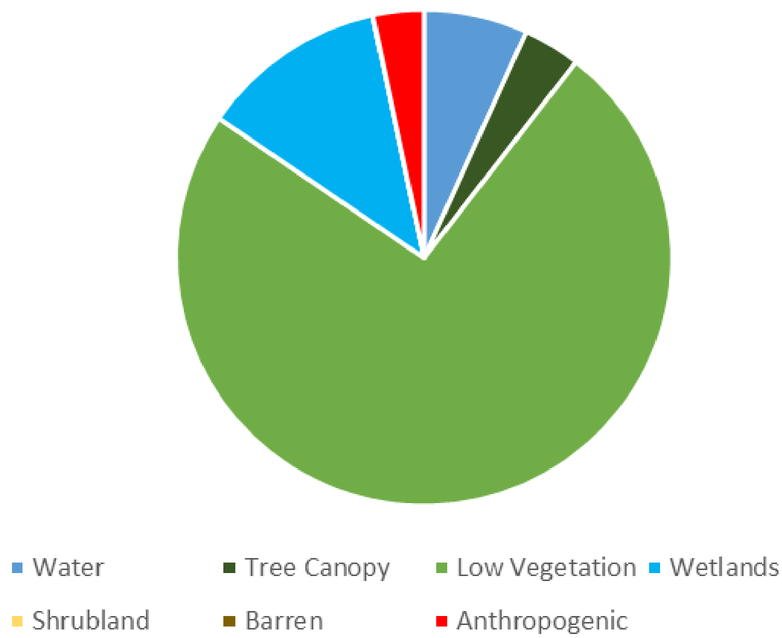


Figure 4-60. Percent natural and anthropogenic land cover that is visible from four historic vistas within Harriet Tubman Underground Railroad National Historical Park (Data source: Chesapeake Conservancy 2016).

Roads are pervasive on the American landscape. Nationally, at least 5% of the total U.S. land area is within 30 m of a road, and the density of roads is even greater for the Mid-Atlantic region of the United States (Riitters and Wickham 2003). For Harriet Tubman Underground Railroad National Historical Park, 8.4% of the land is located within 30 meters of a road (soundscape condition attainment score of 91.6%). The density is higher in the eastern portion of the park than the western half (Figure 4-61).

Averaging the night skies (0% attainment), viewshed (96.7% attainment), and soundscape (91.6% attainment) assessments yields an overall attainment score for the historic landscape indicator of 63%, or Moderate Concern. Data are not available to assess trend at this time.

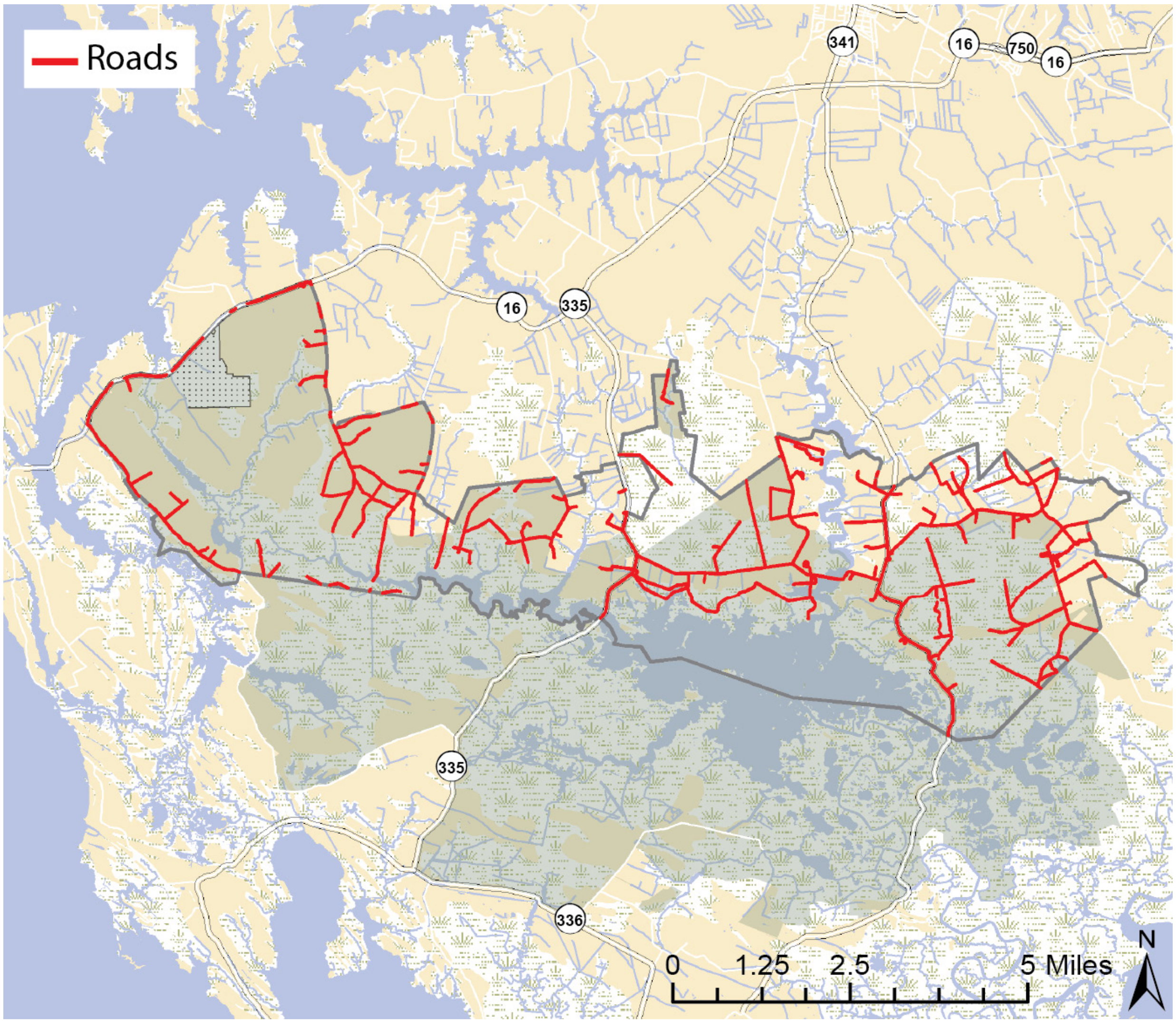


Figure 4-61. Local roads including a 30-meter buffer within the Harriet Tubman Underground Railroad National Historical Park boundary (Data source: Maryland State Highway Administration).

<u>Data Gaps and Level of Confidence</u>

Confidence in this assessment is low. Of the three metrics included in the assessment, confidence is highest in the night skies, which is analyzed at the national level by the NPS Natural Sounds and Night Skies program. However, no field measurements of night sky brightness have been collected in Harriet Tubman Underground Railroad National Historical Park. The closest site is about 70 miles away at Assateague Island National Seashore. A night sky resource inventory would be valuable for the park as the modeled ALR estimates available suggest significant pollution from urban sources in the region. Trend data also are not available. Some parks have been collecting field data on night sky luminance with mosaicking charge-coupled device camera systems for over a decade (Duriscoe et al. 2007). While there is some evidence that light pollution has decreased in recent years within national parks in other regions of the country (e.g., Gillespie et al. 2017), there is no evidence of similar decreases (or increases) for Harriet Tubman Underground Railroad National Historical Park.

The four vista points chosen for the analysis represent different vantage points within the park and are representative of diverse visitor experiences. However, the assessment does not fully capture all vista points within the park's boundaries (e.g., viewsheds along the park roadways). The analysis also does not include an assessment of trend because the high-resolution land cover data are only available for one point in time. For example, if trees were harvested adjacent to one of the vistas, and no longer obstructed the view, far more land would be visible from that site. Although not included in the formal scoring of current condition, changes in land cover and development activity outside park boundaries would also influence the viewsheds. Another uncertainty in the analysis is that the viewsheds are highly dependent on the height estimates of the trees and other surrounding land cover features for this low-lying landscape. All of these height classes were estimated and a more accurate DSM could be created using, for example, unmanned aerial vehicles (UAV) and LiDAR imagery (Zarco-Tejada et al. 2014). Lastly, the lack of a park-specific threshold for this indicator is a source of uncertainty that could be addressed with additional research on park visitor experiences and desired conditions.

Although the NPS Natural Sounds and Night Skies program works to help parks manage the acoustic environment in a way that addresses the protection of park resources to ensure educational and inspirational visitor experiences, noise has not been directly measured in Harriet Tubman National Historical Park. The sound disturbances have only been estimated based on proximity to roads using geospatial tools. Atmospheric and other landscape conditions can have a profound effect on noise levels that are not accounted for in the simple analysis presented here (Hendriks et al. 2013). For example, trees in the park not only influence what can be seen from the historic viewpoints, but they also influence what can be heard at different locations within the park. Typical forest belts that are 10-30 meters wide can act as a sound barrier and reduce noises up to 3-5 decibels (Lee et al. 2008). The analysis presented here assumed that road noise was sufficiently buffered at distances beyond 30 meters to eliminate unwanted disturbances. But traffic is likely to be heard at greater distances in non-forest landscapes, resulting in an underestimation of these impacts to the park soundscape. A study combining distance to roads with land cover attributes would be useful to understand the spatial patterning of noise disturbances. Noise is also corelated to road type. The NPScape SOP for Road Measures uses a weighted analysis that estimates traffic patterns on different road types to better understand the variable impacts of road density (National Park Service 2013). A comprehensive natural sounds assessment that included both enhanced spatial modeling and field data collection would provide valuable feedback to park management.

<u>Source(s) of Expertise</u>

- Sharolyn Anderson, National Park Service - Natural Sounds & Night Skies.

5. Discussion

5.1. Harriet Tubman Underground Railroad National Historical Park Context for Assessment

Harriet Tubman Underground Railroad National Historical Park possesses a mixture of aesthetic, cultural, economic, and scientific resources. The condition of natural resources in the park must be considered in the context of the diverse values of the site in addition to the park's history, geography, and legislative mission. For example, the park serves as a touchstone for the historical and cultural understanding of the Underground Railroad and, thus, natural resources may be interpreted within this cultural and historical context.

The condition of the natural resources of Harriet Tubman Underground Railroad National Historical Park was assessed systematically through consulting National Park Service staff on the assessment approach; compiling available data for resources and stressors; identifying suitable indicators of resource condition and their associated metrics; and deriving a percentage score for each of the indicators. Based on this information, this final chapter summarizes the key conditions, stressors, and threats to resources within the park. It further provides recommendations for better understanding these resources and maintaining or improving future condition.

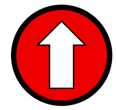
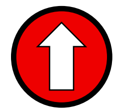
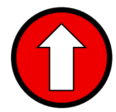
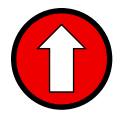
5.2. Park Natural Resource Condition

Condition scores are provided for each of the four vital signs within Harriet Tubman Underground Railroad National Historical Park: air quality, water resources, biological integrity, and landscape dynamics. The natural condition of the park was assessed based on 20 indicators representing the four vital sign categories as outlined in Chapter 3. The detailed methods and final assessment of the conditions and trends are provided for each indicator in Chapter 4. In this chapter, we present the key findings for each vital sign based on direct consideration of the assessment results. Recommendations were developed in collaboration with NPS natural resource personnel and the park superintendent.

5.2.1. Air Quality

The condition of air quality at Harriet Tubman Underground Railroad National Historical Park was assessed as "**significant concern**" based on an average attainment score of 13 percent (Table 5-1). Confidence in this assessment is *high* owing to the rigorous and long-term monitoring protocols developed by the NPS Air Resources Division. The length and temporal resolution of the air quality data allows clear assessment of trends. However, the assessment is based on data collected outside of the park that was interpolated to estimate air quality within the park. Current air quality conditions at Harriet Tubman Underground Railroad National Historical Park, as well as for the entire region, are clearly degraded, but trends for the last decade indicate that conditions are improving for all indicators, especially sulfur deposition and visibility.

Table 5-1. Summary of air quality condition assessment at Harriet Tubman Underground Railroad National Historical Park.

Resource category	Indicator of concern	Condition status/trend	Percent attainment
Air quality	Wet sulfur deposition		25%
Air quality	Wet nitrogen deposition		0%
Air quality	Visibility		0%
Air quality	Ozone		27%
Overall Air quality	–	–	**13%**

Air quality degradation is not an issue specific to Harriet Tubman Underground Railroad National Historical Park. Thus, management at the park level is unlikely to have a quantifiable impact on the region as a whole. However, the park can be a leader in educating the public on the causes and consequences of air pollution (Table 5-2). Causes include vehicular emissions and emissions from wetlands. Consequences include human health issues, plant defoliation, water acidification, and altered nutrient cycling. Providing knowledge about these connections to visitors could influence their daily behaviors in ways that are beneficial to park air resources. We also recommend that the park continue to support any regional initiatives aimed at improving air quality.

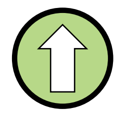
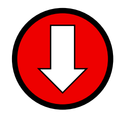
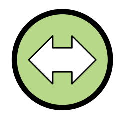
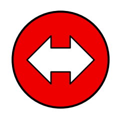
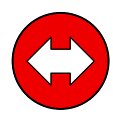
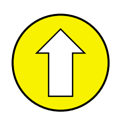
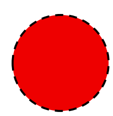
Table 5-2. Key findings and recommendations for air quality at Harriet Tubman Underground Railroad National Historical Park.

Resource category	Key findings	Recommendations
Air Quality	• Regional degradation of air quality • Improving conditions for many indicators	• Support regional air quality initiatives • Spread awareness throughout the region • Educate the public on the causes and consequences of air pollution

5.2.2. Aquatic Resources

The condition of aquatic resources for Harriet Tubman Underground Railroad National Historical Park was assessed as “**moderate concern**” based on average attainment of 49% for all indicators (Table 5-3). Confidence in the assessment of water resources is generally *moderate* based on long-term monitoring data that are replicated well in space only for dissolved oxygen and water clarity and temperature. Benthic invertebrates are poorly replicated in time and space. Trends indicate improving conditions for dissolved oxygen and chlorophyll *a*, stable for temperature and nutrients, and declining conditions for water clarity. Temporal trends are unknown for benthic invertebrates.

Table 5-3. Summary of water resource condition assessment at Harriet Tubman Underground Railroad National Historical Park.

Resource category	Indicator of concern	Condition status/trend	Percent attainment
Water resources	Dissolved oxygen		69%
Water resources	Water clarity		32%
Water resources	Temperature		100%
Water resources	Total nitrogen		19%
Water resources	Total phosphorus		29%
Water resources	Chlorophyll a		43%
Water resources	Benthic Index of Biotic Integrity		33%
Overall Water resources	–	–	49%

High nutrient content within the water column as well as declining water clarity trends and a poor benthic index of biotic integrity are of significant concern. We therefore recommend that the National Park Service establish a water quality and benthic macroinvertebrate monitoring program on the land it manages within Harriet Tubman Underground Railroad National Historical Park (Table 5-4). We recommend that the program interface with Blackwater National Wildlife Refuge's monitoring program while also conforming to NPS standards and protocols. A monitoring program that targets specific NPS-managed lands will allow a more confident assessment of current condition and the monitoring of trends. In addition, we recommend that land-use along streams and rivers be assessed and potential sources of pollution studied so that best management practices can be implemented to reduce nutrient run-off into streams. Watershed development upstream of the park also should be assessed, and the park should work closely with its neighbors to ensure that water quality does not continue to degrade owing to urban expansion, especially from the City of Cambridge.

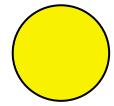
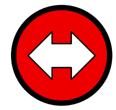
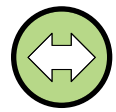
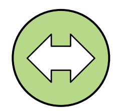
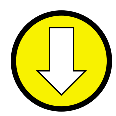
Table 5-4. Key findings and recommendations for water resources at Harriet Tubman Underground Railroad National Historical Park.

Resource category	Key findings	Recommendations
Water Resources	• Dissolved oxygen and temperature in good condition • Nutrients (N and P) and water clarity in poor condition • Benthic invertebrates in poor condition	• Establish a water quality monitoring program within the Jacob Jackson site that interfaces with Blackwater National Wildlife Refuge's monitoring and conforms to NPS standards • Monitor benthic macroinvetebrates as an integrative measure of sediment quality • Adopt best management practices to reduce nutrient run-off into streams and rivers • Watch for urban development upstream of the park near the City of Cambridge and become a stakeholder in decision making

5.2.3. Biological Integrity

The condition of biological integrity within Harriet Tubman Underground Railroad National Historical Park was assessed as "good" based on average attainment of 67% averaged across six indicators (Table 5-5). Confidence in the assessment is generally moderate based on monitoring data that is replicated reasonably well in time and space. One exception is the assessment of bald eagles, whose long-term monitoring data provides high confidence in the indicator. Trends are improving for bald eagles, are stable for deer, Delmarva fox squirrels, and forest interior birds, are declining for bats, and are unknown for forest structure. The high density of deer is of significant concern owing to its potentially large impacts on forest structure that can cascade throughout the food web.

Table 5-5. Summary of biological integrity condition assessment at Harriet Tubman Underground Railroad National Historical Park.

Resource category	Indicator of concern	Condition status/trend	Percent attainment
Biological integrity	Forest structure		49%
Biological integrity	Deer		0%
Biological integrity	Delmarva fox squirrels		100%
Biological integrity	Bald eagles		90%
Biological integrity	Forest interior birds		100%
Biological integrity	Bats		63%
Overall biological integrity	–	–	**67%**

Because Delmarva fox squirrels and bald eagles are iconic species for the area, we recommend that these species be highlighted and celebrated as significant natural resources for the park (Table 5-6). Given that Harriet Tubman must have encountered the species in her life and work in Dorchester County, these natural resources may also serve as a good interpretive tool. Forest interior birds are in good condition, although we recommend that this group of species continue to be monitored within the Jacob Jackson site as data are currently not collected by Blackwater National Wildlife Refuge. Monitoring of forest structure also was started by Blackwater National Wildlife Refuge but was not continued owing to the lack of funding. We recommend that forest structure be monitored at the Jacob Jackson site by adopting established protocols and integrating them with regional NPS protocols. The demise of bats within the region is a concern. We recommend that species diversity and the activity of specific bat species be monitored at the Jacob Jackson site. Finally, deer densities pose a significant risk to forest structure and wildlife associated with it. We recognize that the National Park Service and the US Fish and Wildlife Service have differing management priorities with regards to deer such that management goals may be at odds. We recommend open and honest discussion to determine how to reconcile the US Fish and Wildlife goal of providing a good hunting experience with the National Park Service goal of minimizing impacts to natural ecosystems from invasive species, such as Sika deer.

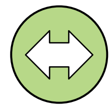
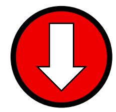
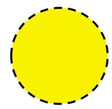
Table 5-6. Key findings and recommendations for biological integrity at Harriet Tubman Underground Railroad National Historical Park.

Resource category	Key findings	Recommendations
Biological Integrity	• Delmarva fox squirrels, bald eagles, and forest interior birds are in good condition • Trends in forest structure could not be assessed owing to a lack of temporal data • Bat populations are diverse in the parks but are declining (based on regional trends) • Deer densities are a significant concern	• The condition of bald eagles, forest interior dwelling birds, and Delmarva fox squirrels can be highlighted and interpreted within the context of the park's cultural resources • Forest monitoring needs to be established at the Jacob Jackson site and continued so that trends can be established • Bat populations need to be monitored and the presence of white nose syndrome in the park assessed • Deer impacts to forest structure should be assessed at the Jacob Jackson site, and differences in NPS and USFWS management priorities recognized

5.2.4. Landscape Dynamics

The condition of landscape dynamics was assessed as "**moderate concern**" based on an average attainment of 54% for all indicators (Table 5-7). Confidence in the assessment was *moderate*, and would be increased by developing a time-series of high-resolution land cover data specific to the park. The park currently has minimal impervious surfaces and large amounts of natural land cover. However, human modifications of the landscape are substantially higher within the 30-km area surrounding the park. There are a number of components of the landscape that were not assessed and that would benefit from further data collection (Table 5-8). For example, the quiet spaces and natural soundscapes are of high value to the park, but the current condition and trajectory of these resources cannot be quantified at this time due to lack of data. Winds are a specific natural sound attribute appreciated by visitors. Other landscape resources, such as the night skies, have only been assessed for a single point in time and using only regional protocols that do not include direct measurements within the park. Future threats to the park include increasing rates of sea level rise and continuing residential and commercial development in the region.

Table 5-7. Summary of landscape dynamics condition assessment at Harriet Tubman Underground Railroad National Historical Park.

Resource category	Indicator of concern	Condition status/trend	Percent attainment
Landscape dynamics	Land cover		100%
Landscape dynamics	Wetlands		0%
Landscape dynamics	Historic landscape		63%
Overall landscape dynamics	–	–	**54%**

The landscape dynamics at Harriet Tubman Underground Railroad National Historical Park are tightly linked to activities over which the National Park Service may have limited or no control (Table 5-8). These risk factors are a function of it being a relatively small park with mixed ownership within its legislative boundaries. Although natural land cover dominates the park itself, development in the surrounding region should be monitored, especially upstream of the park. We recommend that the park work closely with Blackwater National Wildlife Refuge to develop landscape monitoring strategies and to coordinate management activities to ensure continued connectivity of habitat among NPS and USFWS lands. Specific locations within the park and along its borders, such as lands adjacent to the Jacob Jackson parcel, warrant increased monitoring scrutiny. We recommend that the park remain aware of potential impacts to viewsheds of clearing these lands, including any clearing that may be associated with developing the site to promote increased visitation. The NPS is a leader in recognizing the importance to wildlife and wilderness character of night skies and natural sounds, and many parks have begun collecting information on these resources within their boundaries. Since these resources are also central to the historical and cultural character of the park, we recommend that the park consider monitoring them directly. The single, greatest threat to the natural resources of Harriet Tubman Underground Railroad National Historical Park is likely the increasing sea level over which it has little control. Nevertheless, monitoring changes in surface elevation and associated loss of wetland and forest habitat will be a critical part of any landscape planning or management conducted in the park.

Table 5-8. Key findings and recommendations for landscape dynamics at Harriet Tubman Underground Railroad National Historical Park.

Resource category	Key findings	Recommendations
Landscape dynamics	• Land cover is in good condition within the park, but more degraded in the surrounding landscape • Wetland extent is declining owing predominantly to sea level rise • Night skies may be degraded from regional sources but more data are needed for the park • Viewshed is in good condition • No data are available for soundscapes	• Develop or attain access to a time series of high-resolution land cover imagery for the site to monitor landscape change • Monitor changes in surface elevation especially in and near the Jacob Jackson tract • Monitor night skies and soundscapes at specific locations within the park • Monitor and work with neighbors to minimize impacts from development outside the park boundaries; increase community awareness of potential concerns • Establish interpretive waysides within the Jacob Jackson site

5.3. Overall Park Condition

The overall condition of Harriet Tubman Underground Railroad National Historical Park was assessed as “moderate concern” based on an average attainment of 45% for the four vital sign categories that were assessed (Table 5-9). Indicators in the best condition include dissolved oxygen and temperature, although periods of hypoxia are not uncommon during summer months. Biological integrity as a whole is in good condition but may be threatened by high deer herbivory that affects forest structure, with potentially cascading effects on wildlife. Although the park is currently in good condition for land cover, sea level rise threatens the integrity of upland forests that may turn into wetlands. Existing wetlands, in turn may be lost to open water areas. Monitoring data at the Jacob Jackson site will be important to assess conditions and trends in water, biota, and land cover given predicted changes to the park’s ecosystems that are driven by a changing climate.

Table 5-9. Summary of priority resources at Harriet Tubman Underground Railroad National Historical Park including attainment of average resource condition for each of the resources.

Vital sign	Reference condition attainment	Current condition	Confidence in assessment	Overall trend
Air Quality	13%	Significant Concern	High	Increasing
Water Resources	49%	Moderate Concern	Moderate	Variable
Biological Integrity	67%	Good	Moderate	Variable
Landscape Dynamics	54%	Moderate Concern	Moderate	Decreasing
Harriet Tubman Underground Railroad National Historical Park	**46%**	**Moderate Concern**	**Moderate**	**Variable**

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