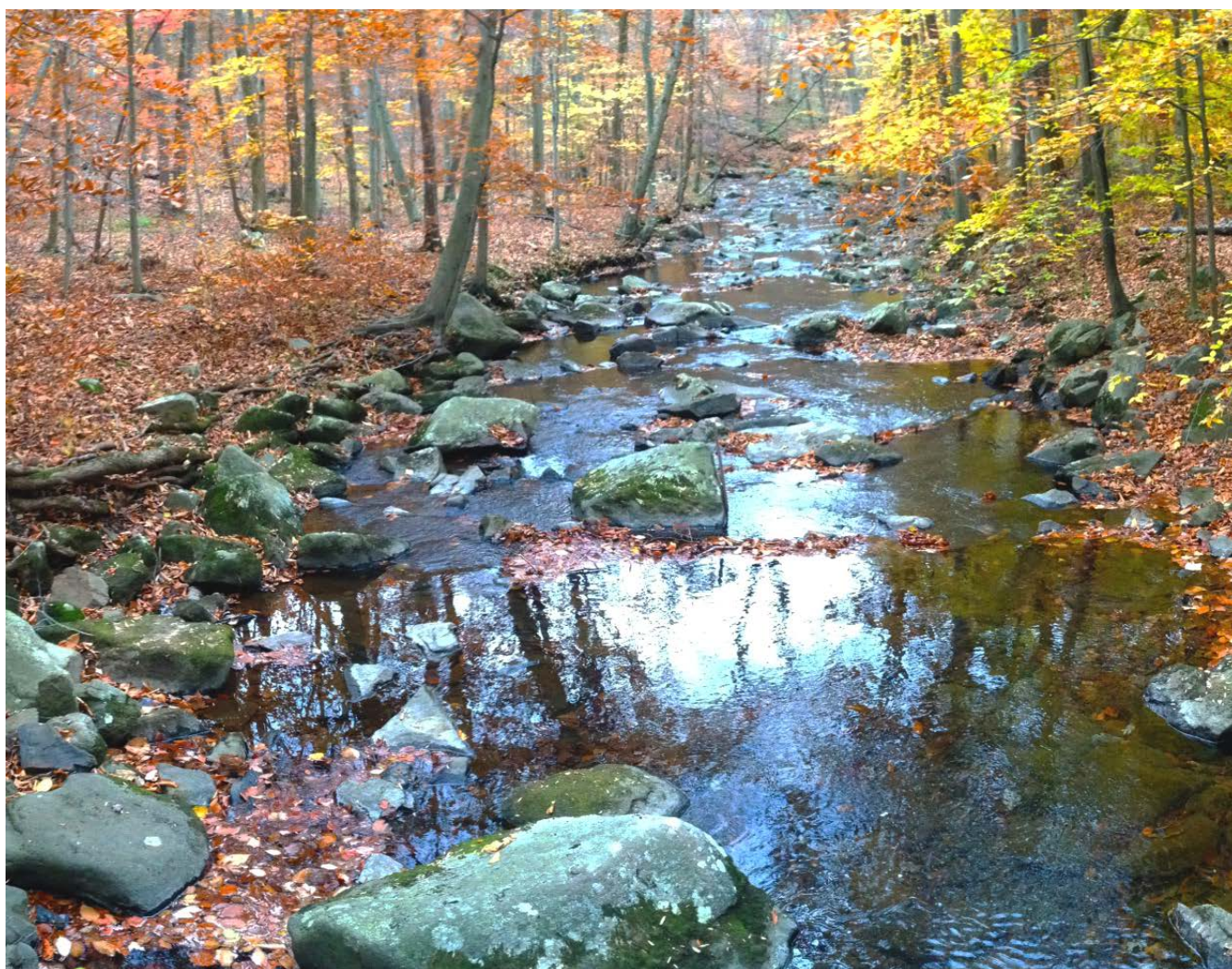




# Morristown National Historical Park Natural Resource Condition Assessment

Natural Resource Report NPS/NERO/NRR—2014/869



**ON THE COVER**

Autumn on the Passiac River, Morristown National Historical Park (MORR).

Photograph by: Ed Sharron, National Park Service

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# **Morristown National Historical Park Natural Resource Condition Assessment**

Natural Resource Report NPS/NETN/NRR—2014/869

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# Executive Summary

## Background and Context

Morristown National Historical Park, the first historical park in the national park system, was established on March 2, 1933. The 1,711 acre (692 ha) park is approximately 30 miles (48 km) west of New York City and situated mostly in Morris County, New Jersey near the town of Morristown, with a small portion located in Somerset County. The park is distributed across four geographically separate units which are historically connected to the Revolutionary War: Washington's Headquarters, Fort Mifflin Unit, New Jersey Brigade Area and Jockey Hollow Encampment Area. The park's mission includes preserving the lands and features associated with the winter encampments of the Continental Army during the War for Independence, specifically commemorating the site General George Washington used as a winter encampment in 1779-1780.

Morristown National Historical Park's (abbreviated as MORR in this report) purpose has been designated as follows:

*Morristown National Historical Park preserves, protects and maintains the landscapes, structures, features, archeological resources, and collections of the Continental Army winter encampments, the headquarters of General George Washington, and related Revolutionary War sites at Morristown for the benefit and inspiration of the public. The park interprets the history and subsequent commemoration of these encampments and the extraordinary fortitude of the officers and enlisted men under Washington's leadership (from NPS 2003a).*

The cultural aspects of MORR are well documented but the natural resources that comprise the park are less well known. The preservation of the natural environment, viewshed and historic structures within all units composing MORR is vital in order to sustain the park's culturally driven purpose. It is the purpose of this report to gather the known data on MORR's natural resources and provide a sound and scientifically driven assessment of the conditions of those resources.



## Approach

We used Vital Sign indicators set forth by the NPS Northeast Temperate Network (NETN) and NPS soundscape and lightscape assessments as a baseline and developed the local data sets that were relevant to the indicators. The majority of natural resource data was collected for the Jockey Hollow Encampment Area and New Jersey Brigade Encampment Area, with a lesser quantity of data available for Fort Nonsense and Washington's Headquarters. For each evaluated natural resource in this NRCA, we began with a brief description of the relevance and context of the resource to the general environment and MORR. We documented the data and methods used to assess the resource, and justified the condition categories by discussing reference conditions or threshold values utilized. The reference conditions and threshold values were based on federal or state agency regulations and criteria, peer-reviewed research, estimates of biotic integrity, or established NPS NETN Vital Signs, NPS Air Resources Division and NPS Natural Sounds and Night Sky condition categories for natural resources. Best professional judgment was used to assign condition categories in the Visitor Usage section. We assigned each natural resource metric to a condition category based on the available data, and assessed the trend of each natural resource's condition. Condition category language generally included three categories: *Resource is in Good Condition*, *Warrants Moderate Concern* and *Warrants Significant Concern* (<http://www.nature.nps.gov/water/nrca/guidance.cfm>, January 2014). We assigned trend conditions of *condition is improving*, *condition is deteriorating* or *condition is unchanging* after statistical analyses of quantitative historical and current data. We discussed data gaps and confidence in our assessment after each metric was assessed. Confidence in the assessment and trend was identified as *high*, *medium*, *low* or *not applicable*. *High* confidence ratings required extensive spatial (and temporal for trend) quantitative data in the assessment; *medium* ratings indicated data were from studies that were quantitative and/or qualitative in nature but not usually spatially explicit; *low* ratings indicated data were from limited studies that collected generally qualitative data; *not applicable* indicated no reliable assessment or trend analysis was possible with the data available or temporal data (for trend) was absent. Finally, the authors recommend in Chapter 5 potential indicators which may be useful for monitoring natural resource conditions in MORR other than those indicators analyzed in this report.

## Threats to MORR

Although MORR fundamentally serves as a historical cultural park, its matrix of forest, fields and streams serve as a unique biological refuge within an increasingly urban environment. External development around MORR is a concern due to negative pressures which may affect the natural and cultural environment. Housing, commercial development and population growth impact land, air and water resources, increase habitat fragmentation and alter the viewshed, soundscape and lightscape of the park. As population grows in the surrounding environment there may be an escalation of demand for recreational space, thereby increasing stress on MORR's environment from rising visitor usage. Contaminants in soil, air and water resources threaten the environmental integrity of MORR. Industrial effluent, municipal wastewater and septic systems and atmospheric deposition can contaminate surface water bodies through overland runoff or enter groundwater through infiltration. Atmospheric conditions such as high ozone, degraded visibility and elevated atmospheric deposition have been shown to stress vegetation and impact terrestrial and aquatic systems. Invasive plant and animal species threaten MORR's terrestrial and aquatic environment. Invasive species are currently

established in the park and are recruited into the park due to development activities, anthropogenic transmittal and changes in climate patterns. Additionally, diseases to vegetation pose an even greater threat to MORR's culturally important mature forests. Disturbance to the natural steep topography of MORR, whether by development or lack of preservation, can result in the loss of habitat quality, degradation of surface water quality, silting of wetlands and alteration of drainage patterns. Furthermore, deer populations have reached historic levels due to habitat modification and the extirpation of natural predators in the northeastern U.S. White-tailed deer reduce MORR's forest regeneration rates and aid in the introduction and expansion of invasive plants.

## **Current Condition of Natural Resources in MORR**

### ***Air Quality***

Air quality can affect visitor health and use, vegetation communities, water quality and the lightscape in MORR. According to NPS ARD 2013 guidance, any park units located in a nonattainment area (ozone or PM<sub>2.5</sub>) automatically receive a *Warrants Significant Concern* rating. MORR is located in both an ozone and PM<sub>2.5</sub> nonattainment area. Parameters of interest for MORR's air quality included ozone, wet nitrogen deposition, wet sulfur deposition, mercury deposition, and visibility. Based upon NPS guidance, MORR's air quality for wet nitrogen and sulfur deposition, ozone, and visibility *Warrants Significant Concern*. NPS has no current guidance for mercury, although MORR's mercury deposition values are higher than a peer-reviewed threshold used for this assessment.

### ***Forest Soil Dynamics***

Soil monitoring is used to understand the effects of acidic deposition on forest health. Using condition ratings developed by the NETN, MORR Ca:Al ratio rated *Resource is in Good Condition*, whereas the C:N ratio rated *Warrants Significant Concern*. The results from samples collected in MORR indicate that the park may be experiencing excess N saturation. Additionally, MORR's slope constraints rated *Warrants Moderate Concern* to *Warrants Significant Concern*, indicating risk of sedimentation and runoff in the park, with a possible decrease in seed bank retention.

### ***Water Quantity and Stream Water Chemistry***

MORR has a number of small streams and wetlands throughout its landscape. The quantity and quality of these aquatic resources is critical to the health and success of the park's biological communities. Due to a lack of long term, baseline data within MORR as well as meaningful condition thresholds, we were unable to assess surface water quantity condition, thereby rating it as *unknown*. With continued growth in the region and potential climate change patterns of drier and warmer seasons, water availability and its quality may become stressed and it is recommended that the park monitor surface and groundwater availability on a long term basis. MORR's stream surface water chemistry varied depending on the stream sampled. Several water quality parameters, such as dissolved oxygen, temperature, pH, chloride, total dissolved solids and acid neutralizing capacity, were compliant when compared to New Jersey's water quality standards or recommended thresholds based upon peer-reviewed research and thus rated *Resource is in Good Condition*. Nutrient parameters such as total nitrogen, total phosphorus and NO<sub>2</sub>+NO<sub>3</sub> exceeded EPA criteria for several streams in the park and therefore were rated *Warrants Significant Concern*. Additionally, *E.coli* levels were a *Warrants Significant Concern* for Primrose Brook.



### ***Invasive Exotic Plants and Animals***

Non-native vegetation has been established in the park as a result of past and present disturbances and is threatening the ecological integrity of MORR's forest and aquatic habitats. MORR's mature, successional and overall forests rated *Warrants Significant Concern*. The most frequent invasive exotic species inventoried in MORR's mature forest plots were Japanese barberry (*Berberis thunbergii*), Japanese stiltgrass (*Microstegium vimineum*), oriental bittersweet (*Celastrus orbiculata*), narrowleaf bittercress (*Cardamine impatiens*) and wineberry (*Rubus phoenicolasius*). The documentation of invasive, emergent vegetation species in and near waterbodies within HUC 8 and HUC 14 boundaries of MORR resulted in a condition assessment of *Warrants Significant Concern* for HUC 8 areas and *Resource is in Good Condition* for HUC 14 boundaries.

Invasive exotic animals and diseases in forest and aquatic habitats are present in MORR. Approximately 60% of forest plots were rated *Resource is in Good Condition* for the tree condition and forest pest measure which included measuring foliage problems and presence of pests. The remaining forest plots were rated *Warrants Moderate Concern* in MORR under NETN rating methods. Although many of the forest plots in MORR were considered *Resource is in Good Condition*, the impact of exotic invasive animals and disease had been observed in several plots in the park. Plots were rated *Warrants Moderate Concern* due to elevated insect herbivory, leaf loss or beech bark disease. Both HUC 8 and HUC 14 boundaries rated *Warrants Significant Concern* for aquatic invasive exotic animals, which pose great risk to the disruption of the brook trout population in the park's streams.

### ***Forest Vegetation***

MORR contains a forested landscape which is vital to the cultural significance of the park and serves as important biological habitat. Forest health metrics in MORR were rated as *Resource is in Good Condition*, *Warrants Moderate Concern* or *Warrants Significant Concern* based on NETN established ratings. Anthropogenic land use, forest patch size and structural stage distribution rated *Resource is in Good Condition* while coarse woody debris and tree growth/mortality rated *Warrants Moderate Concern* for forest plots sampled in MORR. Snag abundance was the only metric rated *Warrants Significant Concern*.

### ***White-tailed Deer Herbivory***

Elevated deer populations have led to overbrowsing of native vegetation in MORR's landscape. Underwood (2007) found deer populations in Jockey Hollow in 1998 to be 57.5 deer/mi<sup>2</sup> (22 deer/km<sup>2</sup>). Over 80% of the forest monitoring plots in MORR were categorized as *Warrants Significant Concern* for tree regeneration measures, with only two of 28 plots rating *Resource is in Good Condition*. Additionally, the *deer browse index* rated MORR's mature, successional and overall forest as being *high*. This index indicates that browse evidence was common, browse preferred species were rare to absent and non-preferred or browse resistant vegetation was limited in height by browsing. Comparison of tree density by size class across four NETN parks showed MORR to have a relatively low density of trees. The lack of regeneration in MORR may be due to a combination of complex environmental variables; however, it is likely that the low density of saplings and young trees in MORR is the result of long-term deer browse pressure. Deer browse

pressure may be suppressing forest regeneration and competition from invasive exotic species may also be limiting tree regeneration in conjunction with the deer browse impacts.

### ***Fish Community***

The New Jersey Fish Index of Biotic Integrity (FIBI) for Northern New Jersey streams used 10 metrics (Table 4.20) which were created and scored based on measures of deviation from regional reference condition streams. Each condition metric scored either a 1 (*significantly*), 3 (*moderately*) or 5 (*none to slight*) based on fish assemblage deviation from reference conditions, with the higher number representing closer reference conditions. We then used the modified Karr *et al.* (1986) metric scores and created *Resource is in Good Condition*, *Warrants Moderate Concern* or *Warrants Significant Concern* categories and used fish data from Mather *et al.* (2003). Because metric 10 (Table 4.20) was not measured in the Mather *et al.* 2003 data, theoretic scores of 1, 3 or 5 were applied to metric 10. This was performed in order to calculate a final IBI score which included a potential score range, and at times, two possible condition categories being assigned to the stream. Jersey Brook scored *Warrants Significant Concern*-*Warrants Moderate Concern*, East Primrose Brook and Primrose Brook both scored *Warrants Moderate Concern*-*Resource is in Good Condition*, West Primrose Brook scored *Warrants Moderate Concern*, and Indian Grove Brook and Passaic River both scored *Resource is in Good Condition*. Of the individual metrics calculated for the streams, MORR's streams scored a 3 (*moderately*) or a 5 (*slight to none*) for the majority of the nine metrics. However, certain metrics for MORR's streams scored 1 (*significantly*), indicating a potential problem in the water quality or habitat of the streams in relation to reference stream conditions.

The Conservation Success Index (CSI) was also used to assess the fish community. CSI thresholds rated from 1 (representing the poorest rating) to 5 (represent the best rating) for 20 indicators, with the established thresholds based on scientific research (Williams *et al.* 2007). Eastern brook trout are the only native trout to the majority of the eastern U.S. and serve as indicators of watershed health. If MORR is being affected by land use changes, changes in water quantity /quality or runoff from roads, then continuous, standardized monitoring the fish community in these streams may be a useful indicator of habitat degradation. Using CSI data, many subwatersheds surrounding MORR were mapped as having extirpated populations of Eastern brook trout, except for the Loantaka Brook subwatershed. This subwatershed includes Primrose Brook, which during a survey by Mele and Mele (1983) contained more than 50% of the brook trout observed in MORR streams. Loantaka Brook subwatershed scored a 48 for the final CSI score, which was categorized as *Warrants Significant Concern*. Low scores (rated 1 or 2) for the Loantaka Brook subwatershed were for indicators such as land stewardship, land conversion, watershed connectivity, watershed conditions, introduced species, population extent and life history diversity.

### ***Bird Community***

Breeding birds are excellent indicators of biotic integrity and ecosystem health because they are visible and vocal, easy to monitor, and individual species have specific habitat requirements and levels of sensitivity making them useful for tracking changes that may be impacting other species that are harder to measure. There is an available assessment for birds developed by the NETN based on guilds for forested and grassland habitats. For the forest avian ecological integrity assessment,

compositional metrics were rated *Resource is in Good Condition* while structural and functional metrics were dominated by *Warrants Moderate Concern* or *Warrants Significant Concern* ratings. The park-wide forest avian ecological integrity assessment for all years combined at MORR resulted in five categories ranked as *Resource is in Good Condition*, six ranked as *Warrants Moderate Concern*, and two ranked as *Warrants Significant Concern*. Overall, these rankings are very good given the urban landscape that surrounds MORR. MORR provides important forest habitat for both Neotropical migrants and also resident species. Management should focus on maintaining the health of the forest and ensuring an understory for mid-canopy nesters such as Wood Thrush. This should include management of nonnative invasive plant species that prevent native tree regeneration and maintaining deer numbers at levels where effects of deer on regeneration are minimal.

### ***Amphibians and Reptiles***

Historical documentation indicates that 34 species of amphibians and reptiles have been observed in MORR and on lands adjacent to MORR (Mele and Mele 1983, New Jersey Audubon Society 2003, NPSpecies 2012). The use of lands by herpetofauna within and near MORR is used by listed species such as the New Jersey listed (as threatened) wood turtle (*Clemmys insculpta*) and the species of special concern eastern box turtle (*Terrapene carolina*). Brotherton *et al.* (2005) determined that 18 species occurring historically at or in the area around MORR appeared to be stable in terms of their population status, and 13 species have declined or have disappeared.

Data used to assess the current condition of the amphibian community was assembled from surveys conducted by Brotherton *et al.* (2005) in MORR. Using these data, the Amphibian Index of Biotic Integrity (AmphIBI) was used as a tool to assess the condition of the amphibian community in MORR. Based on the AmphIBI calculations, the average score for the amphibian community habitats in MORR was 17, which corresponded to the *Warrants Moderate Concern* rating. Sites in MORR that ranked lower in the AmphIBI calculations (*Warrants Moderate Concern*)-Indian Grove Brook Marsh, Lower Primrose Brook Seep, Old Channel Seep and Trail Center Seep-rated lower because of the absence of pond breeding species and spotted or wood frogs at the sites. Sites which rated *Resource is in Good Condition* included Cat Swamp Pond and Cattail Marsh, both of which contained higher abundances of species which are considered sensitive to disturbance and have narrower niches. The aquatic resources in MORR are predominately riparian with limited wetland habitat. Most pond breeding amphibian activity in MORR is located at Cat Swamp Pond. It is important to consider the long-term preservation and connectivity of upland and wetland areas at MORR in order to sustain the current amphibian and reptile populations.

### ***Visitor Usage***

From 1933-2011, MORR has hosted approximately 33,257,818 recreational visitors (NPS Stats 2012). Visitors to MORR may be engaged in many activities during their visit, such as historical education, hiking, jogging, biking, horseback riding, and skiing the trails and roads. NPS Stats (2012) collects visitation data for each NPS park and these data were used to assess visitor activity. Trails and roads used by visitors were mapped in order to spatially assess their locality and possible impact to aquatic habitats and globally rare vegetation communities in MORR. Best professional judgment was used to assess the impacts of visitor use on MORR's natural resources and discuss potential

scenarios of visitor use conflicts in the park. Based on the examination of available data, visitor usage and its impact to MORR's natural resources was assessed as *Warrants Moderate Concern*. Future quantitative assessments of visitor usage within the park by NPS will be beneficial in assessing road and trail conditions, air quality from vehicular use and wildlife impacts.

### ***Landscape Dynamics***

Evaluating landscape patterns around the park is crucial to assessing natural resource conditions within MORR. Housing development has *increased* around MORR from 1970 to 2010 and this area will potentially continue to experience housing expansion. Based on 2006 land cover remote sensing data, MORR is generally surrounded by deciduous forest and development. From 1988-2002, urban land within MORR and within 5 km (3 mi) of the boundary of MORR *increased* by 11% (Wang and Nugranad-Marzilli 2009). This increase in urban land cover has resulted from development within Morristown near the Washington's Headquarters and Fort Nonsense units and from housing construction surrounding the park. Two forest types have *decreased* within the adjacent 5 km (3 mi) buffer around MORR, an expected result due to urban development in the area. Within MORR's boundaries, sources of impervious surface include small parking lots and roads within the park. Overall, the amount of impervious surface within MORR is less than 10% highly developed impervious cover, rating the park *Resource is in Good Condition*. Connectivity to key areas outside of MORR boundaries is vital to safeguarding movement of animals (e.g., amphibians) and preserving habitat integrity, such as forest health. When analyzed at > 500 m (1,640 ft) from major roads only, the two large patch areas in MORR's Jockey Hollow Encampment Area were approximately 9.3 km<sup>2</sup> and 8.9 km<sup>2</sup>. The patch areas decreased to 0.35 km<sup>2</sup> and 0.40 km<sup>2</sup> when analyzed at the buffered scale of >500 m (1640 ft) from all roads. The presence of 'smaller roads', such as the roads in MORR, have decreased these patch areas and have the capacity to affect activities of biota, such as amphibian and reptile migration to and from waterbodies. Additionally, the impact of roads on ecological communities has been extensively studied for a variety of species. Based on a 100 m buffered spatial analysis of roads in the park, MORR was categorized as *Warrants Moderate Concern*. This buffer distance extends into sections of MORR's forests, wetlands, and streams within the park, potentially affecting species distribution or ecosystem function.

### ***Soundscapes***

The natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wildlife" protected by the Organic Act of 1916. NPS Management Policies (§ 4.9) require the NPS to preserve the park's natural soundscape and restore the degraded soundscape to the natural condition wherever possible. Additionally, NPS is required to prevent or minimize degradation of the natural soundscape from noise (i.e., inappropriate/undesirable human-caused sound). Noises which impair the soundscape in MORR can originate from a number of sources, including various motorized equipment, aircrafts, adjacent land uses, general park operations (e.g., mowing), increased visitor use and highway traffic. One of the major issues identified in MORR is the protection of park lands from sound pollution, especially sound that is generated by Interstate 287 near the Washington's Headquarters Unit. The highway noise makes outdoor interpretive talks difficult for park staff. Additionally, natural soundscape alterations may be especially significant for amphibian, reptile, bird and bat populations in MORR. Using acoustic data collected at 244 sites and 109 spatial

explanatory layers, the NPS has developed a geospatial sound model which predicts natural and existing sound levels with 270 meter resolution (Mennitt *et al.* 2013). In addition to predicting these two ambient sound levels, the model also calculates the difference between the two metrics, providing a measure of impact to the natural acoustic environment from anthropogenic sources. The resulting metric (mean L<sub>50</sub> dBA impact) indicates how much anthropogenic noise raises the existing sound pressure levels in a given location. The mean L<sub>50</sub> impact measure for MORR was calculated at 6.3 dBA, categorizing the park as *Warrants Significant Concern*.

### ***Lightscares-Dark Night Sky***

Natural lightscares are critical for nighttime scenery, such as viewing a starry sky, but are also critical for maintaining nocturnal habitat. Adding artificial light to habitats may result in substantial impact to certain species (Rich and Longcore 2006). Additionally, the NPS considers night skies an important part of visibility, which is considered an air quality related value under the 1977 Clean Air Act Amendments. Lightscares can be cultural as well and they may be integral to the historical content of the park, such as in MORR. MORR is categorized as a Level 1 park by the NPS which includes parks where the nighttime photic environment has a greater influence on natural resources and ecological systems. These parks often have higher quality night sky conditions and therefore tend to be more sensitive to the effects of light pollution.

The Anthropogenic Light Ratio (ALR) was calculated in order to assess the condition of the dark night sky in MORR. For Level 1 parks, the threshold separating *Resource is in Good Condition* from *Warrants Significant Concern* is set at an ALR of 0.33 or 1/3<sup>rd</sup> brighter than natural conditions. This value corresponds with the point at which portions of the sky typically become bright enough that humans are unable to fully adapt to the dark when looking toward them. This attribute of human ‘night vision’ is likely similar in other mammals, although certain mammals may be more or less sensitive. The threshold separating *Warrants Moderate Condition* with *Warrants Significant Condition* is set at an ALR of 2.0. This value corresponds with a point at which portions of the sky typically cast shadows at which the Milky Way can no longer be seen in its entirety, at which Zodiacal lights is seldom seen and full dark adaptation is not possible. The ground based ALR in MORR’s Jockey Hollow Unit is 15.00 and is considered *Warrants Significant Concern*. The sky glow produced by the scattering of light from nearby sources around MORR does degrade the view of the night sky for the Jockey Hollow Unit. The trend for ALR was categorized as *unchanging*. The trend was based on the stable population growth rate of towns near MORR.



## **Acknowledgments**

The authors thank personnel of Morristown National Historical Park for discussions and providing access to natural resource reports and documents. Biologists and technicians of the Northeast Temperate Network (NETN) of the National Park Service kindly provided information and data for inclusion in this assessment. A special thank you is extended to reviewers who reviewed and graciously offered constructive comments on the draft document. This study was funded by the National Park Service and administered by The Pennsylvania State University at University Park, PA. List of Terms





# Chapter 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, however, the breadth of natural resources and number/type of indicators evaluated will vary by park
- employ hierarchical indicator frameworks which 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
- identify or develop logical reference condition data against. 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-on response (e.g., ecological thresholds or management “triggers”)
- emphasize spatial evaluation of conditions and GIS (map) products.. As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products
- summarize key findings by park areas. 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
- follow national NRCA guidelines and standards for study design and reporting products

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe 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: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

#### *Important NRCA Success Factors ...*

*Obtaining good input from park and other NPS subjective 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*

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. 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 bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort

to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning<sup>7</sup> and help parks report to government accountability measures. NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project. 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.

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve 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 our present data and knowledge bases across these varied study components.

#### *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)*

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 credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: [http://www.nature.nps.gov/water/NRCondition\\_Assessment\\_Program/Index.cfm](http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm)



## Chapter 2. Introduction and Resource Setting

### Introduction

#### ***History & Enabling Legislation***

Morristown National Historical Park, the first national historical park in the national park system, was established on March 2, 1933 under Public Law 72-409, 47 Stat. 1421. The park's mission includes preserving the lands and features associated with the winter encampments of the Continental Army during the War for Independence, specifically commemorating the site General George Washington used as a winter encampment in 1779-1780. Morristown National Historical Park initially included 1,051.4 acres of authorized land. Acquisition of land by donation, purchase or otherwise followed, with the park containing 1,704.7 NPS fee acres, 1 less than fee acres, and 5 private acres by September 2011 (NPS Stats 2012).

#### Park Purpose

Park purpose statements are based on legislation and legislative history, NPS policies and other special designations. Purpose statements provide the foundation for park use and management. Morristown National Historical Park's (abbreviated as MORR in this report) purpose has been described as follows:

*Morristown National Historical Park preserves, protects and maintains the landscapes, structures, features, archeological resources, and collections of the Continental Army winter encampments, the headquarters of General George Washington, and related Revolutionary War sites at Morristown for the benefit and inspiration of the public. The park interprets the history and subsequent commemoration of these encampments and the extraordinary fortitude of the officers and enlisted men under Washington's leadership (from NPS 2003a).*

#### Park Significance

The significance statement for MORR captures the essence of the park's importance to the United States' natural and cultural heritage. Morristown National Historical Park's significance has been described as follows:

*Attracted by Morristown's strategic location, including defensible terrain, important communication routes, access to critical resources, and a supportive community, General Washington chose it as the site for the main Continental Army encampment during two winters of the War of Independence. Morristown National Historical Park encompasses most of the ground occupied by the army during the vast 1779-80 encampment, as well as smaller encampments in subsequent winters, and the site of the fortification from the 1777 encampment.*

*The winter of 1779-80, the most severe of the century, brought great suffering to the Continental Army at Morristown. Despite this and many other adversities, General Washington demonstrated his leadership by holding the army together as an effective fighting force. The Ford Mansion, where Washington made his headquarters, is an important feature of the park and recalls civilian contributions to the winning of independence.*

*Morristown's resources of the War for Independence were first preserved by the Washington Association of New Jersey, an important early success of the nation's historic preservation movement. Later public and private efforts, sustained by federal action following the designation of Morristown National Historical Park as the first national historical park, illustrate that the park served as a model for historical parks and presents a turning point for the National Park Service's expansion into public history, living history, and historic preservation (from NPS 2003a).*



*George Washington's Headquarters, Morristown National Historical Park. Photo: NPS*

### **Geographic Setting**

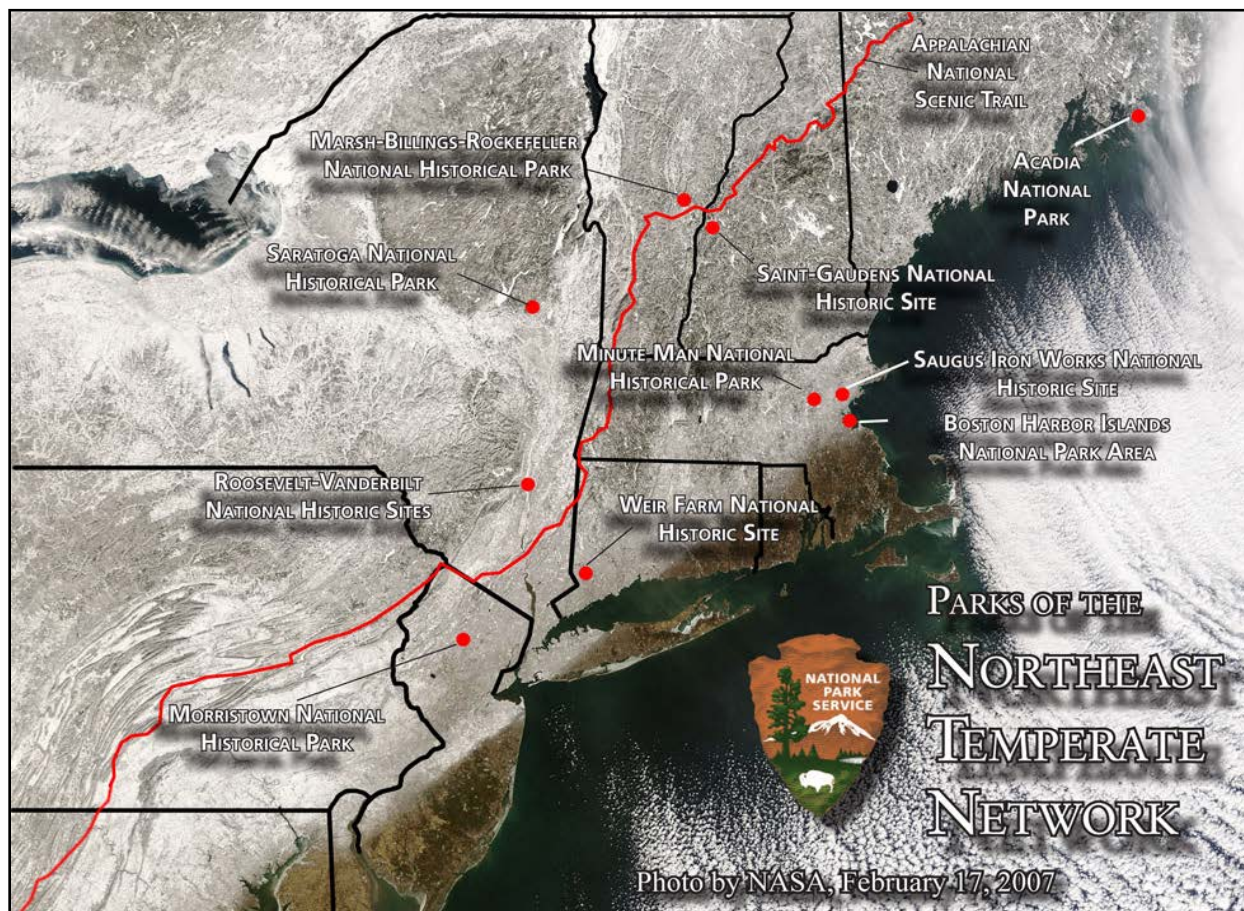
Morristown National Historical Park (MORR) is part of the NPS Northeast Temperate Network (NETN) which is composed of 13 National Park units in the northeastern U.S. (Figure 2.1). The 1,710.7 acre (692.3 ha) park is approximately 30 miles (48 km) west of New York City and situated mostly in Morris County, New Jersey near the town of Morristown, with a small portion located in Somerset County (Figure 2.2) (NPS Stats 2012). MORR has portions in both the Northeastern Highlands and the Northern Piedmont ecoregions and remains one of the few large, undeveloped lands in northern New Jersey. The park is distributed across four geographically separate units which are historically connected to the Revolutionary War: *Washington's Headquarters* (approximately 10 acres [4ha]), *Fort Mifflin Unit* (approximately 35 acres [14 ha]), *New Jersey Brigade Encampment Area* (approximately 321 acres [129 ha]) and *Jockey Hollow Encampment Area* (over 1,300 acres [526 ha]). The Washington's Headquarters unit, Fort Mifflin unit and Jockey Hollow Encampment Area are located in Morris County, NJ, while the New Jersey Brigade Encampment Area has portions in both Morris and Somerset County. MORR's interior landscape consists of forest blocks that are interrupted by roads, trails, and fields. The fields near developed areas and historic sites are mowed annually while fields in remote areas of the park are mowed every 2 to 4 years in order to prevent



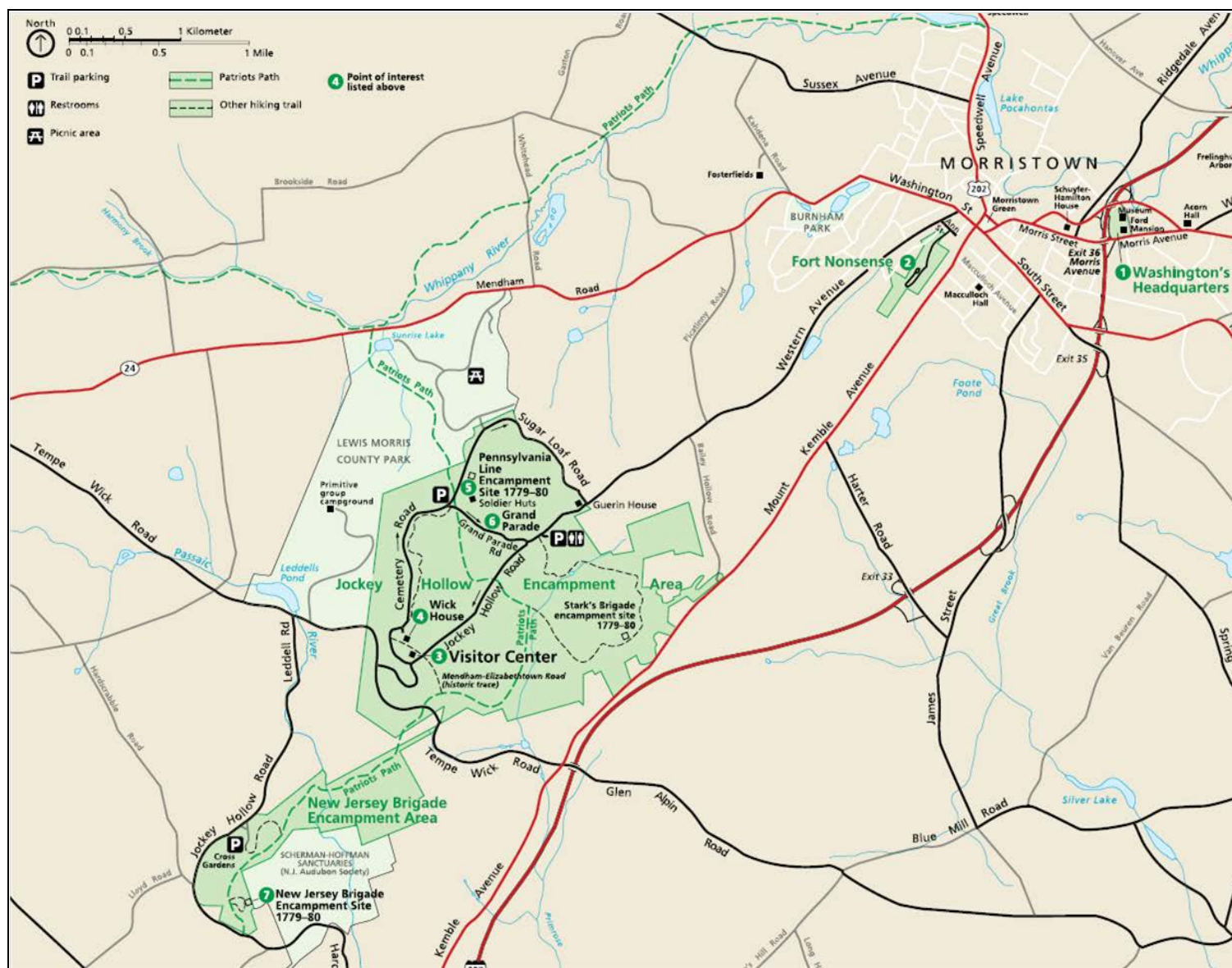
woody plant invasion. The surrounding landscape of these units has been threatened in recent years by residential development and the existence of I-287 along the western boundary of the park. The preservation of the natural environment, viewshed and historic structures within all units composing MORR is vital in order to sustain the park's culturally driven purpose.

### **Visitation Statistics**

From 1933-2011 MORR has hosted over 33 million recreational visitors, averaging 457,800 recreational visitors per year, with 2011 recording 222,395 recreational visitors (NPS Stats 2012). The park is open year-round, with MORR's highest visitation months generally from August through October (NPS Stats 2012). Recreational visitors are primarily from the local area, arriving by car or bicycle (NPS 2003a). Activities for visitors include visiting historical exhibits and participating in recreational activities such as hiking, jogging, picnicking, bicycling, riding horses and skiing the trails. See "Visitor Usage" Section within the report for further assessment of visitation characteristics at MORR.



**Figure 2.1.** Locations of thirteen National Park units situated in the National Park Service Northeast Temperate Network (NETN). Roosevelt-Vanderbilt National Historic Sites consists of Eleanor Roosevelt, Home of Franklin D. Roosevelt, and Vanderbilt Mansion National Historic Sites. Figure from the National Park Service (<http://science.nature.nps.gov/im/units/netn/images/NETN%20map.jpg>).



**Figure 2.2.** Morristown National Historical Park (MORR) located in New Jersey, USA. Figure from the National Park Service ([www.nps.gov/morr/](http://www.nps.gov/morr/)).



## Natural Resources

### ***Ecological Units and Watersheds***

#### Climate

Both topography and proximity to the Atlantic Ocean influence the overall climate characteristics of MORR. MORR averages 26-28 °F (-3 — -2 °C) in January and 72-74 °F (22-23 °C) in July, making MORR one of the warmest NETN parks (NPS 2003a, Davey *et al.* 2006). Mean annual precipitation from 1961-1990 ranged from 1,200-1,400 mm/yr (47-55 in/yr), and mean annual snowfall ranged from 601-800 mm/yr (24-31 in/yr) (Davey *et al.* 2006). These precipitation values categorize MORR one of the wettest parks in the NETN (Figure 2.3).

#### Ecoregions

Ecoregions represent areas of general similarity in the type, quality and quantity of environmental resources. These general regions are intended to provide a spatial framework for ecosystem assessment, research, inventory, monitoring and management for different types of resources within similar geographical areas. The approach used to compile these regions is based on the premise that ecological regions can be identified through the analysis of patterns of geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology. MORR is situated on the level III ecoregion border between the *Northeastern Highlands* and the *Northern Piedmont* ecoregions and the level IV ecoregions *Reading Prong* and *Triassic Lowlands* as derived by Omernik (1995, 2004). The Northeastern Highlands are characterized by nutrient poor soils and the presence of northern hardwood and spruce fir forests. Land-surface in the region grades from low mountains in the southwest and central portions to open high hills in the northeast with many of the numerous glacial lakes in this region having been acidified by sulfur deposition. The Northern Piedmont is a transitional region of low rounded hills, irregular plains and open valleys. It is underlain by a mix of metamorphic, igneous, and sedimentary rocks. Natural vegetation here is predominantly Appalachian oak forest.

#### Watersheds

MORR is situated within the Hackensack-Passaic HUC 8 watershed (Figure 2.4). This park's legislative boundary crosses five HUC 14 level subwatersheds: *Primrose* (3354 acres/1357 ha), *Great Brook-above Green Village Road* (5071 acres/2052 ha), *Passaic River Upper-Osborn Mills* (6486 acres/2624 ha), *Whippany River-Washington Valley Road to 74d 33m* (4075 acres/1649 ha) and *Whippany River-Malapardis to Lake Pocahontas* (4305 acres/1742 ha) (Figure 2.4). All HUC 14 subwatersheds for MORR are within the NJDEP Water Management Area 06, an area with extensive suburban development and reliance upon ground water sources for water supplies. Urban runoff has resulted in siltation, higher stream temperatures and losses of riparian vegetation for this water management area (NJDEP, [www.nj.gov/dep/watershedmgt](http://www.nj.gov/dep/watershedmgt)). MORR's undeveloped environment protects major tributaries that flow through the park into the Great Swamp National Wildlife Refuge, located south of MORR in the Black Brook subwatershed.

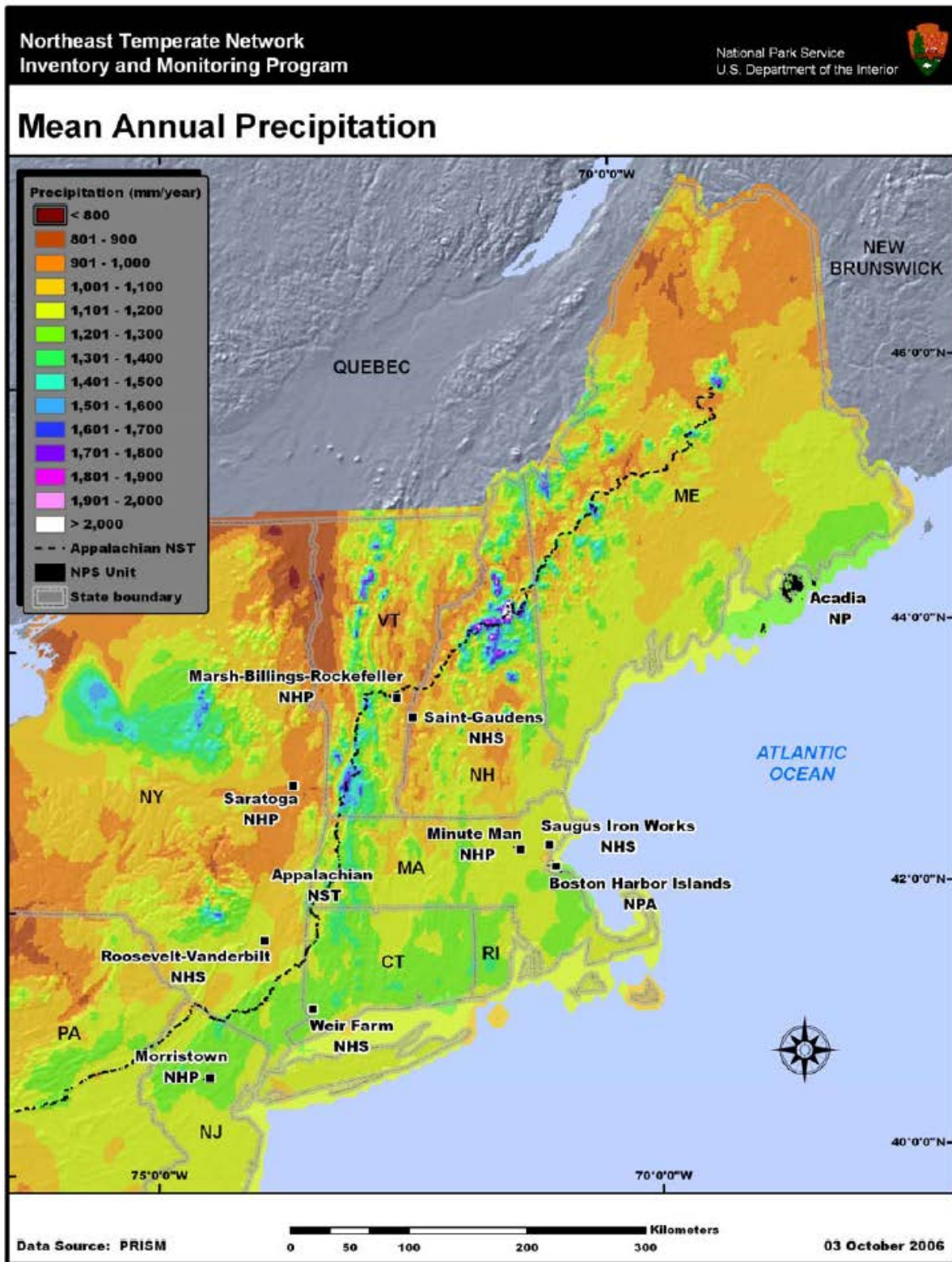
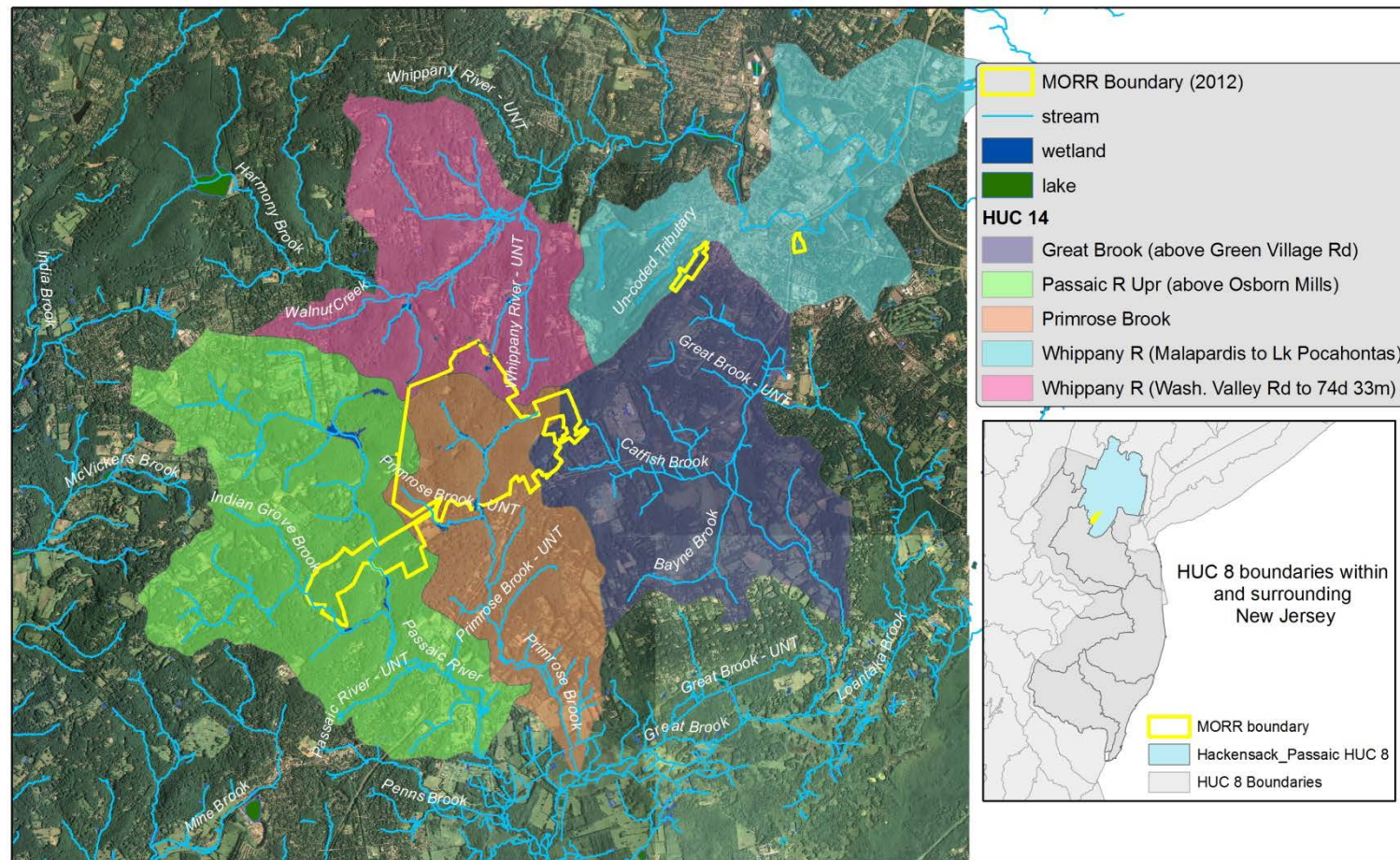


Figure 2.3. Mean annual precipitation from 1961-1990 for NETN. Figure from Davey *et al.*(2006).



# Morristown National Historical Park

Watersheds and streams



GIS Layers Data Source: Boundaries,  
(NETN and MORR park office);  
HUC14 subwatersheds (NJDEP); HUC 8 boundary (USGS)  
NAD 1983



**Figure 2.4.** Hydrological features near MORR.

## ***Resource Descriptions***

### Geology and Topography

MORR is positioned between the Highland and Piedmont physiographic provinces. The Highland hills are comprised of hard crystalline rock (mostly gneiss) and contain deposits of iron, graphite and mica. In the vicinity of the park is an extension of hills known as the Trowbridge Range, part of the Reading Prong. The Piedmont portion consists of a down sloping on the east side of the uplands, which meets coastal-plain sediments. Generally, MORR consists of hilly terrain with plains to the east and mountains to the north and the west (Figure 2.5). Marking the junction between the hills and plains is the Ramapo Fault, which runs southwest-northeast. The hills of MORR are approximately 580-700 ft (175 to 215 m) in elevation, with the lowest elevations of the park located along Indian Grove Brook and Passaic River (360 ft or 110 m in elevation). To date, oil, gas and mineral industries have made no impact on park resources, with the exception of an old abandoned mica mine in the Jockey Hollow Unit (NPS 2003a). Steep slopes within this Highlands Region play an important ecological, recreational, scenic, and functional role, especially in MORR. Steep slopes and rocky ridgelines provide specialized habitats that are home to rare plant and animal species. Within MORR, areas of steep slope provide popular recreational opportunities and provide scenic views and vistas, which contribute to the rural character of the Highlands Region and help to define the landscape.

### Soil

The park's soils and overlaying topology are moderately prone to erosion (NPS 2003a). Much of the park contains gravelly/rocky soil formations on the uplands areas of bedrock and glacial till. Although the Parker soil formations in MORR were not suitable for farming, they were historically utilized for wood and hunting territory (NPS 2003a). The Riverhead soils in MORR would have been suitable for agriculture. Major soil associations for MORR include:

- *Edneyville-Parker-Meckesville*: formed in the western part of the New Jersey Brigade Unit; moderately well-drained to excessively well-drained; gently sloping to steep; gravelly to rocky soil.
- *Edneyville-Parker-Califon*: formed in the central and northern part of the Jockey Hollow Unit; excessively drained to well drained; steep to very steep; gravelly and sandy loams.
- *Parker-Edneyville*: formed in the Jockey Hollow Unit, the eastern portion of New Jersey Brigade Unit and western portion of Fort Nonsense Unit; excessively drained and well drained; steep to very steep; gravelly and sandy loam.
- *Riverhead-Urban*: formed in Washington's Headquarters Unit and eastern part of the Fort Nonsense Unit; well-drained to poorly drained; nearly level to strong slope; gravelly and sandy loams.

## Vegetation

Approximately 500 vascular plant species are *present* or *probably present* in MORR (NPSpecies 2012). MORR's vegetative landscape has changed considerably based on early historical accounts for purposes of battle encampments, settlements and agricultural activities. The landscape has been altered since the early 18<sup>th</sup> century with clearing of forests by the Continental Army for huts and fuel, with fields and pastures being established in the late 1800's for agricultural activities. After the establishment of the park in 1933, brush clearing, planting of black locust trees and abandonment of fields transpired. Today, MORR consists of a mixture of forests, fields, orchards, and landscaped grounds. Forests of MORR contain native hardwood and introduced species common in the Ridge-Valley and Piedmont regions of New Jersey. Based on NPSpecies data, 14 state endangered plants are in MORR, but many of these sightings are older, ornamental plants, or not verified by park staff. However, this number is significantly less than 14 plants, as only one of these plant species (*Juglans cinerea*) has been verified in the park (NPSpecies 2012, ONLM 2001, per communication R. Masson). Historically, chestnut blight eliminated the chestnut tree in the early 20<sup>th</sup> century in MORR while invasive vegetation establishment, white-tailed deer herbivory and pests and diseases continue to threaten the integrity of MORR's forests.

Based on vegetation mapping by Sneddon *et al.* (2008), MORR contains 14 vegetation associations, 11 of which are forested (Figure 2.6). The most common forest types within the park are the Northern Piedmont Mesic Oak-Beech Forest and Successional Tuliptree Forest which cover 81.6% of the park (Sneddon *et al.* 2008). The upland forests that characterize the park include: two American beech (*Fagus grandifolia*) associations, one tuliptree (*Liriodendron tulipifera*) association, two different oak (*Quercus* spp.) associations, one modified successional forest association, one black locust (*Robinia pseudoacacia*) forest association, one upland - wetland transitional forest, and a forest formerly characterized by eastern hemlock (*Tsuga canadensis*) that is now dominated by oaks and hardwoods. Wetland forests include two red maple (*Acer rubrum*) swamp associations. Three herbaceous vegetation associations exist in MORR and are comprised of upland herb-dominated areas consisting primarily of field vegetation and wetland herbaceous associations including a skunk cabbage (*Symplocarpus foetidus*)-dominated community and smartweed (*Polygonum* spp.)-dominated impoundment. The composition of the forest understory has changed over time due to the spread of invasive and exotic plant species. Invasive exotic plants are abundant in the forest understory in all parts of MORR, with the most common nonnative invasive species being Siebold's viburnum (*Viburnum sieboldii*), wire grass (*Microstegium vimineum*), Japanese barberry (*Berberis thunbergii*) and oriental bittersweet vine (*Celastrus orbiculus*) (Miller *et al.* 2010). A globally rare vegetation association, Montane Basic Seepage Swamp, is present in Jockey Hollow.

The Jockey Hollow and New Jersey Brigade Encampment units contain 15 maintained fields, totaling over 120 acres (48 ha) of grasses and herbaceous and woody plants which serve as habitat for several birds, insects and mammals (NPS 2003a). These fields are remnants from agricultural activities prior to 1933 and are mowed to retain their historic appearance. Additionally, landscaped grounds containing trees, shrubs and lawns are common in all park units, especially at Wick Farm, Cross Estate at Washington's Headquarters and Fort Nonsense. Wick Farm's orchard contains over 120 trees of heirloom and modern varieties. An herb garden at the farm contains annuals and

perennials from the Colonial period and another cultivated garden at Cross Estate contains ornamental and native plants. Plantings at Washington's Headquarters unit are primarily ornamental in nature.

### Hydrology

MORR's water features were important factors in the selection of Jockey Hollow for the historical winter encampments. MORR is located in the Hackensack-Passaic HUC 8 subbasin (HUC 02030103), with streams and wetlands located in five HUC 14 subwatersheds: *Whippany River (Malapardis to Lake Pocahontas)*, *Great Brook (above Green Village Road)*, *Primrose Brook, Passaic River Upper (above Osborn Mills)* and *Whippany River (Washington Valley Road to 74d 33m)* (Figure 2.4). Most of the water resources in MORR flow through the Jockey Hollow and New Jersey Brigade units. Five significant waterbodies in MORR comprise 3.7 miles (5.9 km) of perennial, intermittent, and ephemeral rivers and streams within the park boundary, with an additional 0.3 miles (0.5 km) adjacent to MORR's boundary (NPS HIS 2012). These five streams include parts of the East and West Branches of Primrose Brook and Jersey Brook in the Jockey Hollow Unit and parts of the Upper Passaic River and Indian Grove Brook flowing through the New Jersey Brigade Unit (Figure 2.4). New Jersey's surface water quality standards (N.J.A.C. 7:9B General Surface Water Quality Standards) designate surface water classifications as FW1 (freshwater 1-not subject to any man-made wastewater discharges) and FW2 waters (freshwater 2-all other freshwaters except Pinelands waters). Streams which flow through MORR are classified under N.J.A.C. 7:9 B as *Freshwater Two-Trout Production, Category One (FW2-TPC1)*. Category One (C1) waters are protected from any measurable change in water quality because of their "exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resources" (N.J.A.C. 7:9B). The Jockey Hollow Unit and the New Jersey Brigade Encampment Area are in the upper reaches of the Great Swamp watershed, a subunit of the Upper Passaic River Basin. Major tributaries stem from MORR toward the Great Swamp National Wildlife Refuge, in addition to important sources of drinking-water supply for the region.

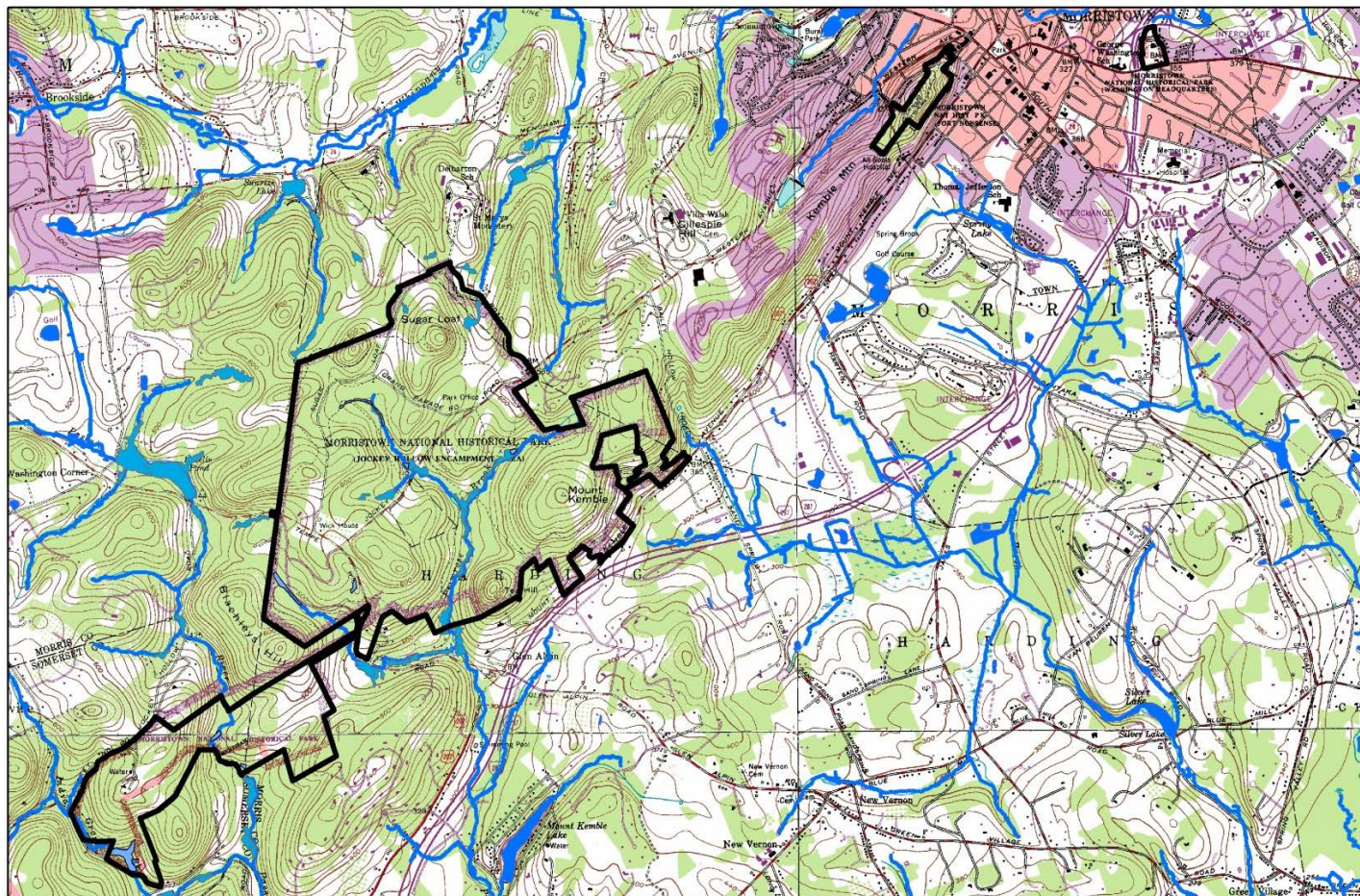
A small artificial pond, Cat Swamp Pond, is a remnant of the water collection and storage system that was built as part of the Morristown Aqueduct Water System. The pond has no natural surface-water outlet but is connected to East Branch Primrose Brook by an overflow outlet pipe. Many small wetland and riparian areas in the park are associated with streams and minor tributaries.

Approximately 22 palustrine wetlands have been inventoried in MORR, although vernal pools and wetlands documented during wetland vegetation mapping may increase this number (Lombard 2004, Sneddon *et al.* 2008). Additionally, an area along the Passaic River lies within a 100-year floodplain. Aquifers provide the primary water supply to many of the communities around the park and MORR's facilities rely on drilled wells for water supply. Precambrian gneiss that underlies the park is fairly impermeable to water but does contain ground water in scattered locations. Both the Jockey Hollow and New Jersey Brigade Units contain numerous natural springs and seeps emanating from a shallow aquifer (Mele and Mele, 1983).

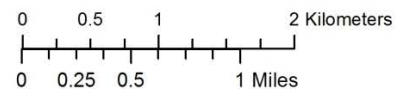


# Morristown National Historical Park

## Topography

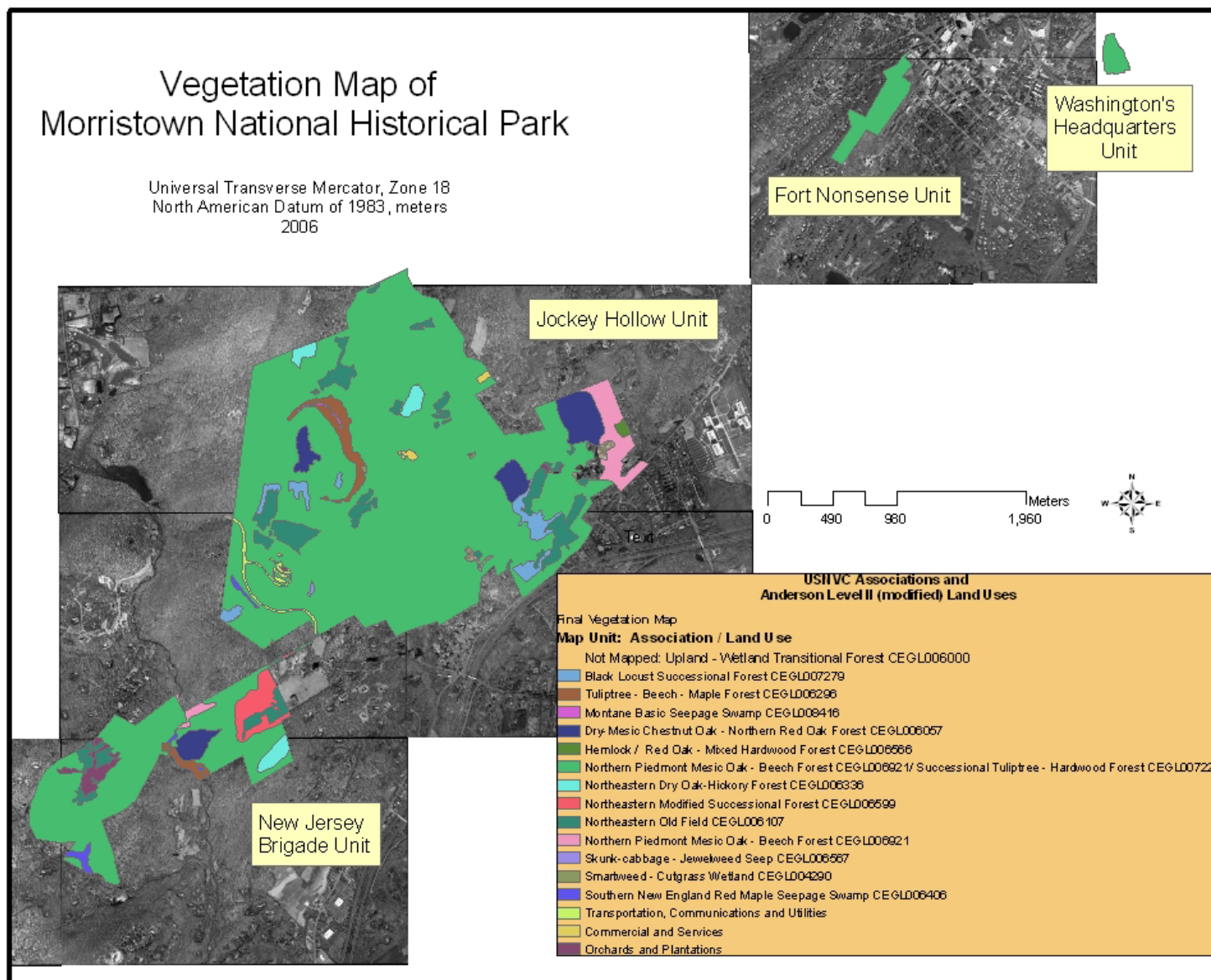


GIS Layers Data Source: Boundaries, water resources, imagery (NETN and MORR park office);



**Figure 2.5.** Topography within and surrounding MORR.





**Figure 2.6.** Vegetation associations and Anderson Level II (modified) land use categories in MORR 2006. Figure from Sneddon et al. 2008.



## Wildlife

Fifteen species of mammals, 135 species of birds, 15 species of fish, 8 species of reptiles, and 14 species of amphibians are listed as *present* or *probably present* in MORR (NPSpecies 2012). Several species identified in MORR have conservation rankings listed, including 29 wildlife species which are considered endangered, threatened or of special concern under NJ State law (Table 2.1). Several other species which have not been documented in MORR but are within habitats surrounding MORR are listed at the Federal and State level as threatened and endangered species, including: bog turtle (*Clemmys muhlenbergii*), Indiana bat (*Myotis sodalis*) and bald eagles (*Haliaeetus leucocephalus*). Some species are problematic to the natural resources in the park, such as white-tailed deer (*Odocoileus virginianus*). White-tailed deer are commonly observed at MORR and have altered the park's vegetation structure, leading to management concerns of the deer population in the park (Gilbert *et al.* 2008, NPS 2003a).

Various wildlife diseases have been of concern for park managers in MORR. West Nile virus (WNV), a mosquito-borne flavivirus that affects both humans and birds, was tested in MORR in 2000 due to dead crows being recovered at Washington's Headquarters. One of the two crows tested positive for WNV. Tick-borne Lyme disease (*Lyme borreliosis*) remains a concern due to the wooded areas, grass fields and the presence of mice and deer in MORR. Studies in MORR in the 1990's detected tick habitat preferences in areas of higher moisture content (i.e., leaf litter) but in lesser abundance along park trails (NPS 2003a). From 2009-2011, bats were inventoried within eight NPS units in the northeastern United States, including MORR, using mist nets, acoustic monitoring equipment, and visual observations (Gates and Johnson 2012). No signs of white-nose syndrome (WNS) were detected on any captured bat in this study. Due to the devastation that WNS may cause to bat populations, the northern myotis (*Myotis septentrionalis*) is currently proposed for listing under the Endangered Species Act.

**Table 2.1.** Listing of species *present* or *probably present* in MORR based on NPSpecies data and their respective New Jersey State Listing of endangered (E), threatened (T), species of special concern (SC), stable or undetermined (NJDEP Division of Fish and Wildlife listed 02/23/12).

Grouping	Scientific Name	Common Name	State Listing	
			breeding	non-breeding
Bird	<i>Botaurus lentiginosus</i>	American Bittern	E	SC
Bird	<i>Tyto alba</i>	Barn Owl, Common Barn-Owl	SC	SC
Bird	<i>Nycticorax nycticorax</i>	Black-crowned Night-Heron	T	SC
Bird	<i>Vireo solitarius</i>	Blue-headed Vireo	SC	stable
Bird	<i>Dolichonyx oryzivorus</i>	Bobolink	T	SC
Bird	<i>Toxostoma rufum</i>	Bown Thrasher, Brown Thrasher	SC	stable
Bird	<i>Buteo platypterus</i>	Broad-winged Hawk	SC	stable
Bird	<i>Wilsonia canadensis</i>	Canada Warbler	SC	stable
Bird	<i>Hirundo pyrrhonota</i>	Cliff Swallow	SC	stable
Bird	<i>Chordeiles minor</i>	Common Nighthawk	SC	SC
Bird	<i>Accipiter cooperii</i>	Cooper's Hawk	SC	stable
Bird	<i>Sturnella magna</i>	Eastern Meadowlark	SC	SC
Bird	<i>Vermivora chrysoptera</i>	Golden-winged Warbler	E	SC
Bird	<i>Ammodramus savannarum</i>	Grasshopper Sparrow	T	SC
Bird	<i>Ardea herodias</i>	Great Blue Heron	SC	stable
Bird	<i>Eremophila alpestris</i>	Horned Lark	T	SC
Bird	<i>Empidonax minimus</i>	Least Flycatcher	SC	stable
Bird	<i>Egretta caerulea</i>	Little Blue Heron	SC	SC
Bird	<i>Vermivora ruficapilla</i>	Nashville Warbler	SC	stable
Bird	<i>Circus cyaneus</i>	Northern Harrier	E	SC
Bird	<i>Parula americana</i>	Northern Parula	SC	stable
Bird	<i>Falco peregrinus</i>	Peregrine Falcon	E	SC
Bird	<i>Podilymbus podiceps</i>	Pied-billed Grebe	E	SC
Bird	<i>Buteo lineatus</i>	Red-shouldered Hawk	E	SC
Bird	<i>Accipiter striatus</i>	Sharp-shinned Hawk	SC	SC
Bird	<i>Caprimulgus vociferus</i>	Whip-poor-will	SC	undetermined
Bird	<i>Icteria virens</i>	Yellow-breasted Chat	SC	stable
Reptile	<i>Terrapene carolina carolina</i>	Eastern Box Turtle		SC
Reptile	<i>Clemmys insculpta</i>	Wood Turtle		T

## ***Resource Issues Overview***

### Examples of past activities that influence current park conditions

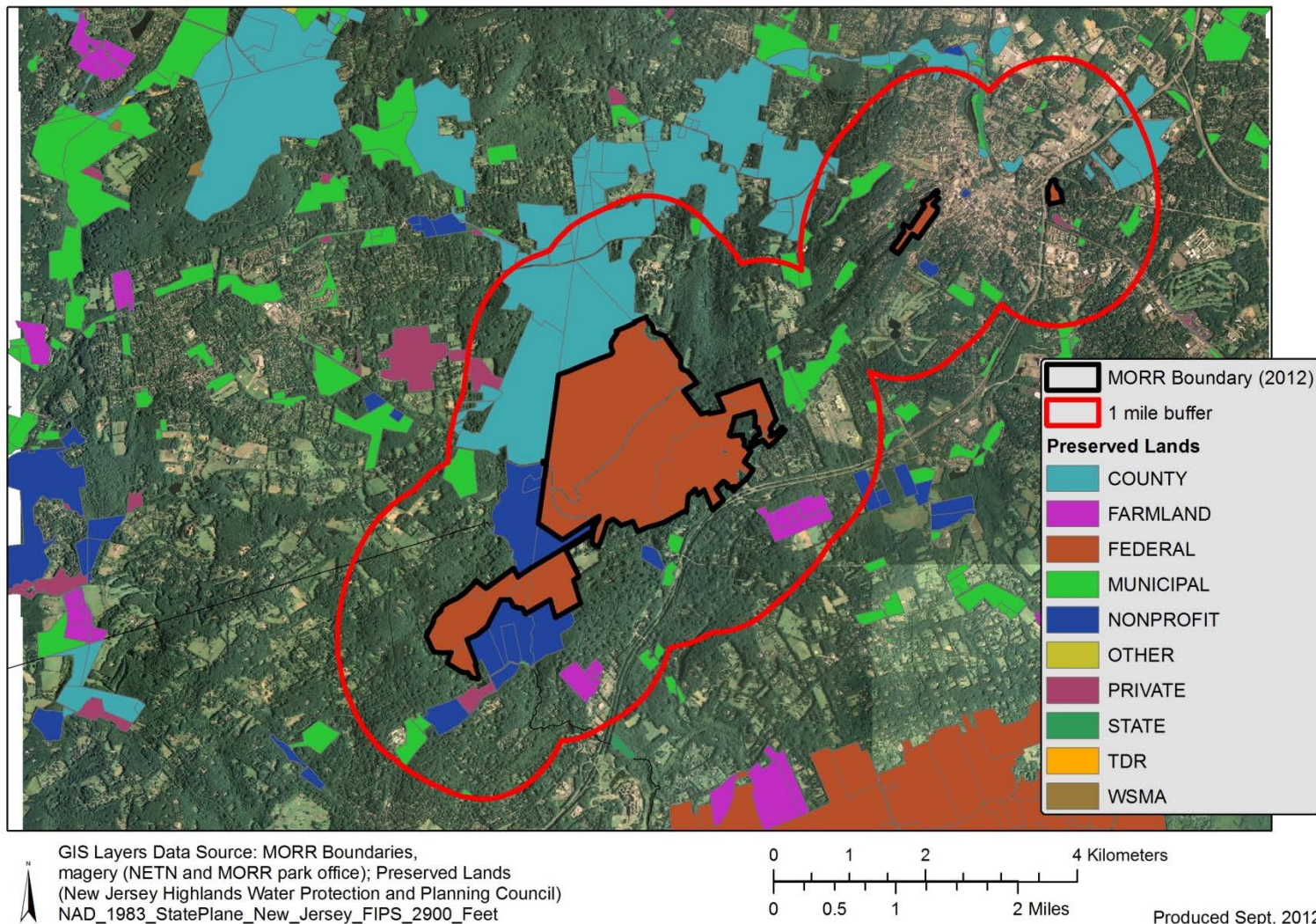
Development trends tend to reflect population and economic conditions in Morris and Somerset counties. In New Jersey, Somerset County is rated in the top three for the fastest growing counties in the state according to 2010 U.S. Census data, while Morris County ranked at number 10 (NJ State Data Center 2012). In 2010, Morris County had an estimated 492,276 people, a 4.7% increase from 2000 to 2010 (U.S. Census Bureau 2010). Somerset County experienced an 8.7% increase in population from 2000 to 2010, with 297,490 people and 323,444 people counted, respectively. In 2010, Morris County experienced an 8% increase in housing units, with 189,842 housing units in 2010 compared to 174,379 units in 2000. Somerset County contained 112,023 housing units in 2000 and grew to 123,127 units by 2010, resulting in a 9% increase (U.S. Census Bureau 2010).

The Washington's Headquarters and a portion of the Fort Nonsense unit are located in the town of Morristown where already densely developed adjacent lands are present. These lands are being redeveloped to even greater densities. Redevelopment examples include a condominium complex, development on land owned by New Jersey Transit and construction of supplemental housing units on a lot that backs up to Fort Nonsense (NPS 2003a). The Jockey Hollow and New Jersey Brigade units have witnessed an increase in development, facilitated by the completion of new highways which have improved access to New York City. The existence of I-287 along MORR's boundary and suburban development on all sides of the park diminish the park's natural and cultural integrity. The development sprawl of single family residential homes, numerous office parks and golf courses adjacent to MORR are changing the land use patterns and character of the natural environment. Additionally, FAA-approved wireless carriers are within the surrounding area, thus increasing pressure on the park to provide sites for future communication towers (NPS 2003a). As this region expands, noise from roadways and aircrafts from Newark International and Morristown airports will continue to infiltrate the park.

### Land Conservation

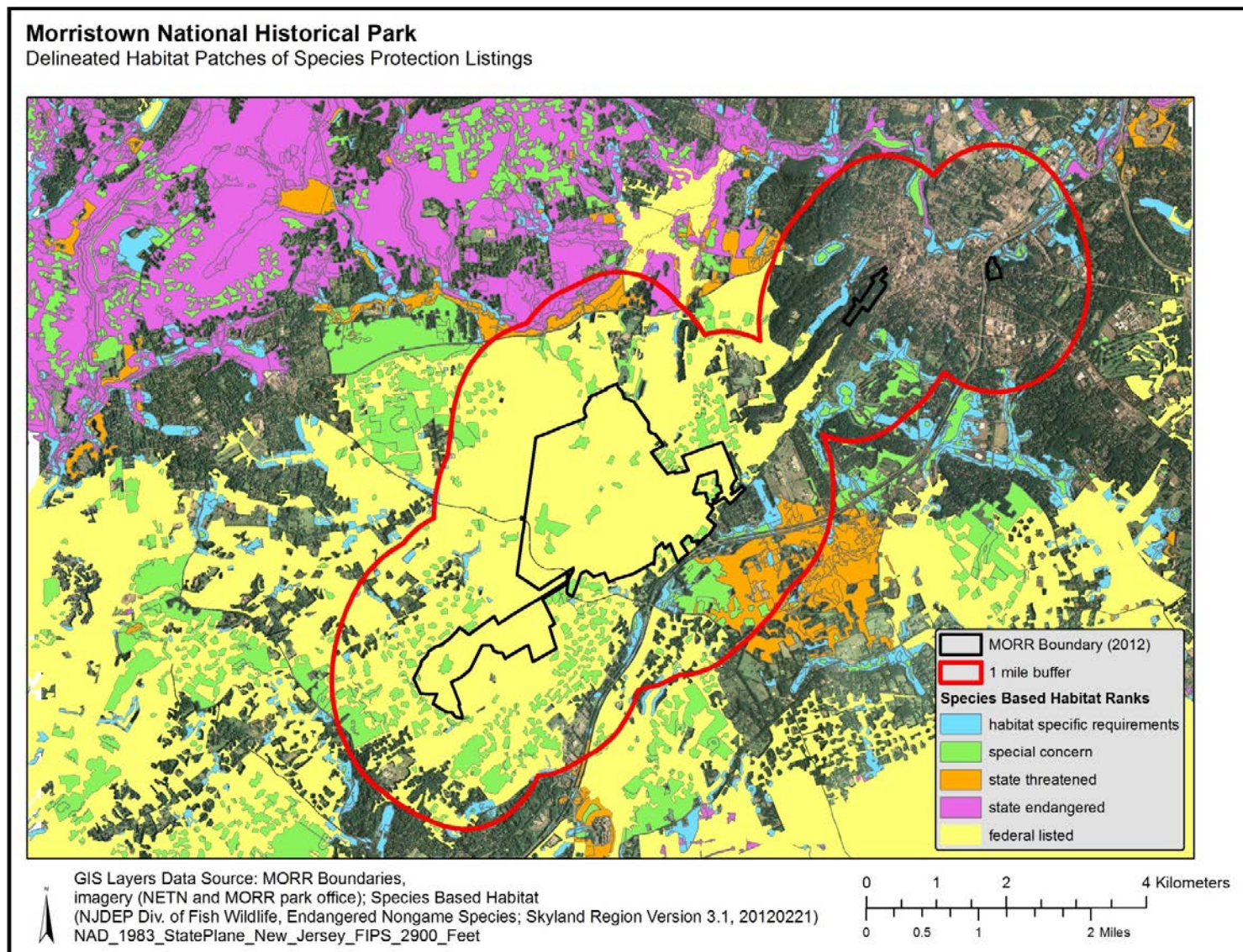
In response to growth in development activities in Morris County, land conservation and preservation efforts have been established near MORR (Figure 2.7). These efforts have been implemented by federal, county, municipal and non-profit entities. The conservation of open space and farmland has resulted in preserving the ecological and agricultural integrity of numerous areas in Morris County and the Highlands Region of New Jersey. The spread of suburbanization in areas of open countryside not currently preserved threatens water supplies and fragments forests, farming areas and wildlife habitats. A lack of interconnected land outside MORR's boundaries to habitats within MORR can affect the integrity of natural resources, especially flora and fauna species deemed threatened, endangered or of special concern (Figure 2.8).

# Morristown National Historical Park Preserved Lands within the NJ Highlands Region



**Figure 2.7.** Ownership of land parcels serving as preserved land around MORR.





**Figure 2.8.** Habitat patches for species listed as species of concern, threatened, endangered, federally listed and species requiring specific habitat conditions.

Examples of threats or stressors identified as being “of concern” in terms of potential risk/harm to important park resources

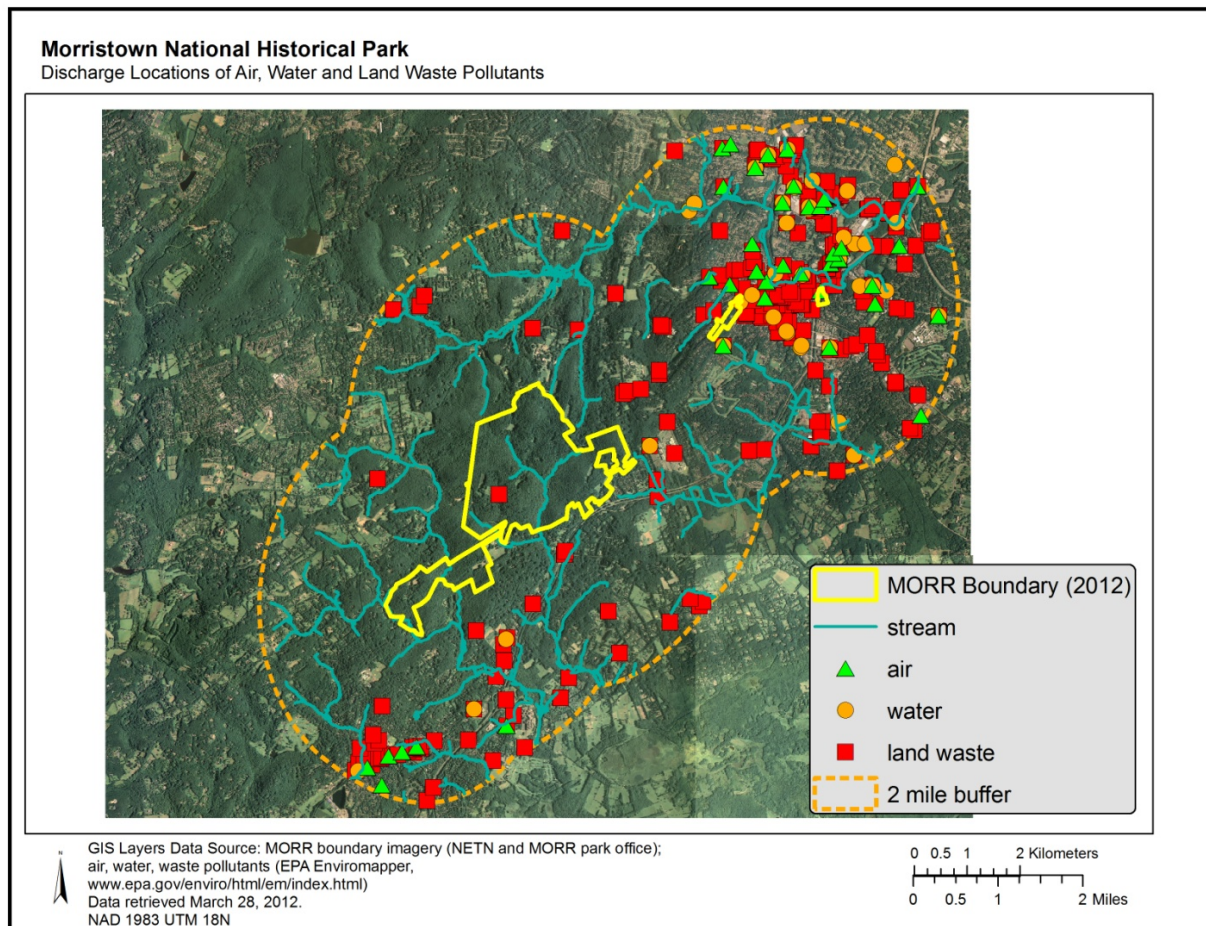
The following were identified as high threats or stressors to MORR by NPS natural resources staff (Mitchell *et al.* 2006-Appendix). Although several magnitudes of threats and stressors can be identified for the park, this listing represents ‘high’ threats to MORR with present management concerns:

- ***Air quality (acid deposition, ozone, visibility).*** Development of industrial facilities along with increased car traffic in the area can reduce air quality in the region. Atmospheric conditions such as high ozone, degraded visibility and elevated atmospheric deposition (e.g., SO<sub>x</sub>, NO<sub>x</sub>, Hg) have been shown to stress vegetation, pose toxicity to terrestrial and aquatic systems and degrade the visibility of MORR’s viewshed.
- ***External development (cell/wind towers, encroachment, habitat fragmentation, residential/commercial development, septic systems, sound).*** External development around MORR is a concern due to negative pressures which may be inflicted on the natural and cultural environment. Development (i.e., housing, commercial development, roads) currently surrounds the park and impacts land, air and water resources (Figure 2.9). Present and future development efforts threaten the park’s viewshed, as buildings and utilities such as cell towers become established around the park. An increase in habitat fragmentation from development projects especially by roads, whether within or outside park boundaries, affects wildlife movement and can increase the mortality of wildlife species. Habitat fragmentation threatens flora and fauna species, especially those which have been listed as species of concern, threatened or endangered at the state or federal level.

Additionally, natural soundscapes and lightsapes within MORR become altered by development projects, potentially affecting wildlife behavior and visitor experience. The natural soundscape is the collection of all natural sounds in MORR and the physical capacity to transmit those sounds. NPS policies state that parks will preserve, to the greatest extent possible, the natural soundscape (NPS Management Policies 2001, DO-47 Soundscape Preservation and Noise Management). No baseline data exists for MORR’s natural background sound levels. Sounds which are common in MORR due to the park’s mission include firing of muskets, hut construction, and mowing of fields. Intrusive sounds in the park are produced from the adjacent urban and suburban settings. Heavy traffic noise from the adjacent Interstate-287 and increased aircraft frequency from Newark International and Morristown airports infiltrate MORR on a daily basis. These noise levels threaten the natural soundscape of the park, diminish visitor enjoyment and inhibit outdoor interpretive talks by NPS staff.

- ***Visitor impacts (car traffic).*** As population increases in the surrounding environment there may be an increase in demand for recreation space. This demand will increase traffic and trail use, thereby elevating ozone levels from car use, increasing noise and augmenting trail degradation from activities that promote soil erosion.





**Figure 2.9.** Permitted discharge localities of air, water and land waste pollutants within a 2 mile buffer surrounding MORR.

- ***Nuisance wildlife (deer over browsing):*** Deer populations have reached historic levels due to habitat modification and the extirpation of natural predators in the northeastern U.S. White-tailed deer reduce MORR's forest regeneration rates and can aid in the introduction and expansion of invasive plants.
- ***Terrestrial animal pest species and invasive plants and non-indeigenous aquatic species:*** Terrestrial and aquatic systems in the northeastern U.S. are being seriously impacted by several pests, pathogens and non-native species. Terrestrial pest species and diseases which threaten MORR include the Asian longhorn beetle, gypsy moth, hemlock-woolly adelgid, Lyme disease and West Nile virus. Destruction of mature forests, loss of native species, impacts to forests, birds and transmission of diseases to animals and visitors can result if pest species monitoring and management is not implemented as part of a natural resources protection plan. Nonnative plant species, which have been inventoried in MORR, threaten the biological and historical integrity of the park. The forested habitat of MORR is regarded as a cultural resource and inventories have found large areas of invasive vegetation replacing

native understory vegetation in sections of the Jockey Hollow forest. This replacement can result in native hardwoods not regenerating, leading to invasive shrubby thickets with reduced scenic value. If left unmanaged, there will not only be a loss of biological integrity, but diminished historical character which is the foundation of the park's mission. MORR's aquatic stream network connects to neighboring watersheds which serve as habitat for non-indigenous aquatic plants and animals. Non-indigenous species in the aquatic habitats around MORR can potentially infiltrate the aquatic systems within park boundaries, which, depending on the species, can disturb aquatic food webs and alter water quality conditions.

- ***Water quality (due to land use change, non-point pollution, point source pollution).***  
Increases in development and changes in land use and land cover surrounding MORR can threaten aquatic systems and stress aquatic biota. Contamination of aquatic systems by road runoff and de-icing chemicals can impair water quality and affect a variety of organisms. Anthropogenic sources from industrial effluent, municipal wastewater and septic systems, runoff from agricultural, residential and urban areas and atmospheric deposition can enter surface water bodies through overland runoff or enter groundwater through infiltration. Disturbance to the natural steep slope topography of MORR, whether by development or lack of preservation, can result in the loss of habitat quality, degradation of surface water quality, silting of wetlands, and alteration of drainage patterns.

## **Resource Stewardship**

### ***Management Directives and Planning Guidance***

The units that comprise MORR are fundamentally cultural landscapes, although each unit has significant natural resources that deserve attention. The General Management Plan (NPS 2003a) recognizes that the historic natural landscapes are one of MORR's most important cultural resources and protecting them from internal and external stressors and threats is vital in order to maintain the park's cultural integrity. The presence of key types of habitat near an area of rapid development in the State of New Jersey argue for the potentially important role that MORR can play in maintaining natural resources in an urbanizing region.

### ***Status of the supporting science***

Our approach to a natural resources assessment for MORR was based on indicators developed by the Northeast Temperate Network (NETN) of the NPS Vital Signs program. This program provides long-term monitoring protocols for more than 270 park units of their most important natural resources (Fancy *et al.* 2009). These Vital Signs are generally intended to be information-rich indicators of the overall health of park ecosystems. Table 2.2 lists the high priority vital signs defined by the NETN (Mitchell *et al.* 2006). Vital signs were used in this assessment if we felt enough historic and current data were available for MORR (e.g., phenology is a Vital Sign but not assessed in this report). Data for these analyses were requested or queried from NPS, State and Federal agencies, and peer-reviewed articles, with the final list of metrics and the period of date used for this NRCA listed in Table 2.3.



**Table 2.2.** NETN Vital Signs (from Mitchell *et al.* 2006).

Level 1	Level 2	Level 3	Vital Signs	Potential Measures
Air & Climate	Air Quality	Ozone	Ozone	Atmospheric ozone concentration (synthesize existing data) foliar injury to indicator species
		Wet & Dry Deposition	Acidic Deposition & Stress	Wet and dry deposition rates (synthesize existing data), streamwater ANC, streamwater nitrate concentration
			Contaminants	Heavy metal deposition (synthesize existing data)
	Weather & Climate	Weather & Climate	Climate	Air temperature, precipitation by type, relative humidity, solar radiation, wind speed and direction, snow water equivalent, snow depth (synthesize existing data)
			Phenology	First flowering of sensitive plant species, first amphibian call dates, length of growing season, ice out/in dates for lakes and ponds
Geology & Soils	Geomorphology	Coastal/ Oceanographic Features	Shoreline Geomorphology	Relative surface elevation (salt marsh), shoreline position
	Soil Quality	Soil Functions & Dynamics	Forest Soil Condition	Ratios of carbon to nitrogen and calcium to aluminum
Water	Hydrology	Surface Water Dynamics	Water Quantity	Water depth, water duration, lake levels, streamflow, groundwater levels/inputs, spring/seep volume, sea level rise
	Water Quality	Water chemistry	Water Chemistry	Stream water nitrate, stream alkalinity/ANC, water temperature, % dissolved oxygen, specific conductance, pH, color, salinity, chlorophyll a, photosynthetically active radiation (PAR)
		WQ Nutrients	Estuarine Nutrient Enrichment	Turbidity, number septic systems in and near park, alga biomass, total and dissolved phosphorus, amount fertilizer used within park, residential density near park
		Aquatic Macroinvertebrates & Algae	Streams - Macroinvertebrates	Diversity of selected communities and sub-communities

**Table 2.3.** Monitoring data collected for the NRCA of Morristown National Historical Park, New Jersey.

Level 1	Level 2	Level 3	Vital Sign	Period of data for condition assessment and/or trend analysis	Main reference/source
<b>Air &amp; Climate</b>	Air Quality	Ozone	Ozone	1999-2008	NPS Air Resources Division
		Wet & Dry Deposition	Atmospheric Deposition & Stress	1981-2009	NPS Air Resources Division; NADP database; Sullivan <i>et al.</i> (2011a,b)
			Contaminants	2006-2009 (Hg)	MDN database
			Visibility	2005-2007	NPS Air Resources Division
<b>Geology &amp; Soils</b>	Soil Quality	Soil Function & Dynamics	Forest Soil Condition	2007, 2009	NETN forest monitoring reports
<b>Water</b>	Hydrology	Surface Water Dynamics	Water Quantity	1985, 2005; 2006-2011	USGS consumption data; NETN water monitoring;
	Water Quality	Water Chemistry	Water Chemistry	2006-2011; trend period varied by parameter	NPS data reports; USEPA STORET database; NETN monitoring data
<b>Biological Integrity</b>	Invasive Species	Invasive/Exotic Plants	Invasive/Exotic Plants-Early Detection; Aquatic Species, Watershed Distribution	Historical presence/absence data; 2007, 2009 NETN monitoring data	USGS; NETN monitoring reports; NPS surveillance reports
		Invasive/Exotic Animals	Invasive/Exotic Animals-Early Detection; Aquatic Species, Watershed Distribution	Historical presence/absence data; 2007, 2009 NETN monitoring data	USGS NAS database; NETN monitoring reports; NJ State Dept. of Conservation surveillance; USDA risk assessments; peer-reviewed research articles
	Focal Species or Communities	Forest Vegetation	Forest Vegetation	2007, 2009	NETN monitoring reports; MORR vegetation mapping
			White-Tailed Deer Herbivory	2007, 2009	NETN monitoring reports; MORR vegetation mapping
		Fishes	Fishes	2000	NPS report (Mather <i>et al.</i> , 2003)
		Birds	Breeding Birds	2006-2012	NETN monitoring reports; historical inventory
		Amphibians & Reptiles	Amphibians & Reptiles	2001	Historical inventory data for the region; NPS survey data
<b>Human Use</b>	Visitor & Recreation Use	Visitor Usage	Visitor Usage	1941-2010 (visitation); 1991-2010 (traffic counts)	NPS Stats

Level 1	Level 2	Level 3	Vital Sign	Period of data for condition assessment and/or trend analysis	Main reference/source
Landscapes	Landscape Dynamics	Landscape Dynamics	Landscapes	Historical data collection and projected models for landscape variables from 1950-2030.	NETN forest monitoring reports; Wang <i>et al.</i> ( 2009); NPScape historical and projected data; NLCD data 1992-2006; US census data (2010); NJ Highlands Region Council
			Soundscape	Geospatial sound model	NPS Natural Sounds Program
			Lightscape	Anthropogenic Light Ratio with US Census data, 2010	NPS Night Sky Program



## Chapter 3. Study Scoping and Design

### Preliminary Scoping

Preliminary scoping efforts for the NRCA of MORR began in 2012 with a meeting of MORR's park staff and NPS coordinators for discussions. Historical reports, photographs, geospatial data (GIS), and data from current sampling efforts were collected through several meetings and communication exchanges with MORR staff and the NPS Northeast Temperate Network staff (NETN). Pennsylvania State University (PSU) continued to collect data from federal (e.g., USGS) and state (e.g., NJDEP) agency databases. Conference calls, meetings at PSU, and e-mail exchanges with the NPS staff continued to assist the authors of this NRCA report by providing information which consisted of environmental issues/concerns in MORR and the surrounding area, current data collection efforts and protocols for MORR, and Vital Signs metric development. These communication efforts were essential to understanding the natural resources in MORR, as the NPS staff invests significant time inventorying, monitoring, and interpreting data for the park.

### Study Design

#### ***Indicator Framework, Focal Study Resources and Indicators***

Although MORR is a historic cultural park, information regarding the natural resources in MORR and the surrounding vicinity was abundant for several metrics. The framework used for MORR's assessment is organized by broad ecosystem resources as designed for the Northeast Temperate Network (NETN) Vital Signs approach (Mitchell et al., 2006, Fancy et al., 2009). We also incorporated soundscape and lightscape assessments for the park using information from current NPS Natural Sounds and Night Sky programs. The use of the Vital Signs metrics in this report allows NPS to utilize the NRCA results in future studies, since the Vital Signs program is a framework for long-term monitoring of park resources. However, the compiled data for MORR's natural resources was limited in terms of quantitative measures or spatial and temporal sample sizes. Thus, the confidence of the historical and present data collected for MORR determined which Vital Sign metrics were included in MORR's NRCA assessment, as well as determining the framework for the condition categories used for assessing MORR's natural resources.

#### ***Reporting Areas***

A total of six broad categories were used as the reporting area framework for the NRCA assessment. These categories included: Air & Climate, Geology & Soils, Water, Biological Integrity, Human Use and Landscapes. Vital Sign metrics in each of the above categories were used in the MORR NRCA and evaluated as whether the metric was relevant to MORR based on environmental occurrence, management objectives or data availability. A list of categories to be evaluated for the NRCA was finalized by the PSU team (Table 2.3). In some cases, such as for water chemistry, data collection efforts enabled a condition assessment of individual streams, allowing for a finer resolution of the natural resource condition assessment. A special section, Section 4.15, discusses the ecological implications the park faces due to the occurrence of Superstorm Sandy in 2012.

### **General Approach and Methods**

Discussion of metric background, approach and justification are provided for each metric assessment in Chapter 4. Each evaluated natural resource metric in this NRCA begins with a brief description of the relevance and context of the resource to the general environment and MORR. A review of the data and methods used to assess the resource was established, followed by justification of condition categories by discussing reference conditions or threshold values utilized. The reference conditions and threshold values were based on federal or state agency regulations and criteria, peer-reviewed research, estimates of biotic integrity, or established NPS NETN Vital Signs condition categories for natural resources, NPS Air Resource Division categories and NPS Natural Sounds and Night Sky Division categories. In cases where the data were qualitative in nature, best professional judgment was used to assign a condition category.

Further analysis of data resulted in each metric being given a condition category rating and assessment of trend of the natural resource condition. Condition category language included three categories: *Resource is in Good Condition*, *Warrants Moderate Concern* and *Warrants Significant Concern*. Best professional judgment was used to assign a condition category in the Visitor Usage section. We assigned trend conditions of *condition is improving*, *condition is deteriorating* or *condition is unchanging* after statistical analyses of quantitative historical and current data. The exception to the trend language was for the Amphibian population section since Brotherton *et al.* (2005) subjectively assessed each species' status and population trend based on prior collection data, habitat suitability and animal behavior. We discussed data gaps and confidence in our assessment after each metric was assessed. Confidence in the assessment and trend was identified as *high*, *medium*, *low* or *not applicable*. *High* confidence ratings required extensive spatial (and temporal for trend) quantitative data in the assessment; *medium* ratings indicated data were from studies that were quantitative and/or qualitative in nature but not usually spatially explicit; *low* ratings indicated data were from limited studies that collected generally qualitative data; *not applicable* indicated no reliable assessment or trend analysis was possible with the data available or temporal data (for trend) was absent. Finally, the authors recommended in Chapter 5 potential indicators which may be useful for monitoring natural resource conditions in MORR other than those indicators analyzed in this report.

## Chapter 4. Natural Resource Conditions

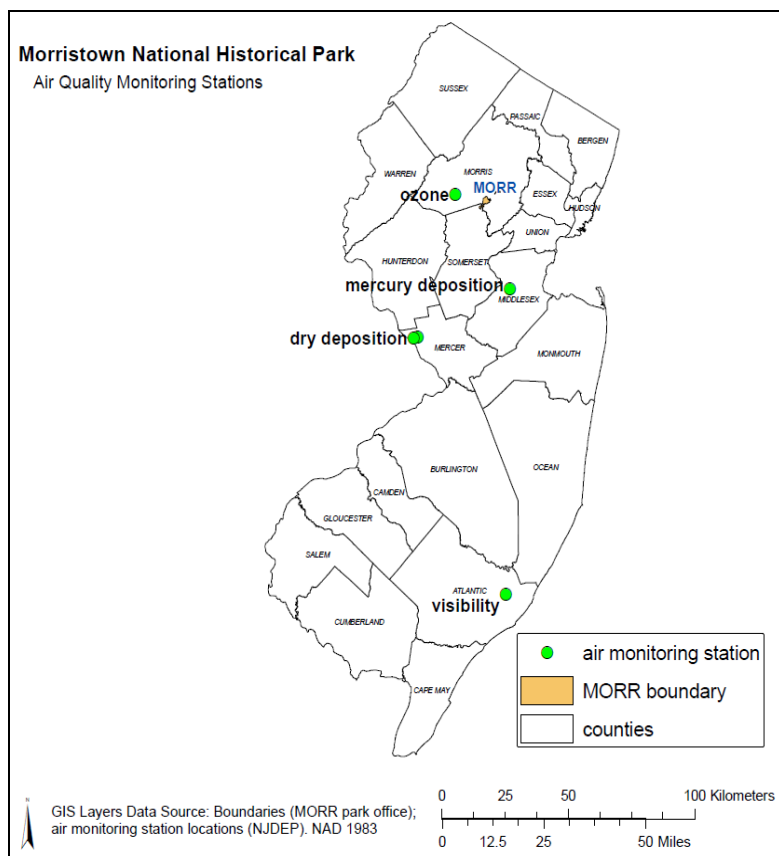
### Air Quality

Although most pollution sources are outside NPS park boundaries, the park's ecological resources continue to be affected by air pollutants. Air quality parameters were assessed for MORR using data collected from various air quality monitoring stations near MORR in conjunction with NPS Air Resource Division analyses (Figure 4.1). Four air quality categories have been individually assessed for MORR: ozone, total atmospheric deposition and stress, contaminants, and visibility. To attain the goals of this report, the NPS Air Resources Division (ARD) air quality kriged results and classification systems were used to assess air quality in MORR (NPS 2013a). The NPS Air

Resources Division developed this approach to assess overall air quality conditions within all NPS parks. Parameters of assessment include *total wet deposition of sulfur (S) and nitrogen (N), mercury (Hg), ozone and visibility*. The ARD uses air quality monitoring data from national, state, and local stations averaged over five-year periods to generate interpolations to derive estimates of air quality parameter at all Inventory and Monitoring Network NPS units. The most current NPS document (NPS 2013a) details the methods of how the NPS determines park air quality and was used for this NRCA. Interpolation condition categories of 1) *Resource is in Good Condition* 2) *Warrants Moderate Concern* and 3)

*Warrants Significant Concern* are then assigned to assess each air quality parameter. The creation of

these categories are based on regulatory standards/criteria and peer-reviewed literature which investigated the effects of air quality parameters on ecological systems. However, gaps in the impacts of air pollution on the environment exist and may underestimate the effects of air pollutants on the environment. Lovett *et al.* (2009) recommended that air quality impacts that are known to occur in the Northeast region be considered in any long-term environmental conservation strategy.



**Figure 4.1.** Air quality monitoring stations near MORR and used in the NRCA.

## Ozone

### Relevance and Context

Sunlight and chemical reactions between volatile organic compounds (VOCs) and oxides from nitrogen produce ground level ozone. These chemicals are primarily emitted from motor vehicle exhaust, industrial emissions, and chemical solvents (U.S. EPA 2006). Ozone is an important air quality indicator and one that is monitored extensively throughout the northeastern U.S. National Ambient Air Quality Standards (NAAQS) indicate that for ozone “...the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm.” New research has shown that the effects of lower ozone concentrations than the federal standards still lead to negative human health as well as ecosystem damages (U.S. EPA 2009). The ecological effects of high ozone levels include its contribution to foliar injury in specific plant species (Skelly 2000, Kohut 2007, Kline 2008). Plants can serve as bioindicators for high ozone levels and these species have been identified for MORR (Appendix A). A qualitative assessment of foliar injury risk for MORR by Kohut (2007) resulted in MORR receiving a *high* risk rating, indicating MORR’s vegetation is likely to experience injury because of high levels of ozone exposure and soil moisture.

### Data and Methods

The evaluation of condition and trends for ozone levels was based on data collected from monitoring stations nearest to MORR (at Bells Labs in Morris Co., NJ), in conjunction with using NPS ARD data and their established condition categories for assessing ozone (Figure 4.1). Interpolated ozone data was collected from 2006-2010 (Table 4.1). Using annual fourth-highest daily maximum eight hour ozone concentration, five year average values were calculated using interpolated values derived from all available monitoring data from NPS ARD (NPS 2013a). Trend assessments are based on NPS ARD regional data from 2000-2009 (NPS 2013b).

### Reference Condition/Threshold Values Utilized

NPS ARD has established the following condition categories for ozone based on regulatory and ecological data and are used in condition assessment for MORR:

*“To attain this standard, the 3-year average of the annual 4<sup>th</sup>-highest daily maximum 8-hour average ozone concentrations measured at each monitor must not exceed 75 parts per billion (ppb). For parks within the contiguous U.S., ozone condition is estimated from the interpolation of the five-year averages of 4<sup>th</sup>-highest daily maximum 8-hour ozone concentration. For sites outside the contiguous U.S., ozone condition is based on five-year averages computed from on-site data. If the resulting five-year average is greater than or equal to 76 ppb then the condition Warrants Significant Concern is assigned to that park. Warrants Moderate Concern condition for ozone is assigned to parks with average five-year 4<sup>th</sup>-highest daily maximum 8-hour ozone concentrations from 61 to 75 ppb (concentrations greater than 80 percent of the standard). Resource is in Good Condition is assigned to parks with average five-year ozone concentrations less than 61 ppb (concentrations less than 80 percent of the standard).” (NPS 2013a).*



### Condition and Trend

Interpolated ozone values for MORR from 2006-2010 were 79.4 ppb. This value does not meet a regulatory threshold of 75 ppb. Based on NPS ARD condition categories of *Resource is in Good Condition*, *Warrants Moderate Concern* and *Warrants Significant Concern*, MORR's air quality for ozone is considered *Warrants Significant Concern*, as ozone levels are greater than 75 ppb (0% attainment for reference values) (Table 4.1). Five year interpolation values calculated since 1995 by NPS ARD for ozone have consistently been categorized as a *Warrants Significant Concern*, with interpolated values ranging from 79.4-95.1 ppb (Table 4.1). A trend assessment of ozone levels for national parks throughout the U.S. from 2000-2009 stated that trend calculations were not available for MORR (NPS 2013b).

**Table 4.1.** NPS Air Resources Division (ARD) 5-Year Interpolated Ozone Values for MORR.

		MORR 5-Year ARD Values						
Measure	Condition Categories	1995-1999	1999-2003	2001-2005	2003-2007	2004-2008	2005-2009	2006-2010
Ozone (ppb)	Warrants Significant Concern ≥76							
	Warrants Moderate Concern 61-75	95.1	91.2	87.26	83.44	82.6	80.4	79.4
	Resource is in Good Condition ≤60							

### Data Gaps and Confidence in Assessment

Confidence in the current assessment was high and confidence in the assessment of trend was high. MORR is lacking in field assessment documentation of foliar injury due to high ozone levels, although a plant bioindicator list for foliar ozone injury is available for MORR (Appendix A, Kohut 2007).

### ***Atmospheric Deposition & Stress***

#### Relevance and Context

Acidic deposition, derived from nitrogen and sulfur emissions from electric utilities, manufacturing, agriculture and other sources, is directly deposited as dry deposition or combined into rain, snow, or cloud droplets allowing for an increase in the acidity of precipitation (wet deposition). The NPS Air Resources Division (ARD) has set a criteria of >3 kg/ha/yr of total wet S or N atmospheric deposition as being a significant concern for acid deposition air quality conditions. Natural background deposition levels in the eastern U.S. are approximately 0.50 kg/ha/yr for N or S, with wet deposition accounting for 0.25 kg/ha/yr (NPS 2013a). The Northeast region of the U.S., including

New Jersey, has experienced elevated wet sulfate and nitrate deposition inputs to its ecosystems compared to the rest of the U.S. (Aber *et al.* 1989, Driscoll *et al.* 2003). Dry and wet sulfur and nitrogen deposition can directly enter the ecosystem and have important implications for aquatic or terrestrial systems (Driscoll *et al.* 2001). Examples of effects to the ecosystem include altering soil composition (Driscoll *et al.* 2001, Mitchell *et al.* 2001), affecting soil invertebrates (Rusek and Marshall 2000), stressing trees and vegetation (Horsley *et al.* 2002, Aber *et al.* 2003, Thormann 2006, Wallace *et al.* 2007), altering aquatic structure and function, and decreasing the diversity of aquatic organisms (Schindler *et al.* 1988, 1989, Dupont *et al.* 2005). These ecosystem effects may be occurring in MORR, thereby altering the function of the environment. For example, the Jockey Hollow and New Jersey Brigade Encampment Area may have been experiencing changes in forested areas due to acid rain deposition, leading to alterations of the structure and composition of tree species in the park. Currently no EPA standards exist for S or N deposition levels. However, studies have been conducted to identify and establish thresholds or critical loads of N and S deposition on terrestrial and aquatic ecosystems (Schindler 1988, Aber *et al.* 2003, Dupont *et al.* 2005). Acid neutralizing capacity (ANC) and soil carbon-to-nitrogen (C:N) ratio have been used as indicators to demonstrate whether deposition has induced changes to chemical, physical, or biological components of an ecosystem (Aber 1989, Bugler *et al.* 2000).

#### Data and Methods

We used NPS ARD results and their guidance establishing condition categories (NPS 2013a) for assessing wet S and N deposition from 2006-2010 for this condition assessment. In order to evaluate the temporal trends of deposition, data from 1981-2009 were queried from NADP monitoring stations nearest to MORR (Washington Crossing, Mercer Co., NJ). Park resources sensitive to acidification were measured at a national scale based on a risk assessment by Sullivan *et al.* (2011a) and included acidification related risk ratings for I & M parks, including MORR. This risk assessment considered three factors that influence acidification risk to parks' resources from sulfur and nitrogen deposition: 1) pollutant exposure, 2) ecosystem sensitivity, and 3) park protection. The three factors each contained several measured variables which were calculated to represent aspects of the factor (see Sullivan *et al.* 2011a for variables). National parks were ranked according to each of these three factors. A summary risk rating was then calculated for each park based on averages of the three above factors. Based on these averages, each factor was classified into one of five overall risk categories to acidification: very low, low, moderate, high, very high (see Sullivan *et al.* 2011a for further details on the variables included for each of the three factors and ranking assessment).

A second risk assessment was conducted by Sullivan *et al.* (2011b) to assess the relative sensitivity of NPS parks to potential nutrient enrichment effects caused by atmospheric nitrogen deposition. This risk assessment considered three factors that influence nutrient enrichment risk to park resources from atmospheric nitrogen deposition: 1) nitrogen pollutant exposure, 2) ecosystem sensitivity, and 3) park protection mandates. National parks were ranked according to each of these factors and an overall risk ranking was calculated based on averages of the three rankings. Results of quintile rankings of national parks throughout the U.S. were used to distinguish the risk levels of nutrient enrichment to a park (i.e., the lowest quintile are the 20% of parks that received the lowest N pollutant exposure ranking and the highest quintile are the highest 20% of park rankings) (see

Sullivan *et al.* 2011b for further details on the variables included for each of the three factors and ranking assessment).

#### Reference Condition/Threshold Values Utilized

Critical loads have not been established in the Clean Air Act for S and N deposition. NPS is creating a critical load approach for wet deposition of S and N to protect and manage its parks' ecosystems (per communication H. Salazer, NER Air Resources Coordinator). The NPS ARD has created conditional assessment categories based on ecological responses documented in scientific literature (see 'Relevance and Context' section above, NPS 2013a). MORR's NPS ARD values for wet S & N deposition were based on interpolated values over a five year average from NADP/NTN data collected from stations operating closest to MORR. Wet deposition was calculated by multiplying N or S concentrations in precipitation by a normalized precipitation amount for sites within the continental U.S. This normalized precipitation is calculated in order to minimize variation in data caused by interannual variation in precipitation. The condition categories established by the NPS ARD for wet deposition of S and N have been stated as the following: "*Evidence is not currently available indicating that wet deposition amounts less than 1 kilogram per hectare per year (kg/ha/yr) cause ecosystem harm. Therefore, parks with wet deposition less than 1 kg/ha/yr are assigned Resource in Good Condition; parks with 1–3 kg/ha/yr are assigned Warrants Moderate Concern; and parks with greater than 3 kg/ha/yr are assigned Warrants Significant Concern for deposition.*" (NPS 2013a).

Risk assessments produced for national parks were used as supplemental information to assess MORR's air quality and natural resources. As a general introduction to the risk assessment of acidification due to S and N deposition on MORR's natural resources, we incorporated the summary risk categories produced by Sullivan *et al.* (2011a). These summary risk ratings included: *very low* (1.0-1.99), *low* (2.0-2.49), *moderate* (2.5-3.49), *high* (3.5-4.24), *very high* (4.25-5). Additionally, the summary risk rankings produced by Sullivan *et al.* (2011b) for nutrient enrichment effects from atmospheric N deposition were used to understand the risk MORR may encounter with nutrient enrichment. The summary risk ratings for nutrient enrichment effects from N deposition included: *very low*, *low*, *moderate*, *high*, *very high*, where each rating was designated according to quintile ranking among all Inventory and Monitoring parks. For example, the parks in the highest quintile (highest 20% of risk rankings) were rated very high, parks in the second highest quintile were rated high, etc).

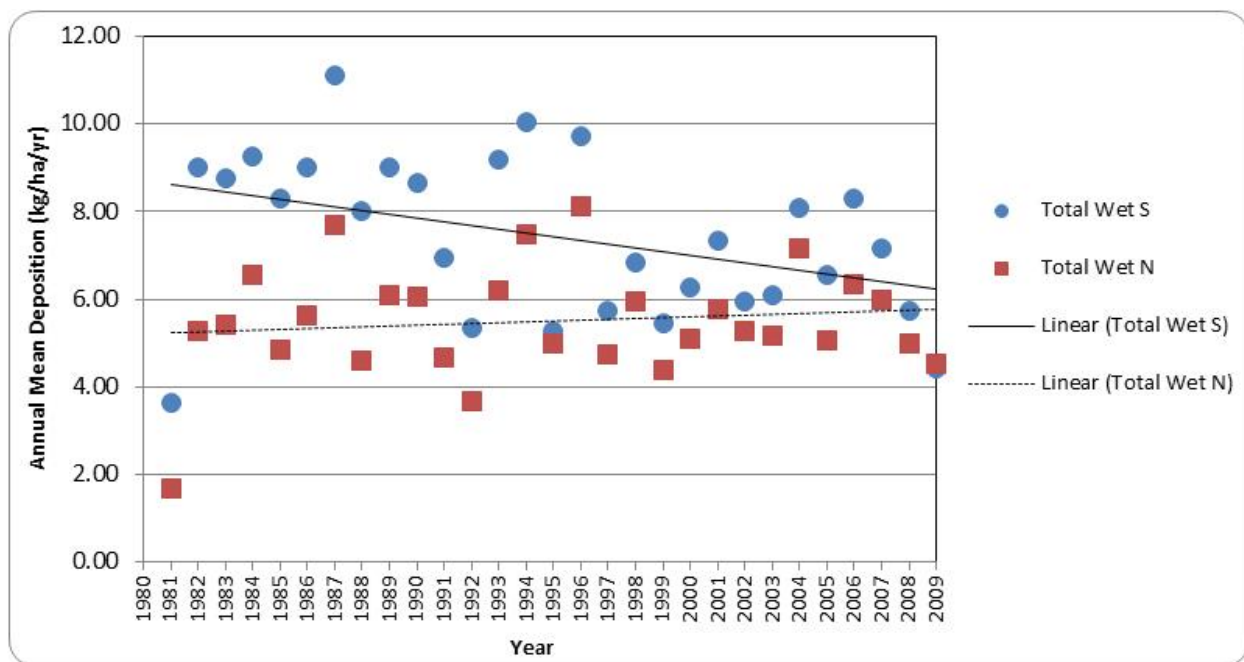
#### Condition and Trend

Interpolated total wet S and N values for MORR between 2006-2010 were 5.6 and 5.2 kg/ha/yr, respectively. These values do not meet an ecological threshold of 1 kg/ha/yr. Based on NPS ARD condition categories of *Resource in Good Condition*, *Warrants Moderate Concern* and *Warrants Significant Concern*, MORR's air quality for wet S and N deposition is considered *Warrants Significant Concern*, as it is >3 kg/ha/yr (0% attainment) (Table 4.2, NPS 2013a).

**Table 4.2.** NPS Air Resources Division (ARD) 5-Year Interpolated Atmospheric Wet N and S Deposition Values for MORR.

			MORR 5-Year ARD Values						
Measure	Condition Categories		1995-1999	1999-2003	2001-2005	2003-2007	2004-2008	2005-2009	2006-2010
<b>Wet N Deposition</b> (kg/ha/yr)	Warrants Significant Concern	>3							
	Warrants Moderate Concern	1-3	3.43	4.52	5.78	5.58	5.47	5.15	5.2
	Resource is in Good Condition	<1							
<b>Wet S Deposition</b> (kg/ha/yr)	Warrants Significant Concern	>3							
	Warrants Moderate Concern	1-3	3.90	5.70	6.81	6.89	6.51	5.94	5.6
	Resource is in Good Condition	<1							

Trends for sulfur wet deposition levels were categorized as *condition is improving* for MORR while nitrogen wet deposition levels were categorized as *condition is unchanging*, as they are slower to decrease within the region and are more variable. Sulfur wet deposition levels collected at station NJ99 near MORR (located in Washington Crossing, Mercer Co., NJ) had significantly decreased from 1981-2008 based on linear regression results (n=1 station,  $p < 0.05$ , Figure 4.2). Nitrogen wet deposition trend data collected from station NJ99 was not significant ( $p > 0.05$ , Figure 4.2). These trends are supported by peer-reviewed literature of deposition trends in the northeast region of the U.S. (Driscoll *et al.* 2001, Driscoll *et al.* 2003). Although the trend for wet S deposition level is decreasing, the values of sulfur and nitrogen wet deposition for MORR are still well above the NPS ARD *Resource is in Good Condition* threshold of 1 kg/ha/yr and therefore, natural resources may still experience negative impacts from higher wet deposition levels. Additionally, long-term trend analyses of data on acidity in precipitation at NJ99 found a significant increase in pH in precipitation ( $p = 0.0261$ ) (NJDEP 2011). pH levels recorded at NJ99 still remain in the range of 4.5 and is 10 times more acidic than expected for unpolluted rain in the Northeast.



**Figure 4.2.** Trend of annual mean total sulfur wet deposition and total nitrogen wet deposition levels (kg/ha/yr) measured at NADP station NJ99 near MORR from 1981-2009.

The NPS risk assessment which evaluated the sensitivity of national parks to acidification effects from S and N deposition was scored for MORR (Sullivan *et al.* 2011a). Based on pollutant exposure, ecosystem sensitivity and park protection measures, MORR scored a summary risk rating of *very high* (score=4.33) (Table 4.3). MORR was also assessed in the NPS risk assessment of nutrient enrichment effects from atmospheric nitrogen deposition (Sullivan *et al.* 2011b). Based on nitrogen pollutant exposure, ecosystem sensitivity and park protection measures, MORR scored a *high* summary risk rating (ranking 117.83) (Table 4.3).

**Table 4.3.** Relative rankings of MORR for Pollutant Exposure, Ecosystem Sensitivity, Park Protection, and Summary Risk from acidification due to S and N acidic deposition and nutrient N deposition enrichment effects (See Sullivan *et al.* 2011a,b for ranking method).

Relative Ranking of Parks to Acidification and Nutrient N Enrichment				
Measure	Avg. of Pollutant Exposure	Avg. of Ecosystem Sensitivity	Avg. of Park Protection	Summary Risk
S and N Acidification	<i>Very High</i>	<i>Very High</i>	<i>Moderate</i>	<i>Very High</i>
Nutrient N Enrichment	<i>Very High</i>	<i>Very Low</i>	<i>Moderate</i>	<i>High</i>

### Data Gaps and Confidence in Assessment

Confidence in the condition assessment of sulfur and nitrogen wet deposition was high and confidence in the trend assessment was medium due to the trend representing a low number of monitoring stations near MORR. Natural resource risk assessments for S and N acidification and nutrient enrichment effects from atmospheric nitrogen deposition are an initial step to providing information and identifying park resources that are thought to be sensitive from acidification and enrichment. These assessments should be considered coarse approximations of true risk and should increase as scientific knowledge of the factors increases and spatial and temporal data collection efforts improve (Sullivan *et al.* 2011a,b).

### **Contaminants (Mercury (Hg))**

#### Relevance and Context

Heavy metal contaminants such as mercury are distributed through natural and anthropogenic processes. Incineration of solid waste and fossil fuel combustion facilities contribute 87% of the emission of mercury in the U.S. (U.S. EPA 2001). The indirect source of mercury to aquatic and terrestrial systems is through deposition from precipitation. After deposition, ionic Hg may be reemitted to the atmosphere or converted to methylmercury (MeHg) which is a bioavailable form to biota. Methylmercury has the ability to bioaccumulate in individuals and biomagnify in food chains, thus potentially compromising reproduction, behavior, growth and development in organisms. Mercury can affect mammals, fish, salamanders, birds, plants, invertebrates and microflora in soils, especially in the northeastern U.S. where contamination has been well-documented (Bringmark and Bringmark 2001, Ericksen *et al.* 2003, Bank *et al.* 2005, Evers *et al.* 2005, Hammerschmidt and Fitzgerald 2005, Yates *et al.* 2005, Hammerschmidt and Fitzgerald 2006, Driscoll *et al.* 2007, Evers *et al.* 2007). Environments known to favor the production of methylmercury include forested areas with shallow surficial materials, high elevation forests, and wetlands and waters with low-productivity (Grigal 2003, Miller *et al.* 2005). Although mercury contamination has been extensively studied in aquatic systems, little research has been conducted in terrestrial systems. Grigal (2002) estimated total atmospheric mercury transferred to terrestrial environments in temperate zones is averaged to be four times higher than atmospheric deposition by precipitation. Forests may provide conditions where Hg methylation can occur as documented by the relationships between litterfall Hg values and blood Hg values of the Bicknell's thrush (Rimmer *et al.* 2005).

The New Jersey Department of Health and Senior Services and the New Jersey Department of Environmental Protection (NJDEP) establishes advisories for consuming sportfish deemed unsafe for human consumption due to mercury contamination from various waterbodies within New Jersey (New Jersey Department of Health and NJDEP 2010). For mercury, the NJDEP has selected a 0.18 ppm threshold for fish tissue based mercury levels. In 2010, no waterbodies within MORR contained cautionary advisories for fish consumption. The U.S. EPA, under the Clean Water Act 304(a), has established a fish tissue criterion for human consumption that should not exceed 0.3 MeHg mg/kg, while the Food and Drug Administration established a 1 ppm MeHg limit level in fish intended for human consumption (U.S. EPA 2001, U.S. FDA, 2004). Hammerschmidt and Fitzgerald (2006) linked atmospheric mercury deposition with mercury concentrations in fish. Meili *et al.* (2003) noted

2 ng/L of mercury in precipitation was modeled to 0.5 MeHg mg/kg wet weight in freshwater fish, but this was dependent on watershed dynamics (i.e., humic vs. non-humic waters). Additionally, chemical thresholds to predict Hg in fish have been identified for lakes and include: total phosphorus concentrations < 30 µg/L; pH <6.0; ANC <100 µeq/L; and DOC > 4 mg carbon/L (Driscoll *et al.* 2007).

#### Data and Methods

Data were queried from the Mercury Deposition Network (MDN) which included one mercury monitoring station within the closest proximity to MORR. Station NJ30 in New Brunswick, Middlesex Co., NJ, is located approximately 29 miles from the Jockey Hollow Unit in Harding, NJ. Annual mean Hg concentrations (ng/L) were calculated for this station from 2006-2009. Trend for mercury deposition for MORR was not reported due to the lack of long term collection data for this MDN station.

#### Reference Conditions/Threshold Values Utilized

NPS ARD has yet to establish a mercury deposition condition category. At this time, the NPS is currently working on guidance for mercury that would include condition categories (personal communication, Holly Salazer, NPS air resources coordinator for NE region). Ecological data representing modeled Hg levels by Meili *et al.* (2003) suggested that 2 ng/L of mercury in precipitation modeled to an equivalent of 0.5 MeHg mg/kg wet weight in freshwater fish. Mercury data were analyzed using this threshold value and MORR was assessed *Warrants Significant Concern* if exceeding the 2 ng/L threshold and categorized as *Resource is in Good Condition* if below this threshold for mercury deposition.

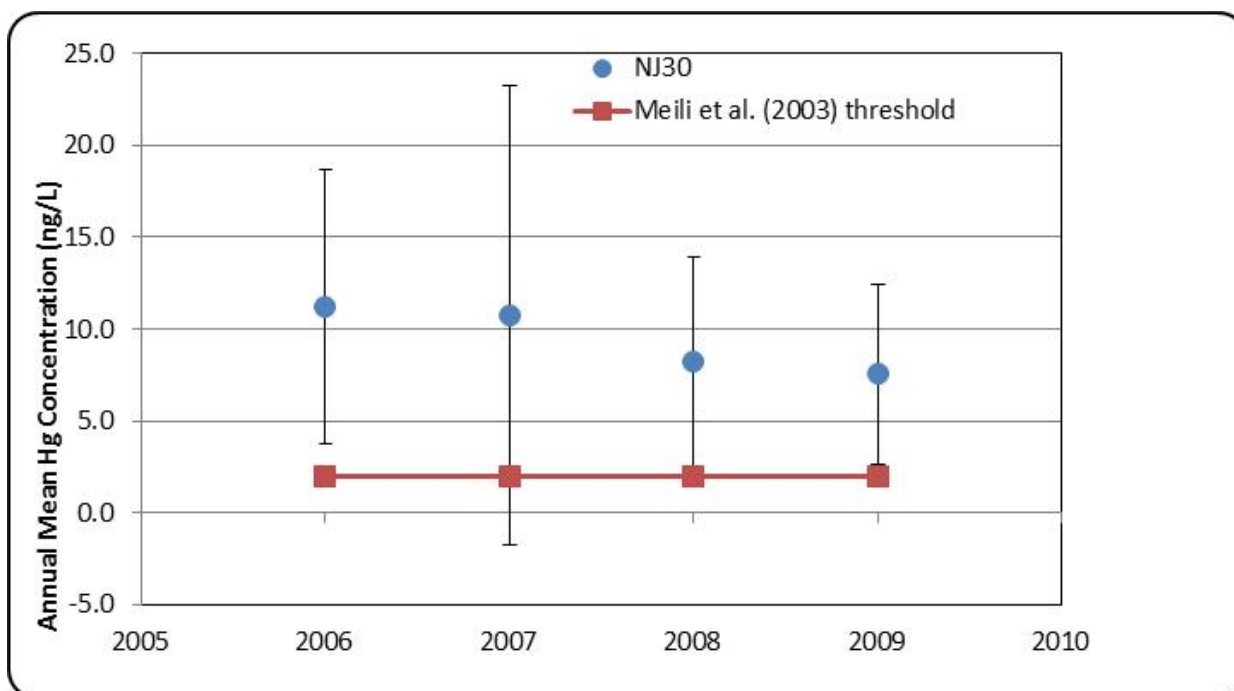
#### Condition and Trend

Annual mean Hg concentrations from 2006-2009 data collected at one monitoring station near MORR was greater than a 2 ng/L threshold established by Meili *et al.* (2003), thus rating Hg contamination for MORR as *Warrants Significant Concern* (Figure 4.3). From 2006-2009, the annual mean Hg atmospheric deposition ( $\pm$ standard deviation) was 9.4 $\pm$ 8.3 (ng/L). Although a trend could not be detected for MORR due to a lack of long term data, Butler *et al.* (2007) found a significant decline in mercury wet deposition from 1985-2005 based on a regional analysis in the northeastern U.S..

#### Data Gaps and Confidence in Assessment

Confidence in the condition assessment of mercury deposition was low and trend assessment was not applicable. Although a 2 ng/L of mercury in rainfall has been identified by Meili *et al.* (2003), this threshold does not necessarily apply to all watershed types.





**Figure 4.3.** Annual mean mercury (Hg) concentrations (ng/L)  $\pm$  standard deviation for MDN station NJ30 recorded from 2006-2009.

## Visibility

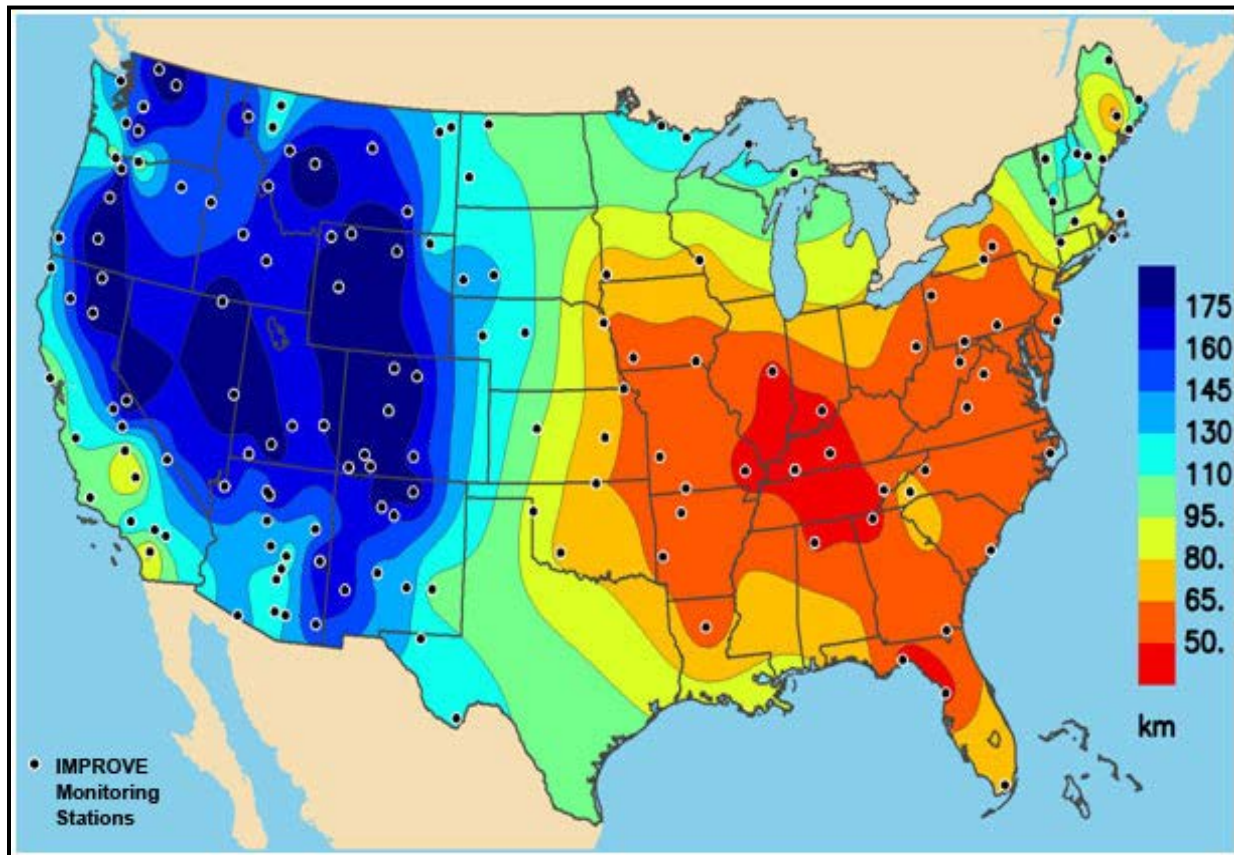
### Reference and Context

Contaminants within the air can degrade visibility in many national parks. The reduced visibility, referred to as haze, is caused when sunlight encounters pollution particles in the air. Haze degrades scenic visibility in many national parks due to the interaction of sunlight and tiny pollution particles (e.g., sulfates, nitrates, soot) in the air, causing discoloration and loss of visual range. In MORR, Fort Nonsense unit's historic vista is prone to poor visibility due to regional haze, auto emission and industrial sources. Recognizing the importance of visibility, the U.S. federal government approved the Clean Air Act (1977) to include visibility as an indicator of air quality. This type of atmospheric impairment which is commonly caused by human-induced activities (e.g., industrial emissions) vs. natural occurrences (e.g., meteorology), has resulted in the monitoring of visibility at a number of national parks and wilderness areas. These areas are designated as Class I areas under the 1977 Clean Air Act Amendments (Figure 4.4). The monitoring of visibility at these parks was implemented with the aid of the IMPROVE (Interagency Monitoring of Protected Visual Environments) program which tracks changes in visibility.

### Data and Methods

The evaluation of condition and trends for visibility was based on data collected from monitoring stations closest to MORR, in conjunction with NPS ARD data and their established condition categories for assessing visibility (Table 4.4). The closest IMPROVE site to MORR is at Brigantine Wilderness Area (BRIG1) in the Edwin B. Forsythe National Wildlife Refuge Headquarters in

Oceanville, New Jersey, 85 miles (137 km) south of MORR. NPS ARD interpolated visibility measures for MORR using 5-year average values from 2006-2010 were used for this assessment. NPS ARD visibility measures were presented as a haze index in deciviews (dv), which indicated that the difference between current group 50 (mean of the 40<sup>th</sup>-60<sup>th</sup> percentile data) visibility and the natural group 50 visibility (estimated visibility in the absence of human caused visibility impairment) (NPS 2013a).



**Figure 4.4.** Location of IMPROVE monitoring stations within the U.S. and the annual average visual range (in kilometers) based on data collected from 2005-2007. From NPS Air Resources Division. [www.nature.nps.gov/air/monitoring/vismonresults.cfm](http://www.nature.nps.gov/air/monitoring/vismonresults.cfm)

#### Reference Conditions/Threshold Values Utilized

Reference visibility levels are regulatory estimates based on natural background conditions for Class I parks and wilderness areas. A reference visibility condition category of *Resource is in Good Condition* has been established by NPS ARD of  $\leq 2$  (dv) (Table 4.4). NPS ARD has established the following categories for assessing visibility condition and these categories were used in the condition assessment for MORR: “*The visibility condition is expressed as: Visibility Condition = average current visibility – estimated average natural visibility. Resource is in Good Condition category is assigned to parks with visibility 2 dv above natural conditions. Parks with visibility ranging from 2 to 8 dv above natural conditions are considered to be in the Warrants Moderate Concern category, and*

*parks with visibility greater than 8 dv above natural conditions are considered to be in the Warrants Significant Concern category. The dv ranges of these categories were chosen to reflect the variation in monitored visibility conditions.” (NPS 2013a).*

#### Condition and Trend

The interpolated visibility value for MORR between 2006-2010 was 11.0 dv. Based on NPS ARD condition categories of *Resource is in Good Condition*, *Warrants Moderate Concern* and *Warrants Significant Concern*, MORR’s air quality for visibility is considered *Warrants Significant Concern*, as visibility is greater than >8 dv (Table 4.4, NPS 2010a). Trend assessment data from 2000-2009 was not available for MORR (NPS 2013b).

#### Data Gaps and Confidence in Assessment

Visibility trend analyses for MORR are not yet available from the NPS ARD’s nation-wide trend calculations. Confidence in the current assessment of condition was medium due to the limited data points used for the basic kriging interpolation and the current assessment of trend was not applicable.

**Table 4.4.** NPS Air Resources Division (ARD) 5-Year Interpolated Visibility Values for MORR.

		MORR 5-Year ARD Values					
Measure	Condition Categories	2001-2005	2003-2007	2004-2008	2005-2009	2005-2009	2006-2010
<b>Visibility</b>  (dv) [Current group 50-Est. Group 50 natural]	Warrants Significant Concern >8						
	Warrants Moderate Concern 2-8	8.76	12.45	12.27	11.9	11.9	11.0
	Resource is in Good Condition <2						

## **Soils**

### **Forest Soil**

#### Relevance and Context

Soil chemistry has been monitored within the park since 2007 as part of the Vital Signs program in order to understand the effects acid deposition may have on the health of MORR’s forests (Figure 4.5) Acidic deposition affects soil chemistry by depleting nutrients such as calcium (Ca), magnesium (Mg), and potassium (K) while mobilizing toxins such as aluminum (Al). These changes affect plant growth and increase the susceptibility of trees to stresses such as disease (Bullen and Bailey 2005). Additionally, nitrogen (N) may be increased due to wet and dry atmospheric deposition levels. This supplementary nitrogen to forests (commonly referred to as “N saturation”) may cause excessive

nitrification and N leaching, thereby intensifying the effects of acidification on soils and vegetation (Aber *et al.* 1989).

#### Data and Methods

The monitoring of soil chemistry variables congruent with measuring forest structure, composition, and function metrics will increase the understanding of the impacts of acid deposition on forest health. Two indicators, the calcium to aluminum ratio (Ca:Al, an acid stress metric) and the carbon to nitrogen ratio (C:N, a nitrogen saturation metric) were measured from the O and A (surface) horizon of soils in MORR during NETN forest monitoring efforts (Miller *et al.* 2010, Tierney 2009, 2011) (Figure 4.5). Composite soil samples from 28 NETN forest monitoring plots in MORR collected in 2007 and 2009 were analyzed in the laboratory for Ca:Al and C:N. Trend analyses were not performed for these indicators due to limited temporal sampling effort.

#### Reference Condition/Threshold Values Utilized

The NETN Vital Signs program has established condition categories (ratings) for Ca:Al and C:N in order to assess the impacts of atmospheric deposition on forest soil (Miller *et al.* 2010). These condition categories are based on ecological studies which have assessed the use of these indicators for acid stress and nitrogen saturation on forest soils (e.g., Aber *et al.* 2003, Cronan and Grigal 1995). Ca:Al condition categories included the following: median Ca:Al ratio >4 was rated *Resource is in Good Condition*, a ratio of Ca:Al from 1-4 rated *Warrants Moderate Concern*, and a ratio <1 was considered *Warrants Significant Concern* (Table 4.5). Nitrogen saturation was assessed using a C:N soil ratio with the following condition categories: a *Resource is in Good Condition* rating included C:N >25, a *Warrants Moderate Concern* rating was between C:N 20-25, and a *Warrants Significant Concern* rating fell below C:N of 20 (Table 4.5).

#### Condition and Trend

NETN soil sampling in MORR resulted in an overall median Ca:Al value of 5.35, thus being rated *Resource is in Good Condition* for MORR (Table 4.5) (Miller *et al.* 2010). The median C:N value for MORR was 14.34 and rated *Warrants Significant Concern*. Even though C:N rated *Warrants Significant Concern*, the higher levels of N in MORR may not have yet affected Ca:Al values (Miller *et al.* 2010). Since acid deposition is a regional problem, there are limited management activities that may be implemented at the park level to reduce it. Additionally, variables such as topography and geology may play a role in influencing these ratios in soils. Continuous monitoring of soils and forest vegetation structure and function will allow trend detection and the understanding of long term impacts of acid deposition on forest health in MORR.

**Table 4.5.** Condition assessment ratings for MORR soil chemistry.

Measure	Condition Categories		Result
Ca:Al	Warrants Significant Concern	ratio < 1	Median Ca:Al 5.35
	Warrants Moderate Concern	ratio 1 - 4	
	Resource is in Good Condition	ratio > 4	
C:N	Warrants Significant Concern	ratio < 20	Median C:N 14.34
	Warrants Moderate Concern	ratio 20 - 25	
	Resource is in Good Condition	ratio > 25	

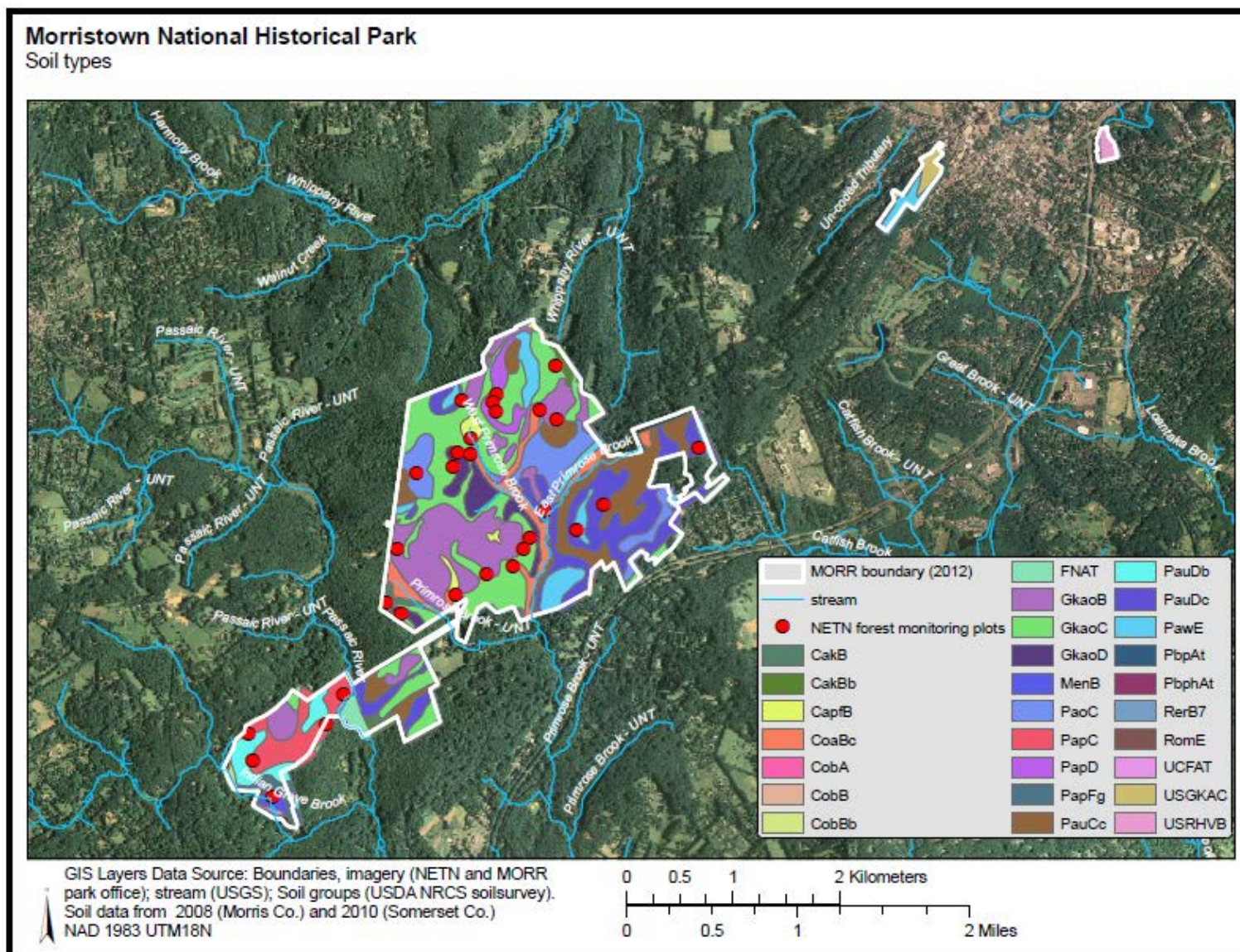
#### Data Gaps and Confidence in Assessment

Confidence in the assessment was medium and trend analysis was not applicable. The sole use of Ca:Al and C:N metrics limits the assessment of acid deposition and stress in forest soils. With increased soil sampling effort, in conjunction with atmospheric deposition data, forest health data and geological data, trend analyses will provide a comprehensive understanding of regional soil acidification and nutrient saturation.

Inaccuracy in the measurements of Ca:Al ratios for MORR are possible due to the type of extractant used for Ca:Al measurements and the methodology of separating the O and A soil layers in field collections (personal communication, NPS, Peter Sharpe February 3, 2012). The ammonium chloride extractant currently used by NPS to derive the Ca:Al ratio has been considered by some forest and soil scientists as being too strong of an extractant and therefore yields inaccurate results. Strontium chloride extractant may be a more suitable alternative as it mimics the Ca:Al ratio that is bio-available in the soil. Furthermore, contamination of the mineral sample A horizon with the O horizon soil during sampling can lead to greater Ca:Al ratios.

The NETN has recognized that Ca:Al and C:N metrics are insufficient to understand atmospheric deposition and stress on forest soils (Miller *et al.* 2011). Spatial and temporal variability of these ratios in forest soils hinders a complete condition assessment of soils in MORR. Spatial variability of individual cations is highly dependent upon local site conditions (e.g. geology, topography), and temporal variability in cation concentrations can be high, reflecting soil water table fluctuations, rainfall patterns, and litter decomposition rates Yanai *et al.* (2005) suggested intensive sampling is needed to detect even small changes in soils. Additional soil indicators are available which can be used in conjunction with C:N and Ca:Al ratios. Information derived from pH measurements can be used at a site-specific level to assess the risk to forest structure from acidification and exotic vegetation establishment (Smart *et al.* 2005). For example, there are a variety of soil pH thresholds and optimal ranges for different soil processes and plant species which could be used to assess risk to soil functions and conservation of habitats. pH plays a major role in the regulation of several soil processes such as cation availability to plants, phosphorus immobilization in acidic soils, and changes in biological communities due to pH levels. High pH has also been used to correlate exotic invasive species proliferation in MORR's forests (Ehrenfeld *et al.* 2001, Kourtev *et al.* 1998).





**Figure 4.5.** Soil associations (USDA NRCA) and NETN forest monitoring plots located in MORR. See Appendix B for listing of soil names and properties

## ***Soil Erosion Features***

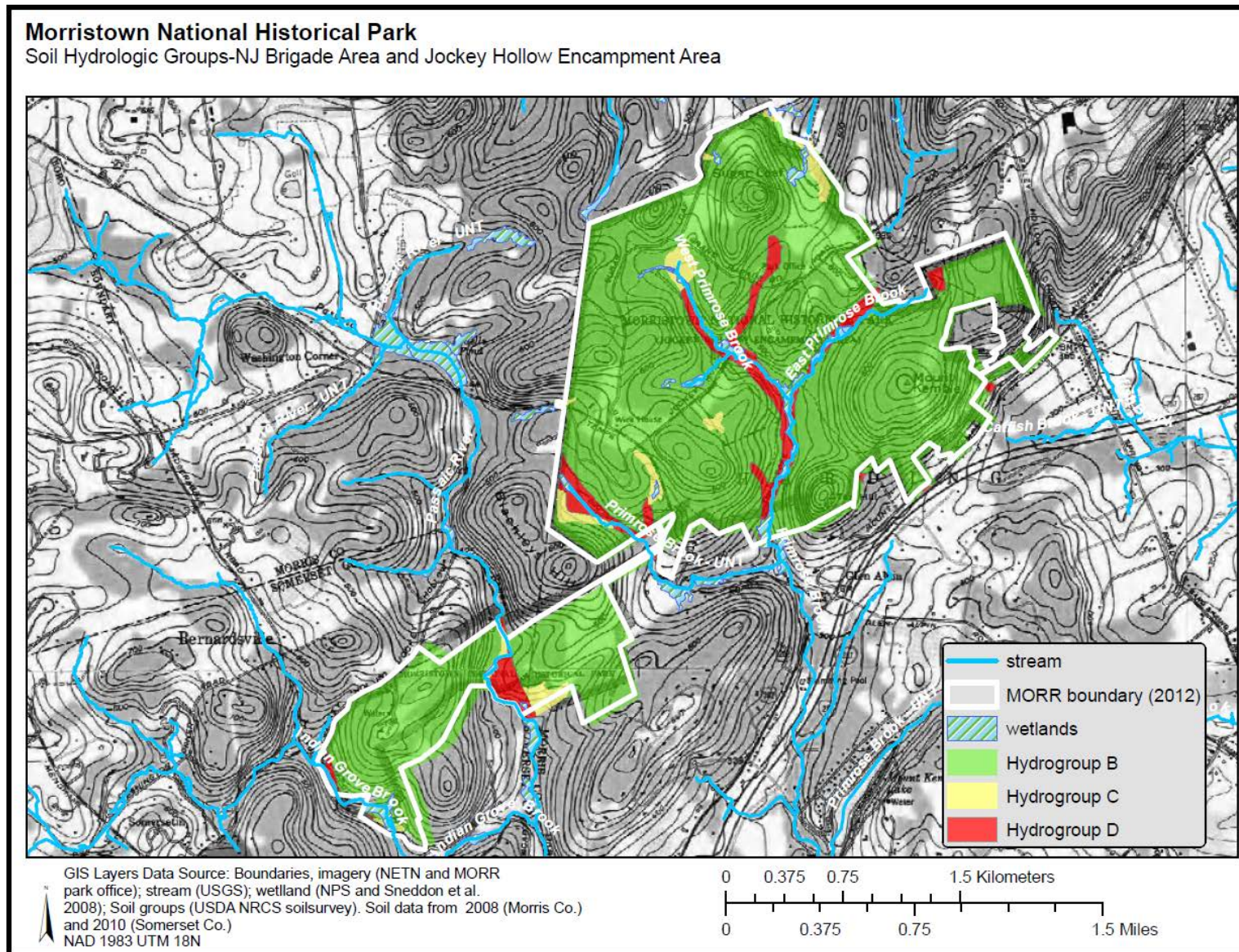
### **Relevance and Context**

MORR is susceptible to a moderate level of soil erosion (NPS 2003a). A number of soil and topographic features, such as steep slopes and hydrologic soil properties determine soil erodability. Steep slopes are of important ecological, recreational and scenic value to MORR. They provide specialized habitats to rare plant and animal species and provide popular recreational opportunities including hiking, climbing, wildlife observation and scenic vistas. However, disturbance of steep slope areas can generate erosion and sedimentation, resulting in the loss of topsoil. The identification and classification of steep slopes is important in order to effectively manage critical natural resources in MORR, especially for areas in MORR where the native seed bank is vulnerable to erosion and tree root exposure is a concern. Additionally, the identification of hydrologic soil groups (HSGs) and supplementation of land cover types in MORR can be beneficial to park managers for restoration and conservation efforts, such as forest habitat restoration and seed bank protection. HSGs are classified by the Natural Resource Conservation Service (NRCS) and are based on estimates of runoff potential. Soils are classified into hydrologic soil groups to indicate the minimum rate of water infiltration obtained for bare soil after prolonged wetting. The majority of land (approximately 90%) in MORR contained hydrological group B soils-soils with moderate infiltration rates moderate infiltration rate (0.15-0.30 in/hr) and lower runoff potential (Figure 4.6). It was estimated that approximately 7% of land near streams flowing through MORR contained group D soils (0-0.05 in/hr and high runoff potential), with a few areas farther from waterbodies containing group C soils (slow infiltration rate at 0.05-0.15 in/hr and greater runoff potential). Hydrological soil groups and slope constraint measures can be useful information for maintaining MORR's historical forested habitats which may be vulnerable to erosion from runoff.

### **Data and Methods**

Slope constraints were used to evaluate various levels of constrained areas due to slopes in MORR. Data was obtained from the New Jersey Highlands Water Protection and Planning Council (NJ Highlands Council) for the Highlands Region which included MORR. These data were a subset of slope mapping which constitutes the Steep Slope Protection Area in the Highlands Region showing areas that are a minimum of 5,000 square feet.





**Figure 4.6.** Hydrological soil group distribution in MORR.

#### Reference Condition/Threshold Values Utilized

Slope constraint estimates were based on the NJ Highlands Council's categorization of slope areas into three categories: 1) *Warrants Significant Concern* (severely constrained slopes): all lands with slopes of 20% or greater and lands within Riparian Areas with slopes of 10% and greater; 2) *Warrants Moderate Concern* (moderately constrained slopes): all non-Riparian Area lands having a slope of 15% to less than 20% which are forested; and 3) *Resource is in Good Condition* (limited constrained slopes): all non-Riparian Area lands having a slope of 15% to less than 20%, which are non-forested, are not highly susceptible to erosion, and do not have a shallow depth to bedrock or a Soil Capability Class indicative of wet or stony soils.

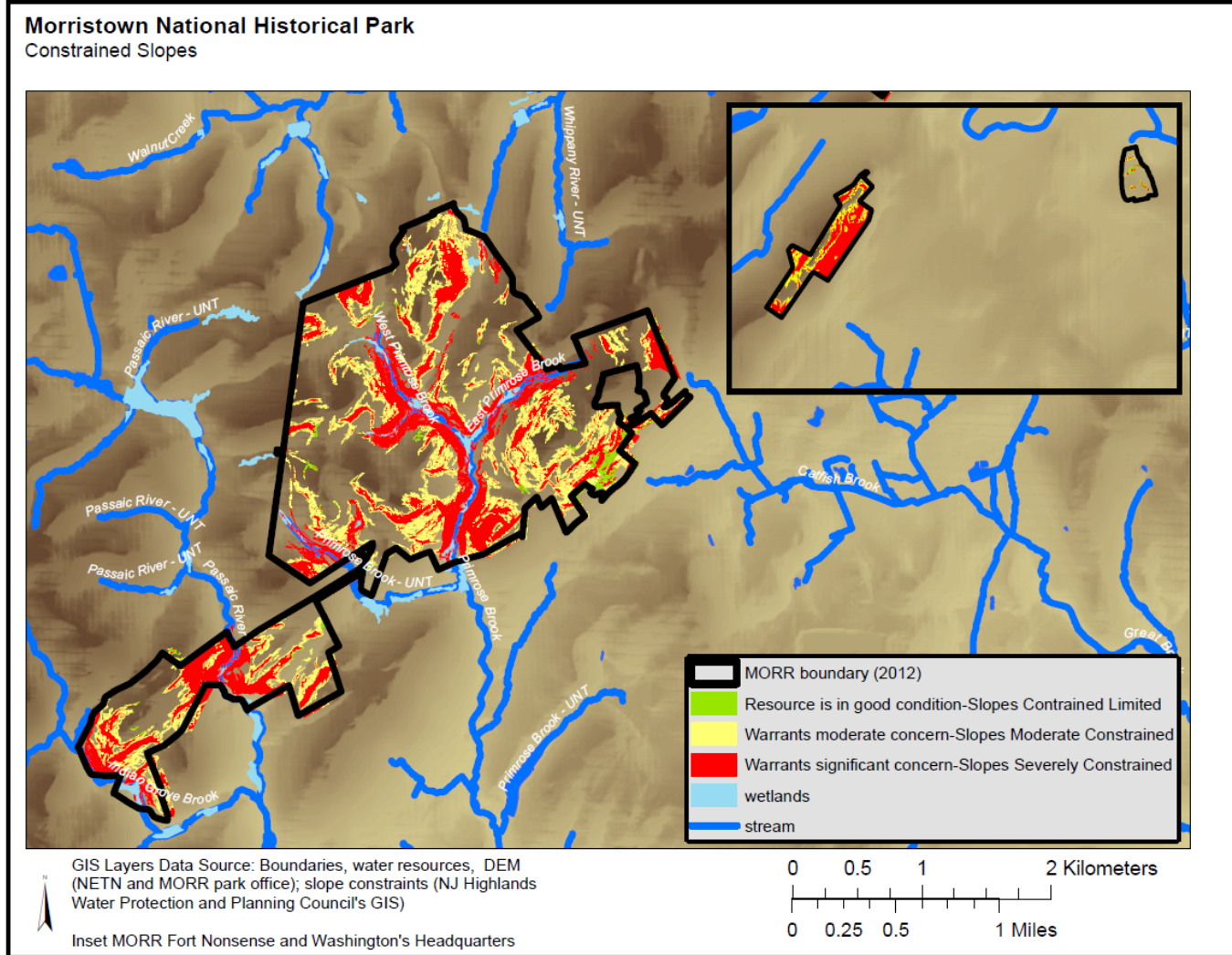
#### Condition and Trend

Severely constrained and moderately constrained slopes are present in all four units of MORR, especially the largest unit, Jockey Hollow, thus rating these areas as *Warrants Moderate Concern* and *Warrants Significant Concern* (Figure 4.7). Severe slope constraints tend to be located in near streams in both the Jockey Hollow and NJ Brigade Encampment area. These areas encompass slopes of 20% or greater and contain lands within riparian areas with slopes of 10% and greater. Steep slopes can induce erosion, creating silting of waterways, especially streams, leading to degradation of these habitats. Particularly, trout streams which are present in MORR and contain some of the State's highest water quality protections as Category One streams are near severely constrained slopes. Steep slope disturbance when severe, can result in land slumping and landslides that can damage both developed property and ecosystems. Heavily traveled trails near steep slopes in MORR can become quickly degraded, threatening the surrounding habitats. Soil characteristics and land cover all affect the potential for damages from the disturbance of steep slopes.

#### Data Gaps and Confidence in Assessment

Confidence was high and trend was not applicable for the variables assessed. A detailed soil erosion and sedimentation study may benefit future management goals for the park. An analysis of runoff potential, which includes a combination of a hydrologic soil group and land cover data will enable managers to generate runoff curve numbers (CNs). Runoff curve numbers can be assigned to calculate the runoff potential of a soil-land cover complex during periods when the soil is not frozen.





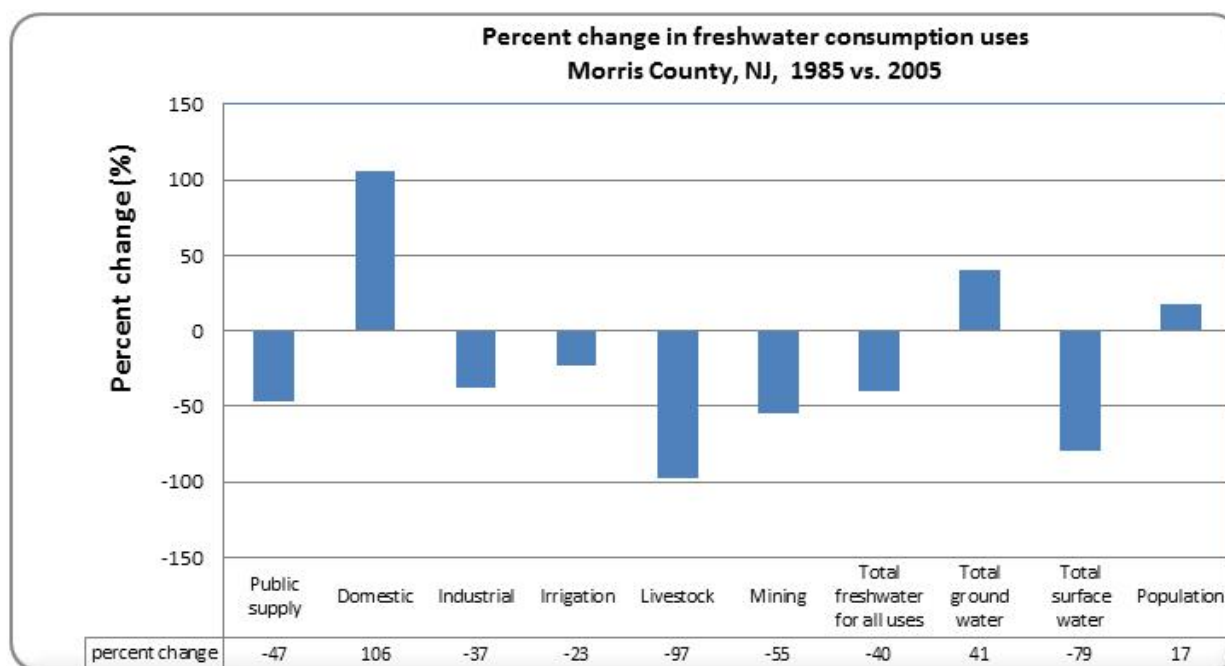
**Figure 4.7.** Constrained slope categories and their occurrence in MORR. Categories include: warrants significant concern (severely constrained slopes): all lands with slopes of 20% or greater and lands within Riparian Areas with slopes of 10% and greater; warrants moderate concern (moderately constrained slopes): all non-Riparian Area lands having a slope of 15% to less than 20% which are forested; and resource is in good condition (limited constrained slopes): all non-Riparian Area lands having a slope of 15% to less than 20%, which are non-forested, are not highly susceptible to erosion, and do not have a shallow depth to bedrock or a Soil Capability Class indicative of wet or stony soils.

## Water

### Stream Water Quantity

#### Relevance and Context

Managing stream surface waters to maintain healthy aquatic ecosystems is a challenge for park managers, as the demand for competing uses of water resources increases with expanding development, recreational use and unexpected changes in weather and climate. Within and surrounding MORR, shallow aquifers serve as the primary water supply to communities for domestic and industrial needs (Van Abs 1983). Additionally, natural springs which emanate from these shallow aquifers are the headwater source of the Primrose Brook and Jersey Brook in MORR (NPS 1993). As population density increases, water consumption demands for a variety of uses may increase, thus jeopardizing ground and surface water interactions for MORR's aquatic systems. Morris County's freshwater groundwater consumption has increased 41% from 1985 versus 2005 while total freshwater surface water consumption has decreased 79% (Kenny *et al.* 2009, USGS 2011) (Figure 4.8). Decreases in water consumption for uses such as public supply, industrial, irrigation, livestock and mining have occurred in Morris County while domestic supply consumption needs have increased 106% for the county since 1985 (Kenny *et al.* 2009, USGS 2011) (Figure 4.8). These increases and decreases in ground and surface waters may suggest a net neutral gain/loss in terms of water quantity resources for the park. However, the increase in domestic supply consumption may be due to an increase in a population which relies on groundwater resources, as Morris County has experienced a 17% increase in population from 1985 versus 2005.

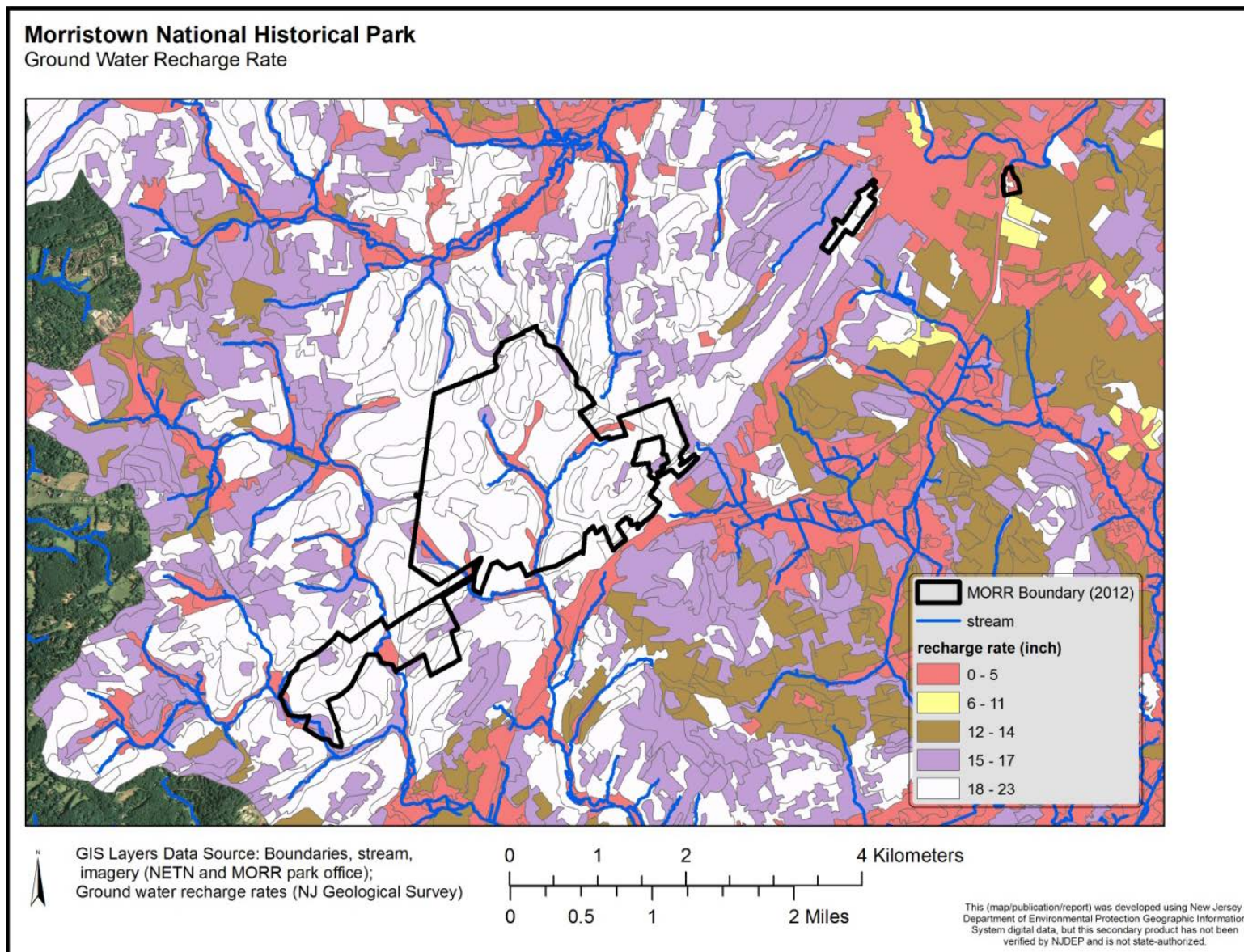


**Figure 4.8.** Percent change in freshwater consumption uses and population for Morris County, NJ in 1985 versus 2005. Data source: USGS, <http://water.usgs.gov/watuse/>.

Understanding the interaction of ground water and surface water is essential for effective management of aquatic systems. Base flow in streams and cold water habitats (e.g. trout habitats) depends on groundwater recharge. Changes in rates of recharge influence both groundwater and surface water quality and quantity. For example, the quantity and quality of surface runoff and groundwater recharge can be significantly affected by urbanization. If groundwater supplies decrease and more streamflow comes from surface runoff rather than groundwater, cold water fish habitats can be severely affected. On a longer time scale, changes in climate can have a significant impact on groundwater availability due to changes in precipitation and evaporation. Ground-water recharge near MORR was estimated using the NJ Geological Survey methodology which combines land-use/land-cover, soil and municipality-based climatic data to produce an estimate of ground-water recharge in inches/year (Charles *et al.* 1993). Parcels within MORR, including parcels north and southwest of the park boundary, contain high groundwater recharge rates when compared at the state and watershed management area level, with an estimated recharge rate of 18-23 in/year (457-584 mm/year) (Figure 4.9).

Surface water flow affects aquatic habitats in a number of ways including but not limited to: concentration of pollutants, oxygen and temperature changes, physical feature composition, transport of sediment, biological cues and minimum instream flow. Factors that affect the volume of flow include precipitation, base flow, vegetation and adjacent water bodies. Balancing ecosystem needs with changes in flow regimes requires the development of methods managers can use to classify streams and determine the ecological and hydrological impacts of changes in stream flow regimes. Flow criteria are vital to managers for water supply planning, drought management and establishing water quality standards and regulations. To protect water supplies, manage for future water supplies and protect aquatic ecology, tools for assisting in managing water resources in New Jersey have been developed. USGS scientists have developed the Hydroecological Integrity Assessment Process (HIP) and a suite of software tools for conducting a hydrologic classification of streams, addressing instream flow needs, and assessing past and proposed hydrologic alterations on streamflow and/or other ecosystem components (Henriksen *et al.* 2006). To date, the HIP has been fully developed for the State of New Jersey for stream sites with a long term-daily streamflow record. However, the development of flow statistics at ungaged stream sites, like those in MORR, have yet to be established.





**Figure 4.9.** Estimated ground water recharge rates (inches/year) for land parcels surrounding MORR.

### Data and Methods

Data from stream discharge measurements (n=5 streams) collected in MORR from NPS NETN Vital Signs monitoring efforts were used to assess MORR's surface water quantity. Average stream discharge and variability for MORR streams were analyzed using hydrologic data collected from May through October (once per month) from 2006-2011 to account for seasonality. Information on human population dynamics surrounding MORR and data from Morris County water consumption uses were also used to supplement the assessment of MORR's water quantity.



*Measuring stream flow discharge at Primrose Brook, July 2011. Photo: Beth Arsenault, NPS.gov*

### Reference Condition/Threshold Values Utilized

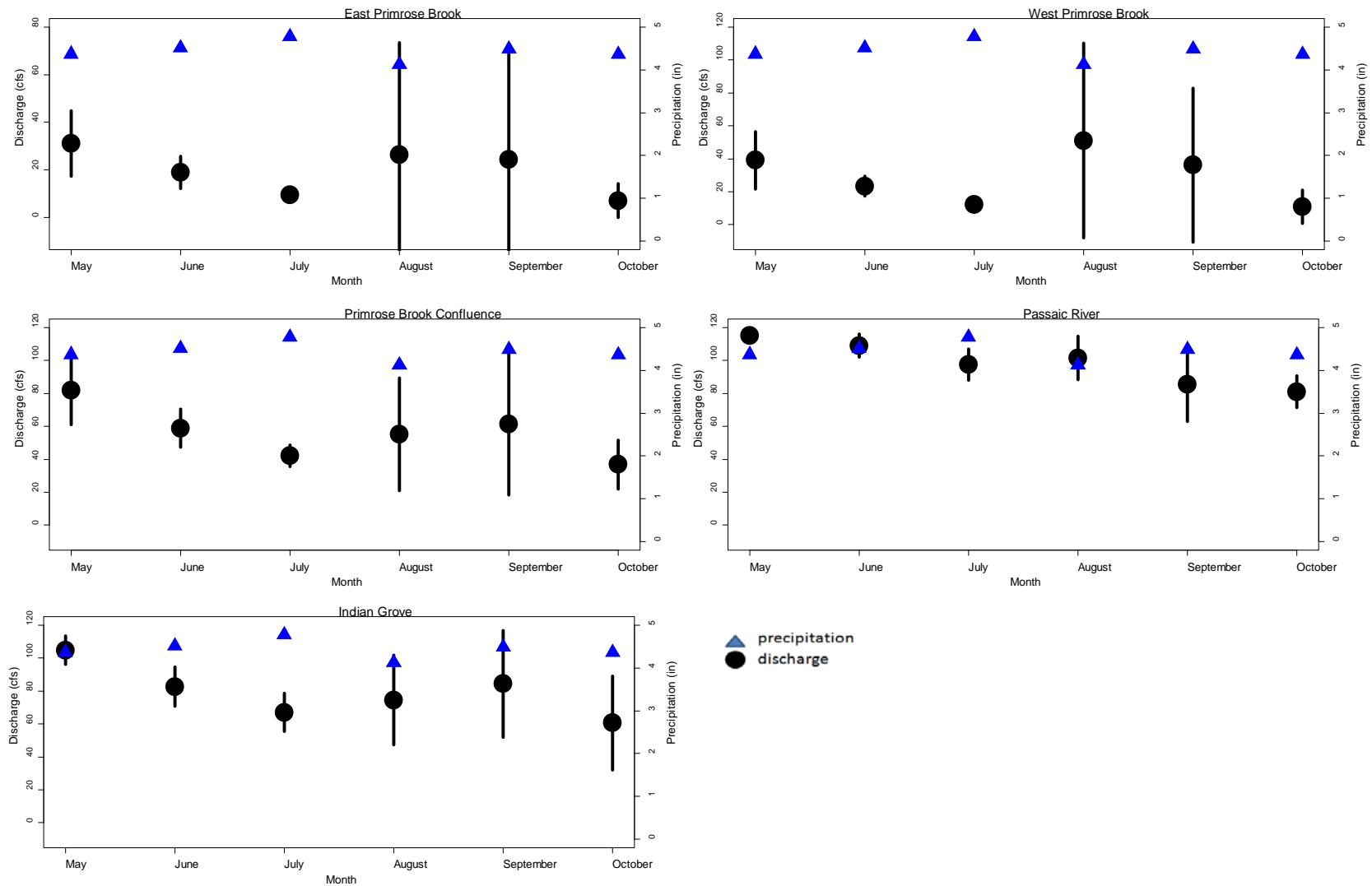
A threshold value could not be established for surface water quantity in MORR. The scarcity of long-term gauging records for hydrologic parameters, including baseflow measurements within MORR, is a limiting factor for assessing stream water quantity condition for the park. Furthermore, the lack of routine biological monitoring data for MORR streams limits the assessment of flow requirements for aquatic species found in the park's stream system.



### Condition and Trend

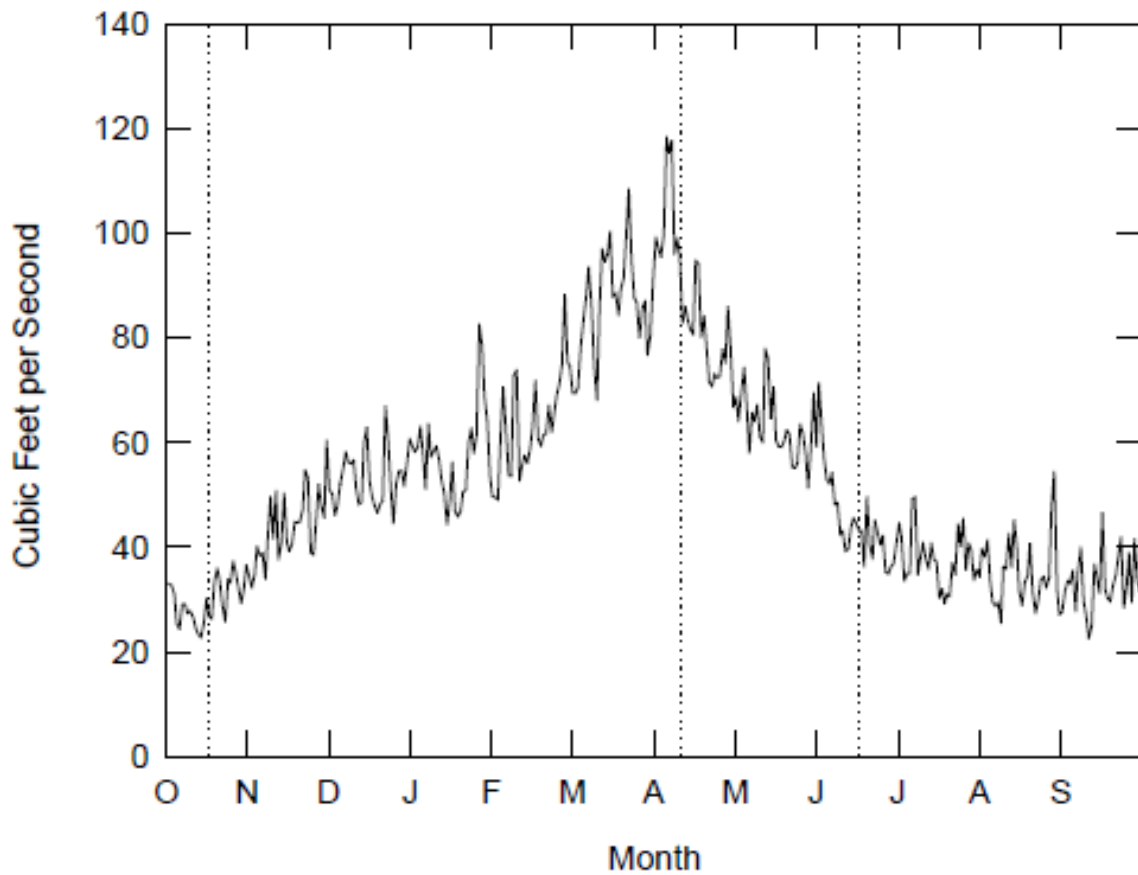
MORR's surface water quantity condition was assessed as *unknown*. The hydrological record for MORR's streams was insufficient to assess the condition or document any statistical trends for water quantity variables. Discharge data from five of MORR's streams demonstrate that discharge generally declines in May through July, which corresponds to the discharge pattern of the long term gaging station of Whippany River (USGS 01381500) located outside of MORR boundaries (Figure 4.10, 4.11). Most seasonal variation in stream water discharge is driven by climatic factors (e.g., precipitation, temperature, snowmelt). However, these temporal factors, such as the snow melt patterns which influence MORR streams, may change based on projected climate changes (Campbell *et al.* 2011). Increasing summer temperatures related to periods of low stream flow is when competition for water is greatest for public supply, agricultural and domestic needs, and may not be suffice for supporting the future needs of MORR's habitats. Population and housing density is projected to expand around MORR by 2020 (see Landscape Dynamics Section), thus increasing pressure on surface and ground water quantity for consumption uses and threatening biological integrity (Svancara *et al.* 2009). Short term temporal variability in discharge is prominent in small catchments such as MORR, where stream discharge can be flashy with flow increasing during heavy rain or snowmelt. Based on discharge data collected from MORR streams from 2006-2011, the greatest variation in discharge measures exists for the months of August and September (Figure 4.10). The exception to this pattern was for the Passaic River, one of the larger basins in MORR, which exhibited lower standard deviations from the mean discharge ( $\text{cfs}^{-1}$ ) for May through October.

The continuance of monitoring efforts in MORR will be critical in explaining the water quantity regimes of MORR's streams and determining future water management strategies for the park. The lack of flow statistics at ungaged streams in MORR produces management challenges for the future protection of stream basins in the park. Based on USGS StreamStats calculations, Indian Grove Brook basin has the greatest mean population density (523 people/sq. mi), potentially threatening the quantity and quality of water within this basin (Figure 4.12) (USGS 2012). Conversely, Primrose Brook basin has the lowest mean population density (226 people/ sq. mi) of the basins within the park and the greatest forested percent area (92.3%), designating conservation of this water resource as a significant importance to the park's ecological integrity (Figure 4.12). Management of aquatic environments should consider public water consumption demands during low water quantity periods (e.g., summer months), the increasing human population and housing density near MORR, the annual and seasonal variability of stream measurements and aquatic biota water quantity requirements. Loss of water quantity from park resources may be monitored by choosing a representative waterway within MORR to sample for water quantity parameters. In addition to monitoring for long term surface water flow, this monitoring effort would establish baseline water flow conditions, data that is essential for trend detection. Sampling efforts may be maintained by community volunteer groups (e.g., Trout Unlimited) in order to reduce NPS costs and the collected data could be verified either on an annual or biannual basis depending on the specific objective of the monitoring program. This effort would enable the park to potentially detect trends in water quantity and could serve as an 'alert' system in terms of the rate at which water quantity may be decreasing (or increasing) in MORR's waterways.



**Figure 4.10.** Mean stream discharge (cfs-1)  $\pm$  standard deviation collected from five MORR streams in May through October (2006-2011, once per month) by NPS and plotted with average monthly precipitation data for Northern New Jersey (1981-2010).

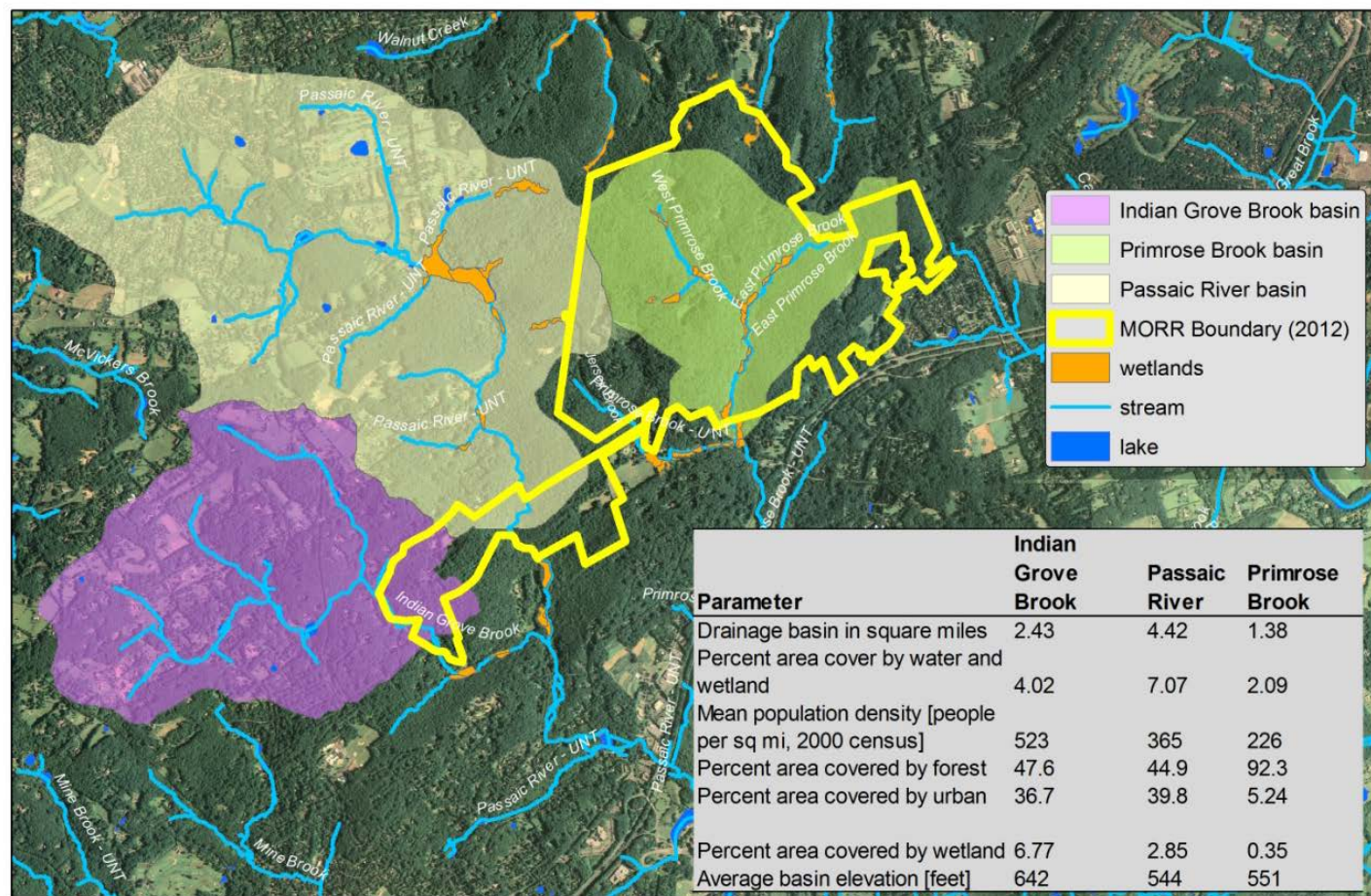
MORRISTOWN NATIONAL HISTORICAL PARK  
Whippany River at Morristown, NJ  
01381500, 66 year record



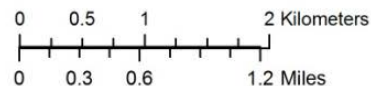
**Figure 4.11.** Mean annual hydrograph for hydrologic season determination. Hydrologic seasons for Morristown National Historical Park are: Jun. 15 to Oct. 15, Oct. 16 to Apr. 10, and Apr. 11 to Jun. 14 (Figure from NPS 1994).

# Morristown National Historical Park

## Stream Basins



GIS Layers Data Source: Boundaries, water sampling locations, streams, lakes, imagery (NETN and MORR park office); wetlands (MORR park office and Sneddon et al. 2008); Basins (USGS StreamStats). Basin estimates are calculated from a subjective point on the map, with the point for this map being when a stream exits MORR.  
NAD 1983 UTM 18N

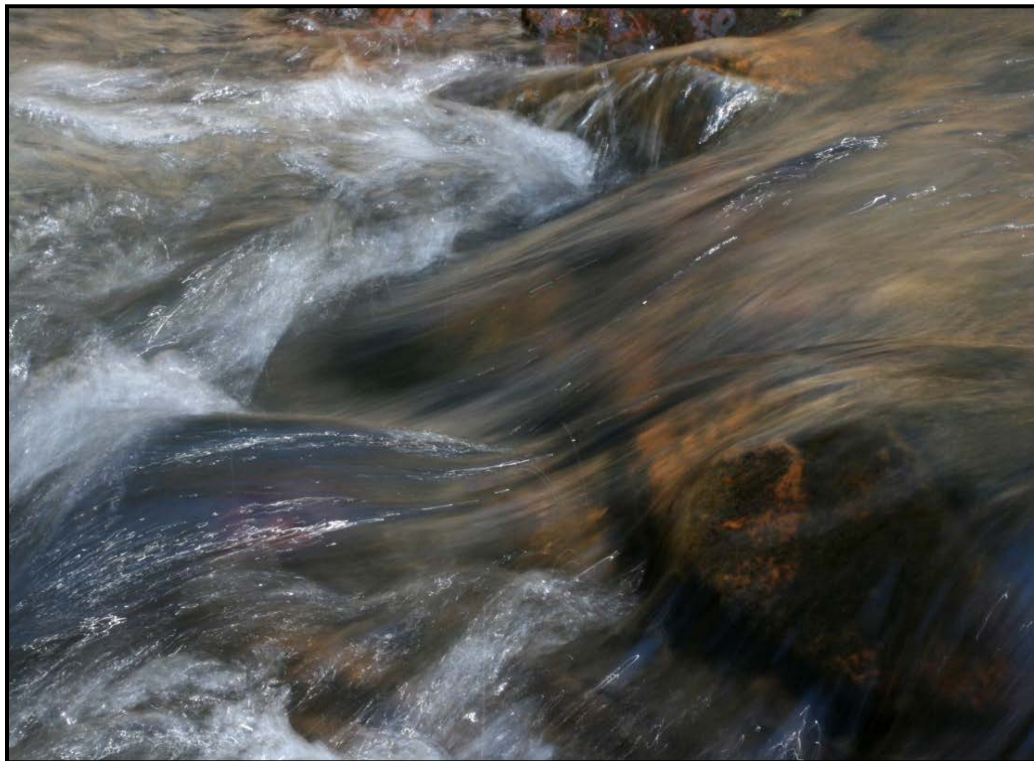


**Figure 4.12.** MORR stream basin descriptive statistics for Indian Grove Brook, Passaic River and Primrose Brook.



### Data Gaps and Confidence in Assessment

Confidence in the condition assessment of stream surface water quantity was low and trend assessment was not applicable. The current data availability hinders analyzing hydrologic data for MORR's surface water due to the infancy of the NETN Vital Signs Program and lack of long-term historical baseflow data. It is important to note that studies investigating changes in streamflow usually use multiple decades of data to determine reference levels and trends (Stewart *et al.* 2005). Long term records would allow comparisons between long term mean annual discharge and annual mean discharge for a particular year. Streamflow is strongly related to many critical physiochemical components of streams and rivers such as dissolved oxygen, channel geomorphology, and water temperature, and can be considered a variable that limits the disturbance, abundance and diversity of many aquatic plant and animal species. These chemical and biological relationships make the estimation of flow statistics for smaller streams in MORR vital to maintaining ecological integrity for the park. Additionally, the estimation of flow statistics for small, ungaged streams would allow for scientifically defensible management decisions by providing reference points that can be used as a basis for comparing pre- and post-watershed conditions. The determination of stream quantity needs or identifying a stream quantity threshold for MORR should consider the management objectives for MORR's surface waters (i.e., to maintain fish and macroinvertebrate communities, conserve a threatened species, recreational value, cultural restoration). Water quality is often tied to water quantity and the synchronization of monitoring quality and quantity variables will provide managers with an improved understanding of water quantity/quality relationships in MORR.



Surface water flow affects aquatic habitats in MORR in a number of ways, such as oxygen and temperature changes, physical feature composition, and biological cues. Photo by R. Wagner.

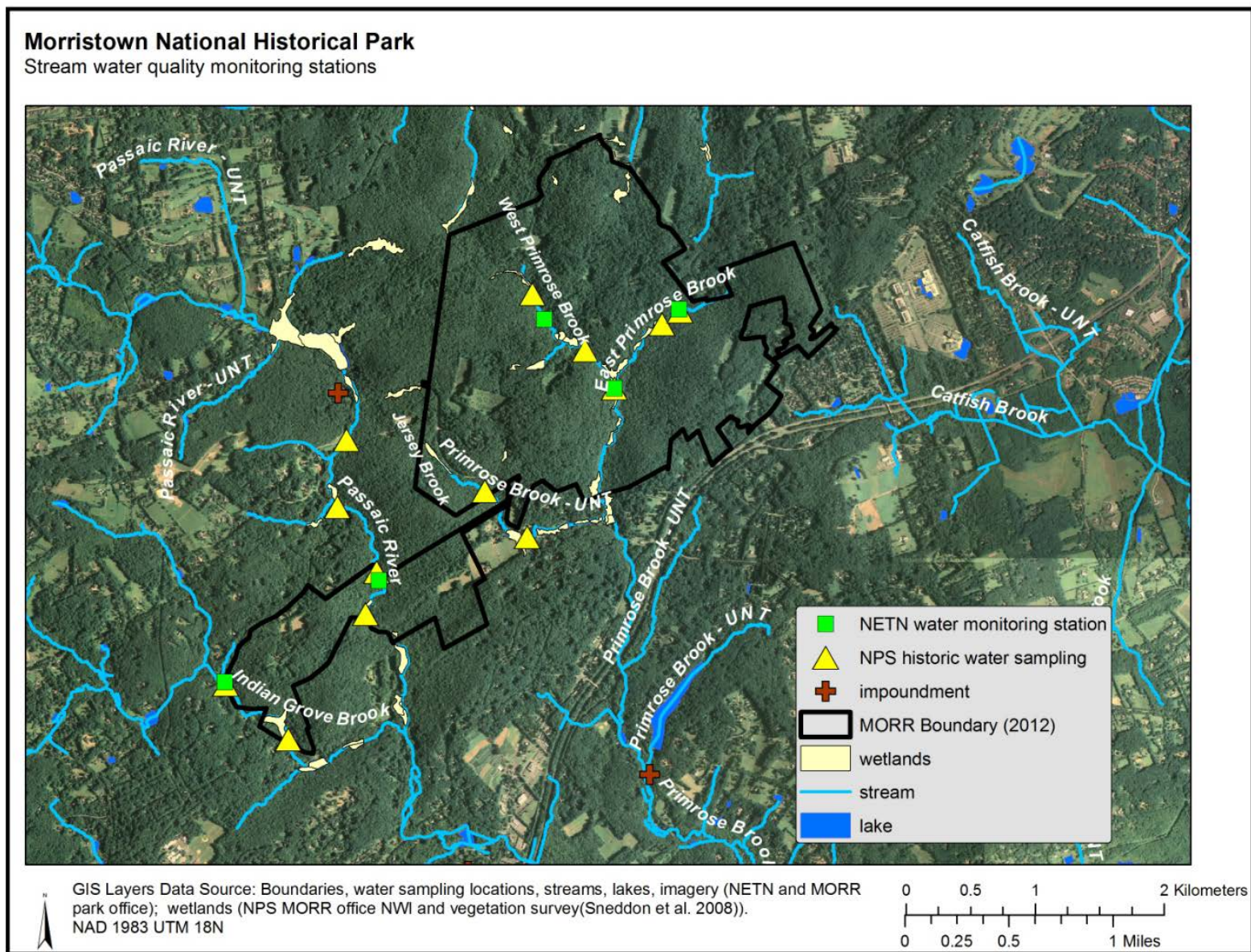
## ***Stream Water Chemistry***

### Relevance and Context

Understanding the physical, chemical and biological components of aquatic environments is vital to assessing overall water quality conditions for MORR. New Jersey's surface water quality standards (N.J.A.C. 7:9B General Surface Water Quality Standards) designate surface water classifications as FW1 (not subject to any man-made wastewater discharges) and FW2 waters (all other freshwaters except Pinelands waters). Streams which flow through MORR are classified under N.J.A.C. 7:9 B as *Freshwater Two-Trout Production, Category One (FW2-TPC1)*. Category One (C1) waters are protected from any measurable change in water quality because of their, "exceptional ecological significance, exceptional recreational significance, exceptional water supply significance, or exceptional fisheries resources." Additionally, the Federal Clean Water Act (1972) mandates that States submit to the U.S. EPA a list of waters that do not support their designated uses because they are not meeting surface water quality standards despite the implementation of technology-based effluent limits. Pollutants causing impairment that are not addressed by a Total Maximum Daily Load (TMDL) have been identified in the 2010 New Jersey 303(d) List of Water Quality Limited Waters (NJDEP 2011). Watersheds which encompass MORR and are listed on the current 303(d) listing include: Primrose Brook (listed for *E.coli*, dissolved oxygen, pH, temperature, phosphorus, total suspended solids), Great Brook above Green Village Road (dissolved oxygen) and Whippany River Malapardis to Lake Pocahontas (pH). The Passaic River Upper above Osborn Road has had a TMDL established previously for total phosphorus loads.

In order to evaluate the surface water quality within MORR, physical and chemical assessments of MORR's waters have been historically conducted for streams but are lacking for other surface waters such as wetland systems. Streams flowing within MORR boundaries include Primrose Brook, Passaic River, Indian Grove Brook and the ephemeral stream, Jersey Brook (Figure 4.13) (see Chapter 2 for details of MORR's hydrology). Historic water quality monitoring of these streams occurred in the late 1980's by agency personnel (e.g., USGS, NPS) and through independent studies (e.g., Mele and Mele 1983) with water quality monitoring resuming as a routine schedule in MORR in 2006 as part of the NPS NETN Vital Signs program. Currently, NETN conducts monthly sampling from May through October at five sites located in the Jockey Hollow and New Jersey Brigade Encampment Area units: Primrose Brook (east branch, west branch and confluence), Passaic River and Indian Grove Brook (Lombard *et al.* 2006). These sites are located near some of the original stream sites that were historically monitored by the aforementioned agencies (Figure 4.13).





**Figure 4.13.** Historic and current water quality monitoring stations established for streams within MORR boundaries and used in this NRCA.



## Data and Methods

Parameters collected monthly by NETN and used in this NRCA report included temperature, dissolved oxygen, pH and specific conductance. NETN biannual water samples collected in May and August included total phosphorus, total nitrogen,  $\text{NO}_2+\text{NO}_3$  and acid neutralizing capacity (ANC) (Lombard *et al.* 2006). Water quality parameters were then used to calculate averages from 2006-2012 (2006-2011 for  $\text{NO}_2+\text{NO}_3$ ) to assess water quality standards for MORR's streams (Table 4.6). Chloride, total dissolved solids and microbial parameters were not part of NETN monitoring (prior to 2012) but were added to this assessment as these variables were monitored in MORR by other agencies. Additionally, a percentage of individual samples which were compliant with water quality standards or criteria were calculated for each stream (Table 4.6). Linear regression of water quality variables queried from the USEPA STORET database, NPS reports (NPS 1993, 1994), and the NETN monitoring program was used to assess trends in water quality data collected from streams in MORR for the months of July through September to account for seasonality. Trends were *improving*, *deteriorating*, or *unchanging* based on the slope parameter of the *date* effect ( $\alpha=0.05$ ).

## Reference Condition/Threshold Values Utilized

The condition categories for water quality variables were rated *Resource is in Good Condition* or *Warrants Significant Concern* in relation to agency standards/criteria (Table 4.6). Surface water quality was assessed using standards and criteria set forth by the New Jersey Department of Environmental Protection surface water quality standards (N.J.A.C. 7:9B General Surface Water Quality Standards), U.S. EPA ecoregional nutrient criteria for region IX (U.S. EPA 2000, 822-B-00-019) and technical reports (U.S. EPA 1997, Stoddard *et al.* 2003). Certain water quality parameters, such as acid neutralizing capacity, do not have numerical criteria under State or Federal standards. In cases where water parameters lacked a standard or criteria, water quality thresholds were identified through peer review journal articles, technical reports or no threshold was assigned. The following identifies the threshold values utilized for each water quality variable analyzed in this report:

- **Temperature:** New Jersey has established temperature standards for FW2-TP streams at 22 degrees C or below. Changes in temperature can affect availability of oxygen to aquatic organisms.
- **Dissolved Oxygen (DO):** Aquatic life generally requires 5 mg/L of dissolved oxygen to thrive. Minimum average DO concentrations for New Jersey standards vary according to the type of trout stream. MORR's FW2-TP trout production waters shall not be less than 7.0 mg/L.
- **pH:** A range of 6.5 to 8.5 is the current New Jersey standard. Changes in pH can result from metal contamination or increases in aquatic plant growth.
- **Specific Conductance:** Conductivity in water is affected by the presence of anions and cations of inorganic dissolved solids such as chloride, nitrate, and phosphate, sodium, calcium, iron, and aluminum. Organic compounds like oil and phenols lower conductivity when in water. Conductivity in streams is affected primarily by the geology of the area through which the water flows. Discharges to streams can change the conductivity such as when failing sewage systems or agricultural runoff raise the conductivity because of the presence of chloride, phosphate, and nitrate. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500  $\mu\text{S}/\text{cm}$  and a range of 50 to 150  $\mu\text{S}/\text{cm}$  for U.S. rivers (USEPA 1997). However, due to the vast

natural variability of specific conductance in streams within this region, a threshold was not established for this assessment.

- **Chloride:** Dissolved chloride in surface waters occurs naturally from geology but high concentrations typically result from runoff of deicing salts applied to road surfaces and parking lots. Other sources of chloride include wastewater treatment plants, septic systems, and farming operations. New Jersey criteria for aquatic life for FW2 streams is 230 mg/L (chronic) and 860 mg/L (acute).

- **Total Dissolved Solids:** Total Dissolved Solids (TDS) is a measure of the amount of material (i.e., carbonate, calcium, sulfate, phosphate, nitrate) dissolved in water. A certain level of these ions in water is necessary for aquatic life; however, if TDS concentrations are too high or too low, the growth of many aquatic species can be limited, and death may occur. TDS may also reduce water clarity, contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals, and lead to an increase in water temperature. New Jersey State water quality standards and criteria list the threshold as no increase in background or >500 mg/L.

- **Acid Neutralizing Capacity (ANC):** ANC measures the ability of water to neutralize strong acid. New Jersey does not have a numerical criteria or standard for their waters. Values greater than 100 µeq/L (equivalent to 5 mg/L, Lombard *et al.* 2006) are considered well buffered and values less than zero are typical of acidic waters (Stoddard *et al.* 2003).

- **Nutrients:** New Jersey has established numerical values for total phosphorus in streams at 100 µg/L but has not established criteria or standards for other nutrient parameters such as total nitrogen. The U.S. EPA has established an ecoregional nutrient criteria for region IX (which encompasses MORR) to represent conditions of surface waters that may be affected by anthropogenic activities (USEPA, 2000):

**Total Nitrogen:** 0.69 mg/L (streams)

**NO<sub>2</sub>+NO<sub>3</sub>:** 0.125 mg/L (streams)

- **Microbial:** Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and stormwater runoff. Fecal coliform bacteria are found in the intestinal tract of all warm-blooded animals and therefore the presence of fecal coliform bacteria in surface waters indicates the presence of human or animal wastes. New Jersey's surface water quality standard for fecal coliform for FW2 streams is a geometric mean of 200 CFU/100 mL. *Escherichia coli* (*E. coli*) is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals and is one of the best indicators of health risk from water contact in recreational waters. New Jersey's surface water quality standard for *E.coli* for FW2 streams includes a geometric mean of 126 counts/100 mL.

#### Condition and Trend

Table 4.6 provides a summary of the condition assessment for water quality parameters of MORR's streams. Based on the six-year mean, temperature (°C), dissolved oxygen (mg/L), pH and acid neutralizing capacity (mg/L) levels were rated *Resource is in Good Condition* in all of MORR's streams when based on regulatory standards or criteria. Attainment of standards for individual water

samples ranged from 87%-100% for these parameters. Additionally, chloride (mg/L) levels measured from 2001-2004 and total dissolved solids (mg/L) measured from 2006-2009 in MORR's streams were compliant according to NJ water quality standards and thus rated *Resource is in Good Condition* (Table 4.6).

Mean total nitrogen (mg/L) levels from 2006-2012 exceeded U.S. EPA ecoregional IX criteria for East Primrose Brook, West Primrose Brook, and Indian Grove Brook and therefore were rated *Warrants Significant Concern*. These streams did attain individual total nitrogen measurements within the recommended ecoregional IX criteria except for Indian Grove Brook, which attained 0% compliance (Table 4.6). NO<sub>2</sub>+NO<sub>3</sub> (mg/L) levels in water samples exceeded criteria in all streams sampled in MORR (Table 4.6). Mean total phosphorus (µg/L) levels exceeded New Jersey standards only in East Primrose Brook and West Primrose Brook, rating these streams as *Warrants Significant Concern*. Overall, 62.3% of the samples in West Primrose Brook and 71.4% of the samples from East Primrose Brook were considered compliant for total phosphorus standards.

Only Primrose Brook was assessed for the microbial water quality parameters, fecal coliform and *E.coli* due to data availability. Mean *E.coli* counts from 2006-2008 exceeded NJ water quality standards, therefore rating this stream as *Warrants Significant Concern* for this parameter. Fecal coliform averages from 2006-2008 were within NJ standards, thus rating Primrose Brook *Resource is in Good Condition* for this parameter. Several individual samples exceeded microbial standards during this time period, as only 57% of samples from Primrose Brook were compliant for *E.coli* measures and 61.5% of samples were compliant for fecal coliform levels (Table 4.6). One of the potential sources of fecal contamination to surface waters in MORR include on-site septic systems, with septic systems being recognized as a high threat to natural resources in MORR by NPS staff (Mitchell *et al.* 2006). Primrose Brook within the Jockey Hollow unit contains 0-12 allowable septic systems in the HUC 14 watershed. However the Passaic River and Indian Grove Brook area which flows through the NJ Brigade unit contains 13-35 allowable septic systems and has a greater surrounding area of agricultural land use and residential development compared to Primrose Brook (Figure 4.14). Therefore, fecal coliform and *E. coli* counts in this watershed area may potentially be higher compared to Primrose Brook.

Changes in water measurements are often more important in assessing stream water quality than the actual measured value. Regression trend analysis for data collected from 1988-2012 and during July through September was performed for temperature, dissolved oxygen, pH, specific conductance measurements, chloride and TDS (Table 4.6). No statistically significant trend was detected for temperature measurements for the streams sampled in MORR ( $p>0.05$ ), thus categorizing MORR's streams as *condition is unchanging* for this parameter. Trends of dissolved oxygen were categorized as *condition is deteriorating* (statistically decreasing [ $p<0.05$ ]) for Primrose Brook Confluence, Indian Grove Brook and West Primrose Brook and *condition is unchanging* for East Primrose Brook and Passaic River (Table 4.6). Streams categorized as *condition is unchanging* for pH (no statistically significant trend [ $p<0.05$ ]) included Passaic River and Indian Grove Brook. East and West Primrose Brook and Primrose Brook Confluence pH levels were statistically increasing. We categorized these resources as *condition is unchanging* as pH levels were still well within the 6.5-8.5 water quality

standards, ranging from 7.1-7.4 measureable pH unit. (Table 4.6). However, if this trend continues, the trend will be assessed as *condition is deteriorating*.

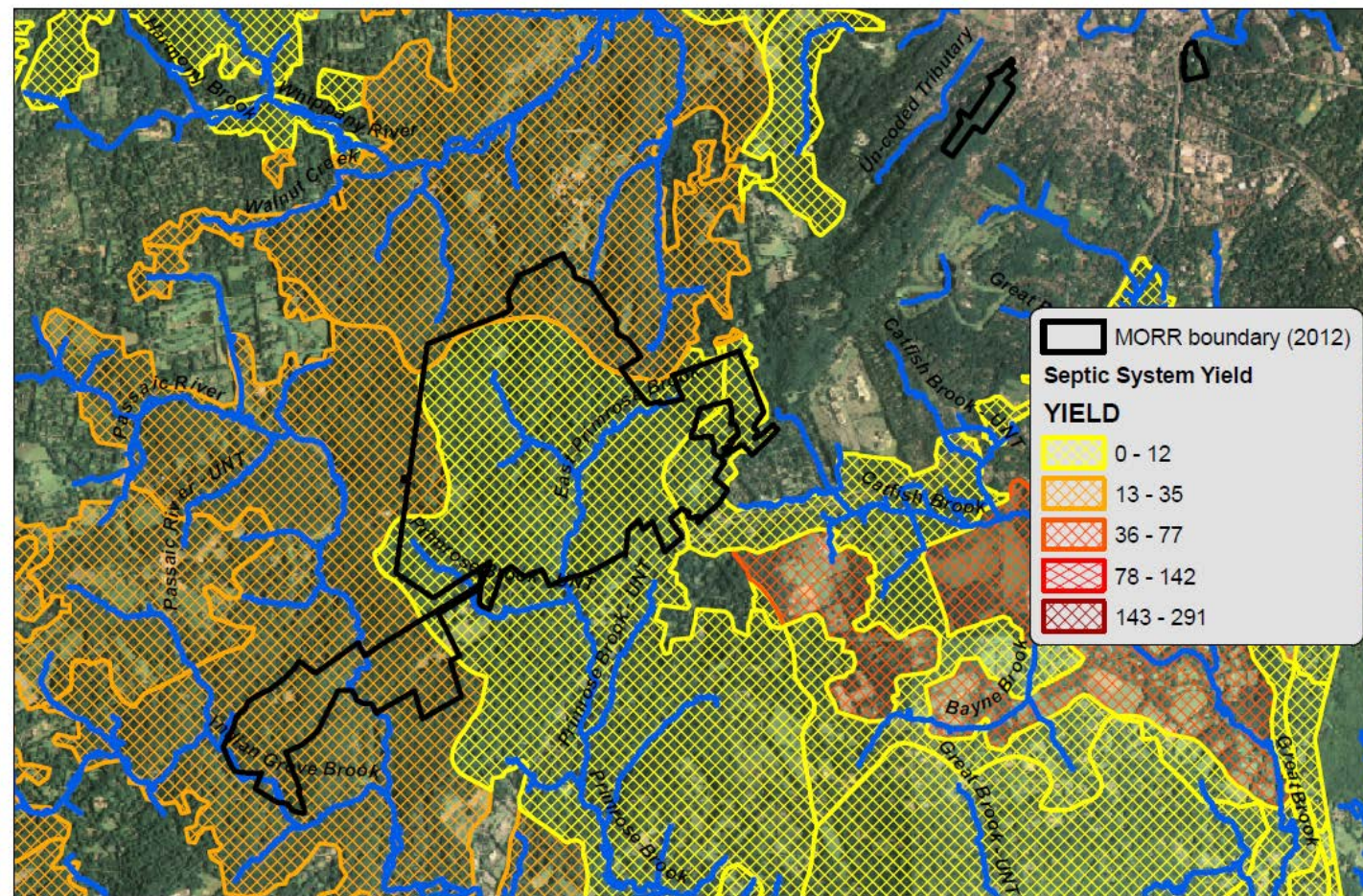
Specific conductance trends were categorized as *condition is deteriorating* due to these levels significantly increasing in all streams except for the Passaic River which was categorized as *condition is unchanging* due to no statistically significant change. The increase in conductance readings may be due to industrial pollution or urban runoff from areas surrounding MORR. Extended dry periods and low flow conditions could have also contributed to increased specific conductance readings in these streams. Likewise, chloride trend levels were categorized as *condition is deteriorating* due to these levels significantly increasing in all streams sampled in MORR. The increase in chloride may be due to road salt practices within the surrounding vicinity of MORR, as increases in chloride levels in streams during the last two decades are consistent with overall increases in salt use in the U.S. for deicing (Mullaney 2009). Additionally, TDS significantly increased only in Indian Grove Brook and Passaic River, thus categorizing the trend of both of these streams as *condition is deteriorating*. Both of these streams are surrounded by residential development and activities common in residential areas (e.g., lawn fertilizer application, urban runoff, soil erosion from development and septic system effluent) may have contributed to a significant increase in TDS for both of these streams in MORR. Trama and Galloway (1988) found that total suspended solids were slightly higher in Indian Grove Brook and Passaic River than the other streams in MORR.

#### Data Gaps and Confidence in Assessment

Confidence in the condition assessment of stream surface water quality was high for chemical parameters and medium for nutrient parameters. Confidence in the trend assessment was considered medium due to the lack of long term and consistent temporal data collection and low sample sizes collected for some of MORR's streams from 1988-2012. The nutrient criteria used for this assessment are used by NETN as a starting point for their stream assessment program. However, the U.S. EPA nutrient criteria used in this assessment may be biased to larger streams, unlike the small streams present in MORR. A lack of multiple sampling events and seasonal nutrient sampling restricts the analysis of linking water nutrient levels to trends in human activity in and around MORR. Depending on the objective(s) established for monitoring water quality in MORR, the park may benefit from switching from traditional once a month grab sampling techniques to the installation of continuously operating multi-parameter sondes. Furthermore, since MORR only manages sections of streams flowing through park boundaries, improving the park's water quality may also involve working with upstream communities and surrounding private landowners.



# **Morristown National Historical Park** Septic System Yield in HUC 14 subwatersheds



GIS Layers Data Source: Boundaries, imagery (NETN and MORR park office); septic system yield, (NJ Highlands Council);  
 Septic system yield =maximum # of allowable septs in a HUC 14 subwatershed.  
 NAD\_1983\_StatePlane\_New\_Jersey\_FIPS\_2900\_Feet

0 0.5 1 2 Kilometers  
 0 0.375 0.75 1.5 Miles

**Figure 4.14.** Septic system yield (number of allowable septs) within HUC 14 watersheds near MORR.

**Table 4.6.** Water quality condition assessment and trend detection for streams within MORR. Water quality condition was based on the corresponding threshold value. The trend of the water metric was either statistically increasing (↑), decreasing(↓), or no trend(Ø) ( $\alpha=0.05$ ).

Measure	Threshold	Samples	Period of Data	Results (Mean± St.Dev)	Condition (% samples within threshold)	Trend/ time series
Temperature (°C)	22 (FW2-TP streams) <sup>1</sup>	East Primrose Brook=66	2006-2012 (Apr.- Oct.)	14±5	Resource is in Good Condition (100)	Ø,a
		Primrose Brook Confluence=64		14±5	Resource is in Good Condition (100)	Ø,a
		Indian Grove Brook=66		14±7	Resource is in Good Condition (89.4)	Ø,a
		Passaic River=57		16±6	Resource is in Good Condition (89.4)	Ø,a
		West Primrose Brook=63		15±4	Resource is in Good Condition (100)	Ø,a
Dissolved Oxygen (mg/L)	7.0 mg/L (FW2-TP streams) <sup>1</sup>	East Primrose Brook=66	2006-2012 (Apr.- Oct.)	10.8±11.5	Resource is in Good Condition (98.5)	Ø,a
		Primrose Brook Confluence=63		9.7±2.3	Resource is in Good Condition (98.4)	↓,a
		Indian Grove Brook=66		9.6±1.4	Resource is in Good Condition (100)	↓,a
		Passaic River=57		9.7±1.4	Resource is in Good Condition (100)	Ø,a
		West Primrose Brook=63		9.5±1.4	Resource is in Good Condition (96.8)	↓,a
pH	6.5≤pH≤8.5 <sup>1</sup>	East Primrose Brook=66	2006-2012 (Apr.- Oct.)	7.2±0.6	Resource is in Good Condition (92.4)	↑,a
		Primrose Brook Confluence=64		7.4±0.5	Resource is in Good Condition (92.1)	↑,a
		Indian Grove Brook=66		7.3±0.6	Resource is in Good Condition (92.4)	Ø,a
		Passaic River=57		7.4±0.4	Resource is in Good Condition (93.0)	Ø,a
		West Primrose Brook=63		7.1±0.5	Resource is in Good Condition (93.4)	↑,a
Specific Conductance (µS/cm)	Due to its natural variability, no criterion is recommended for this parameter.	East Primrose Brook=66	2006-2012 (Apr.- Oct.)	116±23	-----	↑,a
		Primrose Brook Confluence=64		111±26	-----	↑,a
		Indian Grove Brook=66		234±38	-----	↑,a
		Passaic River=57		229±40	-----	Ø,a
		West Primrose Brook=63		105±109	-----	↑,a
Chloride (mg/L)	230 mg/ L (chronic) <sup>1</sup>  860 mg/L (acute) <sup>1</sup>	East Primrose Brook=12	2001-2004 (Apr.- Oct.)	22±9	Resource is in Good Condition (100)	↑,b
		Primrose Brook Confluence=11		18±6	Resource is in Good Condition (100)	↑,b
		Indian Grove Brook=24		43±9	Resource is in Good Condition (100)	↑,c
		Passaic River=36		46±14	Resource is in Good Condition (100)	↑,c
		West Primrose Brook=21		17±8	Resource is in Good Condition (100)	↑,c



Measure	Threshold	Samples	Period of Data	Results (Mean± St.Dev)	Condition (% samples within threshold)	Trend/ time series
Total Dissolved Solids (mg/L)	No increase in background or 500 mg/L <sup>1</sup>	East Primrose Brook=13	2006-2009 (Apr.- Oct.)	55±14	Resource is in Good Condition (100)	Ø,d
		Primrose Brook Confluence=13		52±16	Resource is in Good Condition (100)	Ø,d
		Indian Grove Brook=22		115±16	Resource is in Good Condition (100)	↑,d
		Passaic River=34		106±36	Resource is in Good Condition (100)	↑,d
		West Primrose Brook=24		52±10	Resource is in Good Condition (100)	Ø,d
Acid Neutralizing Capacity (mg/L)	ANC>100 µeq/L (or 5 mg/L) <sup>3</sup>	East Primrose Brook=14	2006-2012 (May & Aug.)	562±246	Resource is in Good Condition (100)	-----
		Primrose Brook Confluence=15		685±126	Resource is in Good Condition (100)	-----
		Indian Grove Brook=18		661±179	Resource is in Good Condition (94.4)	-----
		Passaic River=15		729±314	Resource is in Good Condition (86.7)	-----
		West Primrose Brook=14		452±183	Resource is in Good Condition (92.8)	-----
Total Nitrogen (mg/L)	0.69 mg/L (streams) <sup>3</sup>	East Primrose Brook=14	2006-2012 (May & Aug.)	0.76±0.33	Warrants Significant Concern (35.7)	-----
		Primrose Brook Confluence=15		0.43±0.07	Resource is in Good Condition (100)	-----
		Indian Grove Brook=16		1.08±0.17	Warrants Significant Concern (0)	-----
		Passaic River=13		0.68±0.21	Resource is in Good Condition (46.7)	-----
		West Primrose Brook=12		1.21±3.19	Warrants Significant Concern (78.6)	-----
Total Phosphorus (µg/L)	36.56 (ug/L) <sup>3</sup>	East Primrose Brook=11	2006-2012 (May & Aug.)	59.77±138.55	Warrants Significant Concern (71.4)	-----
		Primrose Brook Confluence=13		21.33±7.46	Resource is in Good Condition (93.3)	-----
		Indian Grove Brook=15		30.35±30.44	Resource is in Good Condition (83.3)	-----
		Passaic River=11		28.66±11.85	Resource is in Good Condition (66.7)	-----
		West Primrose Brook=11		195.09±544.64	Warrants Significant Concern (62.3)	-----
NO <sub>2</sub> +NO <sub>3</sub> (mg/L)	0.125 mg/L (stream) <sup>3</sup>	East Primrose Brook=12	2006-2011 (May & Aug.)	0.550±0.180	Warrants Significant Concern (0)	-----
		Primrose Brook Confluence=13		0.310±0.070	Warrants Significant Concern (0)	-----
		Indian Grove Brook=16		0.920±0.160	Warrants Significant Concern (0)	-----
		Passaic River=13		0.470±0.180	Warrants Significant Concern (0)	-----
		West Primrose Brook=12		0.200±0.090	Warrants Significant Concern (18.2)	-----
Microbial- <i>E.coli</i> (count)	126/100 mL (geometric mean, FW2) <sup>1</sup>	Primrose Brook (01378780)=14	2006-2008	182	Warrants Significant Concern (57)	-----



#### Thresholds

<sup>1</sup> New Jersey State N.J.A.C. 7:9B General Surface Water Quality Standards.  
[http://www.nj.gov/dep/rules/rules/njac7\\_9b.pdf](http://www.nj.gov/dep/rules/rules/njac7_9b.pdf)

<sup>2</sup> Stoddard *et al.* (2003).

<sup>3</sup> U.S. EPA ecoregional nutrient criteria for region IX. (USEPA 2000, 822-B-00-018).  
[http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers\\_9.pdf](http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_9.pdf)

#### Trend time series data

<sup>a</sup> 1988-2012; <sup>b</sup> 1997-2003; <sup>c</sup> 1997-2004; <sup>d</sup> 1997-2009

#### Data

-U.S. EPA STORET database; NPS Northeast Temperate Network Vital Signs Monitoring Program

## **Invasive Exotic Plants**

### ***Invasive Vegetation in Forests***

#### Relevance and Context

Invasive exotic vegetation has diminished the cultural character of MORR by engulfing historic trails and roads and replacing native understory vegetation. The continued establishment of these species threatens both the historic and biological integrity of the park. New Jersey contains more than 140 exotic invasive plant species, with several of these species occurring within MORR (EDDMapS 2012). In order to address the issue of invasive plants establishing in MORR, early detection strategies for invasive and exotic plants in MORR's forests have been implemented by NETN Vital Signs efforts (Table 4.7). The early detection strategy detects listed invasive species and provides the opportunity for eradication of those populations before becoming establishing within the park, thus minimizing ecosystem degradation (Keefer *et al.* 2010).

**Table 4.7.** Early Detection Species for MORR (Keefer et al. 2010).

Scientific Name	Common Name
<i>Aralia elata</i>	Japanese aralia
<i>Cardamine impatiens</i>	narrowleaf bittercress
<i>Frangula alnus</i>	glossy buckthorn
<i>Heracleum mantegazium</i>	giant hogweed
<i>Oplismenus hirtellus</i> ssp. <i>undulatifolius</i>	wavyleaf basketgrass
<i>Polygonum perfoliatum</i>	mile-a-minute
<i>Pueraria montana</i> var. <i>lobata</i>	kudzu
<i>Ranunculus ficaria</i>	lesser celandine
<i>Rhamnus cathartica</i>	common buckthorn

Furthermore, a list of key nonnative plant species that tend to be highly invasive in northeastern forests and succession habitats was developed by NETN in order to understand their potential threat to forest regeneration (Table 4.8). MORR currently contains 21 species and subspecies of NETN key nonnative plant species within its boundaries based on documentation by The New Jersey Invasive Species Strike Team NJISST (2011), Keefer *et al.* (2010) and Miller *et al.* (2012) (Table 4.8). NJISST has developed an invasive target plant list and ranking system for the state, in addition to identifying species which are a “Top 20” priority for removal (two Top 20 species are aquatic) (NJISST, [www.njisst.org](http://www.njisst.org)). Nine of the 18 terrestrial Top 20 invasive species have been documented in MORR (Table 4.8).

**Table 4.8.** Invasive plant species list representing four categories: the “2011 Target Plant List” by NJISST (2011), plant species serving as NPS NETN key indicator species, NETN early detection species and species found in MORR. The 2011 Top 20 priority target invasive plants for New Jersey by NJITSS are highlighted in yellow.

Scientific Name	Common Name	NJISST Threat Level <sup>1</sup>	NETN Key Indicator Species <sup>2</sup>	NETN Early Detection Species <sup>3</sup>	Present in MORR <sup>3,4,5</sup>
<i>Acer palmatum</i>	Japanese maple	<i>moderate</i>			✓
<i>Acer platanoides</i>	Norway maple		✓		✓
<i>Ailanthus altissima</i>	tree-of-heaven		✓		✓
<i>Akebia quinata</i>	chocolate vine	<i>high</i>			✓
<i>Alliaria petiolata</i>	garlic mustard		✓		✓
<i>Aralia elata</i>	Japanese angelica tree	<i>high</i>		✓	✓
<i>Berberis thunbergii</i>	Japanese barberry		✓		✓
<i>Berberis vulgaris</i>	European barberry	<i>moderate</i>	✓		
<i>Buddleja davidii</i>	orange eye butterflybush	<i>moderate</i>			
<i>Cardamine impatiens</i>	narrowleaf bittercress		✓	✓	✓
<i>Celastrus orbiculatus</i>	Oriental bittersweet		✓		✓
<i>Cynanchum louiseae</i>	black swallowwort	<i>high</i>	✓		✓
<i>Cynanchum rossicum</i>	European swallow-wort		✓		
<i>Euonymus alatus</i>	winged burning bush		✓		✓
<i>Euonymus fortunei</i>	winter creeper	<i>high</i>	-		
<i>Frangula alnus</i>	glossy buckthorn	<i>high</i>	✓	✓	
<i>Hedera helix</i>	English ivy	<i>moderate</i>			✓
<i>Heracleum mantegazzianum</i>	giant hogweed	<i>moderate</i>		✓	

Scientific Name	Common Name	NJISST Threat Level <sup>1</sup>	NETN Key Indicator Species <sup>2</sup>	NETN Early Detection Species <sup>3</sup>	Present in MORR <sup>3,4,5</sup>
<i>Ligustrum</i> spp. ( <i>obtusifolium</i> , <i>vulgare</i> )	privet		✓		✓
<i>Lonicera japonica</i>	Japanese honeysuckle		✓		✓
<i>Lonicera</i> spp. ( <i>morrowii</i> , <i>tatarica</i> , x <i>bella</i> )	exotic honeysuckle	moderate	✓		✓
<i>Luzula luzuloides</i>	forest woodrush		✓		
<i>Microstegium vimineum</i>	Japanese stiltgrass		✓		✓
<i>Miscanthus sinensis</i>	Chinese silvergrass	high			
<i>Oplismenus hirtellus</i>	wavy-leaf basket grass	high		✓	
<i>Photinia villosa</i>	Oriental photinia	high			✓
<i>Polygonum caespitosum</i>	Oriental ladythumb		✓		✓
<i>Polygonum cuspidatum</i>	Japanese knotweed		✓		✓
<i>Polygonum perfoliatum</i>	mile-a-minute			✓	✓
<i>Pueraria montana</i>	kudzu	high		✓	
<i>Pyrus calleryana</i>	callery pear	high			
<i>Rhamnus cathartica</i>	common buckthorn	high		✓	
<i>Ranunculus ficaria</i>	lesser celandine			✓	
<i>Rhodotypos scandens</i>	jetbead	high	✓		✓
<i>Rosa multiflora</i>	multiflora rose		✓		✓
<i>Rubus phoenicolasius</i>	wineberry		✓		✓
<i>Viburnum dilatatum</i>	Linden viburnum	high			✓
<i>Viburnum sieboldii</i>	Siebold's viburnum	high			✓
<i>Wisteria floribunda</i>	Japanese wisteria	high			✓

<sup>1</sup> New Jersey Invasive Species Strike Team (NJISST). 2011 Target Plant List. [www.njisst.org](http://www.njisst.org). NJISST threat levels include *mild*, *moderate*, and *high*. Two aquatic plant species were removed from the "Top 20" list in the table above due to the lack of relevancy.

<sup>2</sup> Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski, and D. Faber-Langendoen. 2009. Long-term forest monitoring protocol: Northeast Temperate Network. Natural Resource Report NPS/NETN/NRR—2009/117. National Park Service, Fort Collins, Colorado.

<sup>3</sup> Keefer, J. S., M. R. Marshall, and B. R. Mitchell. 2010. Early detection of invasive species: surveillance, monitoring, and rapid response: Eastern Rivers and Mountains Network and Northeast Temperate Network. Natural Resource Report NPS/ERMN/NRR—2010/196. National Park Service, Fort Collins, Colorado.

<sup>4</sup> Miller, K. M., B. R. Mitchell, and J. S. Wheeler. 2012. Forest health monitoring in the Northeast Temperate Network: 2011 summary report. Natural Resource Technical Report NPS/NETN/NRTR—2012/604. National Park Service, Fort Collins, Colorado.

<sup>5</sup> per communication R. Masson, NPS

### Data and Methods

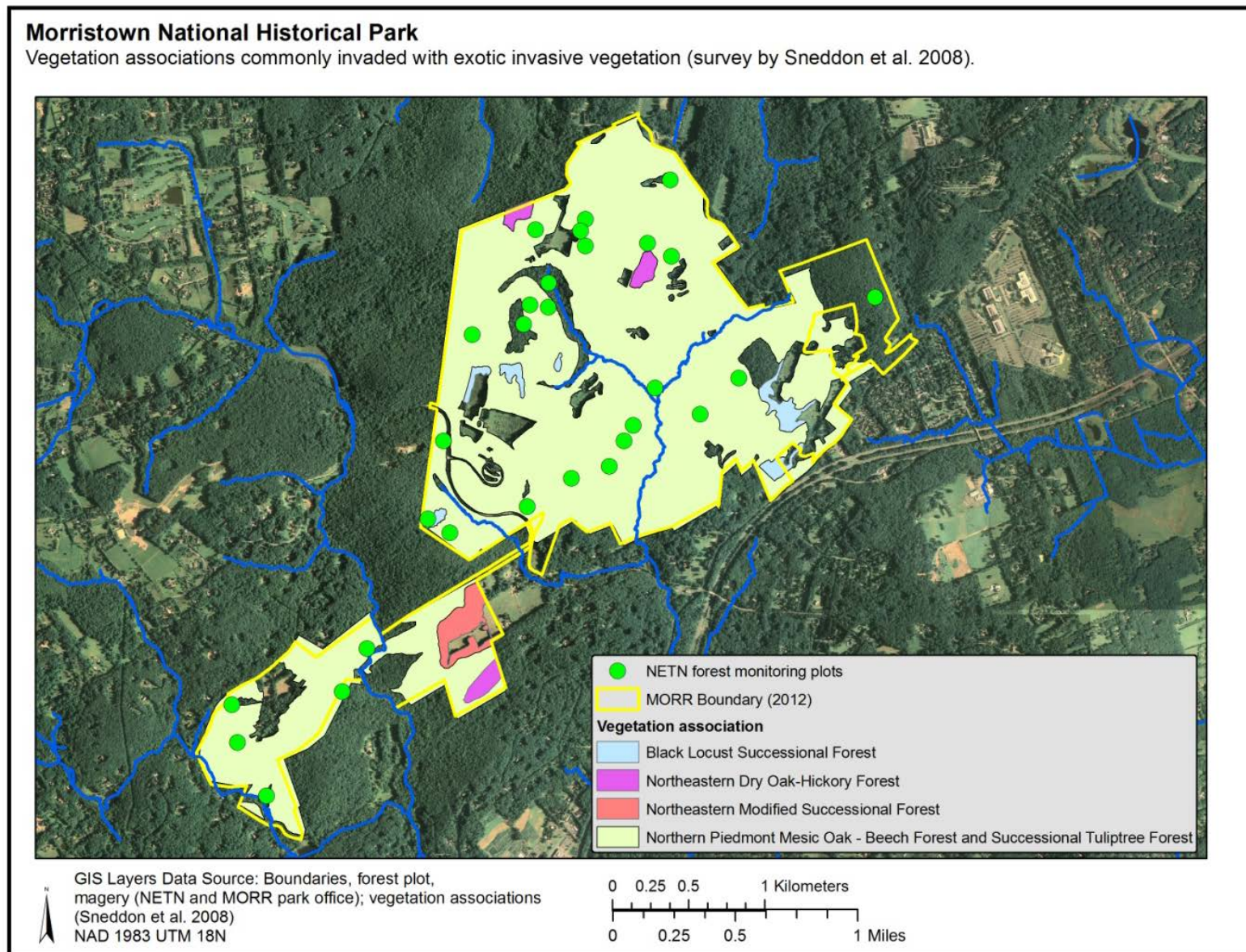
Key invasive exotic plant indicator species in the northeastern U.S. were identified and used for rating the condition of MORR's forest vegetation composition, as this was the most quantitative and recent data for the park. Indicator species were selected based on the threat they pose as invaders of northeastern forest, woodland and successional habitats, as documented by the Invasive Plant Atlas of New England, the NatureServe Explorer database or by studies within NETN parks (Tierney *et al.* 2010). The average number of key indicator invasive plant species per forest plot (N=28 plots) surveyed in 2009 and 2011 was calculated and compared to a condition assessment rating system established for the NETN Vital Signs Program (Miller *et al.* 2012). Statistical trend analyses were not calculated due to the currently limited data collected by the NETN monitoring program.

### Reference Condition/Threshold Values Utilized

Condition categories established for the NETN Vital Signs Program were used to assess invasive species within forest habitat in MORR (Miller *et al.* 2012). Less than 0.5 key indicator species/plot rated *Resource is in Good Condition*, 0.5 to <3.5 species/plot rated *Warrants Moderate Concern*, and 3.5 or more species/plot rated *Warrants Significant Concern* (Table 4.9).

### Condition and Trends

Monitoring of MORR forests by the NETN for invasive exotic vegetation resulted in a *Warrants Significant Concern* rating for mature, successional and overall forests in MORR (4.05, 8.67 and 5.54 key species per plot, respectively) (Table 4.9) (Miller *et al.* 2012). The most frequent invasive exotic species inventoried in MORR's mature forest plots were Japanese barberry (*Berberis thunbergii*), Japanese stiltgrass (*Microstegium vimineum*), oriental bittersweet (*Celastrus orbiculatus*), narrowleaf bittercress (*Cardamine impatiens*) and wineberry (*Rubus phoenicolasius*) (Miller *et al.* 2012). These species were also the most frequently sampled species in successional forest plots sampled in MORR along with multiflora rose (*Rosa multiflora*) and Japanese honeysuckle (*Lonicera japonica*) (Miller *et al.* 2012). All species listed above are NETN key indicator species but are not listed on the NJISST 2011 Target Plant list (Table 4.8). Sneddon *et al.* (2008) mapped MORR's vegetation associations and noted the associations commonly infested with invasive plant species. These associations cover the majority of the park, further indicating the role of invasive exotic vegetation in the composition of MORR's forests (Figure 4.15). Additionally, a new species, mile-a-minute (*Polygonum perfoliatum*), a NETN early detection species, was discovered in MORR in 2013 along with the biological control weevil that consume this invasive plant (per communication, R. Masson, NPS).



**Figure 4.15.** Vegetation associations mapped by Sneddon et al. (2008) and noted as containing communities of invasive vegetation.





Mile-a-minute (*Polygonum perfoliatum*) invasion. Photo: Leslie J. Mehrhoff, University of Connecticut, Bugwood.org

Studies have been conducted examining the invasive vegetation species such as Japanese barberry (*Berberis thunbergii*) and Japanese stiltgrass (*Microstegium vimineum*) in relation to vegetation structure, soil properties (pH, nitrification), exotic earthworms and deer browsing in MORR's forests (Kourtev *et al.* 1998, Ehrenfeld *et al.* 2001, Southgate 2002, Miller *et al.* 2011). These specific invasive plants were common in areas in MORR's forests with less oak trees (*Quercus* sp.) in the forest canopy and a lack of native understory shrubs (Kourtev *et al.* 1998). Additionally, pH of soils in invaded areas was significantly higher than in the uninvaded areas, with litter and organic horizons being thinner (Kourtev *et al.* 1998). Soils in invaded areas often had higher net N mineralization rates than did soils beneath adjacent patches of native understory shrub

(Ehrenfeld *et al.* 2001). Southgate (2002) noted that the non-native shrubs, Japanese barberry and multiflora rose, tend to grow better without deer browsing in MORR, based on enclosure plot studies. Continued monitoring efforts of forest soil properties, invertebrate and deer browsing studies and removal of invasive vegetation in forests are necessary in MORR to determine 1) if an invasive species range is expanding in MORR, 2) whether invasive vegetation density levels are increasing in the park's forest habitat and 3) determine areas in MORR's forests which, based on soil properties, may become vulnerable to invasive vegetation establishment. Because Superstorm Sandy created large gaps in the park's canopy in late 2012, there is an increase in sunlight hitting the forest floor, thereby increasing the probability of invasive plants becoming established in these areas. Therefore, monitoring and managing invasive plant species in MORR is even more vital in order to assess MORR's vulnerability and condition of invasive plants.

**Table 4.9.** Condition assessment for MORR invasive exotic plants in forest communities.

Measure	Condition Categories		Result
Invasive exotic plants in forest habitat	Warrants Significant Concern	3.5 or more key species per plot	Overall: 5.54
	Warrants Moderate Concern	0.5 to < 3.5 key species per plot	Mature: 4.05
	Resource is in Good Condition	< 0.5 key species per plot	Successional: 8.67

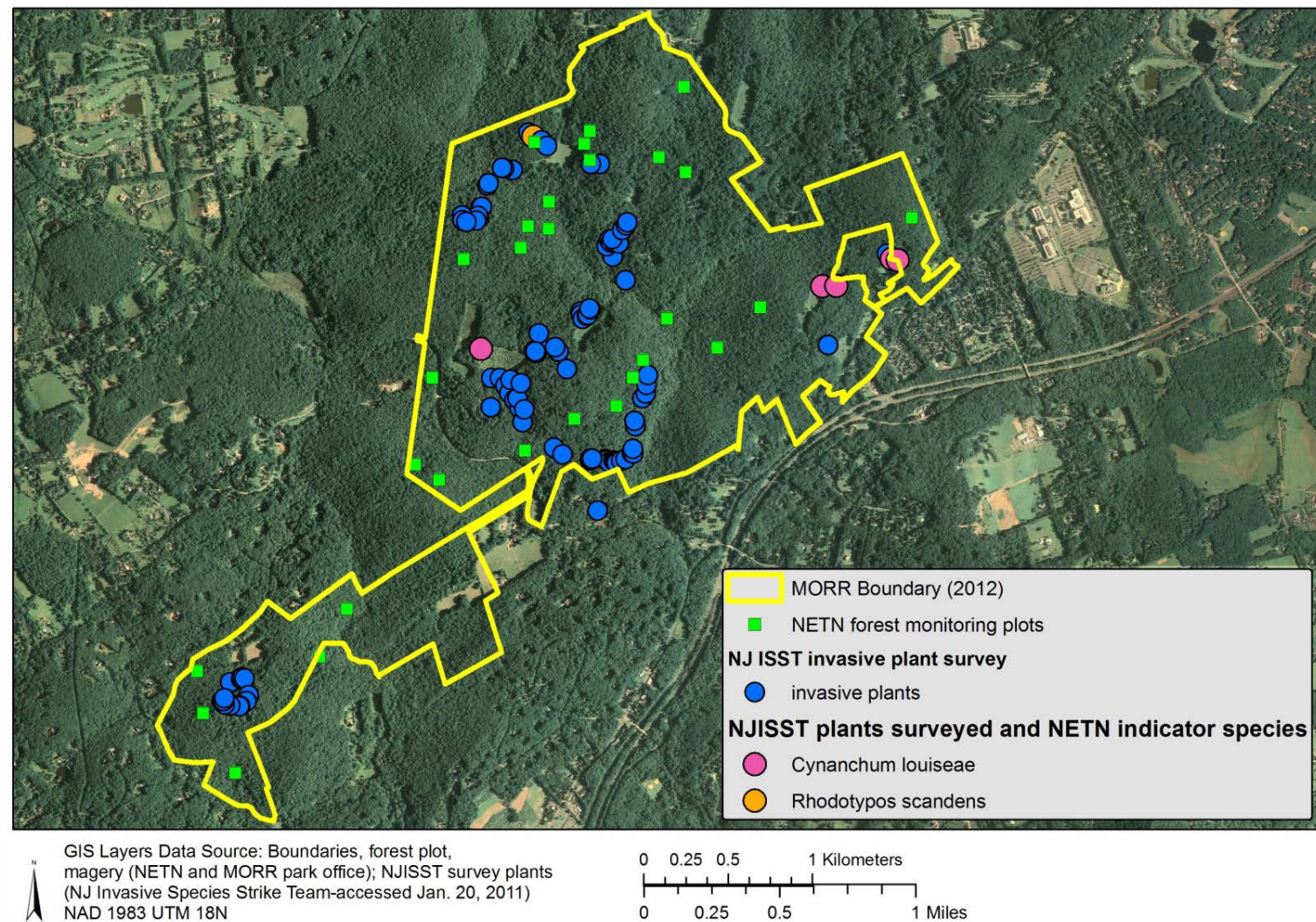
#### Data Gaps and Confidence in Assessment

The confidence in the condition assessment for forest systems was high and confidence in the trend analysis was not applicable. Overall, a quantitative condition assessment of invasive vegetation in MORR was limited to only forests in which data collection efforts are in the early stages of the NETN program. The infancy of the NETN sampling program limits trend analyses based on key indicator species density in MORR's forests. Although the NETN key indicator species list encompasses species common throughout the northeast, the listing does not contain several species which are an issue at the State level. For example, several invasive exotic species are present in MORR which are on the NJ 2011 Target Plant List but are not considered NETN key indicator species (Table 4.8). Even though this condition assessment focused on invasive forest species located in NETN forest plots, it is important to note that several invasive plants are located outside NETN forest plots and should be prescribed for removal (Figure 4.16).



# Morristown National Historical Park

New Jersey Invasive Plant Survey Results in Relation to NETN Forest Monitoring Plots



**Figure 4.16.** NETN forest plots in relation to invasive plant species documented by NJISST (2011) in MORR.

## Non-indigenous Invasive Aquatic Vegetation

### Relevance and Context

A current and quantitative emergent and submergent invasive aquatic plant survey in MORR is not available. Several non-indigenous aquatic plants have been identified within the HUC 8 basins surrounding MORR (02030103 Hackensack-Passaic and 02030105 Raritan) and have the potential to be dispersed into MORR's waters (USGS 2004) (Figure 4.17). Two of The New Jersey Invasive Species Strike Team (NJISST) Top 20 invasive species are aquatic and include *Myriophyllum aquaticum* (parrot feather) and *Trapa natans* (water chestnut) (Table 4.10). Although parrot feather has not been detected within HUC 8 basins surrounding MORR, water chestnut has been found in Morris County, NJ in 2010 within the Loantaka Brook Reservation (EDDMapS 2012). Water chestnut can grow in any freshwater habitat, preferring nutrient rich lakes and rivers. The dense floating mats it forms severely limits light and reduces oxygen levels thereby increasing aquatic organism mortality.

**Table 4.10.** Species listing of New Jersey's 2011 Target Aquatic Plant List species (New Jersey Invasive Species Strike Team, NJISST 2012) and nonindigenous aquatic plant species found in Raritan and Hackensack-Passaic HUC 8 basins. NJISST threat level categories include *mild*, *moderate* and *high*. NJISST planted species considered a "Top 20 Priority" are highlighted in yellow.

Scientific Name	Common Name	NJISST 2011 Threat Level <sup>1</sup>	Watershed (Hackensack-Passaic or Raritan) <sup>2</sup>
<i>Callitriche stagnalis</i>	pond water starwort		Hackensack-Passaic
<i>Didymosphenia geminata</i>	rock snot	<i>high</i>	
<i>Egeria densa</i>	Brazilian water-weed	<i>high</i>	Raritan
<i>Eichhornia crassipes</i>	water hyacinth	<i>high</i>	
<i>Glossostigma cleistanthum</i>	mudmat	<i>moderate</i>	Raritan
<i>Hydrilla verticillata</i>	hydrilla	<i>high</i>	
<i>Lythrum salicaria</i>	purple loosestrife		Raritan
<i>Marsilea quadrifolia</i>	European water clover		Hackensack-Passaic
<i>Myriophyllum aquaticum</i>	parrot feather	<i>high</i>	
<i>Myriophyllum spicatum</i>	Eurasian water-milfoil		Raritan; Hackensack-Passaic
<i>Pistia stratiotes</i>	water lettuce	<i>mild</i>	
<i>Potamogeton crispus</i>	curly pondweed		Raritan; Hackensack-Passaic
<i>Trapa natans</i>	water chestnut	<i>high</i>	Hackensack-Passaic

<sup>1</sup> New Jersey Invasive Species Strike Team (NJISST). 2011 Target Plant List. [www.njisst.org](http://www.njisst.org).

<sup>2</sup> USGS. 2004. Non-indigenous Aquatic Species Database. Gainesville, FL. <http://nas.er.usgs.gov>. Accessed January 30, 2012.

### Data and Methods

Presence/absence observations of non-indigenous invasive species identified by park staff, consultants and environmental agencies (e.g. USGS, EDDMapS) occurring within and near MORR's waterbodies were collected and used to assess the condition of MORR's aquatic resources. The locations of the observations were spatially mapped by HUC 8 and HUC 14 boundaries and a qualitative condition assessment category was applied to HUC 8 and HUC 14 watersheds near MORR.

### Reference Condition/Threshold Values Utilized

The ideal reference condition for MORR's waters was recognized as the absence of non-indigenous invasive submergent/floating plant species from the HUC 8 basins and HUC 14 subwatersheds of MORR. Due to the lack of quantitative data for several non-indigenous aquatic species, the condition categories used to assess waters in MORR were based on broad, qualitative assessments. A rating of *Resource is in Good Condition* was given if plants were absent from the watershed; a *Warrants Moderate Concern* rating was given if plants were absent from the watershed but present in adjacent tributaries; a *Warrants Significant Concern* rating was applied if species were present within the watershed.

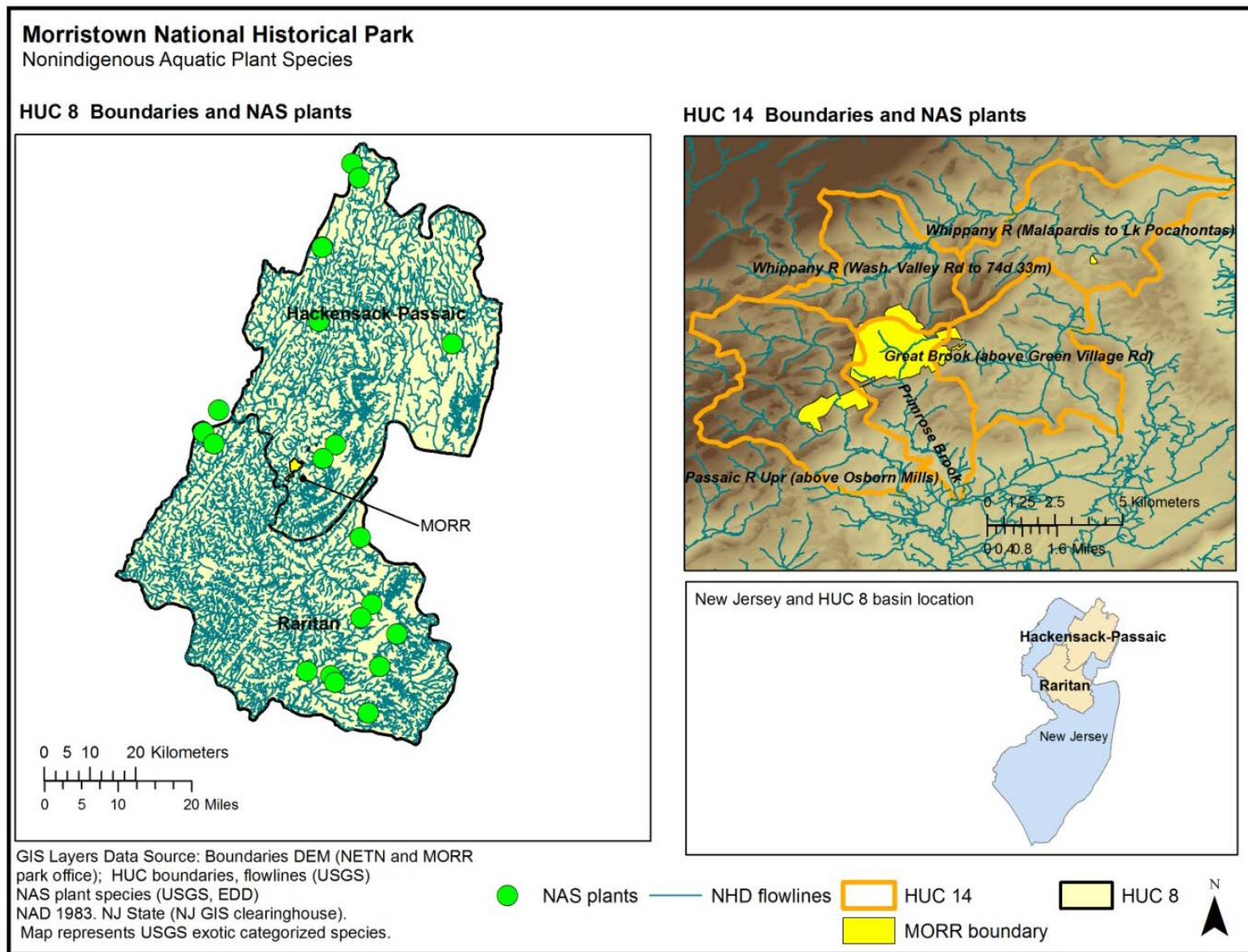
### Condition and Trends

Within MORR's HUC 14 watersheds, no non-indigenous plant species were detected, leading to a condition assessment of *Resource is in Good Condition* based on the available data (Figure 4.17). At the HUC 8 spatial level, non-indigenous plant species were documented in both the Hackensack-Passaic and Raritan basins, threatening the integrity of MORR's waterbodies (Figure 4.17). The condition assessment at the HUC 8 level for MORR was *Warrants Significant Concern* (Table 4.11). Various species documented in these watersheds are also rated at a threat level of *high* on the NJ 2011 Target Plant List, including *Egeria densa* (Brazilian water weed) and *Trapa natans* (water chestnut) (Table 4.10).

**Table 4.11.** Condition assessment for MORR's non-indigenous aquatic plant community for selected species.

Measure	Condition Categories		Result
Non-indigenous invasive plants in aquatic habitats	Warrants Significant Concern	plants present within the watershed	HUC 8 level: Plants present in watershed
	Warrants Moderate Concern	plants absent from the watershed but present in adjacent tributaries	HUC 14 level: Plants absent from watershed and tributaries
	Resource is in Good Condition	plants absent from the watershed and adjacent tributaries	





**Figure 4.17.** Non-indigenous aquatic plant species based on data from USGS non-indigenous aquatic species (NAS) database (USGS 2004) for HUC 8 (Hackensack-Passaic and Raritan) and HUC 14 subwatersheds surrounding MORR.

### Data Gaps and Confidence in Assessment

The confidence of the assessment for aquatic systems was low and confidence in the trend analysis was not applicable. Data needs include continued surveys, population estimates and mapping to determine the extent and trend of non-indigenous invasive aquatic species within MORR's watersheds. The proactive surveying for species yet to colonize in MORR's waters will reduce damaging economic and ecological impacts to aquatic communities and maintain the biological integrity of MORR's waters. Similar to the early detection strategy lists for terrestrial species, MORR would benefit from early detection strategy lists for aquatic environments.

## **Invasive Exotic Animals and Disease**

### ***Tree Condition/Forest Pests***

#### Relevance and Context

Invasive exotic species and disease commonly enter through two avenues: human activities and natural range extension due to climate and environmental changes. The eastern U.S. is experiencing an influx of terrestrial and aquatic invasive species which pose severe threats and disruptions to MORR's environmental composition, structure and function. Historically, MORR has experienced tree decimation from a chestnut blight in the early 1920's to gypsy moth infestations in the 1960's and 1970's. Table 4.12 describes the current distribution and risk of several forest pests within MORR and Morris County, NJ. Beech bark disease (BBD) is an example of a rampant invasion MORR's forests have encountered, threatening vegetation composition (Miller *et al.* 2010). BBD results when the beech scale insect (*Cryptococcus fagisuga*) attacks the bark of the beech tree (*Fagus grandifolia*), creating a scale-induced alteration to the bark. The result of this destructive duo is approximately 50% mortality of trees in five years (USFS 2010). Qualitative observations of specific tree health problems and canopy foliage condition can provide an early warning to problems or decline in the health of vegetation. NETN has created an early detection species list of invasive animal species for MORR's forests as a system to provide managers with timely identification and removal of an invasion (Table 4.13) (Keefer *et al.* 2010).

#### Data and Methods

As part of the Northeast Temperate Network Vital Signs monitoring program, invasive exotic animals and disease have been monitored in MORR in 2007, 2009 and 2011 with a total of 28 forest monitoring plots established in the park during this time period (Miller *et al.* 2010, 2012) (Figure 4.18). Details of the monitoring protocols for assessing invasive exotic animals and disease in MORR can be found in Tierney *et al.* (2009, 2011). A number of pest species pose serious threats to MORR's forests if they advance into the northeast region, including *NETN Priority 1 pests*: Asian long-horned beetle, emerald ash borer, hemlock woolly adelgid and sudden oak death and *NETN Priority 2 pests*: balsam woolly adelgid, beech bark disease, butternut canker and elongate hemlock scale. Priority 2 pests are forest pests which cause problems that are deemed by NETN as not as severe as Priority 1 pests. Trend analyses were not performed for this measure due to the temporal limitation of the NETN monitoring data.

**Table 4.12.** Pests and tree diseases identified as a significant concern for NETN forests, their presence in Morris County and assessment risk to Morris County, NJ forests (highlighted columns).

Pest/Disease <sup>1</sup>	Scientific Name	NETN Priority <sup>2</sup>	Present in Morris County <sup>*</sup>	Risk for Morris County, NJ based on Host Volume <sup>3</sup> (m <sup>3</sup> /ha)				
				Very Low	Low	Medium	High	Extreme
Hemlock woolly adelgid	<i>Adelges tsugae</i>	1	Yes	0	0.54-75.1	75.1-248.26	248.26-713.51	713.51-2850.06
Gypsy moth	<i>Lymantria dispar</i>		Yes	0	0.24-425.54	425.54-1422.02	1422.02-2686.83	<del>2686.83-11082.74</del>
Emerald Ash Borer	<i>Agrilus planipennis</i>	1	No	0	0.12-43.19	43.19-125.87	125.87-289.14	<del>289.14-2446.17</del>
Balsam woolly aphid	<i>Adelges piceae</i>	2	No	0	0.48-82.34	82.34-358.93	358.93-1007.70	1007.70-18247-48
Asian long-horned beetle	<i>Anoplophora glabripennis</i>	1	No	0-0.14	0.14-43.19	43.19-125.87	125.87-289.14	<del>289.14-2446.17</del>
Sirex woodwasp	<i>Sirex noctilio</i>		No	0-0.23	0.23-255.45	255.45-1071.95	1071.95-3031.03	3031.03-10809.79
Butternut canker	<i>Sirococcus clavigignenti-juglandacearum</i>	2	No	0-0.29	0.29-3.95	3.95-9.80	9.80-23.64	23.64-126.61
Sudden oak death	<i>Phytophthora ramorum</i>	1	No	0	0.52-92.20	92.20-275.77	275.77-577.22	<del>577.22-10560.56</del>
Dogwood anthracnose	<i>Discula destructiva</i>		Yes	0-0.26	0.26-2.17	2.17-4.97	4.97-9.88	9.88-74.42
Beech bark disease	<i>Nectria coccinea</i>	2	Yes	0-0.45	0.45-34.49	34.49-116.05	116.05-298.30	298.30-2533.61
Elongate hemlock scale	<i>Fiorinia externa</i>	2	Yes	0-0.47	0.47-69.47	69.47-318.54	318.54-978.28	978.28-10088.18

<sup>1</sup> Pest column does not indicate all potential species which may be detrimental to MORR's forests. Species evaluated were identified as potential species of concern under the NETN Vital Signs Program.

<sup>2</sup> Miller *et al.* 2012.

<sup>\*</sup> USDA Forest Service. 2010. Alien Forest Pest Explorer (AFPE). Data displayed in table represents mapping results accessed on 1/20/2012.

**Table 4.13.** Early Detection Species for MORR (Keefer *et al.* 2010)\*.

Scientific Name	Common Name
Emerald Ash Borer	<i>Agrilus planipennis</i>
Asian long-horned beetle	<i>Anoplophora glabripennis</i>
Sirex woodwasp	<i>Sirex noctilio</i>

\* Hemlock woolly adelgid (*Adelges tsugae*) identified as present in MORR.



### Reference Condition/Threshold Values Utilized

Threshold values were based on current NETN condition categories (Miller *et al.* 2012). To incorporate the impact forest pests have on tree condition, areas with minor foliage problems (< 10 %) averaged across a plot and within individual species, minor damage from BBD ( $BBD \leq 2$ ), and no evidence of damage by Priority 1 or other Priority 2 pests and pathogens received a condition category rating of *Resource is in Good Condition*; plots with Priority 2 pests or beech bark disease (BBD) >2 were rated *Warrants Moderate Concern*; plots with only Priority 1 pests received a *Warrants Significant Concern* rating (Miller *et al.* 2012) (Table 4.14).

### Condition and Trend

Based on NETN forest assessments, approximately 60 % of forest plots were categorized as *Resource is in Good Condition*, 40% were grouped as *Warrants Moderate Concern*, and 0% were categorized as a *Warrants Significant Concern* for forests pests in MORR (Table 4.14) (Miller *et al.* 2012). Although many of the forest plots in MORR were considered *Resource is in Good Condition*, the impact of exotic invasive animals and disease had been observed in several plots in the park. Plots which rated *Warrants Moderate Concern* were the result of elevated insect herbivory, leaf loss or beech bark disease (Miller *et al.* 2012). The hemlock woolly adelgid (HWA) was cited as present within the park (Keefer *et al.* 2010); however, Sneddon *et al.* (2008) stated that HWA may no longer be present due to a loss of eastern hemlock (*Tsuga canadensis*) trees to woolly adelgid in the eastern portion of the park forests since Ehrenfeld (1977) surveyed the park. Hemlock woolly adelgid are present on ornamental hemlock in the New Jersey Brigade Unit and MORR utilizes an insecticide to control the pest on these specific hemlocks. Sections of MORR are currently mapped as Hemlock – Red Oak – Mixed Hardwood Forest because it can still be recognized as this type, but the eastern hemlock (*Tsuga canadensis*) trees are now dead and the canopy is considerably more open as a result (Sneddon *et al.* 2008).

Both the emerald ash borer (EAB) and Asian long-horned beetle (ALB) are early detection species for MORR and a possible threat to the integrity of MORR's forest. Locations of ash (*Fraxinus* sp.) tree dominated vegetation communities in MORR based on a Sneddon *et al.* (2008) survey in relation to the current NETN monitoring plots is reflected in Figure 4.18. Ash trees are scattered throughout New Jersey but are primarily located within five counties in New Jersey, with Morris being identified as one of the counties ([http://www.nj.com/news/index.ssf/2009/08/emerald\\_ash\\_borer\\_beetle\\_provi.html](http://www.nj.com/news/index.ssf/2009/08/emerald_ash_borer_beetle_provi.html)). ALB first appeared in New Jersey for the first time in 2002 in Jersey City and is noted to be an extreme risk for Morris County (Table 4.12).

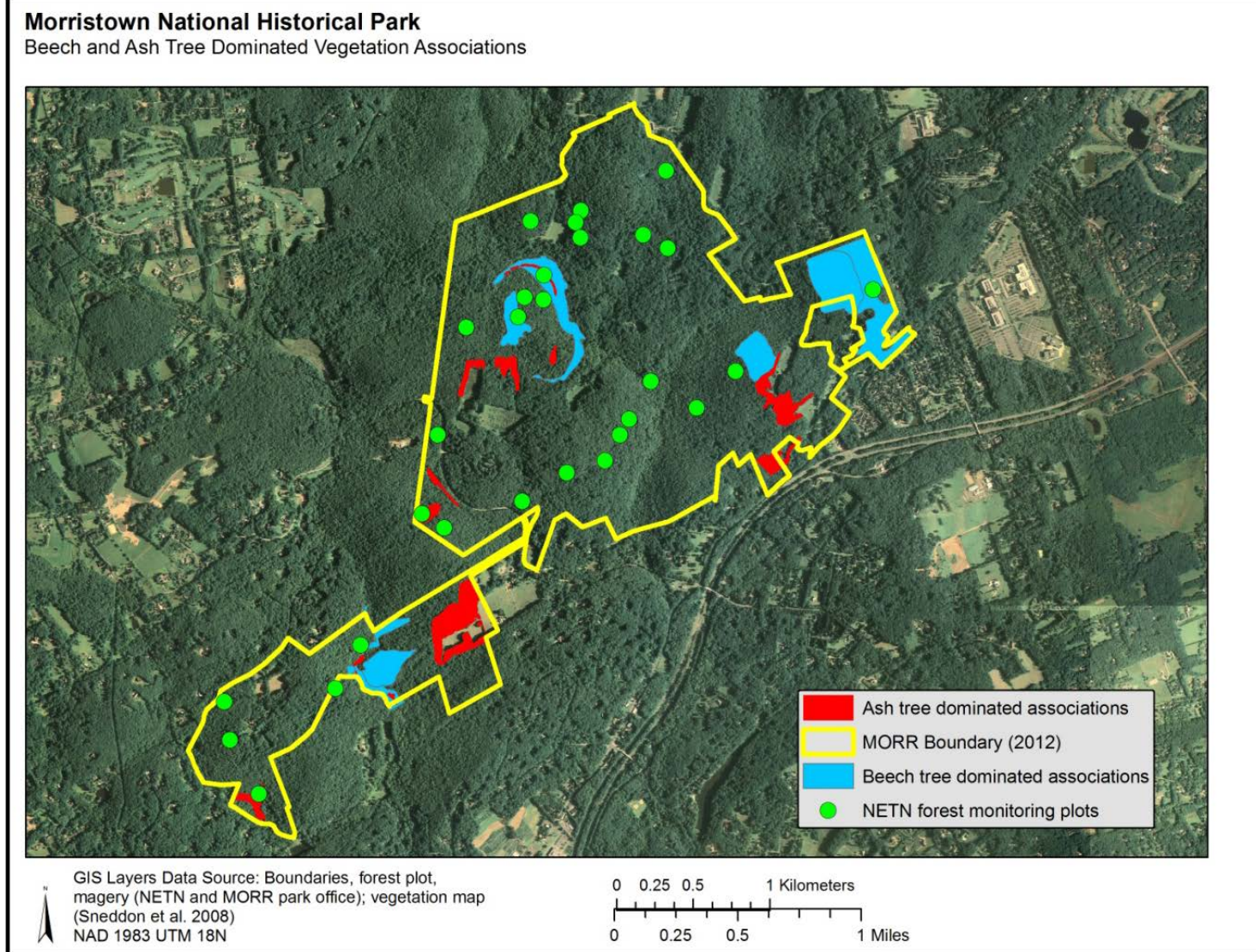
**Table 4.14.** Condition assessment for MORR exotic animals in forested habitats.

Measure	Condition Categories		Result
Tree Condition/Forest Pests	Warrants Significant Concern	Foliage problem > 50% or priority 1 pest present	0% forest plots =Warrants Significant Concern
	Warrants Moderate Concern	Foliage problem 10 - 50% or priority 2 pest present or BBD > 2	~40% forest plots=Warrants Moderate Concern
	Resource is in Good Condition	Foliage problem < 10% and no priority 1 or 2 pests and BBD ≤ 2	~60% forest plots=Resource is in Good Condition

#### Data Gaps and Confidence in Assessment

The proactive surveying for species yet to colonize in MORR's terrestrial habitats will reduce damaging economic and ecological impacts to communities and maintain the biological integrity of MORR. Confidence in the assessment for invasive exotic animals and disease in forest habitats was high and confidence in the trend analysis was not applicable. Continued monitoring of the plots in MORR will enable managers to establish trend analyses for these metrics, with the number of years to monitor forest plots for trend based on study objectives and statistical power analyses. The continued effort of monitoring for exotic, invasive species and disease is especially significant for detection of the destructive emerald ash borer (EAB), which is prevalent in the neighboring state of New York and an extreme risk for Morris County (Table 4.12)

(<http://www.dec.ny.gov/animals/42674.html>). Additionally, NETN forest monitoring plots should continue to be established in ash and beech tree dominated areas in MORR to assess the health of these ecologically and historically important trees (Figure 4.18).



**Figure 4.18.** Beech and ash tree dominated vegetation associations in MORR in proximity to NETN forest monitoring plots. Beech or ash tree occurrence in MORR was mapped in relation to species presence in the forest canopy or subcanopy based on Sneddon et al. (2008). This figure does not indicate individual stands of beech or ash trees in MORR.

## ***Non-indigenous Aquatic Species***

### **Relevance and Context**

A non-indigenous aquatic species is an aquatic organism that does not occur naturally in New Jersey's aquatic environments. Many aquatic species have become naturalized over time, as they were introduced a relatively long time ago either as non-intentional introduction or intentional stocking, and have become fully integrated into New Jersey's aquatic ecosystems. At issue is that during the introduction period newly introduced aquatic species disrupt the natural balances and relationships existing between other species already present, causing significant changes to the ecosystem. New Jersey has historically over 130 introduced animal and plant species to the aquatic environment, with more than 32 non-indigenous aquatic species having been identified in MORR's HUC 8 Hackensack-Passaic basin (Figure 4.19, Appendix C) (USGS 2004). Although many species pose a threat to MORR's aquatic environment, non-indigenous species warnings emerge yearly in New Jersey which alert managers and citizens to be proactive in the identification and reporting of species. In recent years, species such as the Chinese pond mussel, Chinese mitten crab and flathead catfish have been newly identified by New Jersey state biologists as reproducing within New Jersey or connecting waterways.

### **Data and Methods**

MORR's aquatic environment was assessed using presence/absence data of invasive species in MORR's aquatic systems as well as invasive species present in connecting waterways (HUC 8 and HUC 14 basins). Data were collected from the USGS non-indigenous aquatic database (NAS) for HUC 02030103 (Hackensack-Passaic) and 02030105 (Raritan) and was supplemented by presence/absence observations by park staff and environmental agencies (e.g., NJDEP) to assess the condition of MORR's aquatic systems. The locations of the observations were spatially mapped by HUC8 and HUC14 boundaries and a condition assessment category was applied to the HUC 8 and HUC 14 boundary which encompasses MORR. Trend analyses were not performed for aquatic habitats due to the scarcity of quantitative population data for aquatic non-indigenous animals.

### **Reference Condition/Threshold Values Utilized**

The ideal reference condition for MORR's waters was recognized as the absence of non-indigenous exotic species from aquatic environments. Due to the lack of quantitative data for several non-indigenous aquatic species, the condition categories used to assess waters in MORR were based on broad, qualitative assessments. A rating of *Resource is in Good Condition* was given if species were absent from the watershed; a *Warrants Moderate Concern* rating was given if species were absent from the watershed but present in adjacent tributaries; a *Warrants Significant Concern* rating was applied if species were present within the watershed. Species which were considered non-indigenous species but had been naturalized over time due to their introduction from a relatively long time ago (e.g., bluegill, red-eared slider turtles) were excluded from the assessment based on USGS' categorization as 'native' species (USGS 2004).

### **Condition and Trend**

Non-indigenous exotic fishes, mollusks and coelenterate/hydrozoans are present within waterways of the HUC 8 encompassing MORR (HUC 02030103 Hackensack-Passaic) and the neighboring

southern HUC 8 basin (HUC 02030105 Raritan). Based on a HUC 8 spatial assessment (Figure 4.19), the Hackensack-Passaic condition was assessed as Warrants Significant Concern (USGS 2010). Several non-indigenous fish, mollusk and coelenterate/hydrozoans species are found within the Hackensack-Passaic basin (Appendix C). These non-indigenous species are also found in the southern Raritan basin, with mollusks dominating the basin's waterways (Figure 4.19). Within MORR's HUC14 subwatersheds, Primrose Brook watershed was categorized as Warrants Significant Concern due to the presence of a brown trout population. Although brown trout are often stocked in streams by state agencies, brown trout have been implicated in reducing native fish populations (especially salmonids) through predation, displacement, and food competition (Taylor et al. 1984). A study by Fausch and White (1981) identified that adult brown trout displaced adult native brook trout (*Salvelinus fontinalis*) from the best habitats in a Michigan stream, and in the northeast in general.

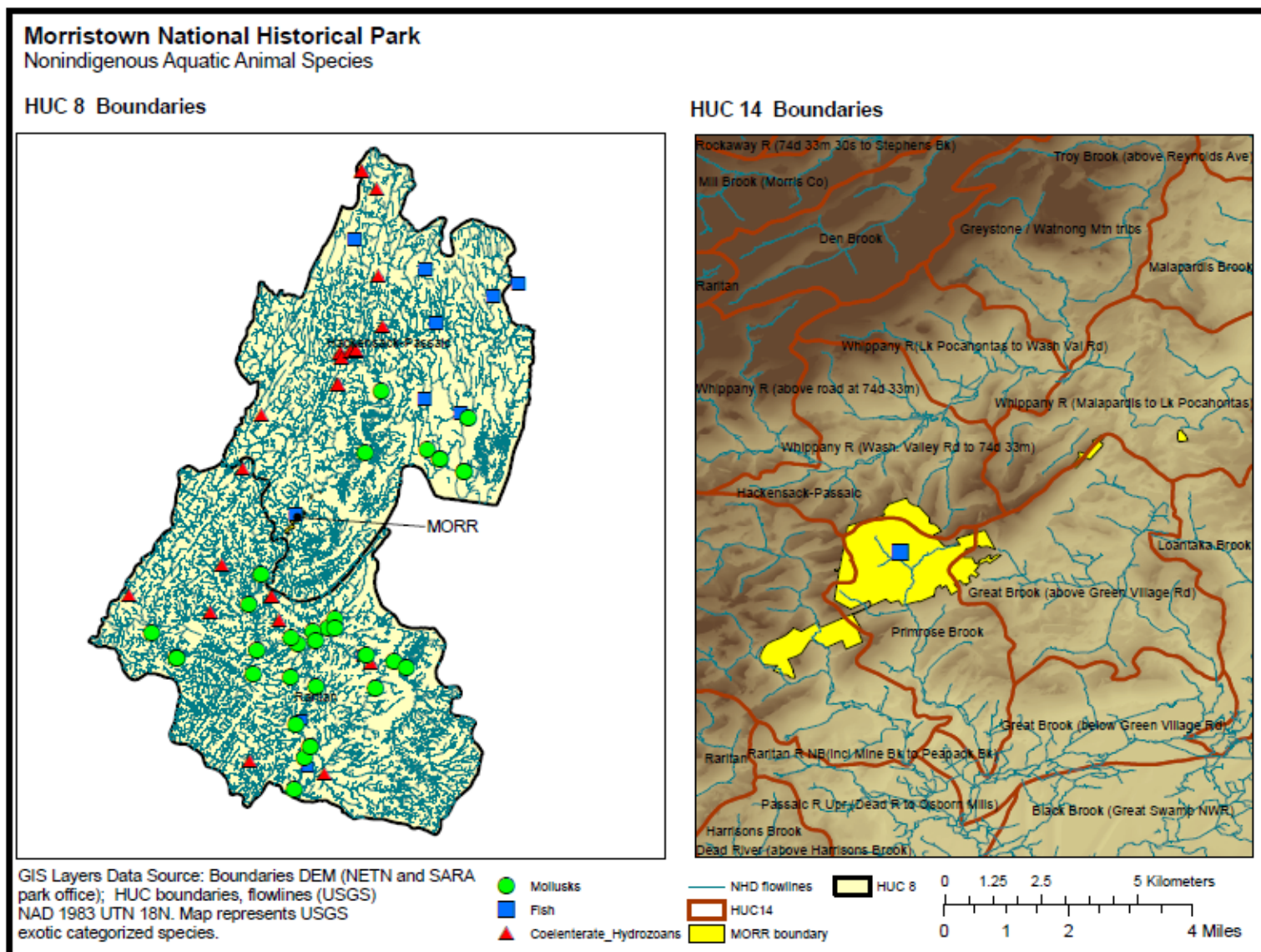
**Table 4.15.** Condition assessment for MORR exotic animals in aquatic habitats.

Measure	Condition Categories		Result
Aquatic Invasive Animals	Warrants Significant Concern	species present within the watershed	HUC 8: Species present in watershed
	Warrants Moderate Concern	species absent from the watershed but present in adjacent tributaries	HUC 14: Species present in watershed
	Resource is in Good Condition	species absent from the watershed and adjacent tributaries	

#### Data Gaps and Confidence in Assessment

The confidence in the assessment of non-indigenous exotic aquatic animals was low and the assessment of trend was not applicable. Data needs include continued surveys, population estimates and mapping to determine the spatial extent and trend of non-indigenous aquatic species within MORR's watersheds. The proactive surveying for species yet to colonize in MORR's aquatic environment will reduce damaging economic and ecological impacts to communities and maintain the biological integrity of MORR. Establishing routine sampling events and deploying monitoring substrates in MORR's waters may aid in the detection of invasive species. Although an early detection list for exotic species has been created for MORR's forests by NPS, an early detection list has yet to be created for MORR's aquatic systems.





**Figure 4.19.** Non-indigenous aquatic animal species based on data from USGS Non-indigenous aquatic species database (NAS) for HUC 8 02030103 Hackensack-Passaic and 02030105 Raritan (left) and for HUC 14 subwatersheds encompassing MORR (right).

## Forest Vegetation

### **Relevance and Context**

The vegetation in MORR is of cultural significant and ecological value. Therefore, managing this resource in the park must meet both cultural and natural resource protection objectives. Vegetation in MORR is dominated with a mix of mowed fields, orchards, gardens and forest stands. The forests within MORR are primarily a mix of native hardwood species, with three forest types dominant in Jockey Hollow: mature, successional and pure stands. Mature types comprise approximately 55.7% of coverage in MORR and contain primarily mixed oaks while succession stands (37.5%) consist of broad mix of species (Ehrenfeld 1977). The vegetation within the New Jersey Brigade Encampment Area consists of several types of upland hardwood forest species such as yellow poplar, black birch, and chestnut oak. MORR's forests have experienced disease and invasion, with chestnut blight exterminating chestnut trees in the early 20<sup>th</sup> century and exotic black locust trees becoming established in MORR in the 19<sup>th</sup> and 20<sup>th</sup> centuries. Additionally, natural disasters have changed the structure of forests, as what was experienced in October 2012 when Hurricane Sandy damaged trees in MORR. The overall integrity of the forest's health has been altered due to surrounding residential, commercial and recreational development. From 1988-2002, urban land cover within a 5 km (~3 mi) buffer around MORR had increased 11%, replacing valuable forest systems (Wang and Nugranad-Marzilli, 2009). Conversely, acreage has decreased for coniferous forest (-61%) and mixed forests (-19%) during this time period (Wang and Nugranad-Marzilli, 2009). The conversion from forest to urban landscapes around MORR has the potential to drastically affect biodiversity, watershed functioning and habitat condition within the park.

### **Data and Methods**

As part of the Northeast Temperate Network Vital Signs monitoring program, forest health was monitored in MORR in 2007, 2009 and 2011 with a total of 28 forest monitoring plots established in the park, with one plot per 42 (17 ha) acres of forest. Miller *et al.* 2010, 2011, 2012) (Appendix D). Details of monitoring protocols for assessing forest health in NETN can be found in Tierney *et al.* (2009, 2010). Trend analysis was not performed due to the temporal limitation of the NETN monitoring data. Measures that have been used to assess MORR forest health based on include the following: Landscape Context-Anthropogenic land use (ALU) and Forest patch size Northeastern U.S. forests typically are highly fragmented and impacted by anthropogenic land use and human disturbance. Several negative



*Snags are important components for overall forest health. Photo by R. Wagner.*

impacts on forests stem from fragmentation and human land use (i.e., invasive species, loss of biodiversity). Forest patch size and adjacent anthropogenic land use were used to examine the extent that the surrounding landscape may be influencing forest condition in MORR. These landscape parameters were examined using NETN monitoring reports which delineated forest patch size at the park level and adjacent land-use analyses that were performed at the level of the forest plot. Spatial analyses were performed using recent leaf-on orthophotography (delineated at the 1:6,000 scale or finer) and vegetation map delineations were incorporated when appropriate into the assessment (Miller *et al.* 2011).

#### Structural stage distribution

Forests recovering from disturbances may differ structurally from later successional stands. Disturbances such as anthropogenic alteration have changed the structural stage distribution of forests, with distribution being further affected by factors such as climate change, pathogens and pests. The structural stage distribution of MORR's forest is important for maintaining native vegetation species, which varies depending upon successional stages.

#### Snag abundance & coarse woody debris

Snag abundance and coarse woody debris were rated for overall forest stands and mature forest stands in MORR. Mature stands were defined as second growth stands that originated from areas cleared by General Washington's forces around 1788 to 1789 (Miller *et al.* 2012). Standing dead trees (snags) and fallen coarse woody debris (CWD defined as  $\geq 10$  cm diameter and  $\geq 1$  m long) are important dead wood structural features in forests that provide adequate habitat for species. Land management strategies can maintain and enhance snags and CWD, while other forest activities, such as hazard tree removal, can reduce the quantity and quality of these features.

#### Biotic homogenization and Understory dynamics

Biotic homogenization is the process of declining regional biodiversity often due in part to the addition of widespread exotic species and the loss of native species. This process can be driven by the spread of invasive exotic species associated with physical and environmental habitat modification by humans (including land use and climate change) and by natural causes. Species, such as exotic earthworms, have the potential to alter forest soils and understory communities and have been shown to have synergistic effects with deer overabundance on the forest understory (Miller *et al.* 2010).

#### Tree Growth and Mortality Rates

Tree growth and mortality rates are indicators of tree vitality and health. Growth rates may decline or mortality rates may increase in response to environmental factors and anthropogenic stressors. Assessment of tree growth and mortality rates can also indicate health problems for specific species in an area or indicate a regional environmental stress (i.e., acid deposition) for tree species.

#### **Reference Conditions/Threshold Values Utilized**

NETN Vital Signs metrics and condition categories were used to assess MORR's forest health. These condition categories were based on ecological studies and management goals and included ratings of *Resource is in Good Condition*, *Warrants Moderate Concern* or *Warrants Significant Concern* for each forest metric (Miller *et al.* 2011, 2012). The combination of these metrics covers the forest's

structural, compositional and functional integrity in relation to their natural and historical range of variation and theoretical modeling of metrics:

#### Landscape Context- Anthropogenic land use (ALU) and Forest patch size

Landscape context was analyzed using delineated forest patch size data at park level and adjacent land-use analyses at the level of the forest plot. Spatial analyses were performed on leaf-on orthophotography and incorporated into vegetation map delineations (Miller *et al.* 2011). ALU condition categories were derived from theoretical models that examined the combined impacts of habitat loss and fragmentation (Miller *et al.* 2011). These condition categories included: <10% anthropogenic land use rated *Resource is in Good Condition*; 10-40% anthropogenic land use rated *Warrants Moderate Concern*; >40% anthropogenic land use rated *Warrants Significant Concern* (Table 4.16). Forest patch size was defined as an area of continuous medium to high-canopy ( $\geq 8$  m height) forest vegetation with at least 60% overall canopy closure (Miller *et al.* 2011). Condition categories for forest patch size included: patches  $\geq 50$  ha rated *Resource is in Good Condition*; patches 10 to less than 50 ha rated *Warrants Moderate Concern*; patches 0.5 to less than 10 ha rated *Warrants Significant Concern* (Table 4.16).

#### Structural stage distribution

Existing structural stage distributions versus those expected under natural disturbance regimes were used as an indicator of altered disturbance regimes. Ratings based on expected percentage of late-successional forest stages across the landscape were compared to expected structural stage distributions based on the dominant matrix forest ecosystem (Miller *et al.* 2010). A category of *Resource is in Good Condition* was indicated by  $\geq 25\%$  late-successional structure, *Warrants Moderate Concern* was assigned for forests with < 25% late-successional structure and *Warrants Significant Concern* was categorized as < 25% combined mature and late-successional structure for MORR (Miller *et al.* 2010, Table 4.16).

#### Snag abundance & Coarse woody debris (CWD)

Assessing the percentage of standing trees that are snags and calculating the ratio of CWD volume to live tree volume are metrics that were used to rate the condition of the forest community in MORR. Forests that had  $\geq 10\%$  standing snags and  $\geq 10\%$  medium-large trees (medium-large trees are >30 DBH) as snags were rated *Resource is in Good Condition*. Less than 10% standing tree snags or <10% medium-large trees as snags was categorized as *Warrants Moderate Concern*. Less than 5 medium-large snags per hectare categorized the area as *Warrants Significant Concern* (Miller *et al.* 2012) (Table 4.16). For CWD, >15% live tree volume was categorized as *Resource is in Good Condition*, 5-15% live tree volume indicated *Warrants Moderate Concern*, and <5% live tree volume was categorized as *Warrants Significant Concern* (Table 4.16).

#### Biotic Homogenization

This measure used the Jaccard Similarity Index and the percentage of plots found with earthworms to address biotic homogenization in MORR. A condition category was not assigned to these metrics due to a lack of repeat data. However, the data collected by NETN provided MORR with a baseline similarity score to detect park-level changes in understory diversity over time, as well as to examine

patterns in species diversity and abundance. The Jaccard's Similarity Index compared plant species composition between plots, with the index ranging from 0 to 1. The more species in common between two plots, the closer their index score was to 1. The percentage of plots found with earthworms will serve as a baseline in future forest plot assessments in order to understand their synergistic effects with deer overabundance on forest understories and potentially assist in explaining biotic homogenization patterns and changes.

#### Tree Growth and Mortality Rates

To examine patterns of tree growth, mean basal area growth (% basal area / year) was calculated for MORR and compared to regional growth rates. These regional growth rates were derived from U.S. Forest Service Forest Inventory and Analysis (FIA) data collected from plots in the same Ecological Subsection of MORR (Miller *et al.* 2012). A *Warrants Significant Concern* rating has not yet defined by NETN biologists. For a growth rate of < 60% of the regional mean or a mortality of > 1.6%, the park was rated *Warrants Moderate Concern*. Growth  $\geq$  60% of the regional mean or mortality of  $\leq$  1.6% rated the park as *Resource is in Good Condition* (Miller *et al.* 2012).

#### **Condition and Trend**

The following list contains forest health measures and their condition assessments for MORR (Table 4.16).

#### Anthropogenic land use

*Resource is in Good Condition*; Anthropogenic land use based on a 200 m buffer averaged 5.3% per forest plot and consisted primarily of forested habitat (Figure 4.20) (Miller *et al.* 2011). MORR's boundary is buffered by forests, but residential development does exist at the outside margins of several forest patches within the park.

#### Forest patch

*Resource is in Good Condition*; Forest habitat in MORR consisted of two extensive patches which extended beyond MORR boundary and into neighboring Lewis Morris County Park and the Scherbamm-Hoffman Audubon Sanctuary (Miller *et al.* 2011) (Figure 4.21). These patches were > 50 ha in size (609.62 ha and 818.37 ha), with 56% of the patches outside park boundaries (Miller *et al.* 2011). The connectivity of these vast forest patches to areas outside of MORR are vital to maintaining the integrity of fauna and flora communities.

#### Structural stage distribution

*Resource is in Good Condition*; MORR rated 68% late successional structure and 100% mature and late successional structure (Miller *et al.* 2010). The distribution of these forest successional stages in MORR is within the range of natural variation (Miller *et al.* 2010).

#### Snag abundance

*Warrants Significant Concern*; MORR was estimated to have  $1.79 \pm 1.24$  med-lg snags/ha ( $\pm$ standard error) when assessing the overall forest and  $1.32 \pm 1.32$  med-lg snags/ha in mature forested areas (Miller *et al.* 2012). This park contains some of the lowest snag abundance estimates of all NETN parks (Miller *et al.* 2010).



### Coarse Woody Debris (CWD)

*Warrants Moderate Concern*; MORR contained an average of 6.66% CWD in the overall forest system and 6.82% CWD when surveyed in mature forested areas (Miller *et al.* 2012). The occurrence of Superstorm Sandy in 2012 led to downed trees with large root balls attached, casting shade on the forest floor. Although CWD is considered important for overall forest health, some of the trees in MORR may need to be removed to allow for increased sunlight to hit the forest floor, allowing for a potential increase in native plant regeneration.

### Biotic Homogenization and Understory Dynamics

*Unrated*; Jaccard Similarity Index and the percent of plots with nonnative earthworms were measurements used to assess biotic homogenization in MORR. Jaccard Similarity Index from data collected in MORR was 0.24, indicating that a pair of plots shared about 24% of the same species within MORR. Earthworm detection was also measured in MORR plots as an indicator of biotic homogenization. From 2007-2010, non-native earthworms were detected in 82.1% of the plots. Since this metric is preliminary in the NETN forest monitoring protocol (Miller *et al.* 2011), a rating has not been established for this metric but MORR contained the greatest percentage of earthworm detection per forest plot when compared to all NETN parks. MORR is the only NETN park where the average coverage of exotic species is greater than the coverage of native species. High deer browse pressure, along with earthworm presence, may be contributing factors to the alteration of the forest understory.

### Tree Growth and Mortality Rates

*Warrants Moderate Concern*; The average percent growth rate (% basal area/year) in MORR was 1.12 and the FIA average growth rate was 4.34. This was calculated to be less than 60% of the regional mean. The average annual percent mortality rate in MORR was 1.50 compared to an average FIA growth rate of 1.05. Specifically, Miller *et al.* (2012) noted that MORR's white ash tree population was near 5% mortality. It is important to note that these ratings are tentative until more plots and multiple surveys have been sampled in MORR.

### ***Data Gaps and Confidence in Assessment***

Confidence in the assessment was high, excluding the biotic homogenization metric (unknown) and the tree growth and mortality rates metric (medium). Trend analyses were not applicable for all metrics. Continued monitoring of forest vegetation in MORR will



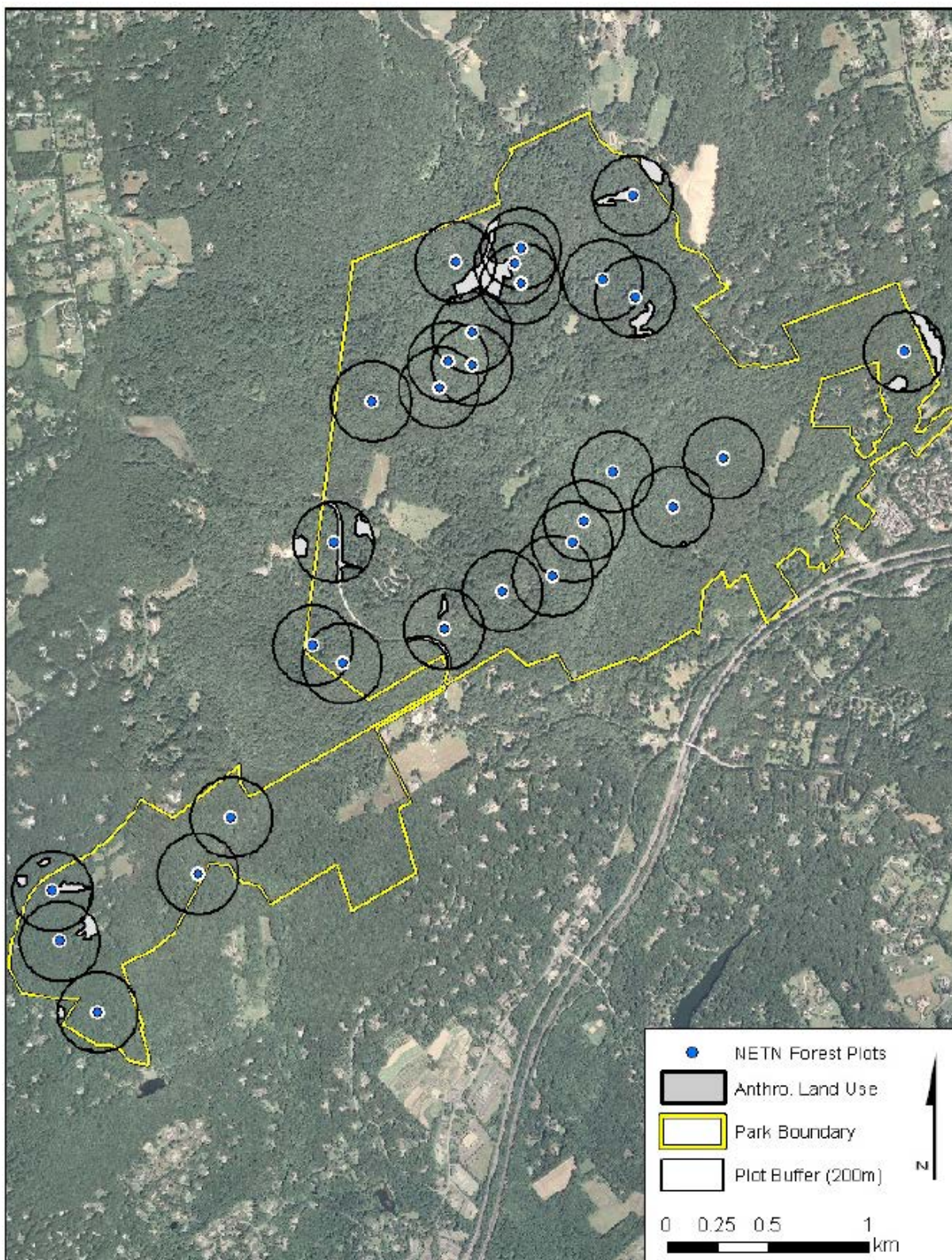
*Successional tuliptree forest in MORR, July 2005. Photo from Sneddon et al. 2008)*

enable managers to establish trend analyses for these metrics, with the number of years to monitor forest plots for trend based on study objectives and statistical power analyses. The continued monitoring of the forest understory in MORR will allow ground truthing to be performed within the park and offer a ‘soil to sky’ view of forest health. For example, exotic earthworm monitoring within the park is underway by NETN in order to assist in explaining possible patterns and changes in biotic homogenization. The continued investigation of biotic homogenization in the understory will enable managers to detect if biodiversity is declining over time due to processes such as invasive plant and animal species, environmental modifications due to anthropogenic activity and climate change. If forest management practices do not address the current concerns in MORR, then it is possible that changes in structural and compositional dynamics of the forest could impact the habitat and distribution of species such as the Indiana bat (*Myotis sodalis*), Cerulean Warbler (*Dendroica cerulean*) and Cooper’s Hawk (*Accipter cooperi*).

**Table 4.16.** Condition assessment for MORR forest vegetation based on 2007 and 2009 data collection efforts.

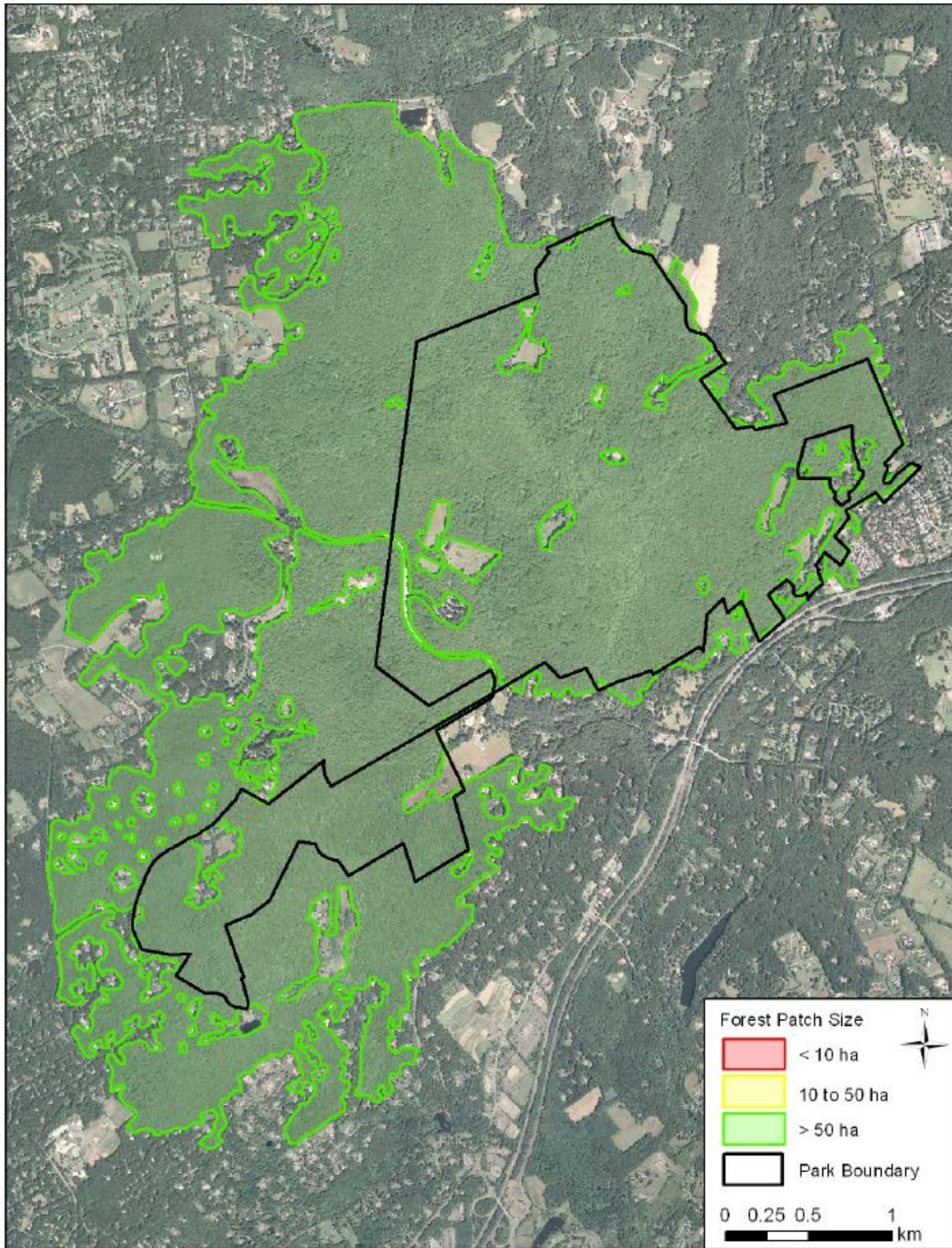
Measure	Condition Categories	Result
Anthropogenic Land Use (ALU)	Warrants Significant Concern:> 40% Warrants Moderate Concern: 10-40% Resource is in Good Condition:<10%	Averaged 5.3%
Forest Patch	Warrants Significant Concern:0.5<10 ha Warrants Moderate Concern: 10-50 ha Resource is in Good Condition:>50 ha	Two patches measured 609.62 ha and 818.37 ha
Structural Stage Distribution	Warrants Significant Concern: < 25% combined mature and late-successional structure Warrants Moderate Concern: < 25% late-successional structure Resource is in Good Condition: ≥ 25% late-successional structure	68% Late successional, 100% mature and late successional
Snag abundance	Warrants Significant Concern:< 5 med-lg snags/ha Warrants Moderate Concern: < 10% standing trees are snags or < 10% med-lg trees are snags Resource is in Good Condition: ≥ 10% standing trees are snags and ≥10% med-lg trees are snags1	Overall: 1.79±1.24 (# of med-lg snags/ha) (±st.error) Mature:1.32±1.32 (# of med-lg snags/ha) (±st.error)
Coarse Woody Debris	Warrants Significant Concern:< 5% live tree volume Warrants Moderate Concern:5 - 15% live tree volume Resource is in Good Condition:> 15% live tree volume	Overall: 6.66% Mature: 6.82%
Biotic Homogenization	Warrants Significant Concern: metric not established Warrants Moderate Concern: increased homogenization Resource is in Good Condition: no change	Unrated; From 2007-2010, Jaccard Similarity Index calculated at 0.24. Non-native earthworms present in 82.1% of plots sampled in MORR.
Tree Growth and Mortality Rates	Warrants Significant Concern: metric not established Warrants Moderate Concern:growth < 60% mean or mortality > 1.6% Resource is in Good Condition: growth ≥ 60% mean or mortality ≤1.6%	Miller et al. (2012) found growth rate to be less than 60% of the regional mean and the mortality rate of 1.50 within NETN range, rating MORR as Warrants Moderate Concern.





**Figure 4.20.** Anthropogenic land use (ALU) within 200 m buffers around NETN forest plots within MORR (Figure from Miller et al. 2011).





**Figure 4.21.** Forest patch sizes divided into three hectare category sizes within MORR (Figure from Miller et al. 2011).



## White-Tailed Deer Herbivory

### Relevance and Context

White-tailed deer (*Odocoileus virginianus*) populations have been increasing since the early to mid-20<sup>th</sup> century in the eastern U.S. due to activities such as landscape alterations (i.e., suburbanization) and a decline in predation (e.g., hunting efforts). Elevated deer populations have led to overbrowsing of native vegetation in MORR's landscape and deer browse preference and avoidance vegetation species occurring in MORR have been identified from past vegetation surveys (Table 4.17, 4.18). In the mid 1980's Christie and Sayre (1989) reported that deer adversely affected both structure and composition of vegetation at MORR, specifically affecting oak regeneration due to the relatively high population density of deer (135 deer/mi<sup>2</sup> [52.1 deer/km<sup>2</sup>] in spring, 170 deer/mi<sup>2</sup> [65.4 deer/km<sup>2</sup>] in fall). Underwood (2007) found deer populations in Jockey Hollow in 1998 to be 57.5 deer/mi<sup>2</sup> (22 deer/km<sup>2</sup>). Ruhren and Handel (2003) later studied forest herb restoration from 1997 through 2000 in Jockey Hollow and found that plant survival was low outside of exclosures and the surviving plants did not flower, concluding that plant restoration was not feasible with this amount of herbivory unless protective



White-tailed deer (*Odocoileus virginianus*). Photo by R. Wagner

fencing was used. Seedling vegetation species and size classes of 12-30 in (30-75 cm) tall are preferentially browsed by deer (Cornett *et al.* 2000), with significant impacts on regeneration occurring with deer densities at  $\geq 22$  deer/mi<sup>2</sup> ( $\geq 8.5$  per km<sup>2</sup>) (Russell *et al.* 2001), although densities as low as 10 mi<sup>2</sup> (4 km<sup>2</sup>) can prevent regeneration of woody species (Alverson *et al.* 1988). The predominantly natural landscape of MORR serves as prime habitat for deer since the park is surrounded by development.

Due to deer browsing native vegetation, invasive species unpalatable to deer have proliferated and MORR is a source for invasives uncommon in New Jersey, such as Siebold's Viburnum (*Viburnum sieboldii*). In order to assess the potential impact of deer browse in forests, the NETN Vital Signs program uses a tree regeneration indicator to assess the quantity and composition of advance tree regeneration in the forest understory.

### Data and Methods

The NETN Vital Signs *tree regeneration*, *deer browse index* and *deer browse indicator species* were measured in MORR forest plots by NETN and used to assess deer impacts in 2007, 2009, and 2011 (Tierney *et al.* 2011, Miller *et al.* 2011, 2012). The *tree regeneration* indicator was rated using the seedling ratios and stocking index for mature, successional and for the overall forest. The seedling ratio that was used for this assessment considered preferential browse of deer on seedling species and



size classes in conjunction with a ratio of seedling species richness in browsed versus unbrowsed size classes of preferred species (Sweetapple and Nugent 2004, Miller *et al.* 2012). The stocking index developed by McWilliams *et al.* (2005) quantifies whether current seedling numbers are sufficient to restock a mid-Atlantic hardwood forest stand.

Additionally, the *deer browse index*, which is a qualitative assessment of deer browse impact using data collected from 2009-2011, was used to assess deer browse impact at each forest plot based on the presence of preferred and non-preferred vegetation (Brose *et al.* 2008, Perles *et al.* 2010). The *deer browse indicator species* measure was used to further assess deer browse activity in MORR based on 2011 data (Miller *et al.* 2012). This metric monitors the frequency of fifteen common, highly-visible herbaceous species that are preferred by deer, have been reported to be intolerant of deer browsing due to life history traits or have been shown to increase in abundance under heavy deer browse pressure (Miller *et al.* 2012). This metric is reported as percent decrease in browse preferred plant species and percent increase in browse avoided plant species. Trend was not assessed for these indicators due to temporal limitations in the available data.

**Table 4.17.** Listing of tree species observed in MORR (NPSpecies database 2012) and rated by their potential to deer browsing.

Scientific name	Common name	Potential Deer Impact	Citation*
<i>Acer rubrum</i>	red maple	High	2
<i>Acer saccharum</i>	sugar maple	High	2
<i>Cornus florida</i>	flowering dogwood	High	1
<i>Liriodendron tulipifera</i>	tulip popular	High	2
<i>Sassafras albidum</i>	sassafras	High	1
<i>Thuja occidentalis</i> **	northern white cedar	High	1
<i>Tilia americana</i>	basswood	High	1
<i>Tsuga canadensis</i>	eastern hemlock	High	2
<i>Betula lenta</i>	black birch	Medium	2
<i>Carya</i> spp.	hickories	Medium	2
<i>Fraxinus</i> spp.	ashes	Medium	2
<i>Hamamelis virginiana</i>	witch hazel	Medium	1
<i>Juglans cinerea</i> **	butternut	Medium	1
<i>Juglans nigra</i>	Black walnut	Medium	1
<i>Nyssa sylvatica</i>	blackgum	Medium	3
<i>Quercus</i> spp.	oaks	Medium	2
<i>Ulmus</i> spp.	elm	Medium	1
<i>Abies balsamea</i>	balsam fir	Medium/Low	2
<i>Fagus grandifolia</i>	American beech	Medium/Low	2

Scientific name	Common name	Potential Deer Impact	Citation*
<i>Pinus resinosa</i>	red pine	Medium/Low	1
<i>Pinus rigida</i>	pitch pine	Medium/Low	1
<i>Pinus strobus</i>	white pine	Medium/Low	1
<i>Alnus</i> spp.	alder	Low	1
<i>Betula papyrifera</i>	paper birch	Low	1
<i>Betula populifolia</i>	graybirch	Low	1
<i>Carpinus caroliniana</i>	musclewood	Low	1
<i>Juniperus virginiana</i>	red cedar	Low	1
<i>Ostrya virginiana</i>	hop hornbeam	Low	1
<i>Picea</i> spp.	spruces	Low	1
<i>Populus</i> spp.	aspens	Low	1
<i>Prunus serotina</i>	black cherry	Low	2
<i>Robina pseudoacacia</i>	black locust	Low	1

\*1-New York State Department of Environmental Conservation (NYS DEC). A Preference List of Winter Deer Foods ([www.dec.state.ny.us/website/dfwmr/wildlife/deer/foodlist.html](http://www.dec.state.ny.us/website/dfwmr/wildlife/deer/foodlist.html)); 2—USFS 2003. Forest Inventory and Analysis. Northeast Field Guide, Version 1.7, App. 12; 3—USFS Fire Effects Information System tree description. ([www.fs.fed.us/database/feis/plants/index.html](http://www.fs.fed.us/database/feis/plants/index.html)).

\*\*Designated as NJ state threatened and endangered species listings.

**Table 4.18.** Understory indicator species of deer browse pressure. Species listed were documented as occurring in MORR (NPSpecies database 2012).

Scientific Name	Common Name	Deer Preference <sup>1</sup>
<i>Ageratina altissima</i> v. <i>altissima</i>	White snakeroot	Avoided
<i>Aster divaricatus</i>	White wood aster	Preferred
<i>Carex</i> spp.	Sedge	Avoided
<i>Clintonia borealis</i>	Blue bead lily	Preferred
<i>Dennstaedtia punctilobula</i>	Hay-scented fern	Avoided
<i>Maianthemum</i> sp.	Canada may flower and false Solomon's seal	Browsed
<i>Polygonatum</i> spp.	Smooth Solomon's seal	Browsed
<i>Sanguinaria canadensis</i>	Bloodroot	Browsed
<i>Thelypteris noveboracensis</i>	New York fern	Avoided
<i>Uvularia</i> spp.	Bellwort	Preferred

<sup>1</sup> Deer preference citations are located in Tierney *et al.* 2009.

### **Reference Condition and Threshold Values Utilized**

NETN Vital Signs ecological integrity scorecard (thresholds) and condition categories were used to assess MORR's vegetation impact from white-tailed deer browsing. These condition categories are based on ecological studies and management goals and included ratings of *Resource is in Good Condition*, *Warrants Moderate Concern* or *Warrants Significant Concern* for the *tree regeneration* indicator (Table 4.19). Tree regeneration was categorized as *Resource is in Good Condition* when the seedling ratio was  $\geq 0$ . The *Warrants Moderate Concern* rating was designated when the seedling ratio was  $< 0$  and the *Warrants Significant Concern* rating was assigned when the stocking index was outside the acceptable range for the park (Miller *et al.* 2012). A stocking index less than 25 is considered inadequate for mid-Atlantic hardwood stands, and is the assessment point that distinguishes *Warrants Moderate Concern* from *Warrants Significant Concern* for MORR (Miller *et al.* 2012). Baseline information on plant community composition and rarity is critical to establishing desired conditions and park management goals relating to native plant communities, non-native plants and the effects of deer browse and other disturbances. Since Ehrenfeld (1977) did not describe the herbaceous component of the communities when surveying the vegetation communities in MORR, it is not possible to determine whether the composition of today's herbaceous layer is substantially different than it appeared over 30 years ago.

An impact level from 1 to 5 was assigned for the *deer browse index* (Table 4.19). The *deer browse index* for reference level 1 (or called 'none' for browse impact) was assigned to a forest plot located inside the deer exclosure which had no evidence of browsing. An index of 5 indicated a very high impact to vegetation from deer browsing. The *deer browse indicator species* data were not assigned condition categories due to limited research available to assist in defining the categories.

### **Condition and Trend**

Data collected in 2007, 2009 and 2011 showed that over 80% of the monitoring plots in MORR were categorized as *Warrants Significant Concern* for tree regeneration measures, with only two of 28 plot rating *Resource is in Good Condition* (Miller *et al.* 2012) (Table 4.19). One of the plots rating *Resource is in Good Condition* was located in an exclosure study plot. Additionally, the *deer browse index* rated MORR's mature, successional and overall forest as being *high* due to index estimates over 4 (Table 4.19). This index indicates that browse evidence was common, browse preferred species were rare to absent and non-preferred or browse resistant vegetation was limited in height by browsing.

MORR's forest canopy is composed primarily of beech (*Fagus grandifolia*), tulip poplar (*Liriodendron tulipifera*), and several species of maple (*Acer* spp.), birch (*Betula* spp.), hickory (*Carya* spp.), oak (*Quercus* spp.), and ash (*Fraxinus* spp.). However, a comparison of tree density by size class across four NETN parks showed MORR to have some of the lowest density of trees with 10-30 cm diameter at breast height (DBH) and the lowest count at 15-30 cm for sapling height (Figure 22). The lack of regeneration in MORR may be due to a combination of complex environmental variables; however, it is likely that the low density of saplings and young trees in MORR is the result of long-term deer browse pressure. Deer browse pressure may be suppressing forest regeneration and competition from invasive exotic species may also be limiting tree

regeneration in conjunction with the deer population. Deer exclosure studies have found that positive and negative impacts occur on the forest understory in MORR. When excluded from deer, exclosure plots have resulted in native shrubs, herbs and seedlings to survive within the plots (Southgate 2002). Conversely, the exclosure plots also allowed non-native shrubs such as Japanese barberry and multiflora rose to grow more vigorously without deer browsing, thus allowing for the proliferation of even more non-native shrubs in MORR (Southgate 2002). In 2012, Superstorm Sandy created several large gaps in the forest canopy (See section 4.15). A benefit to the creation of canopy gaps is that the gaps will allow for more native plant regeneration, which was recommended as a management strategy by MORR's Vegetation and Deer Plan's Science Team (per communication, R. Masson, NPS). However, these new gaps will need to be intensely managed to prevent invasive plants from competing with native plants and becoming established in these areas.

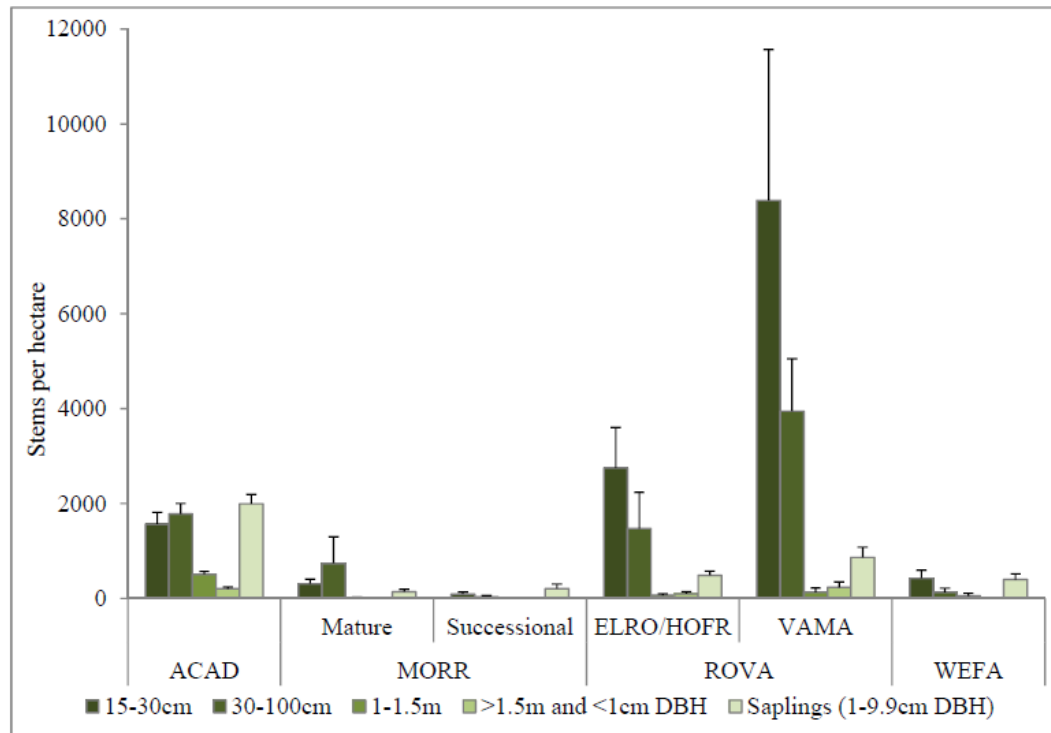
Data collected in MORR illustrated that seedling and sapling densities were below levels required to adequately restock the forest canopy in MORR, and dominant canopy species were depleted in the regeneration layer (beech was the exception) (Miller *et al.* 2012). Oak was rare in MORR and deer browsing is frequently cited as a reason for failure of regeneration in oak communities of eastern parks (e.g., Storm *et al.* 1989, Healy 1997). Additionally, tulip poplar regeneration was absent in the park. Since there is a lack of seedlings that survive for more than a few years in MORR, these areas should be monitored to find out why (other than deer browsing) seedlings are not surviving (i.e., soil chemistry, canopy density).

A compositional in the canopy and a sparser canopy may result if forest regeneration continues to decline due to issues such as deer browse pressures in MORR (Rooney and Waller 2003, Miller *et al.* 2010, 2012). Long-term browsing studies have found that decades of over browsing have led to complete recruitment failure in size classes of >2.5 cm DBH for preferred deer browse species (White 2012). Long term browsing pressure may lead to homogenous forested landscapes, resulting in forests that are less resilient to emerging stressors such as climate change and disease. For example, if tree pathogens, such as beech bark disease becomes severe in the park, then the dominant beech trees will decrease and MORR's forests will experience even more dynamic changes to the integrity of the forest canopy.

**Table 4.19.** Condition assessment for MORR forest vegetation with reference to deer herbivory.

Measure	Condition Categories		Result
Tree Regeneration	Warrants Significant Concern	Stocking index outside acceptable range (25)	<b>Warrants Significant Concern:</b> Regeneration well below levels required to restock future forest. Over 80% of plots were rated as <i>Warrants Significant Concern</i> (Miller <i>et al.</i> 2012)  Average Seedling ratio: overall: -0.61±0.19; mature: -0.53±0.22; successional: -1.00±0  Average stocking index: overall =11.94±3.15; mature: 11.37±3.75; successional: 13.15±6.06
	Warrants Moderate Concern	Seedling ratio < 0	
	Resource is in Good Condition	Seedling ratio ≥ 0	
Deer Browse Index	Index of deer browse impacts assessed for each plot in national historical parks and sites (adapted from Brose <i>et al.</i> 2008 and Perles <i>et al.</i> 2010).		<b>Overall:4.39±0.12</b>  <b>Mature:4.42±0.16</b>  <b>Successional:4.33±0.17</b>
	<b>Level</b>	<b>Browse Impact</b>	
	1	None	
	2	Low	
	3	Moderate	
	4	High	
	5	Very High	





**Figure 4.22.** Mean seedling and sapling density (stems/ha) based on data collected from 2008-2011. Error bars denote +1 SE around the mean. Figure from Miller et al. (2012).

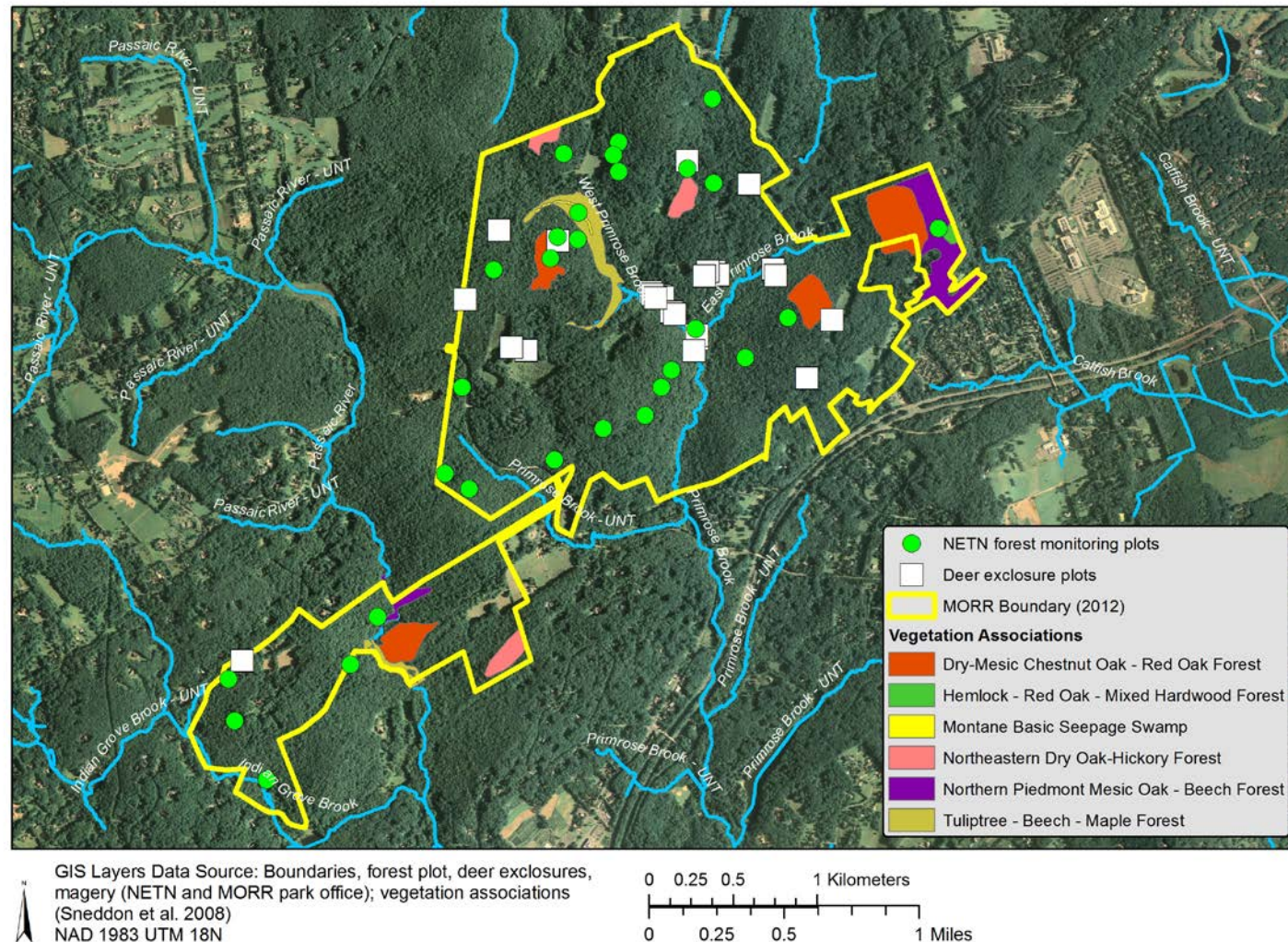
#### **Data Gaps and Confidence in Assessment**

Confidence in the assessment was medium and trend was not applicable. The *tree regeneration* indicator is useful for detecting moderate impacts of deer browse, but is less effective in habitats that lack browse preferred species for reasons other than deer browse or in environments with relatively low tree diversity, such as in MORR (Miller *et al.* 2011). Recently, a *deer browse indicator species* metric had been implemented in 2011 in the NETN forest health surveys. Miller *et al.* (2012) noted that this metric relies on changes in species frequency and therefore has limited value for sites already highly impacted by deer browse.

Since MORR contains a high palatable vegetation structure as measured by Miller *et al.* (2010, 2012), it is important to continue annually monitoring and analyzing deer density, age and sex data in MORR in order to determine if they exceed 22 mi<sup>2</sup> (8.5 km<sup>2</sup>). Coordinating with neighboring parks surrounding MORR for deer measurement estimates (e.g., fertility rates, density) along with spatial invasive plant community mapping and native tree regeneration measurements may aid in establishing management tools to assess the deer density MORR can tolerate before experiencing native plant species loss or reduction due to browsing. Monitoring plots for deer browsing assessments and forest health metrics have been established in MORR. However, monitoring plots in MORR were absent in some vegetation associations noted by Sneddon *et. al* (2008) as being subjected to severe deer browse (Figure 4.23). Estimates of deer browse on native vegetation may be even more severe in MORR than current estimates suggest (Miller *et al.* 2010, 2012).

# Morristown National Historical Park

Vegetation associations subjected to severe deer browse



**Figure 4.23.** NETN forest monitoring and deer exclosure plots in relation to vegetation associations surveyed in MORR which have been subjected to severe deer browse.

## Fish Community

### ***Relevance and Context***

#### Fish Community Composition

MORR's aquatic environment supports a variety of cold-freshwater fish species within several habitat types: small ponds and impoundments, low gradient streams (e.g., East Primrose Brook), moderate gradient streams (e.g., West Primrose Brook) and higher gradient streams (e.g., Indian Grove Brook, Passaic River). A fish inventory by Mather *et al.* (2003) resulted in 11 freshwater fish species representing six families being collected in MORR's waterways, including: blacknose dace, bluegill sunfish, brook trout, brown trout, rainbow trout, creek chub, golden shiner, slimy sculpin, spottail shiner, tessellated darter, and white sucker. All species, excluding bluegill, sunfish, brown trout, and rainbow trout are native, although bluegill and sunfish been in many northeastern systems for over a hundred years. Bluegill and sunfish are naturally reproducing and are not typically considered a threat to native biodiversity, while brown trout and rainbow trout are often stocked in streams and valued by anglers. The composition of the fish community in MORR may be altered due to changes in water chemistry from surrounding development, invasive species colonization or sedimentation.

#### Eastern brook trout populations

In New Jersey, surface water quality criteria and stream classification are closely aligned with descriptors based on fish assemblages, such as trout production, trout maintenance and non-trout waterways. Streams in MORR have been classified as trout production streams, which include streams where young of the year trout may be found, indicating a nursery or spawning site (Figure 4.24). Trout reproduction is desired in cool waters of high quality, a rating granted to less than 5% of streams in NJ (Hudy 2005). Specifically, trout production streams in MORR are classified as Fresh Water Two, Category One (FW2-C1) waters by NJDEP. The C1 categorization is designated to waters of exceptional values based on water quality, scenic setting, recreational significance, ecological significance, water supply or fisheries resources. Additionally, Indian Grove Brook and a section of Passaic River have been designated as "Wild Trout Streams" by the NJ Division of Fish, Game and Wildlife. This designation identifies a viable wild trout population and regulates stocking and fishing. The Eastern brook



*Eastern brook trout (Salvelinus fontinalis). Photo by R. Wagner*



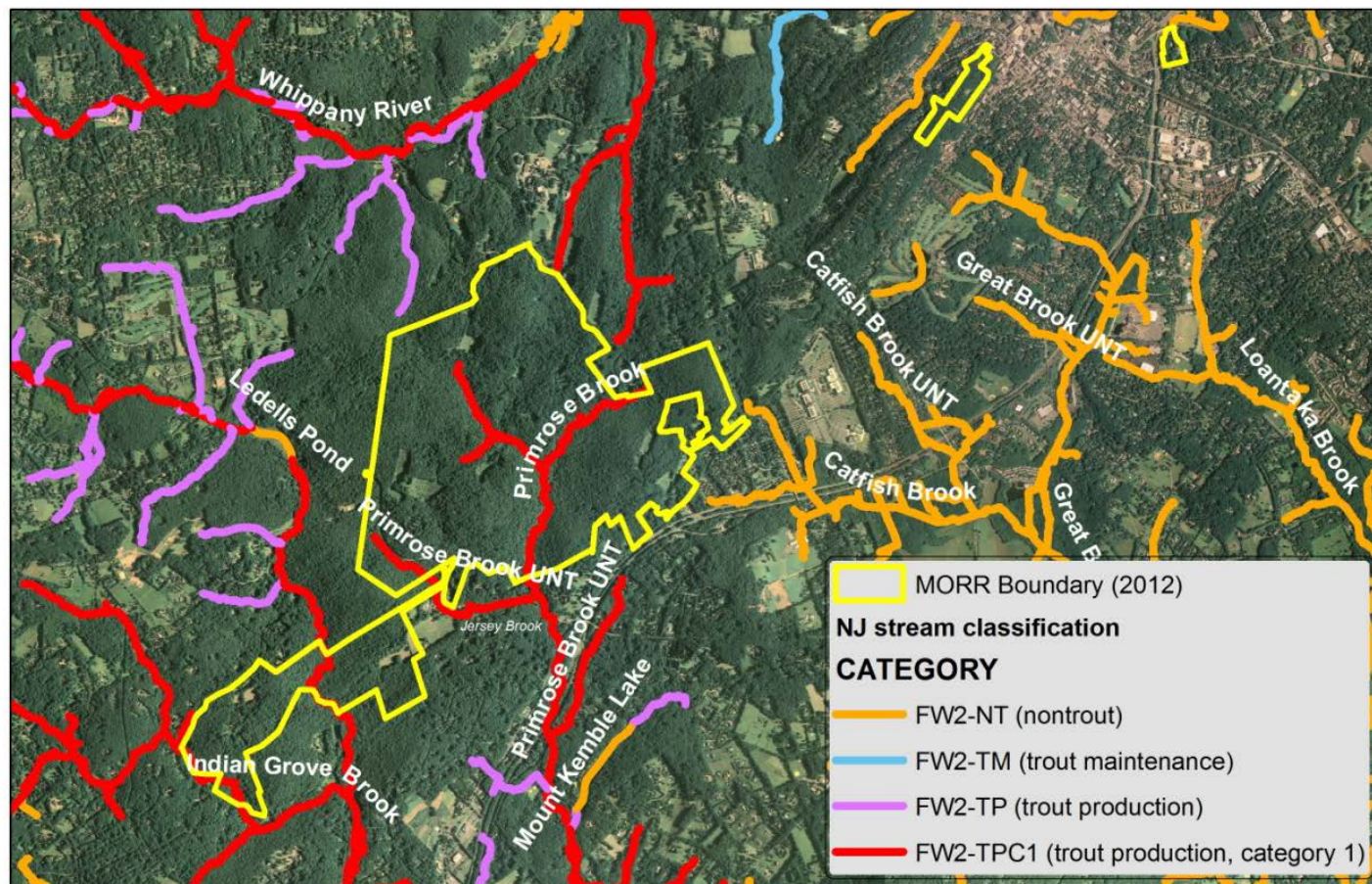
trout (*Salvelinus fontinalis*)-New Jersey's official state fish, the only trout species native to New Jersey waters, and resident to MORR's streams-is a highly valued fish sport fish, along with being an important water quality indicator. However, brook trout populations have been dramatically reduced over the years in New Jersey due to degraded habitats and poor quality waters. Today, this species survives in less than half of its original range and have been completely extirpated from 62% of its original range in New Jersey-the largest recorded loss by any state within the brook trout's natural range (Hudy 2005, Barno 2008). Conservation and restoration strategies are needed in order to maintain existing brook trout populations in New Jersey waters, with the strategies being dependent on the causes of the population declines in specific watersheds within the State.

### **Data and Methods**

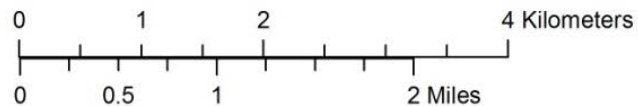
#### Fish IBI and inventory

The New Jersey Department of Environmental Protection has developed a Fish Index of Biotic Integrity (FIBI) for the State's northern waterbodies ([www.state.nj.us/dep/wms/bfbm](http://www.state.nj.us/dep/wms/bfbm)) but fish IBI surveys have not been conducted by the NJDEP within MORR. The FIBI was used in conjunction with the most recent fish survey conducted in MORR in October 2000 (Mather et al. 2003) to assess the condition of the park's fish community (Table 4.20) (Figure 4.25). A final true IBI score was not calculated for MORR's streams due to the sampling design of the most recent fish data collected (Mather et al. 2003) and the absence of a specific measurement needed for the metric 'proportion of individuals with disease/anomalies' (Table 4.20). However, knowing that the missing scores for this last metric must be a 1, 3 or 5, we put bounds on the scores to account for these absences, thus allowing for an estimated IBI score for MORR. Due to this absence, nine out of the ten metrics were calculated for streams in MORR and each metric was given a condition score representing a measure of deviation from reference condition communities: 1 (significantly), 3 (moderately) or 5 (none to slight). If all ten metrics were scored, an overall IBI score based on the sum of the condition metric scores would be applied to gain a final fish IBI score for each stream (e.g., 10-28 poor, 29-36 fair, 37-44 good, 45-50 excellent [modified from Karr et al. 1986]). We then used the modified Karr et al. (1986) metric scores and created Resource is in Good Condition, Warrants Moderate Concern or Warrants Significant Concern categories. Additionally, Karr (1986) noted that it is often of value to examine the individual metrics (Table 4.20). Ponds located in MORR were not assessed using the FIBI, which was developed for lotic (flowing waters) systems. Trend analysis was not conducted due to a lack of quantitative, temporal data available for MORR's fish community.

# Morristown National Historical Park NJ Stream Classification

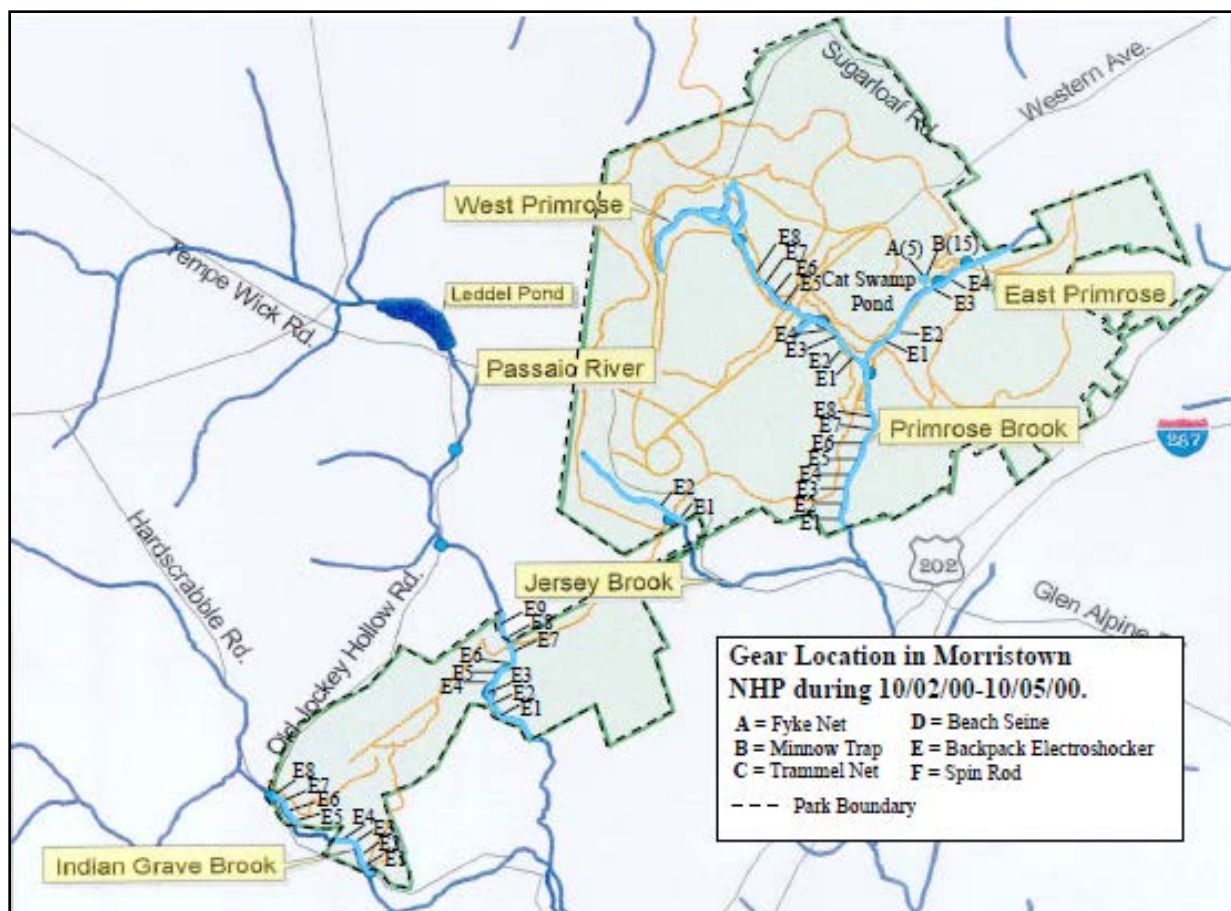


GIS Layers Data Source: Boundaries,  
imagery (NETN and MORR park office);  
Stream classifications (NJDEP)  
NAD 1983 UTM 18N



**Figure 4.24.** New Jersey Department of Environmental Protection stream classification designation for waters within and surrounding MORR.





**Figure 4.25.** Fish sampling locations and sampling gear used for a fish inventory by Mather *et al.* (2003) in Morristown National Historical Park during 2000. Figure from Mather *et al.* (2003).

### **Conservation Success Index**

A secondary assessment was completed for MORR's Eastern brook trout population. Using the Conservation Success Index (CSI) tool created by Trout Unlimited, subwatersheds located within MORR were evaluated to analyze the population status of salmonids and facilitate discussions of protection, restoration, reintroduction and monitoring efforts of the species (Williams *et al.* 2007). The coarse CSI framework is useful as it was designed to be applied to track trends over time, compare status among and within fish species, deal with data uncertainty, implement spatial scale applications, determine management and conservation priorities, and increase public awareness of conservation issues (Williams *et al.* 2007). CSI evaluated 20 indicators grouped into four categories: *population integrity*, *habitat integrity*, *future security* and *range-wide conditions* (see Trout Unlimited methods available at [tucsi.tu.org/CSIMethods.aspx](http://tucsi.tu.org/CSIMethods.aspx)). Each indicator (Table 4.21) was scored from 1 (the equivalent to a *poor* rating) to 5 (the equivalent to a *very good* rating). These indicator ratings were based on general CSI rulesets determined by data availability, species ecology for a specific subwatershed and recent scientific literature on salmonid persistence. A total possible score of 100 for subwatersheds was then calculated, with 100 representing the optimum conditions based on available data (Williams *et al.* 2007) (Table 4.21). These methods were used only for

Loantaka Brook subwatershed, as Black Brook and Passaic River subwatersheds have extirpated populations based on Trout Unlimited analyses (Figure 4.26).

### **Reference Condition/Threshold Values Utilized**

#### Fish IBI

The New Jersey Fish Index of Biotic Integrity (FIBI) for Northern New Jersey streams used 10 metrics (Table 4.20) which were created and scored based on measures of deviation from regional reference condition streams. Each condition metric scored either a *1 (significantly)*, *3 (moderately)* or *5 (none to slight)* based on fish assemblage deviation from reference conditions, with the higher number representing closer reference conditions. If all ten metrics were scored, an overall IBI score based on the sum of the condition metric scores would be applied to gain a final fish IBI score for each stream (e.g., 10-28 *poor*, 29-36 *fair*, 37-44 *good*, 45-50 *excellent* [modified from Karr *et al.* 1986]). We then used the modified Karr *et al.* (1986) metric scores and created *Resource is in Good Condition*, *Warrants Moderate Concern* or *Warrants Significant Concern* categories. The resulting thresholds for the final fish IBI scores for the six streams in MORR included: 10-28 *Warrants Significant Concern*, 29-36 *Warrants Moderate Concern* and 37-50 *Resource is in Good Condition*. Because metric 10 (Table 4.20) was not measured in the Mather *et al.* 2003 data, theoretic scores of 1, 3 or 5 were applied to metric 10. This was performed in order to calculate a final IBI score which included a potential score range, and at times, two possible condition categories being assigned to the stream. Further details on New Jersey's Northern Fish IBI are presented in Vile (2010). Fish surveys by Mele and Mele (1983) were used for qualitative comparisons to recent fish surveys conducted in MORR.

#### Conservation Success Index

CSI thresholds rated from *1* (representing the poorest rating) to *5* (represent the best rating) for the 20 indicators, with the established thresholds based on scientific research, including major factors which influence salmonid population persistence (Williams *et al.* 2007). General scoring rules and thresholds for the indicators are located in Table 4.21 and Table 4.22. A total CSI rating was also calculated which potentially rated from 20 -100 based on the indicator scores. These ratings were originally mapped by Trout Unlimited using GIS color symbology applications (six colors: red, orange, yellow, green blue and tan), with red indicating the lowest score range for the Conservation Success Index, blue representing the highest score range, and tan representing extirpated populations within the subwatersheds. For the purpose of this assessment, we categorized these scores as follows: a score of 71-100 rated *Resource is in Good Condition*, 51-70 *Warrants Moderate Concern* and 0-50 *Warrants Significant Concern* for the subwatershed (Figure 4.26).

### **Condition and Trend**

#### Fish IBI

The results in Table 4.20 list the metric scores using the New Jersey Northern Fish IBI metrics in conjunction with data collected by Mather *et al.* (2003) in October 2000. Jersey Brook scored *Warrants Significant Concern* or *Warrants Moderate Concern* (due to uncertainty in the IBI value), East Primrose Brook and Primrose Brook both scored *Warrants Moderate Concern* or *Resource is in*

*Good Condition*, West Primrose Brook scored *Warrants Moderate Concern*, and Indian Grove Brook and Passaic River both scored *Resource is in Good Condition*. Of the metrics calculated for the streams, MORR's streams scored a 3 (*moderately*) or a 5 (*slight to none*) for the majority of the metrics. However, certain metrics for MORR's streams scored 1 (*significantly*), indicating a potential problem in the water quality or habitat of the streams in relation to reference stream conditions. All streams assessed in MORR scored 1 or 3 for the metric *# of fish species*. A reduction in species richness may indicate a pollution problem or a physical habitat loss. However, the low number of fish species may be a result of stream order and the small drainage area of the watershed or inadequate sampling methods used to capture a species of low abundance. Primrose Brook, including the west branch of the stream and the Passaic River scored 1 for the metric *proportion of individuals as insectivorous cyprinids*. Insectivorous cyprinids are the dominant insectivorous fish in New Jersey (excluding Pineland streams). A shift from specialized invertebrate feeders to generalist feeders often indicates poor conditions associated with water quality and/or physical habitat degradation (Karr et al. 1986). Indian Grove Brook scored 1 for the metric *# of benthic insectivorous species*. Many benthic insectivores require clean gravel or cobble substrate for reproduction, and degradation of this habitat from siltation is reflected by a loss of benthic species richness and abundance. Further, these fish may decline when benthic oxygen depletion occurs and may also be an indirect indicator of a toxicity problem (Ohio EPA 1987). Jersey Brook scored 1 for the metric *# of trout and sunfish species*. Trout are water-column species which are sensitive to habitat degradation and loss of instream cover (Peters 1967, Meehan 1991). Trout typically inhabit highly oxygenated pools and feed off benthic invertebrates which occur in stream drift. Jersey Brook, however, is a smaller stream and contains low water flow/quantity, especially during warmer months. These characteristics could also account for the lower number of these fish species.

Mele and Mele (1983) noted that MORR's surface waters supported diverse and balanced fish communities based on species relative abundance estimate, with each stream having its own unique hydrological and microhabitat characteristics. Furthermore, Mele and Mele (1983) found that East Primrose Brook, West Primrose Brook and Primrose Brook had the greatest composition of Eastern brook trout (*Salvelinus fontinalis*) compared to MORR's other streams. This species continues to dominate the community composition of these three streams based on Mather *et al.* (2003) surveys. Eastern brook trout are the only native trout to the majority of the eastern U.S. and serve as indicators of watershed health. If MORR is being affected by land use changes, changes in water quantity /quality or runoff from roads, then continuous, standardized monitoring the fish community in these streams may be useful indicators of habitat degradation.

**Table 4.20.** Metrics for NJ Northern Fish IBI (Vile 2010) and calculated condition metric scores for streams in MORR based on Mather et al. (2003) sampling data. Condition metric scoring includes categorical measures of deviation from reference streams: 1 (significantly), 3 (moderately) or 5 (none to slight). Metric 10 could not be assessed due to lack of measurements needed for its calculation.

Fish Index of Biotic Integrity Metric		East Primrose Brook	Indian Grove Brook	Jersey Brook	Passaic River	Primrose Brook	West Primrose Brook
<b>species richness and composition</b>							
1.	total number of fish species <sup>a</sup>	1	3	1	3	1	1
2.	# of benthic-insectivorous species <sup>a</sup>	5	1	3	3	5	3
3.	# of trout and/or sunfish species <sup>a</sup>	3	5	1	5	3	3
4.	# of intolerant species <sup>a</sup>	5	5	3	5	5	5
5.	Proportion of tolerant individuals <sup>b</sup>	5	5	5	5	5	5
<b>trophic composition</b>							
6.	Proportion of individuals as generalists <sup>b</sup>	5	5	5	5	5	5
7.	Proportion of individuals as insectivorous cyprinids <sup>c</sup>	3	5	5	1	1	1
8.	Proportion of individuals as trout or individuals as piscivores <sup>d</sup>	5	5	1	5	5	5
<b>fish abundance and condition</b>							
9.	Number of individuals in the sample <sup>e</sup>	1	5	1	5	3	3
10.*	Proportion of individuals with disease and anomalies (excluding blackspot disease) <sup>f</sup>	1, 3 or 5					
<b>FINAL IBI SCORE**</b>		<b>34-38</b> Warrants Moderate Concern-Resource is in Good Condition	<b>40-44</b> Resource is in Good Condition	<b>26-30</b> Warrants Significant Concern-Warrants Moderate Concern	<b>38-42</b> Resource is in Good Condition	<b>34-38</b> Warrants Moderate Concern-Resource is in Good Condition	<b>32-36</b> Warrants Moderate Concern

\*Theoretic scores of 1, 3 or 5 were applied to metric 10 in order to calculate a final IBI score which included a potential score range, and at times, two possible condition categories.

\*\*10-28 Warrants Significant Concern, 29-36 Warrants Moderate Concern and 37-50 Resource is in Good Condition.

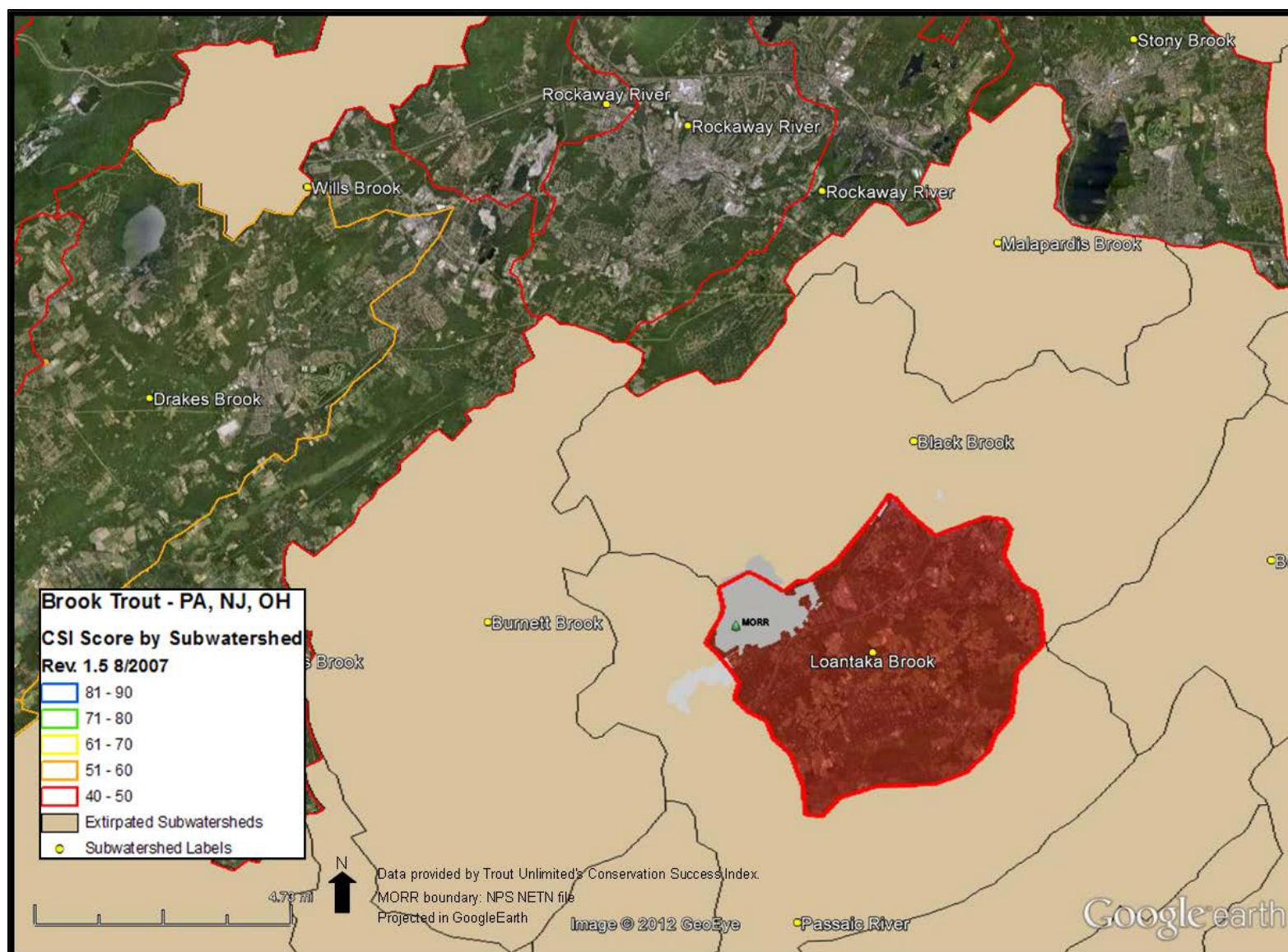
<sup>a</sup> See Vile (2010) for calculation using maximum species richness line (MSRL); <sup>b</sup> 5:<20%, 3:20-45%, 1:>45%; <sup>c</sup> 5:>45%, 3:20-45%, 1:<20%; <sup>d</sup> 5:>10%, 3:3-10%, 1:<3% (trout)/ 5:>5%, 3:1-5%, 1:<1% (piscivores); <sup>e</sup> 5:>250, 3:75-250, 1:<75; <sup>f</sup> 5:<2%, 3:2-5%, 1:>5%

### Conservation Success Index

Using CSI data, many subwatersheds surrounding MORR were mapped as having extirpated populations of Eastern brook trout except for Loantaka Brook subwatershed (ID 340133) (Figure 4.26). This subwatershed includes Primrose Brook, which during a survey by Mele and Mele (1983) contained more than 50% of the brook trout observed in MORR streams. Loantaka Brook subwatershed scored a 48 for the final CSI score, which is the lowest color scoring category (red) and was categorized as *Warrants Significant Concern* (Table 4.21, Figure 4.26). Low scores (rated 1 or 2) for Loantaka Brook subwatershed were for indicators such as land stewardship, land conversion, watershed connectivity, watershed conditions, introduced species, population extent and life history diversity (Table 4.21). Land within the subwatershed is vulnerable to conversion as it contains several thousand acres of undeveloped private land with slopes less than 15% and is near population centers or existing roads (Trout Unlimited 2007, [tusci.tu.org](http://tusci.tu.org)). Watershed connectivity and conditions scored low due to the number of barriers in this subwatershed and high road density (10.85 miles/ sq. mi). The higher road density also increases the threat of exotic species transfer and establishment (Trout Unlimited 2007, [tusci.tu.org](http://tusci.tu.org)).

A Subwatershed Conservation Strategy based on the CSI habitat indicators (score of 14) and population indicators (score of 7) suggested “restore habitat and population” as a conservation need for this subwatershed (Table 4.22). Future Security indicator scores suggest that restoration efforts may be offset by future events if the subwatershed is not protected from future threats, with the greatest future threat to Eastern brook trout possibly being climate change and land conversion. The fragmentation of these relatively small populations and the presence of degraded habitat do not provide many of the remaining populations the resistance and resilience needed to survive the stresses of a changing climate. High human population densities, a dense road network and lack of protected land make much of the brook trout’s habitat vulnerable to future development. Furthermore, a study by Princeton Hydro, LLC (2004) found that the headwater streams in the Jockey Hollow area of Primrose Brook were impacted due to a variety of factors. Stream bank erosion from foot bridge traffic and the presence of erodible soil types were evident in MORR in addition to storm sewer discharge, barriers to migration at several small impoundments, swale discharge and debris at easily accessed points (Princeton Hydro, LLC 2004). Restoration efforts may encompass a wide variety of activities for this watershed, particularly reconnection to reduce fragmentation of land and water resources.





**Figure 4.26.** Map of overall Conservation Success Index (CSI) scores for subwatersheds located around MORR, including Loantaka Brook subwatershed which encompasses most of Primrose Brook (data from Trout Unlimited 2007).

**Table 4.21.** Twenty CSI indicators, definitions, general scoring rules and their relevance to salmonid conservation (from Williams *et al.* 2007). Each subwatershed was scored from 1-5 for each indicator based on the general scoring rules. Highlighted scores (when available) represent Loantaka Brook subwatershed which encompasses MORR (Trout Unlimited 2007).

Indicator	Definition	General Scoring Rules	Relevance to Conservation
<b>Range-wide Condition Indicators: <i>Loantaka Brook</i> overall score=12/20</b>			
% historic stream habitat occupied	% historic stream habitat currently occupied (km) versus historic conditions.	5= >50% historic range occupied; 4= 35-49%; <b>3= 20-34%;</b> 2= 10-19%; 1= <10%	Species that occupy a larger proportion of their historic range will have an increase likelihood of persistence.
% subbasins (4 <sup>th</sup> level HUC) occupied	% 4 <sup>th</sup> level hydrologic units currently occupied versus those within historic range.	5= 90-100% historic subbasin occupied; <b>4= 80-89%;</b> 3= 70-79%; 2= 50-69% 1= <50%	Larger river basins often correspond with District Population Segments or Geographic Management Units that may have distinct genetic or evolutionary legacies for the species.
% subwatersheds (6 <sup>th</sup> level HUC) occupied within subbasin	% 6 <sup>th</sup> level hydrologic units currently occupied compared to those within historic range.	5= 81-100% historic subwatersheds occupied; 4= 61-80%; 3= 41-60%; <b>2= 21-40%;</b> 1= 1-20%	Species that occupy a larger proportion of their historic subwatersheds are likely to be more broadly distributed and have an increased likelihood of persistence.
% Habitat by stream order occupied	% current habitat occupied in 1 <sup>st</sup> and 2 <sup>nd</sup> order streams compared to larger stream systems in each subwatershed.	5= > 25% of stream habitat is 2 <sup>nd</sup> order or greater; 4= 20-25% is 2 <sup>nd</sup> order or greater; <b>3= 15-20% is 2<sup>nd</sup> order or greater;</b> 2= 10-15% is 2 <sup>nd</sup> order or greater; 1= < 10% is 2 <sup>nd</sup> order or greater	Species that occupy a broader range of stream sizes will have an increased likelihood of persistence.
% Historic lake habitat occupied	% lake habitat (surface area) currently occupied versus historic condition.	5= > 50% historic lake habitat occupied; 4= 35-50%; 3= 20-35%; 2= 10-20%; 1= < 10%	Lakes often harbor unique life histories and large populations that are important to long-term persistence of the species.
<b>Population Integrity Indicators: <i>Loantaka Brook</i> overall score=7/15</b>			
Population density	Number of adult salmonids per habitat unit area.	5= more than 400/mile 4= 151-400/mile; 3= 50-151/mile; 2= less than 50/ mile, overall population 500; 1= less than 50/ mile, overall population <500	Small populations, particularly those below 500 effective population size, are more vulnerable to extirpation

Indicator	Definition	General Scoring Rules	Relevance to Conservation
Population extent	Amount of stream habitat (km or mi) or lake habitat (surface area) available to population.	5= large interconnected populations, no barriers; 4= 30-50 km of connected habitat; 3= 20-30 km connected habitat; 2= 10-20 km connected habitat; 1= <10 km connected habitat	Populations with smaller available habitats are more vulnerable to extirpation.
Genetic purity	Measure as % of fish known or suspected to be hybridized with non-native salmonids, including hatchery fish.	5= no hybridization; 4= no hybridization known but proximity to non-native trout causes concern; 3= hybridization < 10%; 2= hybridization 10-20%; 1= hybridization >20%	Hybridization and loss of the native genome via introgression with non-native salmonids are among the leading factors in declines of native salmonids.
Disease vulnerability	Measured as presence of non-native diseases or parasites and/or accessibility of vectors of disease or parasites.	5= no disease/pathogens; 4= none present but proximity >10km; 3= disease/pathogens present but not in target fish; 2= disease/pathogen present in habitat but not in target fish; 1= disease/pathogens in target fish	Non-native pathogens and parasites, including the myxozoan parasite that causes whirling disease, can infect native trout and reduce their populations.
Life history diversity	Number of life history forms present as compared to presumed historic condition.	5= all life history forms present; 3= two or more life histories present but at least one absent; 1= one life history present, others absent;	Loss of life history forms, particularly migratory forms, increases risk of extirpation; loss of migratory forms may reduce genetic diversity.
<b>Habitat Integrity Indicators: Loantaka Brook overall score=14/25</b>			
Land stewardship	Amount (acres or ha) of federal or state lands with regulatory or congressionally-established habitat protections.	5= 30% or more of subwatershed in protected status; 4= 20-29% protected; 3= 10-19% protected; 2= 1-10% protected; 1= no protected habitat	Subwatersheds with higher proportions of protected federal and state lands typically support higher quality habitat than do other lands.
Watershed connectivity	Measured by instream barriers, water diversions, and dewatered segments.	5= all streams connected; 4= streams connected but fragmented at watershed scale; 3= minor fragmentation within subwatershed; 2= moderate fragmentation; 1= high fragmentation	Increased hydrologic connectivity provides more habitat area and facilitates development of multiple life histories, which increase likelihood of persistence.
Watershed conditions	Measured by road	If road density is used:	Habitat conditions as

Indicator	Definition	General Scoring Rules	Relevance to Conservation
	density, riparian function, stream habitat complexity and /or deep pools.	5= 0-0.1 density; 4= 0.1-0.7; 3= 0.7-1.7; <b>2= 1.7-4.7;</b> 1= >4.7	indicated by road density, presence of deep pools or riparian vegetation are the primary determinant on persistence of most populations.
Water quality	Measured by presence of 303(d) water quality limited stream segments; number of mines and point sources of pollution.	5= high quality, no 303(d) segments; <b>4= high quality, minor pollution sources;</b> 3= moderate to high quality; 2= moderate quality with significant sources of pollution; 1= poor quality	Decreases in water quality, including reduced dissolved oxygen, increased turbidity, increased temperature and the presence of pollutants, reduces habitat suitability for salmonids.
Flow regime	Measured by seasonal fluctuations and total flows, compared to historic regime.	<b>5= flow regime unaltered;</b> 4= flows approx. 90% of historic; 3= flows approx. 75%; 2= flows approx. 50%; 1= flows highly modified, <50% of historic	Natural flow regimes are critical to proper ecosystem function. Reduced or altered flows reduce capability of watershed to support native biodiversity.
<b>Future Security Indicators: Loantaka Brook overall score=15/25</b>			
Land conversion	Amount of land vulnerable to conversion based on proximity to population centers, slope, land ownership, and road density	5= amount of land vulnerable to conversion <20%; 4= 20-40%; 3= 40-60%; <b>2= 60-80%;</b> 1= >80%	Conversion of lands from natural habitats will reduce habitat quality and availability.
Resource extraction	Amount of land vulnerable to resource extraction based on energy leases, undeveloped mineral resources, oil and gas deposits	<b>5= no potential development;</b> 4= no active development; low potential; 3= no active development but recoverable deposits present; 2= recoverable deposits present, moderate likelihood of active development; 1= high likelihood of active development	Increased mining and energy development will increase road densities, modify natural hydrology, and increase likelihood of pollution.
Flow modification	Amount of water vulnerable to future diversion, impoundment or other development	5= no known vulnerability; <b>4= one site or application;</b> 3= 2 or 3 sites or applications; 2= multiple sites or applications indicate likely modifications in significant portion of subwatershed; 1= multiple applications indicate likely modifications	Changes in natural flow regimes are likely to reduce habitat suitability for native salmonids and increase the likelihood of invasion by non-native species.

Indicator	Definition	General Scoring Rules	Relevance to Conservation
		throughout subwatershed	
Climate change	Resistance to climate change impacts as a function of watershed connectivity, habitat conditions, and elevational gradient	5= high condition; high connectivity; 4= moderate condition; moderate connectivity; 3= moderate conditions but low connectivity; 2= low conditions, low connectivity; 1= very low conditions	Climate change is likely to threaten most salmonid populations because of warmer water temperatures, changes in peak flows and increased frequency and intensity of disturbances such as flood and wildlife.
Introduced species	Future vulnerability to introduced species determined as a function of roads in riparian corridors, human population density, and occurrences of introduced species	5= threats minor or nonexistent; 4= nonnatives present in larger watershed, chance of spread low; 3= nonnatives present in watershed, chance of spread moderate; 2= nonnatives in watershed, chance of spread high; 1= nonnatives present in subwatershed, chance of spread high	Introduced species are likely to reduce native salmonid populations through predation, competition, hybridization and the introduction of non-native parasites and pathogens.

**Table 4.22.** Subwatershed Conservation Strategy scoring system used in conjunction with the Conservation Strategy Index (CSI) (Trout Unlimited 2009, Williams *et al.* 2007). The subwatershed which encompasses a portion of MORR, Loantaka Brook, resulted in an overall conservation strategy of 'Restore Habitat and Population' for Eastern brook trout (highlighted in yellow).

Conservation Strategy	Habitat Integrity Score (without land stewardship)	Population Integrity Score
Protect	≥16	≥21
Restore Population	≥16	<21
Restore Habitat	<16	≥21
Restore Habitat and Population	<16	<21
Reintroduce	≥16	Extirpated
Restore, then reintroduce	<16	Extirpated

### **Data Gaps and Confidence in Assessment**

Confidence in the IBI assessment was medium and trend analysis was not applicable. This condition assessment was based on the best available data for MORR, which was a single survey conducted in MORR in 2000. Additionally, an overall IBI score could not be calculated due to a lack of fish community data needed for one metric (metric 10), but the analysis of individual metrics was valuable in the assessment of structural composition and function of the fish community. Appropriate assessment methods for smaller streams that occur in MORR include measurements of trout abundance or young of the year production. An assessment of MORR's fish community with the



inclusion of relevant metrics will provide managers with an improved assessment of the fish community in MORR in relation to water and habitat parameters. Repeated surveys at the same stream habitat types along with intense sampling effort over a period of time (i.e., years) will allow for baseline data to become established and temporal changes to be detected with greater statistical confidence.

Confidence in the CSI assessment was medium and trend analysis was not applicable. CSI is helpful in identifying conservation strategies at a coarse scale but local knowledge and partnerships are keys to identifying finer resolution variables for on-the-ground projects and for implementing successful protection and restoration strategies. Constraints for implementing strategies using the CSI for Eastern brook trout populations include: dependence upon regional data availability, inappropriate for use at scales finer than subwatershed, inappropriate for stream-reach management (requires site-specific knowledge), unsuitable for detecting trends over short to mid time frames (< 10 years), dependence upon availability of broad-scale species and habitat data, subjectivity bias may occur in assessments, and scoring may overly simplify complex issues leading to inappropriate comparisons (Williams *et al.* 2007).

## **Bird Community**

### ***Relevance and Context***

Breeding birds are excellent indicators of biotic integrity and ecosystem health because they are visible and vocal, easy to monitor and individual species have specific habitat requirements and levels of sensitivity making them useful for tracking changes that may be impacting other species that are harder to measure. In addition, there is considerable public interest in birds, there are standardized methods for surveying birds, and there are many skilled amateurs who can assist with data collection at multiple levels from reporting the presence of a species at a park to conducting point count surveys.

MORR is located within Bird Conservation Region BCR28-Appalachian Mountains (<http://pif.rmbo.org/>). In 2012, Partner's in Flight updated a species assessment database for all native North American landbirds (<http://pif.rmbo.org/>). The database provides information on population size, trends, and threats. It allows one to sort species by Bird Conservation Region and then select species by "importance". Important species include those of regional concern (species that have undergone declines and where the region of interest is important to the well-being of the species), common birds in steep population declines (common birds whose populations have declined an estimated 50% or more in the last 40 years), continental species of concern, and Canada/US stewardship species. For the purpose of park management, the most important groups to look at are species of regional concern and common species showing steep declines (Table 4.23, 4.24). Species of regional concern that are also continental concern species would be particularly important to be aware of and to manage for when the opportunity is available. Note that a number of species of regional concern for BCR28 such as Red-cockaded Woodpecker, Bachman's Sparrow and Lark Sparrow are found in the southern portion of the region, and MORR is north of the northern limit of their distribution and therefore these species would not be appropriate to manage for.

New Jersey maintains a state list of threatened, endangered, and special concern species. Twenty-seven breeding bird species that have been identified as ‘present’ or ‘probably present’ in MORR based on NPS species data have been listed as endangered, threatened or of special concern in New Jersey (<http://www.nj.gov/dep/fgw/tandespp.htm>). Understanding breeding and population trends of these species and threats to their specific habitat type is critical in order to implement conservation management plans.

### **Data and Methods**

The following is a list of the types of data sets that are available for MORR with information on our assessment of how each data set might contribute to the evaluation of resource conditions. Park staff and local birders have recorded 135 bird species known to occur in the park at some time during the year (NPSpecies 2012). This provides a checklist of birds and seasonal abundance data but does not provide information distribution, an attribute that is needed in order to assess condition and track change. Standardized surveys provide additional information on abundance and distribution, and there are a number of data sets available for MORR. The most significant studies and datasets are described below.

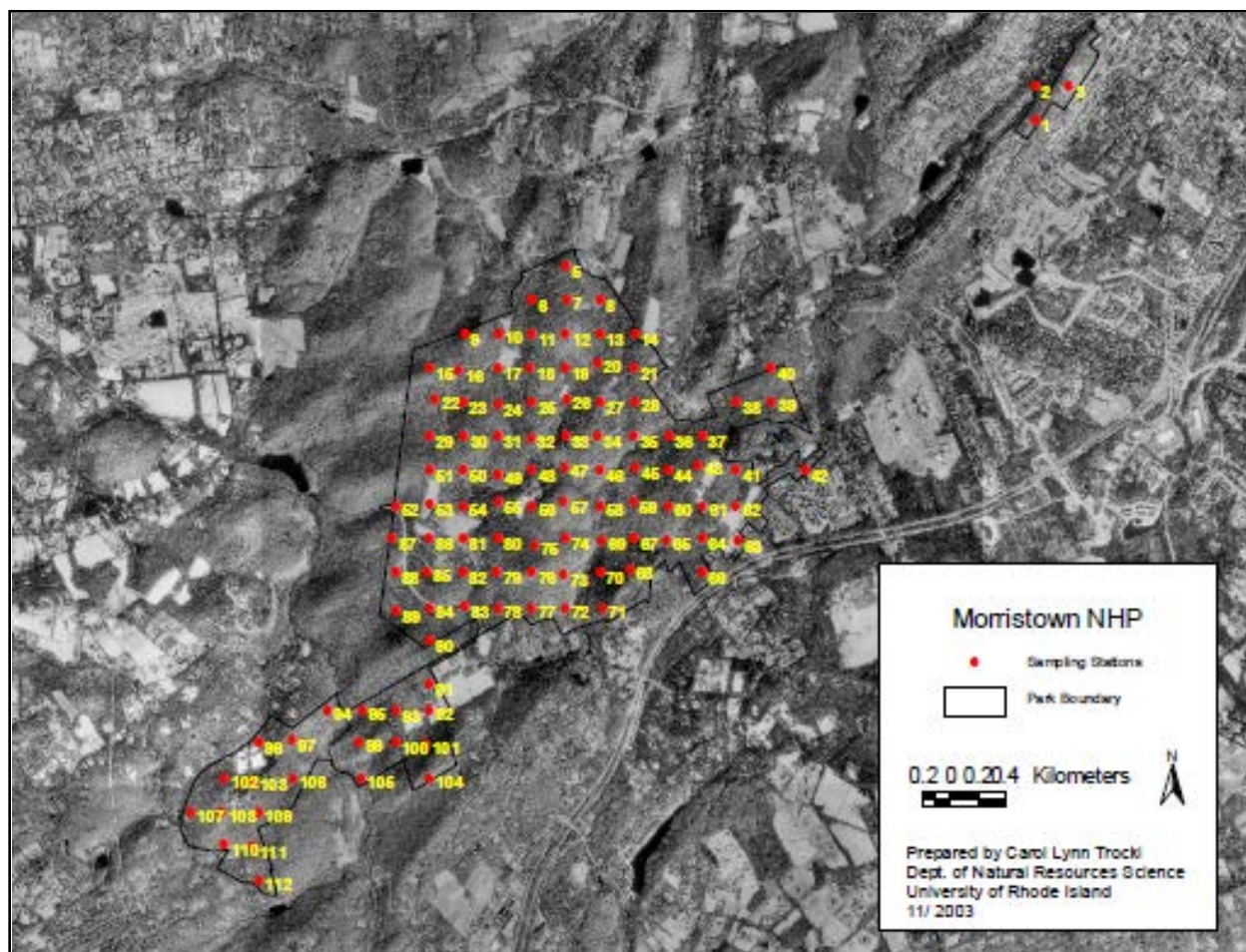
**Table 4.23.** Common species in steep decline in Bird Conservation Region 28, the region that includes MORR (<http://pif.rmbo.org/>).

Common Name	Habitat <sup>a</sup>	Common Name	Habitat <sup>a</sup>
Northern Bobwhite	AG-GR	Northern Flicker	FOR
Ruffed Grouse	SES	Loggerhead Shrike	FOR
Yellow-billed Cuckoo	FOR	Bank Swallow	WET
Black-billed Cuckoo	FOR	Prairie Warbler	SES
Eastern Whip-poor-will	FOR	Field Sparrow	AG-GR
Chimney Swift	OTH	Grasshopper Sparrow	AG-GR
Belted Kingfisher	WET	Bobolink	AG-GR
Red-headed Woodpecker	FOR	Eastern Meadowlark	AG-GR

<sup>a</sup> Habitat associations AG-GR – Agricultural fields, pastures, old fields, grasslands; FOR- Forest, deciduous or mixed; SES – Shrub and early successional habitat; WET- Wetlands, lakes, streams

*Trocki and Paton (2003)* quantitatively assessed populations of birds at MORR during 2002-2003. They established randomly generated survey points across the park with the abundance of points per habitat type based on the abundance of that particular habitat type within the park. Prior to the 2002 breeding season, they identified 110 randomly-generated point counts (Figure 4.27). Half were surveyed in 2002 and half in 2003. Ninety of the sampling stations (82%) were located in deciduous forested habitat. Seven stations (6%) were located in forested wetlands, seven (6%) in early successional / edge habitat, five (5%) in forested habitat adjacent to streams. One station (1%) was located in conifer forest.

A total of 72 species were detected during field surveys with 64 detected during point counts. Thirty-two species were considered breeders at MORR. The three most common species were Wood Thrush, Red-Bellied Woodpecker and Red-Eyed Vireo. Breeding species of regional concern that were identified during this survey included: Black and White Warbler, Cerulean Warbler, Chimney Swift, Eastern Towhee, Eastern Wood-Pewee, Field Sparrow, Kentucky Warbler, Louisiana Waterthrush, Northern Flicker, Purple Martin, Red Crossbill, Wood Thrush, Worm-Eating Warbler, Yellow-Throated Vireo. This group includes species breeding in forest (e.g., Northern Flicker), early successional habitats (e.g., Eastern Towhee), wetlands (e.g., Purple Martin) and in grasslands and field habitat (e.g., Field Sparrow). Four breeding species classified as common species showing steep declines were present (Chimney Swift, Northern Flicker, Field Sparrow and Yellow-Billed Cuckoo).



**Figure 4.27.** Locations of point count stations in Morristown National Historical Park (MORR) surveyed during the breeding season in 2002 and 2003. Figure from Trocki and Paton (2003).

**Table 4.24.** Partners-in-Flight species of regional concern in Bird Conservation region 28. \*\*\* indicates a species that is also of continental concern (<http://pif.rmbo.org/>).

Common Name	Habitat <sup>a</sup>	Common Name	Habitat <sup>a</sup>
Northern Bobwhite	AG-GR	Brown Thrasher	SES
American Kestrel	AG-GR	Worm-eating Warbler	FOR
Peregrine Falcon	OTH	Louisiana Waterthrush	FOR
Black-billed Cuckoo	FOR	Golden-winged Warbler***	SES
Northern Saw-whet Owl	FOR	Blue-winged Warbler	SES
Chuck-will's-widow	FOR	Black-and-white Warbler	FOR
Eastern Whip-poor-will	FOR	Kentucky Warbler	FOR
Chimney Swift	OTH	Cerulean Warbler***	FOR
Belted Kingfisher	WET	Prairie Warbler	SES
Red-cockaded Woodpecker***	FOR	Yellow-breasted Chat	SES
Northern Flicker	FOR	Eastern Towhee	SES
Olive-sided Flycatcher***	FOR	Bachman's Sparrow	FOR
Eastern Wood-Pewee	FOR	Field Sparrow	AG-GR
Acadian Flycatcher	FOR	Lark Sparrow	AG-GR
Loggerhead Shrike	FOR	Grasshopper Sparrow	AG-GR
Yellow-throated Vireo	FOR	Henslow's Sparrow***	AG-GR
Purple Martin	WET	Summer Tanager	FOR
Barn Swallow	AG-GR	Eastern Meadowlark	AG-GR
Bewick's Wren	SES	Red Crossbill	FOR
Wood Thrush***	FOR		

<sup>a</sup> Habitat associations AG-GR – Agricultural fields, pastures, old fields, grasslands; FOR- Forest, deciduous or mixed; SES – Shrub and early successional habitat; WET- Wetlands, lakes, streams.

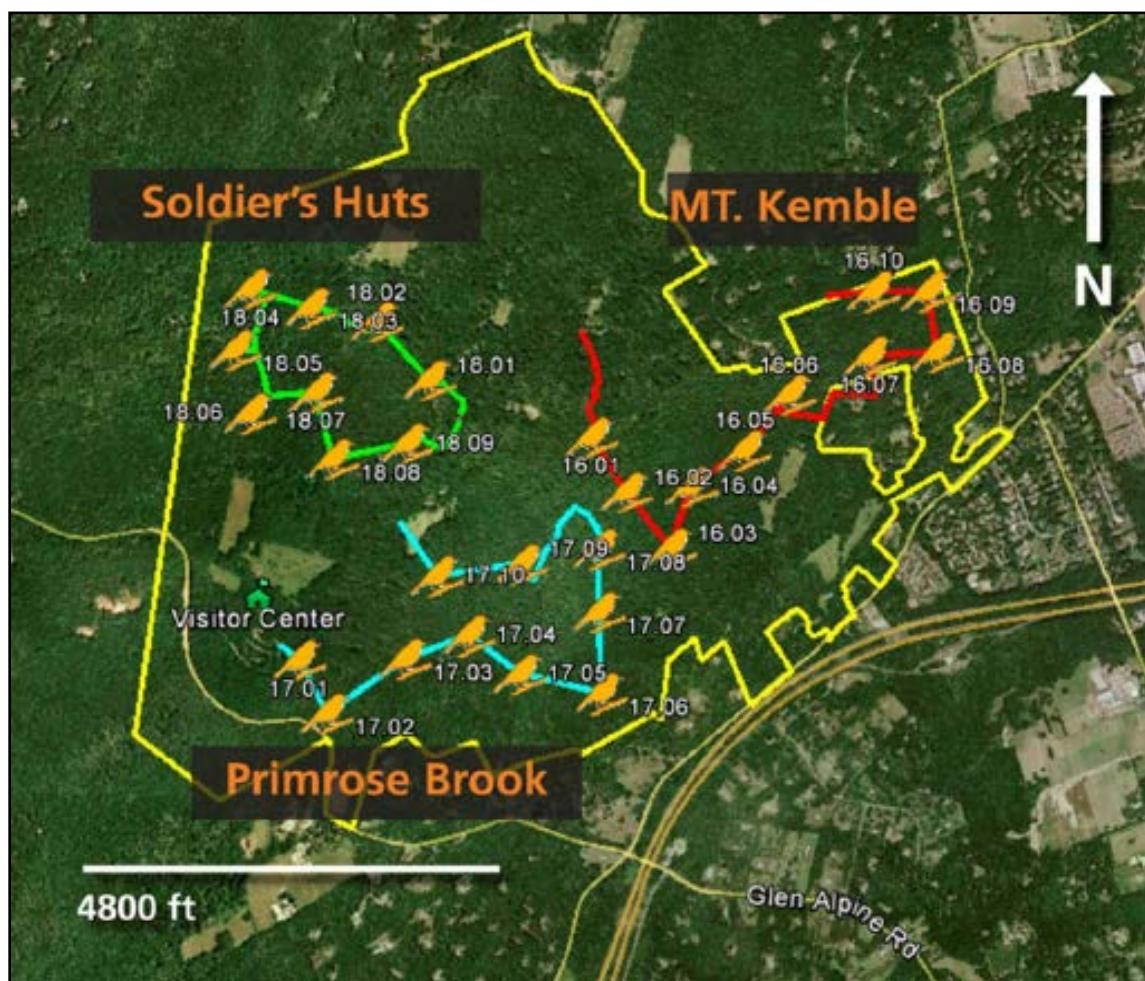
*Faccio and Mitchell (2013)* - Beginning in 2006, volunteers associated with NETN established point count stations and surveyed birds at MORR (Figure 4.28). A total of three study sites consisting of 29 point counts were established in both mature broadleaf and successional broadleaf habitat. Ten minute point counts were conducted by volunteers between mid-May – June. Points were surveyed annually (Faccio and Mitchell 2013). See Faccio and Mitchell (2013) appendix A and B for a list of species, their relative abundances, and other summary statistics for surveys conducted from 2006-2012.

For the combined years 2006-2012, a total of 58 species have been detected (Faccio and Mitchell 2013). The ten most common species detected during this period included: Red-Bellied Woodpecker, Eastern Wood-Pewee, Red-Eyed Vireo, Blue Jay, Tufted Titmouse, Veery, Wood Thrush, American Robin, Ovenbird and Scarlet Tanager. Eleven species of regional conservation concern within BRC28 were reported at MORR including three species (Eastern Wood- Pewee, Wood Thrush, and



Eastern Towhee) that were detected in all six years. Eastern Wood-Pewee and Wood Thrush were also among the 10 most abundant species detected from 2006-2012.

*Breeding Bird Atlas*-The New Jersey breeding bird atlas was completed from 1994-1997 (Walsh *et al.* 1999). The atlas provides an overview of the breeding birds within a larger landscape around the park. Because the park is included in a number of blocks and no one block is entirely park property, it is not possible to use these as lists of birds breeding within MORR. However, they can be used to see what species are breeding in the general area of the park which would give an indication of the source population that might respond to management activities.



**Figure 4.28.** Breeding bird point count locations in MORR. Figure from Faccio and Mitchell 2013.

#### **Reference Values/Threshold Values Utilized**

Breeding birds are one of the groups that NETN is monitoring. Faccio and Mitchell (2009) developed a guild-based Avian Ecological Integrity Assessment that can be used to track the condition of the bird community based on traits of the species reported on bird surveys in a particular park. Birds are



grouped into guilds based on traits such as where the species feeds or nests, whether they are residents or migrants, and other characteristics. This guild based approach is much more useful than simply counting the total number of species because you may have the same number of species or even an increase in number of species as a park becomes more disturbed, but the types of species present will change. As habitat becomes more disturbed, shifts in the bird community occur with birds that are generalists and able to tolerate disturbance becoming more abundant while those that are specialists often decline. In other words, the total number of species present could stay the same, but the types of species present could change dramatically.

For MORR there is one guild-based biotic integrity scorecard for forest habitat. This scorecard consists of 13 guilds (Table 4.25) with each guild being broadly categorized as “specialist” or “generalist”. Specialist guilds may be thought of as those indicative of a high-integrity habitat condition, while generalist guilds are those indicative of a low-integrity condition. To calculate the ecological assessment, species are first assigned to guilds (some species may be assigned to more than one guild, depending on their life history traits). The proportional species richness of each guild is then calculated by dividing the number of guild members detected by the total number of species detected. This value is then used to determine a rank of *Resource is in Good Condition*, *Warrants Moderate Concern*, or *Warrants Significant Concern* based on the proportional species richness thresholds and ranks listed in Table 4.25. The thresholds and ranks are largely based on those derived by O’Connell *et al.* (2000) for birds in forested habitats in the central Appalachians, and from those derived by Glennon and Porter (2005) for New York’s Adirondack State Park.

**Table 4.25.** Avian Ecological Assessment Ranks for 13 response guilds and proportional species richness thresholds (based on O’Connell et al. 2000, and Glennon and Porter 2005).

Biotic Integrity Element	Response Guild Metric (Percent Species Richness)	Condition Categories		
		Resource is in Good Condition	Warrants Moderate Concern	Warrants Significant Concern
Compositional:	Exotic Species	0%	0.5 -7%	> 7%
	Nest Predators/Brood Parasite	< 10%	10 -15%	> 15%
	Residents	< 28%	28 -41%	> 41%
	Single Brooded	> 68%	50 -68%	< 50%
Functional:	Bark Prober	> 11%	4 -11%	< 4%
	Ground Gleaner	> 9%	4 -9%	< 4%
	High Canopy Forager	> 12%	7 -12%	< 7%
	Low Canopy Forager	> 22%	14 -22%	< 14%
	Omnivore	< 30%	30 -50%	> 50%
Structural:	Canopy Nester	> 35%	29 -35%	< 29%
	Forest-ground Nester	> 18%	5 -18%	< 5%
	Interior Forest Obligate	> 35%	10 -35%	< 10%
	Shrub Nester	< 18%	18 -24%	> 24%

### Condition and Trend

The park-wide forest avian ecological integrity assessment for all years combined at MORR resulted in five categories ranked as *Resource is in Good Condition*, six ranked as *Warrants Moderate Concern*, and two ranked as *Warrants Significant Concern* (Table 4.26). Overall, these rankings are very good given the urban landscape that surrounds MORR. The Ecological Integrity Assessment for forest birds is based on birds in forested habitat with the best conditions associated with large blocks of forest habitat that are structurally diverse. Parks that have relatively small areas of forest habitat or forest that is fragmented by roads, managed landscapes, and open habitat will tend to have lower ecological assessment scores just by virtue of the fact that the forest patches are small with relatively large amounts of edge habitat. The index can still be useful in terms of monitoring direction of change. The goal should be to maintain or improve the score instead of a goal of obtaining a score of *Resource is in Good Condition* in all categories. This goal may be unattainable given the configuration of the park and the other management mandates. There is currently discussion about revising these indices to incorporate Park missions (Faccio and Mitchell 2009). If this is done, it may be useful to maintain the current index and then add a second park-specific one based on its own land configuration and mission. This would be an index where the top value would correspond to the best a park could be with different parks having different scales.

MORR provides important forest habitat for both Neotropical migrants and also resident species. Management should focus on maintaining the health of the forest and ensuring an understory for mid-canopy nesters such as Wood Thrush. This should include management of nonnative invasive plant species that prevents native tree regeneration and maintaining deer numbers at levels where effects of deer on regeneration are minimal.

**Table 4.26.** Index of Avian Biotic Integrity based on survey data (2006-2012) for forested study areas at MORR (Faccio and Mitchell 2013).

Biotic Integrity Element	Response Guild Metric (% species richness)	Proportion Rating & Condition Category
Compositional:	Exotic Species	0% <b>Resource is in Good Condition</b>
	Nest Predators/Brood Parasite	8% <b>Resource is in Good Condition</b>
	Residents	29% <b>Warrants Moderate Concern</b>
	Single Brooded	56% <b>Warrants Moderate Concern</b>
Functional:	Bark Prober	12% <b>Resource is in Good Condition</b>
	Ground Gleaner	8% <b>Warrants Moderate Concern</b>
	High Canopy Forager	10 % <b>Warrants Moderate Concern</b>
	Low Canopy Forager	23 % <b>Resource is in Good Condition</b>
	Omnivore	37 % <b>Warrants Moderate Concern</b>
Structural:	Canopy Nester	29 % <b>Warrants Significant Concern</b>
	Forest-ground Nester	15 % <b>Warrants Moderate Concern</b>
	Interior Forest Obligate	35 % <b>Resource is in Good Condition</b>
	Shrub Nester	25 % <b>Warrants Significant Concern</b>

### **Data Gaps and Confidence in Assessment**

Confidence in this assessment was high and trend analysis was not applicable. The assessment was based on multiple years of data greatly increasing confidence in these numbers. Criteria exist that are probably not useful for assessing the ecological conditions of MORR's bird community. One of the criteria that is easy to measure and often tempting to use as a measure of ecological integrity is number of species either represented as total number of species ever reported in the park or total number of breeding species. Lists of the names of all species ever reported in the Park (such as the NPS species list) are interesting and useful as a comprehensive document about which species have ever been reported there, but they are not useful as measures of ecological health or integrity. There is no information on abundance, frequency of occurrence or habitat use. There is no way to distinguish between the vagrant that might have shown up there for a day, and a species which nests there annually. An additional problem in terms of tracking changes is the time that surveys or reports occurred and the survey locations are not reported. The number of breeding species and measures of species richness also are not in themselves good measures of ecological condition. The reason is that species numbers are often highest at intermediate levels of disturbance. Thus, a healthy high integrity forest would often have fewer species than an area that was more fragmented.

### **Amphibians and Reptiles**

#### **Relevance and Context**

Historical documentation indicates that 34 species of amphibians and reptiles have been observed in MORR and on lands adjacent to MORR (Mele and Mele 1983, New Jersey Audubon Society 2003, NPSpecies 2012). The most recent inventory of amphibian and reptiles was conducted in MORR from March through September 2000, which resulted in 22 species being documented (Brotherton *et al.* 2005). Of these 22 species, 13 amphibian and nine reptiles were recorded. By taxonomic group, anurans comprised 47.8% of all individuals, salamanders 44.6%, snakes 6.6%, and turtles 0.1%. The most abundant species in each taxonomic group based on the total numbers of adults recorded included the northern green frog (*Rana clamitans melanotar*), eastern red-backed salamander (*Plethodon cinereus*), eastern box turtle (*Terrapene carolina*) and eastern gartersnake (*Thamnophis s. sirtalis*). Species richness of amphibians and reptiles varied across habitats in MORR, with the greatest richness occurring in upland habitats, followed by streams and wetlands (Figure 4.29) (Brotherton *et al.* 2005).

Breeding, foraging and dispersal activities require the use of different habitats in and near MORR for the survival of amphibians and reptiles. Amphibians at MORR, with the exception of the eastern red-backed salamander and the slimy salamander, depend on aquatic habitat for reproduction. Spring peeper, gray treefrog, wood frog, spotted salamander and American toad depart from wetland habitats following the breeding season, foraging and hibernating in the uplands within and surrounding MORR (Conant and Collins 1998, Petranksa 1998). The use of lands by herpetofauna within and near MORR is of particular management interest for all species, but particularly state and federally listed species. 'Listed' species by the NJDEP Division of Fish and Wildlife include the wood turtle (*Clemmys insculpta*), which is threatened and the eastern box turtle (*Terrapene carolina*), which has been listed as a species of concern (NJDEP Division of Fish and Wildlife listed 02/23/12).

The wood turtle not only utilizes NPS property but also the property of the Scherman-Hoffman Sanctuary of the NJ Audubon Society, located south of MORR's New Jersey Brigade Unit.

### **Data and Methods**

Data used to assess the current condition of the herpetofauna community was assembled from surveys conducted by Brotherton *et al.* (2005) in MORR. From March through September 2000, MORR's Jockey Hollow and New Jersey Brigade Encampment Area were inventoried for the presence of amphibians and reptiles using six standardized sampling methods at 25 standardized sampling sites: anuran call-counts, egg-mass counts, time-constrained search, coverboards, turtle trapping, and minnow trapping (Brotherton *et al.* 2005). Using data collected from Brotherton *et al.* (2005), the Amphibian Index of Biotic Integrity (AmphIBI) was used as a tool to assess the condition of the amphibian community in MORR. The State of New Jersey currently has not established an amphibian index of biotic integrity. However, the Ohio State Environmental Protection Agency has developed AmphIBI to assess wetland quality (Micacchion 2002, 2004). Six lentic waterbodies in MORR that were surveyed from March to September 2000 using time constrained surveys and minnow traps were used in the AmphIBI assessment for MORR (Table 4.27).

The AmphIBI used five metrics related to the composition of amphibian communities: 1. the Amphibian Quality Assessment Index (AQAI); 2. relative abundance of sensitive taxa; 3. relative abundance of tolerant taxa; 4. number of species of pond-breeding amphibians; and 5. presence of spotted salamanders and/or wood frogs (Micacchion 2004). The AQAI is a weighted index that accounts for the number of individuals of each species and their sensitivity to disturbance. The AQAI assigns a coefficient of conservatism (C of C) to wetland breeding amphibian species based on their varying sensitivities to disturbance and habitat requirements. The C of C ranges from 0 to 10-lower C of C's are species that are adapted to a greater degree of disturbance and a broader range of habitat requirements. Species assigned higher C of C's are sensitive to disturbance and have narrower habitat requirements (Micacchion 2004). In order to calculate AQAI, the total number of individuals for each species is multiplied by the corresponding C of C to yield a subtotal for the species. Subtotals for all species are summed and divided by the total number of amphibians present. The five metrics



*Common amphibians and reptiles found in MORR. Photos by R. Wagner.*

are given a score of 0, 3, 7, or 10 based upon values established by Micacchion (2004). The sum of the five scores is the final condition score, with the maximum AmphIBI score being 50. Trends of amphibians and reptile populations in MORR were assessed based on a qualitative analysis performed by Brotherton *et al.* (2005).

Historical data for MORR has been limited to post 1980 and quantitative data are not available for population trend assessments. However, Brotherton *et al.* (2005) subjectively assess each species' status and population trend based on prior collection data, habitat suitability and animal behavior (Table 4.28). Detailed information of trend assessment methods can be found in Brotherton *et al.* (2005).

#### **Reference Condition/Threshold Values Utilized**

The condition categories of the amphibian community were based on the methods established by Micacchion (2004), with Micacchion's AmphIBI categorical language changing to fit the NRCA language of *Resource is in Good Condition*, *Warrants Moderate Concern* or *Warrants Significant Concern*. Micacchion's AmphIBI scores and categories included 30-50 excellent, 20-30 good, 10-20 fair and < 10 poor. For this report, an AmphIBI score ranging from 20-50 represents an amphibian community in *Resource is in Good Condition* condition; a score from 10-19 is a community rated *Warrants Moderate Concern*; and score less than 10 is representative of a community being rated *Warrants Significant Concern* (Micacchion 2004). Population trend categories of amphibian and reptile species in MORR included *increasing*, *decreasing*, *stable* or *unknown*. These categories were established from a subjective process by Brotherton *et al.* (2005) based on data collected post 1980 up to 2000.

#### **Condition and Trend**

Based on the AmphIBI calculations, the average score for the amphibian community habitats sampled by Brotherton *et al.* (2005) in MORR was 17, which corresponded to the *Warrants Moderate Concern* rating (Table 4.27). Sites in MORR that ranked lower in the AmphIBI calculations (*Warrants Moderate Concern*)-Indian Grove Brook Marsh, Lower Primrose Brook Seep, Old Channel Seep and Trail Center Seep-were the result of the absence of pond breeding species and spotted or wood frogs at the sites (Figure 4.30, Table 4.27). These habitats also support higher relative abundances of species which are considered tolerant, particularly the northern green frog. Sites which rated *Resource is in Good Condition* included Cat Swamp Pond and Cattail Marsh, both of which contained higher abundances of species which are considered sensitive to disturbance and have narrower niches. These species include the pickerel frog, spotted salamander and the red spotted newt. (Figure 4.30, Table 4.27). The aquatic resources in MORR are predominately riparian with limited wetland habitat and most pond breeding amphibian activity in MORR is located at Cat Swamp Pond. Therefore, it is important to consider the long-term preservation and connectivity of upland and wetland areas in order to protect the sustainability of populations.

When assessing the park's overall herpetological species based on species richness calculations, the greatest number of species occurred in the permanently wet habitats: Cat Swamp Pond, Lower West Primrose Brook and Passaic River. Conversely, the lowest species richness of amphibian and reptile species was accounted for within the majority of the fields and woodlands of MORR (Figure 4.29).

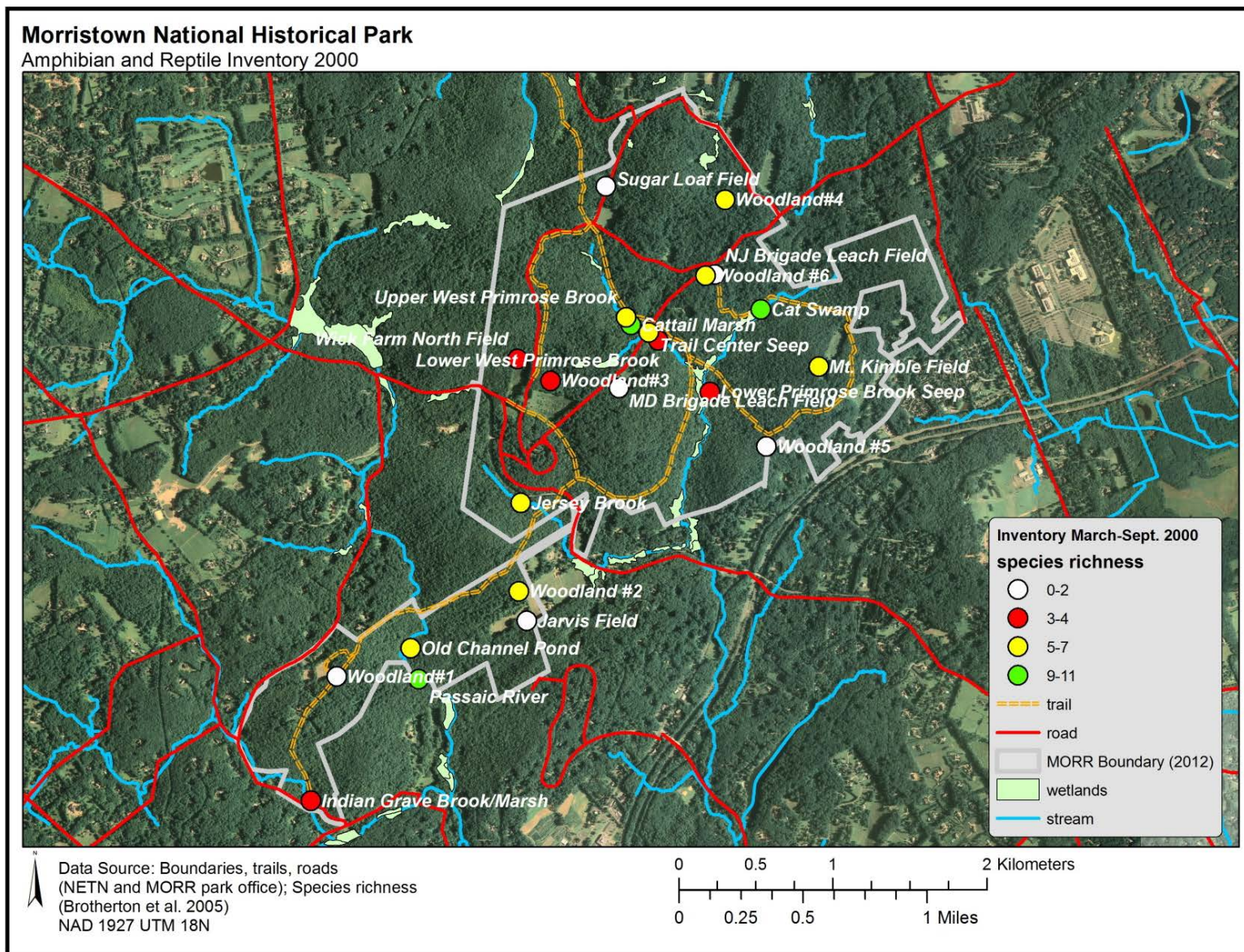


Due to a lack of quantitative historical data for MORR, a statistical trend analysis of the amphibian and reptile community was not applicable for this park. However, Brotherton *et al.* (2005) assessed each species' status and population trend from a subjective process. Brotherton *et al.* (2005) determined that 18 species occurring historically at or in the area around MORR appeared to be stable in terms of their population status, and 13 species have declined or have disappeared (Table 4.28).

Brotherton *et al.* (2005) noted that species decline in MORR may be due to a variety of causes: habitat limitations in MORR (e.g., few pond habitats and introduction of fish and invasive plant succession to current habitats), increased deer populations and invasive earthworms. Other factors of these noted declines may involve species that have been initially uncommon or rare in MORR. However, for these species identified as declining, truly "historic" data are uncertain and it is impossible to know how common or rare they were at MORR, except in recent decades. Additionally, their decline in MORR may be due to a broader global or regional decline, along with a variety of potential environmental stressors. Atmospherically transported pollutants, pesticides, fertilizers, degraded water quality, disease, habitat degradation, fragmented landscape, mowing and roads are commonly identified as variables which may affect amphibian decline (Clark and Hall 1985, Sanzo and Hecnar 2001, Karraker *et al.* 2008). Due to MORR experiencing continued suburban development and population expansion, unpolluted habitats are at risk of declining and the avenues for safe immigration or emigration are decreasing. For example, excess nutrients into waterways can cause dense masses of algae, creating an environment not conducive to egg laying for amphibians. Excess nutrients can also reduce the amount of oxygen within the water for amphibian larvae and alter the composition of invertebrate communities that are food for larvae. The occurrence of roads in close proximity to herpetofauna habitats in MORR creates habitat fragmentation, increases road runoff into aquatic habitats and increases herpetofauna mortality due to road kill. Furthermore, mowing in MORR fields may impact turtle nests if mowed in June or July, a period when turtle nesting is prevalent in fields (Brotherton *et al.* 2005).

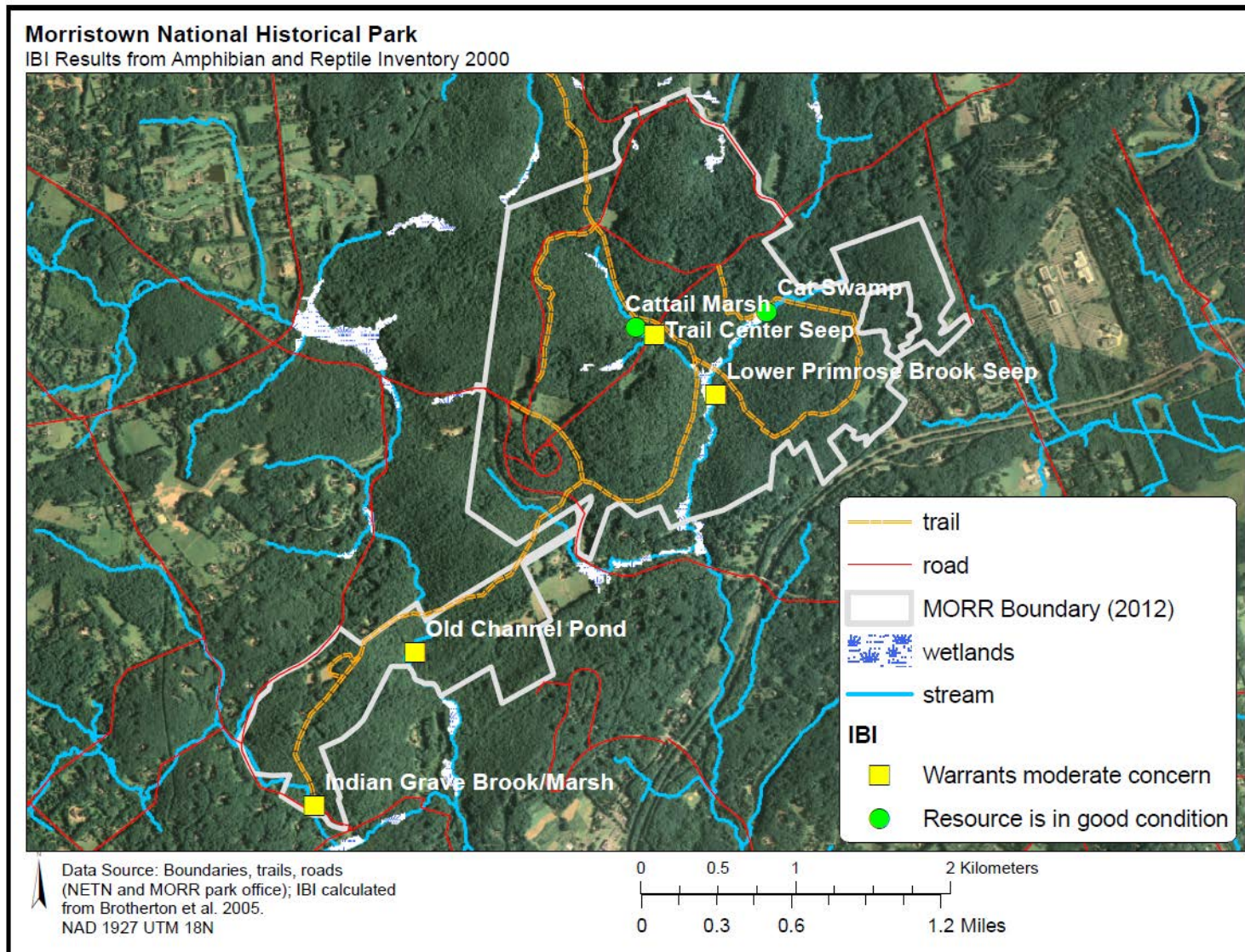
#### **Data Gaps and Confidence in Assessment**

Confidence in the assessment was medium and confidence in the assessment of trend was low. The data for this assessment was based on an inventory effort which occurred in 2000 and do not represent the most current conditions of the amphibian community in MORR. Although the AmphIBI was developed for the assessment of Ohio wetlands, the index was being used as a general guide to assess the condition of MORR's wetland breeding amphibian community. A caveat for the use of the AmphIBI is that it is weighted toward wetlands with moderate to long hydroperiod, vernal pools and semi-permanent ponds. Thus, permanent ponds, such as Cat Swamp pond, may not rate as high as they should using AmphIBI. Quantitative baseline information on the herpetofauna community is lacking and the apparent decline of amphibian and reptiles species occurring in MORR highlights the need for systematic and quantitative monitoring in order to identify potential causes of change (i.e., terrestrial habitat quality, stream and wetland water quality) occurring in the herpetofauna community.



**Figure 4.29.** Species richness distribution of herps inventoried in MORR in 2000 by Brotherton *et al.* (2005).





**Figure 4.30.** Results of the AmphIBI (Micacchion 2004) used to assess MORR's amphibian community from data (N=6 lentic waterbodies) collected in 2000 by Brotherton et al. (2005).

**Table 4.27.** Condition assessment for MORR's amphibian community based on sampling by Brotherton *et al.* (2005) in MORR, with condition scoring and rating being modeled after Micacchion (2004). A condition score of 20-50 represents communities in *Resource is in Good Condition* condition; 10-19 represents communities in *Warrants Moderate Concern* condition; and a score <10 indicates communities in *Warrants Significant Concern* condition.

AmphIBI Measures & Results						
Site	AQAI <sup>1</sup>	Relative Abundance of Sensitive Species <sup>2</sup>	Relative Abundance of Tolerant Species <sup>3</sup>	Number of Pond Breeding Species <sup>4</sup>	Presence of Spotted Salamanders or Wood Frogs <sup>5</sup>	Condition Score & Rating
Cat Swamp Pond	3	10	3	2	10	28 Resource is in Good Condition
Cattail Marsh	7	7	7	0	0	21 Resource is in Good Condition
Indian Grave Brook Marsh	0	0	10	0	0	10 Warrants Moderate Concern
Lower Primrose Brook Seep	3	0	10	0	0	13 Warrants Moderate Concern
Old Channel Pond	3	0	10	0	0	13 Warrants Moderate Concern
Trail Center Seep	3	3	10	0	0	16 Warrants Moderate Concern
<b>Average MORR Score</b>						<b>17 Warrants Moderate Concern</b>

<sup>1</sup> AQAI scores: 0: <3.00; 3: 3.00-4.49; 7: 4.50-5.49; 10: ≥5.5

<sup>2</sup> Relative abundance of sensitive species scores: 0: 0%; 3: 0.01-9.99%; 7: 10-49.99%; 10: ≥50% P

<sup>3</sup> Relative abundance of tolerant species scores: 0: >80%; 3: 50.01-79.99%; 7: 25.01-50%; 10: ≤25%

<sup>4</sup> Number of pond-breeding salamander species: 0: 0-1; 3: 2; 7: 3; 10: >3

<sup>5</sup> Presence of spotted salamander and/or wood frogs score: 0: absent; 10: present

**Table 4.28.** Abundance status and trends in amphibians and reptiles species which occur in Morristown National Historical Park as assessed by Brotherton *et al.* (2005). Apparent trend symbols include: stable ↔, declining ↓, increasing ↑ and unknown.

Common Name	Scientific Name	Historic Status	Apparent Trend
American bullfrog	<i>Rana catesbeiana</i>	common	↔
American toad	<i>Bufo americanus</i>	common	↔
Eastern box turtle	<i>Terrapene carolina carolina</i>	common	↔
Eastern cricket frog	<i>Acris crepitans crepitans</i>	rare	↓
Eastern gartersnake	<i>Thamnophis sirtalis</i>	common	↔
Eastern milksnake	<i>Lampropeltis triangulum triangulum</i>	rare	↔
Eastern red-backed salamander	<i>Plethodon cinereus</i>	abundant	↔
Four-toed salamander	<i>Hemidactylium scutatum</i>	uncommon	↓
Gray treefrog	<i>Hyla versicolor</i>	uncommon	↓
Jefferson salamander	<i>Ambystoma jeffersonianum</i>	unknown	unknown
Long-tailed salamander	<i>Eurycea longicauda longicauda</i>	rare	↓
Marbled salamander	<i>Ambystoma opacum</i>	unknown	unknown
Northern black racer	<i>Coluber constrictor constrictor</i>	rare	↓
Northern brownsnake	<i>Storeria dekayi dekayi</i>	rare	↓
Northern Dusky salamander	<i>Desmognathus fuscus</i>	abundant	unknown
Northern green frog	<i>Rana clamitans melanota</i>	abundant	↔
Northern ring-necked snake	<i>Diadophis punctatus edwardsi</i>	uncommon	↔
Northern two-lined salamander	<i>Eurycea bislineata</i>	abundant	↔
Northern watersnake	<i>Nerodia sipedon</i>	common	↔
Painted turtle	<i>Chrysemys picta</i>	uncommon	↔
Pickrel frog	<i>Rana palustris</i>	common	↔
Red salamander	<i>Pseudotriton ruber</i>	uncommon	↔
Red-spotted newt	<i>Notophthalmus viridescens</i>	common	↔
Slimy salamander	<i>Plethodon glutinosus</i>	uncommon	↓
Snapping turtle	<i>Chelydra serpentina</i>	uncommon	↔
Spotted salamander	<i>Ambystoma maculatum</i>	common	↓
Spring peeper	<i>Pseudacris crucifer</i>	common	↓
Spring salamander	<i>Gyrinophilus porphyriticus</i>	rare	↓
Stinkpot	<i>Sternotherus odoratus</i>	rare	↔
Wood frog	<i>Rana sylvatica</i>	uncommon	↔
Wood turtle	<i>Glyptemys insculpta</i>	rare	↔



## Visitor Usage

### **Relevance and Context**

From 1933-2011, MORR has hosted approximately 33,257,818 recreational visitors (NPS Stats 2012). Visitors to MORR may be engaged in many activities during their visit, such as historical education, hiking, jogging, biking, horseback riding, and skiing the trails and roads. The effect visitors may have on the integrity of MORR's natural resources were evaluated in order to provide information on possible deleterious effects (i.e., trampling, removal of resources) occurring in the park.

### **Data and Methods**

NPS Stats (2012) collects visitation data for each NPS park and these data were used to assess visitor activity. Visitation counts were analyzed from 1933-2011 and traffic counts were examined from 1993-2011. The *number of visitor vs. year* and *traffic count vs. year* were modeled using linear regression analyses to assess for trends in the data. Trails and roads used by visitors were mapped in order to spatially assess their locality and possible impact to aquatic habitats and globally rare vegetation communities in MORR.



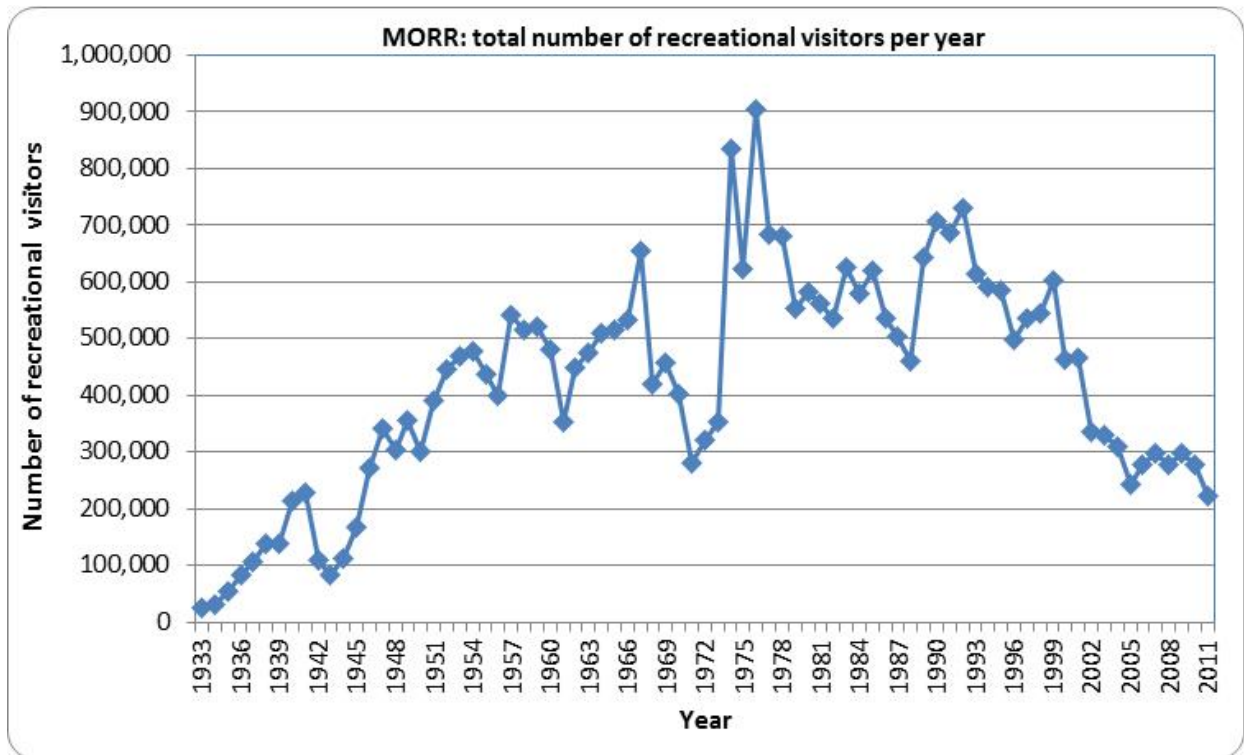
*Jockey Hollow Area Entrance Sign. Photo: NPS*

### **Reference Condition/Threshold Values Utilized**

Visitation trends were either *decreasing*, *increasing*, or *no change* detected based on statistical analyses ( $p < 0.05$ ). Quantitative data regarding visitor use impacts on natural resources (i.e., area of soil erosion, percent trampling) were absent for MORR; therefore best professional judgment was used to assess the impacts of visitor use on MORR's natural resources and discuss potential scenarios of visitor use conflicts in the park.

### **Condition and Trend**

Based on the examination of the data presented below, visitor usage and impact to MORR's natural resources was assessed as *Warrants Moderate Concern*. In 2011, MORR ranked 20 out of 43 for the highest number of recreation visitors to any National Historical Park, with 222,395 visitors (NPS Stats 2012). From 1933-2011, the average number of recreational visitors to MORR was 420,985 (median value=457,800). Visitation levels to MORR from 1933-2011 significantly increased based on yearly visitation records ( $p < 0.05$ ,  $N=79$ ), with yearly visitation tending to be extremely variable from 1933-2011 for the park. On average, MORR experienced approximately a 1.6% per year increase in visitors based on 1933-2011 visitation records. However, from 2000-2011 the number of visitors significantly decreased ( $p < 0.05$ ,  $N=12$ ) by approximately 5% per year (Figure 4.31). Although visitation has decreased over the past 11 years in MORR, this pattern may be cyclical. The Jockey Hollow unit receives the most number of visitors and accounts for approximately 80% of all park visits (NPS 2003a). Peak visitation at Jockey Hollow occurs during October during foliage season and drops off in midwinter. The popularity of the Jockey Hollow unit seems to be based on recreational activities and not directly related to historical education of the park.

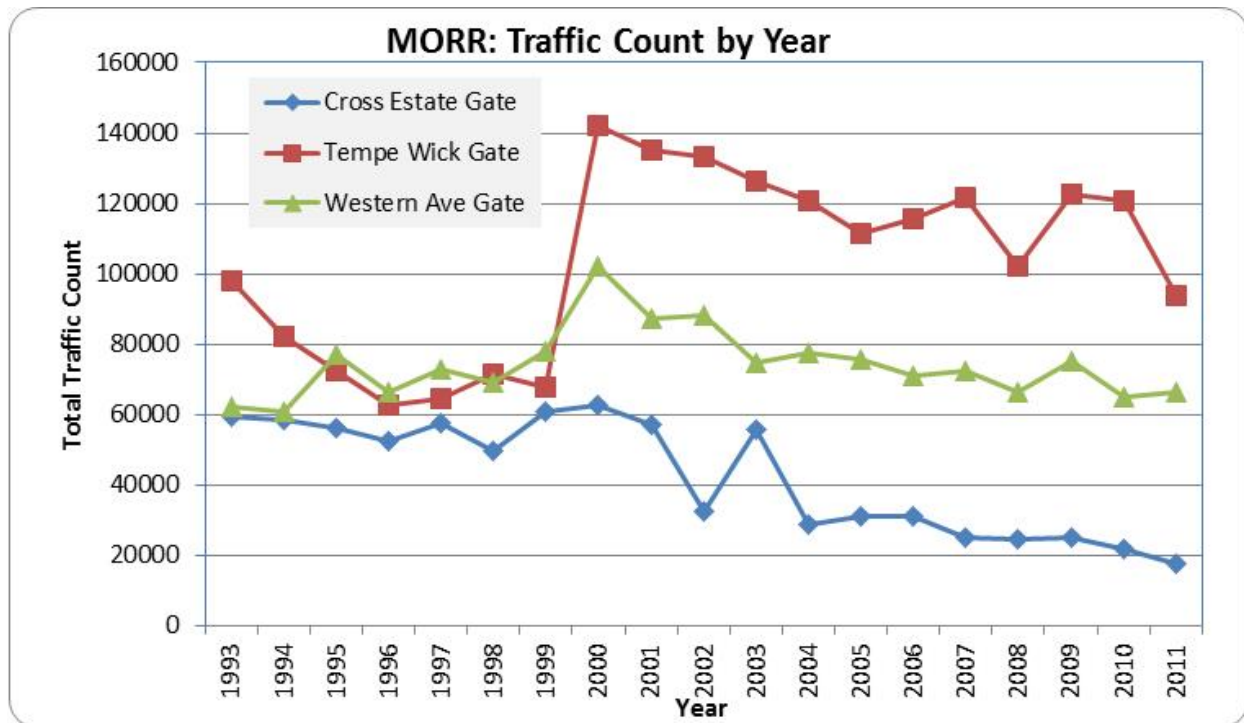


**Figure 4.31.** Number of individual recreational visitors to MORR per year from 1933-2011.

Traffic counts were recorded from 1993-2011 at six points of entrance to MORR: Cross Estate Gate, Cross Estate Residence Section, Fort Nonsense, Sugar Loaf Road, Tempe Wick Gate and Western Ave. Gate (Figure 4.32). These counts represent visits, not visitors, as visitors appear at more than one unit. Tempe Wick Gate experienced the highest traffic count from 1993-2011, with an average of 100,087 counts per year, followed by Western Ave. Gate (71,509) and Cross Estate Gate (40,744) (NPS Stats 2012). Based on simple linear regression analysis of these three park entrances, significant decreases in traffic counts from 1993-2011 occurred, which are a direct reflection of the overall decrease in recreational visitor counts for those years. None of the traffic entrances have significantly increased in use over the last 10 years, from 2000-2011 (Figure 4.32).



View of restored Tempe Wick Road. Photo: NPS



**Figure 4.32.** MORR total traffic counts enumerated at three of six entrances to the park from 1993-2011: Cross Estate Gate, Tempe Wick Gate and Western Ave. Gate.

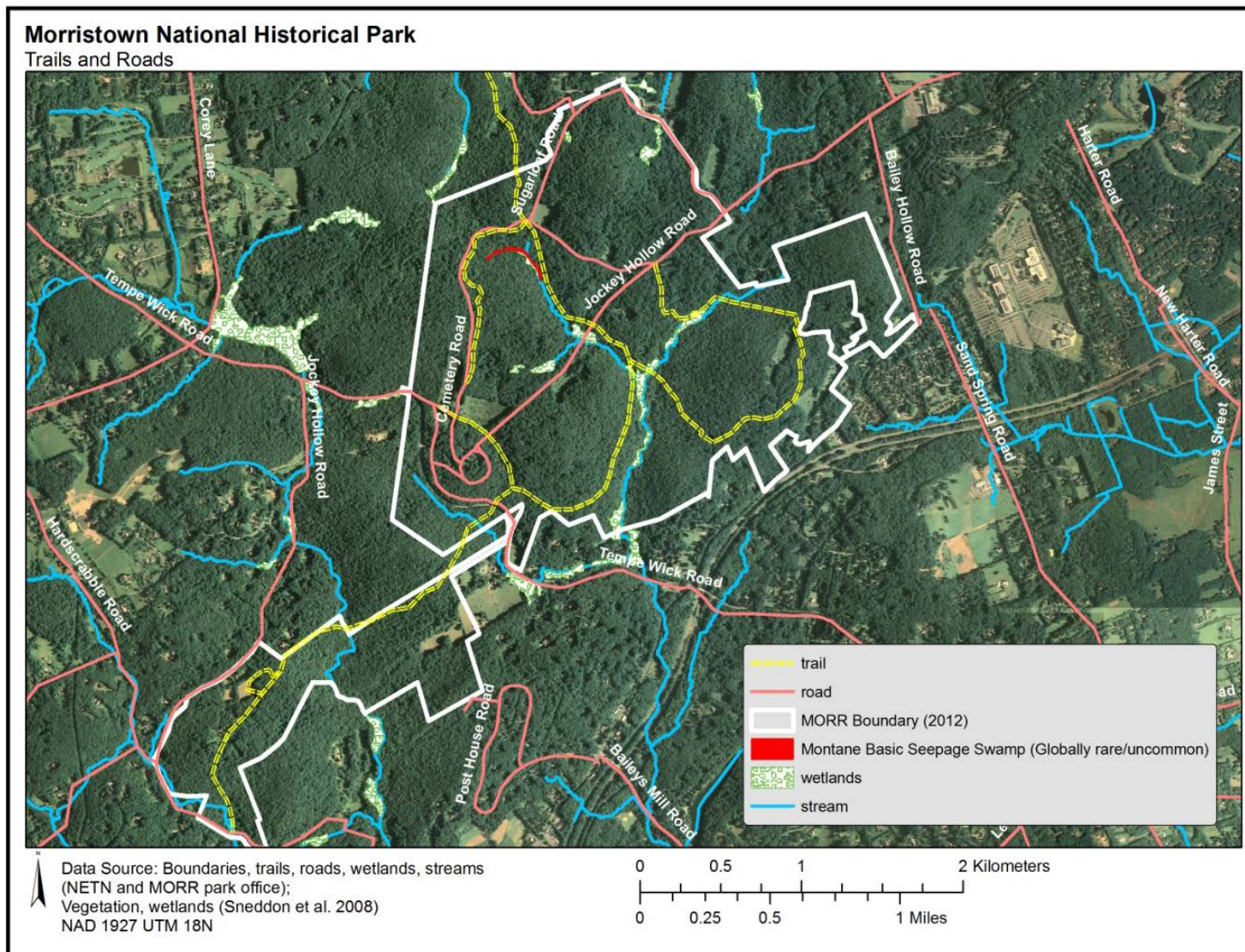
With 27 miles (43 km) of trails accessible to visitors year round in MORR, visitors may be altering these trails by inducing soil erosion, creating side trail formation and increasing trail width. Likewise, horses increase trail erosion and may aid in the spread of invasive exotic species, (<http://science.nature.nps.gov/im/units/netn/monitor/vitalSigns/VisitorUse/VisitorUse.cfm>). The risk of trail erosion and invasive species spreading is decrease in MORR due to the park only allowing horses on the wider trails and fire roads in the park. We were unable to quantitatively determine the intensity of impacts on soils, vegetation and wildlife along trails in MORR from existing levels of public use. However, the continuation and creation of proactive recreation rules will continue to preserve the integrity of natural resources in MORR. For example, bicycle use on unpaved trails is currently prohibited in order to protect the park's natural and cultural integrity as well as providing safety considerations for other visitors (NPS Management Policies 2001). Continuing the prohibition of bicycles on unpaved paths will serve to prevent any soil and vegetation degradation resulting from this activity. Additionally, trails and roads may impact wildlife migration and habitat from travel activity in MORR. Trails and roads within the Jockey Hollow unit are near wetlands and a globally rare vegetation community (Montane Basic Seepage Swamp), and MORR's roads can fragment migration routes of amphibians and reptiles in MORR from neighboring wetland and upland habitats, thereby increasing wildlife fatality (Figure 4.33).

Trends for development in Morris and Somerset counties tend to reflect population and economic fluctuations (NPS 2003a). If residential and commercial development increases, the expected demands for recreational space may subsequently rise, thereby increasing pressure on MORR's natural resources and the surrounding viewshed. For example, in 2010 various areas surrounding MORR contained 13-24 housing units per sq. km. By 2030, those areas are projected to have 25-49 housing units per sq. km (NPS-IMD 2009). Visitor use conflicts within MORR can change based on the future development surrounding of the park, especially in the more rural area of the Jockey Hollow and New Jersey Brigade Encampment Area units. Although several parcels of land are conserved outside MORR, some parcels do still exist for development. If medium to large-scale development is established within the vicinity of MORR, the lightscape and soundscape will be altered, generating particular recreational activities less enjoyable for visitors.

#### ***Data Gaps and Confidence in Assessment***

Confidence in the assessment was low and confidence in trend analyses were medium. Little quantitative data are available regarding impacts to natural resources due to visitor use. The NETN Forest Monitoring Protocol currently lists 'percent trampled' as a qualitative measurement to be sampled within MORR as part of assessing forest floor condition, which can be indirectly related to visitor use impacts (although wildlife vs. human trampling would not be distinguishable) (Tierney *et al.* 2012). Other specific measurements which may supplement assessing visitor impacts to MORR's popular walking paths and trails based on MORR's management goals include, 'soil surface compaction measured from x ft. from trail center' and 'tree root exposure within x feet of trail edge'. Carrying capacity assessments and monitoring traffic congestion during peak visitor months and days can supplement management decisions related to visitor usage and the park's natural resources (e.g., fatalities of amphibians and reptiles during breeding season on roads, air quality and wildlife impacts).





**Figure 4.33.** Trails and roads within and near MORR's Jockey Hollow and New Jersey Brigade units in relation to aquatic habitats and globally rare vegetation associations.



## **Landscapes**

### ***Relevance and Context***

Landscape changes due to natural and anthropogenic efforts within and surrounding MORR is a fundamental component for evaluating the park's overall natural resource condition. Several indicators have been used to assist in evaluating current and future landscape quality as well as identifying potential threats to natural resources. Data on housing unit density can provide important information for evaluating the condition of adjacent park lands and reveal potential threats to park resources (Svancara *et al.* 2009a). Increases in human population may result in land cover conversion for housing and business development and increased transportation routes. The conversion of natural landscapes to agriculture and urban landscapes is usually a permanent change, and the replacement of natural habitat with development has been documented as the primary cause of biodiversity declines (Heinz 2008, Wilcove 1998, Luck 2007). Therefore, the rate of conversion and development of landscapes to support population growth is a vital concern for MORR.

Morris County has increased in population by 4.7% from 2000 to 2010 (U.S. Census Bureau 2012). MORR has a close spatial relationship to towns in Morris County experiencing housing and population growth which may increase pressure on MORR's natural resources. From 1990 to 2010, the nearby town of Morristown had a population growth of 2,222 people, with a census of 18,411 people in 2010 (U.S. Census Bureau 2012). This growth in population has resulted in a demand for housing development within and surrounding Morristown. The development of new housing units has caused construction of impervious surfaces, such as roads and parking lots. The effects of roads to natural resources include affecting biotic and abiotic variables of landscapes by creating wildlife mortality, habitat fragmentation and loss of connectivity. Additionally, roads increase exotic plant dispersal rates, promote erosion and sedimentation, introduce chemical pollutants to water resources, act as a barrier to animal movement and create noise, lighting and vibrations that interfere with wildlife (Forman *et al.* 2003).

Although land development constraints due to private ownership, conservation efforts and environmental properties are present surrounding MORR, unconstrained portions still exist for development in order to meet the needs of population growth in Morris County. Since anthropogenic land use demands will expand over time, monitoring the extent and pattern of the landscape (i.e., composition, configuration, connectivity) around and within MORR is important to evaluate the current status of park biota, identify threats to cultural and ecological resources and identify conservation opportunities for the park (Levin 1981, Noss 1990, Dunning *et al.* 1992, Wade *et al.* 2003, Svancara *et al.* 2009a,b). Hansen *et al.* (2001) hypothesized that only protected areas with sufficient expanses of surrounding habitat in addition to linkages to other protected areas will be able to support an environment's current biodiversity into the future. Temporal and spatial measures of land cover types, impervious surface estimates and habitat connectivity can provide insight into how MORR and its surrounding environment may be impacted from landscape alterations.

### ***Data and Methods***

Feasibility studies, park reports and NJ Highland Council data were used in conjunction with NPScape data to provide a comprehensive assessment of MORR's landscape. NPScape products

were used to evaluate a 30 km (18.6 mi) area around MORR for a suite of landscape variables that focused on anthropogenic drivers, natural systems and conservation context. The NPScape program used local, regional, and national spatial products such as 1992-2006 National Land Cover Database (NLCD) produced under the Multi-Resolution Land Characteristics Consortium (MRLC) and NOAA C-CAP data, among several other data sources which can be found in the NPScape Measure Development Summaries (MDS) for each measure (Svancara *et al.* 2009a,b). The following spatial and temporal measures were used in the assessment of landscape dynamics for MORR:

#### Housing and Land Cover Change

The analysis combined historic and current U.S. Census data with statistical projection models and was processed for 30 km (18.6 mi) area around MORR at a 100 m (328 ft) spatial resolution and mapped as #units/km<sup>2</sup> for 1970, 1990, 2010 and 2030. Resources included NPScape MDS (Svancara *et al.* 2009a) and historical U.S. Census Data.

Land cover data at local, regional and national scales for various years were utilized for the assessment, all with different processing methods. NPScape (Svancara *et al.* 2009b) were processed for 30 km (18.6 mi) area around MORR at 30 m (18.6 mi) cells and processed for 1976-2006 land cover and land conversions. Wang and Nugranad-Marzilli (2009) analyzed land cover changes from 1976-2002 for MORR with remote sensing data using 5 km (3.10 mi), 1km (0.62) , and 500 m (1640 ft) buffers. Due to changes in resolution in 1976 versus 1988 (changed from 100 m cell to 30m cell, respectively) we reported analyses only from 1988-2002 from this study. Other resources used in the assessment included the 2006 National Land Cover Database (NLCD) and USGS.

#### Impervious Cover and Road Ecology

Impervious cover was calculated as percentage of impervious surfaces developed using NLCD 2006 spatial data. Resources included NPScape MDS (Svancara *et al.* 2009a,b), National Land Cover Database (NLCD) and USGS flowlines.

Road ecology analyses were processed for 30 km (18.6 mi) area around MORR for 30 m (18.6 mi) cells and projected for major and minor roads (Gross and Svancara 2009). Patch area was mapped by NPScape at > 500 (1640 ft) m from major roads and > 500 m (1640 ft) from all roads. Additionally, road buffers were mapped at 100 m (328 ft) from road edges within and surrounding MORR to assess possible ecological effects resulting from roads.

#### **Reference Condition/Threshold Values Utilized**

##### Housing and Land Cover Change

Condition categories were not established for housing and land cover change. However, it is recognized that these factors are stressors on natural resources. Data obtained from the NPScape project offer a representation of regional scale changes for areas within and surrounding MORR. Historic and modeled future projections were used to assess housing trends surrounding MORR. Land cover/use for MORR was discussed by using data which explained the type of land cover and land use conversion occurring around MORR in Morris and Somerset County. We discussed if trends

in these measures were increasing, decreasing or no change based on mapped projections provided by the NPScape program.

#### Impervious Cover and Road Ecology

The influence of impervious surfaces, particularly roads, on natural resources in MORR was assessed using a threshold of 10% impervious surface developed. This threshold value was based on studies by Goetz *et al.* (2003) and Schiff and Benoit (2007). Goetz *et al.* (2003) found that for a water quality rating of *Resource is in Good Condition*, imperviousness cover in a Maryland watershed could not be greater than 10%. Likewise, Schiff and Benoit (2007) found water quality and habitat quality declined when using 10% impervious area as an analysis threshold. For the purpose of this assessment, impervious cover <10% was categorized as *Resource is in Good Condition* and 11-100% as *Warrants Significant Concern*.

Patch area calculations and buffer distances from roadways within and surrounding MORR were also analyzed and incorporated into discussions for assessing the effects of roads on landscape connectivity and ecology. Several studies have found that roads have ecological effect thresholds ranging from a little as 100 m (328 ft) up to 1000 m (3280 ft) from the edge of the road, with analyses being dependent on the species studied, variables being measured (i.e., sound, mortality) and spatial measures of roads (i.e., road width, density) (Forman and Alexander 1998, Forman and Deblinger 2000, Haskell 2000, Forman *et al.* 2002, Eigenbrod *et al.* 2009). Haskell (2000) found for macroinvertebrate soil fauna, lightly traveled roads through continuous forests have significant impacts up to 100 m (328 ft) away. Forman *et al.* (2002) studied grassland bird patterns in a suburbanizing landscape and concluded that > 100 m (328 ft) from roads with traffic is an essential measurement to incorporate into effective land-use and transportation policy. For this assessment, if a buffer distance of 100 m from the edge of the road extended into MORR's forests, wetlands, and streams within the park, we assessed this as *Warrants Moderate Concern*. We did not assign a *Warrants Significant Concern* category since we believe that level of categorization for this measure requires additional quantitative traffic data and habitat information. If this buffer distance did not extend into the habitat areas above, a condition category of *Resource is in Good Condition* was assigned.

#### **Condition and Trend**

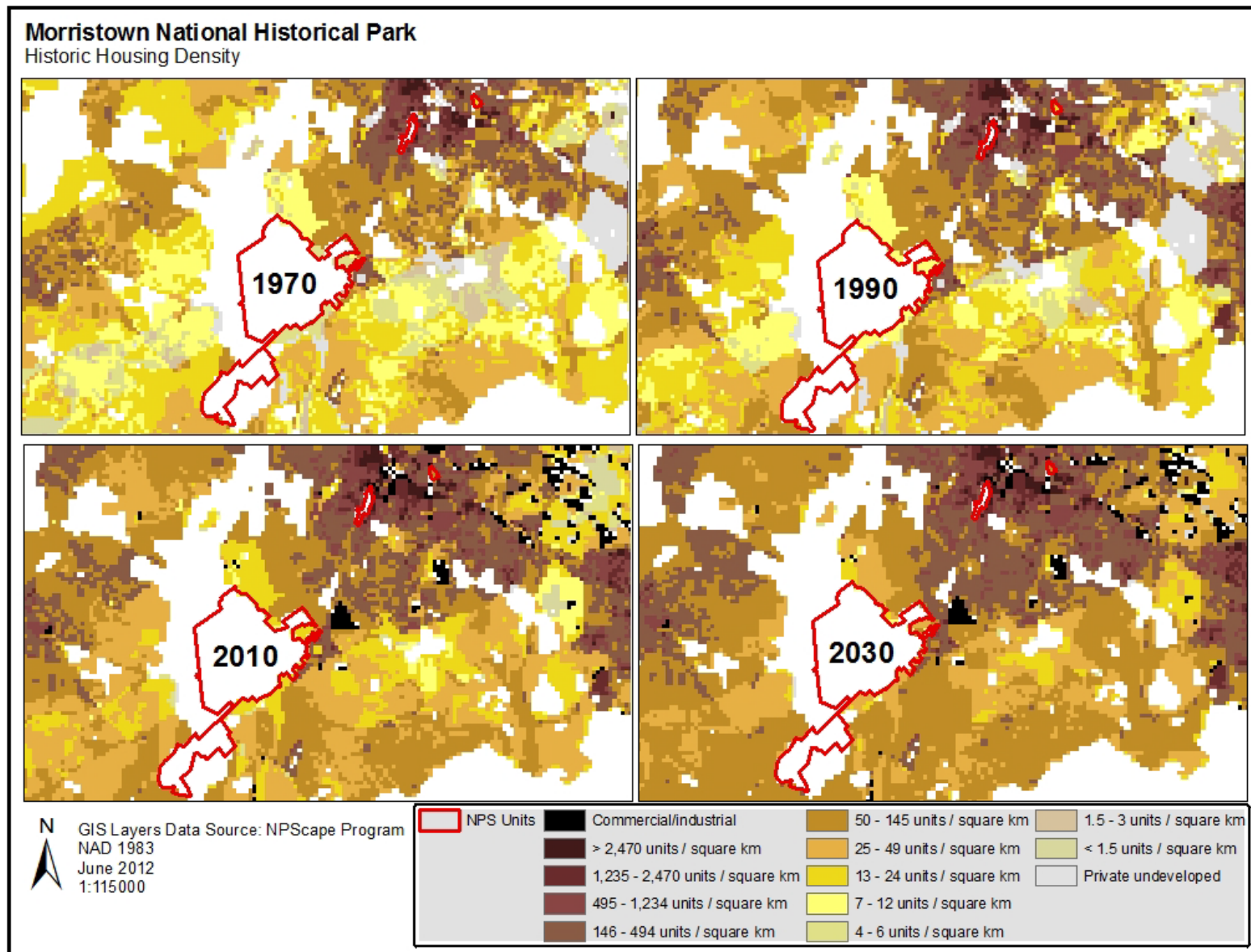
The following measures were analyzed and the following was concluded for MORR:

#### Housing and Land Cover Change

Housing development has *increased* around MORR from 1970 to 2010 (Figure 4.34). Based on 2010 data, the greatest housing density is within the northeast direction of MORR near Fort Nonsense and Washington's Headquarters units with housing units reaching >2,470 units/sq. km. This density is largely due to these units being near the town of Morristown. This area has also experienced an increase in commercial/industrial development from 1990 to 2010. Based on an analysis of 2010 housing development, increases in housing units closest to MORR's boundary has been the greatest within the south and southwest of the Jockey Hollow unit, with housing density ranging from 13-145 units/sq. km. MORR will continue to experience housing expansion in this general area by 2030 with a majority of the land being projected to house 50-145 units/sq. km (Figure 4.34). Historic and

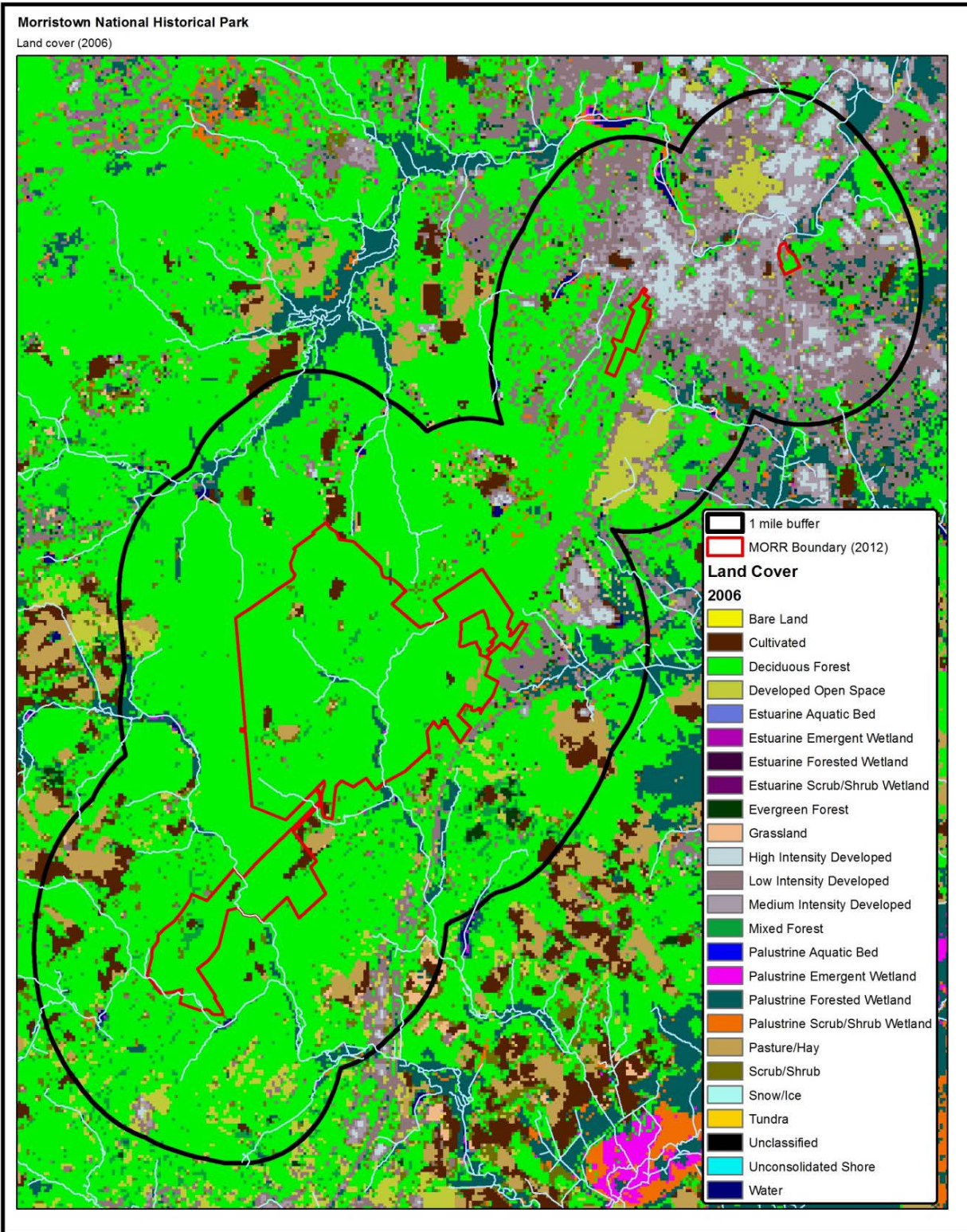
current land preservation efforts decelerate the future efforts of housing expansion surrounding MORR. Additionally, natural features in the environment (e.g., slopes, soil characteristics) may deter development around MORR.

Based on 2006 land cover remote sensing data, MORR is generally surrounded by deciduous forest and development (Figure 4.35). Changes in land cover within and surrounding MORR are evident from 1988-2002 (Table 4.29). From 1988-2002, urban land within MORR and within 5 km (3.10 mi) of the boundary of MORR *increased* by 11% (Wang and Nugranad-Marzilli 2009). This increase in urban land cover has resulted from development within Morristown near the Washington's Headquarters and Fort Nonsense units and from housing construction surrounding the park. From 2001-2006, land use changes around MORR included medium intensity development northeast of Jockey Hollow and low intensity development south of Jockey Hollow unit (NOAA Coastal Services Center 2012). Two forest types have *decreased* within the adjacent 5 km (3.10 mi) buffer around MORR, an expected result due to urban development in the area. Coniferous and mixed forests have decreased (61% and 19% respectively) while deciduous forests have *increased* by 35% from 1988-2002 (Table 4.29). The mechanisms which lead to these decreases in coniferous and mixed forests has not been identified but may be due to construction activities, diseases and pests or even inaccuracies in the remote sensing Landsat calculations.



**Figure 4.34.** Historic housing density (units/square km) estimates and projections surrounding MORR in 1970, 1990, 2010 and 2030.





**Figure 4.35.** Land cover types within and surrounding MORR based on the 2006 National Land Cover Database (NLCD).

**Table 4.29.** Percent change in acreage and acerages of each land cover type within the MORR boundary and an adjacent 5-kilometer buffer zone in 1988 and 2002 (based on land cover analyses by Wang and Nugranad-Marzilli, 2009).

Land Cover Type	Changes Within MORR Boundary			Changes Within MORR Boundary and adjacent 5-km buffer zone		
	1988-2002	1988 acerage	2002 acerage	1988-2002	1988 acerage	2002 acerage
Urban	-20%	20	16	11%	12,670	14,096
Deciduous Forest	53%	666	1,020	35%	10,283	13,746
Coniferous Forest	-64%	25	9	-61%	1139	440
Mixed Forest	-31%	864	599	-19%	11,086	9121
Wetland	-93%	41	3	-24%	3040	2350
Vegetation (Herbaceous)	-35%	83	57	-14%	10,416	8944

### Impervious Cover and Road Ecology

Within MORR's boundaries, sources of impervious surface include small parking lots and roads within the park. Overall, the amount of impervious surface within MORR is less than 10% highly developed impervious cover, rating the park *Resource is in Good Condition* (Figure 4.36). The majority of the park contains 0-5% impervious surface with few isolated areas from 5.1% to 41% impervious.

The connection of patch areas of natural habitats within and surrounding MORR was dependent on the type of road and distance from roads. Patch areas within the Jockey Hollow unit and NJ Brigade Encampment Area ranged from 0-10 km<sup>2</sup> (0-6.2 mi<sup>2</sup>) when spatially analyzed > 500 m (1640 ft) (from both major roads) and > 500 m (1640 ft) from all road types within and surrounding MORR (Figure 4.37). When analyzed at > 500 m (1640 ft) from major roads only, the two large patch areas in MORR's Jockey Hollow unit were approximately 9.3 km<sup>2</sup> and 8.9 km<sup>2</sup>. 56% of these patches are outside park boundaries. These extended patch areas are due to the Lewis Morris County Park and non-profit conservation areas such as the NJ Audubon's Scherman Hoffman Wildlife Sanctuary. Connectivity to these key areas outside of NPS boundaries is vital to safeguarding movement of animals (e.g., amphibians) and preserving habitat integrity, such as forest health. Note that this analysis by NPScape treated all roads equally when; however, roads vary widely in size and use intensity and therefore may vary in their effects related to landscape fragmentation. Despite these differences, roads still cause fragmentation of natural landscapes and are viewed here as stressors to MORR.

The patch areas decreased to 0.35 km<sup>2</sup> (0.22 mi<sup>2</sup>) and 0.40 km<sup>2</sup> (0.25 mi<sup>2</sup>) when analyzed at the scale of > 500 m (1640 ft) from all roads. The presence of 'smaller roads', such as the roads in MORR, have decreased these patch areas and have the capacity to affect activities of biota, such as amphibian and reptile migration to and from waterbodies. The impact of roads on ecological communities has been extensively studied for a variety of species. Based on a 100 m spatial analysis of roads in the park, MORR was categorized as *Warrants Moderate Concern*. This buffer distance extends into

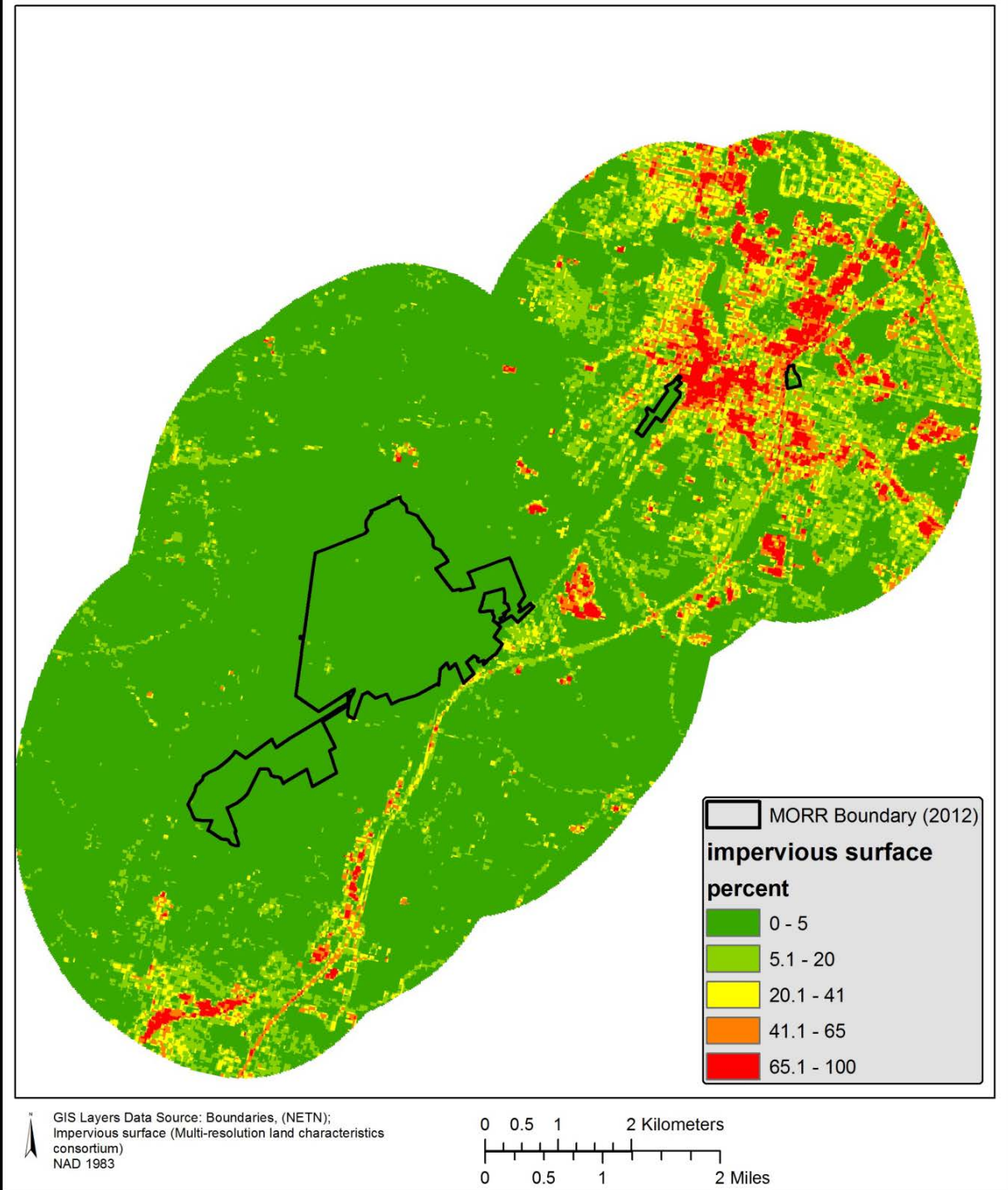
sections of MORR's forests, wetlands, and streams within the park, potentially affecting species distribution or ecosystem function (Figure 4.38). Ecological effects due to roads include but are not limited to: invasive plant spread, increased wildlife mortality, reduction in amphibian and reptile movement, and chemical pollution to aquatic and terrestrial environments (Eigenbrod *et al.* 2009, Flory and Clay 2006, Forman and Alexander 1998, Forman *et al.* 2002, Van Bohemen *et al.* 2003).

#### ***Data Gaps and Confidence in Assessment***

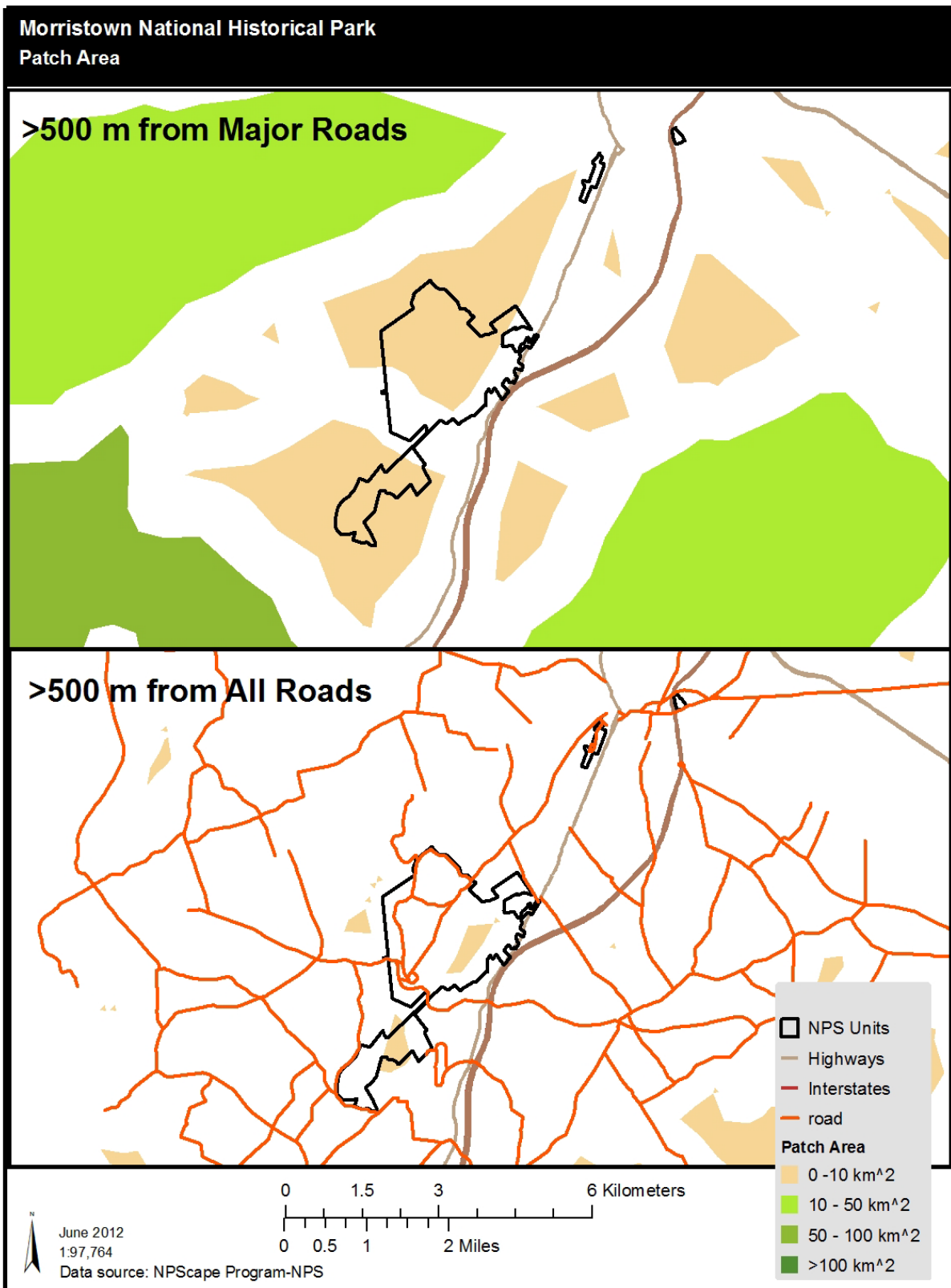
Overall, confidence of the variables assessed in this section was medium and confidence in trend was medium for housing density and land cover and not applicable to impervious surface and patch size. Using projected modeling estimates is an advantageous method to forecast changes within areas around MORR. However, factors such as township or State development regulations and economic growth/decline trends are variables which also regulate future patterns of the landscape but are far more complex to predict. The land cover data which was analyzed at local, regional and national scales for various years utilized different processing methods and thus were subjected to error in spatial, thematic and temporal classification. Additionally, using isolated factors to assess landscape patterns for land management decisions, such as impervious surface for analyses on streams health, is not recommended due to the nonlinear relationships that may exist between impervious cover and instream variables.



**Morristown National Historical Park**  
NLCD 2006 Percent Developed Imperviousness

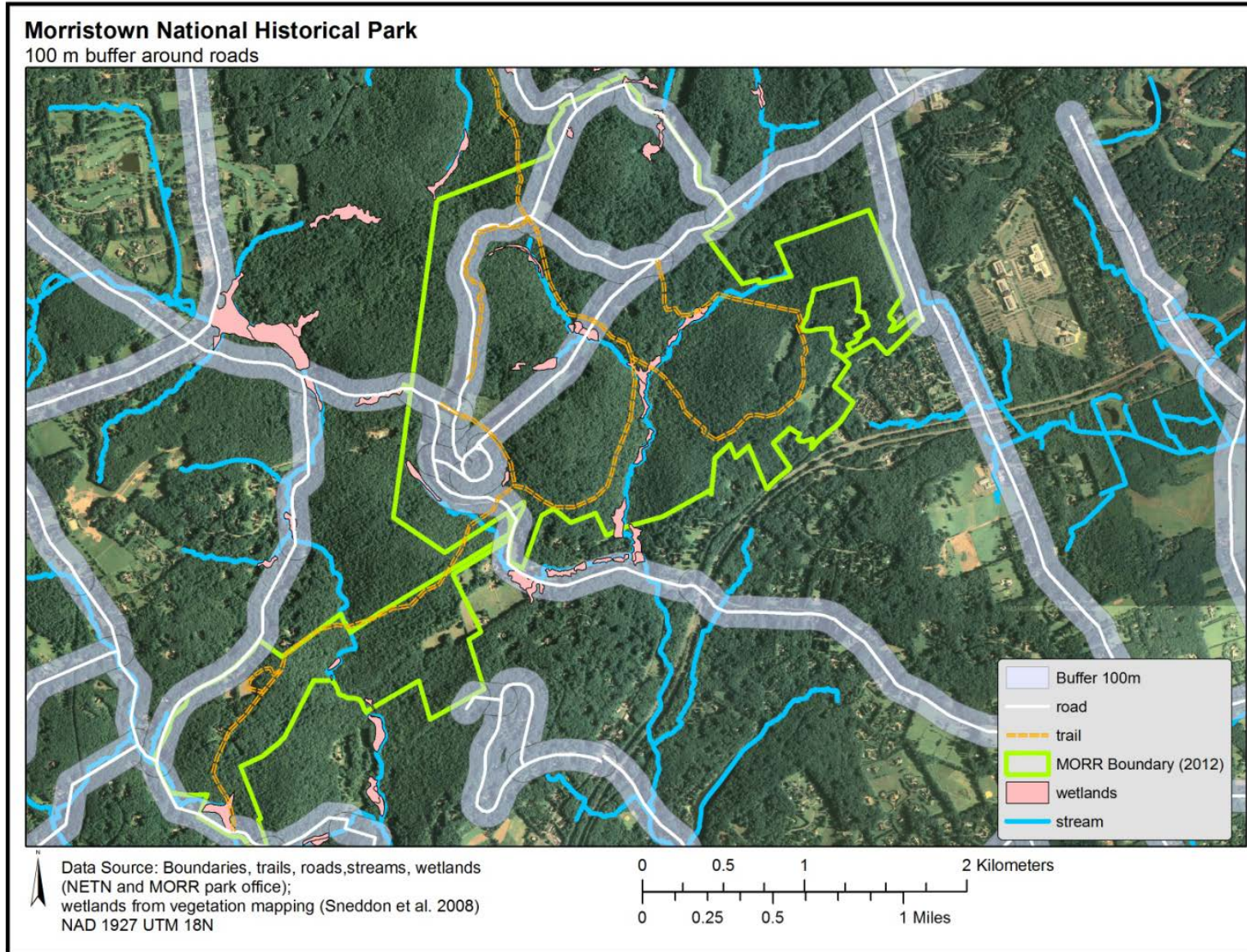


**Figure 4.36.** Percent developed imperviousness within and surrounding MORR based on 2006 National Land Cover Data.



**Figure 4.37.** Patch areas (km<sup>2</sup>) defined by > 500 m from major roads (top) and > 500 m from all roads (bottom) within and surrounding MORR.





**Figure 4.38.** 100 m buffers around roads within MORR and their locality to wetlands, streams and forested areas.

## Soundscape

### ***Relevance and Context***

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

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

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

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

Soundscapes possess both ecological and social value and should be considered natural resources worthy of management and conservation (Dumyahn and Pijanowski 2011). Natural sounds have been referred to as an endangered resource because the ability to experience them is becoming progressively rarer (Jensen and Thompson 2004). Noises which impair the soundscape in MORR can originate from a number of sources, including various motorized equipment, aircrafts, adjacent land uses, general park operations (e.g., mowing), increased visitor use and highway traffic. One of the

major issues identified in the MORR 2004 General Management Plan is the protection of park lands from sound pollution, especially sound that is generated by Interstate 287, a busy eight lane highway adjacent to the park's Washington's Headquarters Unit. The highway noise makes outdoor interpretive talks difficult for park staff. Some preliminary modeled traffic noise data for the Washington's Headquarters Unit has suggested that noise barriers along embankments at the western boundary of the park unit may assist in potential noise mitigation (NPS 2011). Additionally, increased noise can adversely affect not only individual species but populations of species in MORR. Natural soundscape alterations may be especially significant for amphibian, reptile, bird and bat populations in MORR.

The soundscape is also important for cultural or historic values as some sounds accompany the use, interpretation and appreciation of cultural or historic settings in MORR. In 2000, Director's Order 47 specified how parks should monitor and plan to protect park acoustical environments. NPS Management Policies (NPS 2006b, section 5.3.1.7) added yet another section establishing the concept of cultural soundscapes (e.g., cultural and historic sounds [e.g., battle reenactments, tribal ceremonies, quiet reverence]) for NPS protection. However, soundscape management is becoming more complex and challenging as threats to acoustic resources, both internal and external to park boundaries, increase. Understanding the status and trends in MORR's soundscape will assess the need, if any, for management and restoration efforts.

### ***Data and Methods***

#### **Sound Science 101**

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

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

Besides the pitch of a sound, we also perceive the amplitude (or level) of a sound. This metric is described in decibels (dB). The decibel scale is logarithmic, meaning that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy. This also means that small variations in sound pressure level can have significant effects on the acoustical environment. For instance, a 6 dB increase in a noise source will double the distance at which it can be heard, increasing the affected area by a factor of four. Sound pressure level is commonly summarized in terms of dBA (A-weighted sound pressure level). This metric significantly discounts sounds below 1,000 Hz and above 6,000 Hz to approximate human hearing sensitivity. Table 4.30 provides examples of A-weighted sound levels measured in national parks.

**Table 4.30.** Examples of sound levels measured in national parks.

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

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

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

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

Examples of human-caused sounds heard in parks include:

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

#### Characterizing the acoustical environment

Oftentimes, managers characterize ambient conditions over the full extent of the park by dividing total area into “acoustic zones” on the basis of different vegetation zones, management zones, visitor use zones, elevations, or climate conditions. Then, the intensity, duration, and distribution of sound sources in each zone can be assessed by collecting sound pressure level (SPL) measurements, digital audio recordings, and meteorological data. Indicators typically summarized in resource assessments include natural and existing ambient sound levels and types of sound sources. *Natural ambient* sound level refers to the acoustical conditions that exist in the absence of human-caused noise and represents the level from which the NPS measures impacts to the acoustical environment. *Existing ambient* sound level refers to the current sound intensity of an area, including both natural and human-caused sounds.

The influence of anthropogenic noise on the acoustical environment is generally reported in terms of SPL across the full range of human hearing (12.5-20,000 Hz), but it is also useful to report results in a much narrower band (20-1250 Hz) because most human-caused sound is confined to these lower frequencies.

### **Reference Condition/Threshold Values Utilized**

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

Various characteristics of sound can contribute to how noise may affect the acoustical environment. These characteristics may include rate of occurrence, duration, a, pitch, and whether the sound occurs consistently or sporadically. In order to capture these aspects, the quality of the acoustical environment is assessed using a number of different metrics including existing ambient and natural ambient sound level (measured in decibels), percent time human-caused noise is audible, and noise free interval. In summary, if we are to develop a complete understanding of a park's acoustical environment, we must consider a variety of sound metrics. This can make selecting one reference condition difficult. For example, if we chose to use just the natural ambient sound level for our reference condition, we would focus only on sound pressure level and overlook the other aspects of sound mentioned above.

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

There is an ongoing effort to assess condition and trend of acoustic resources for the state of the parks (SOP) project, and although SOPs generally report one metric per resource (while NRCAs often incorporate multiple metrics), it may serve as a useful template (see this link for more information: <https://irma.nps.gov/App/Reference/Profile/2206094>). Table 4.31 reports suggested thresholds for the mean  $L_{50}$  impact, which is a measure of the impact of anthropogenic sources on the acoustic environment. Because the National Park System is comprised of a wide variety of park units, two threshold categories are considered (urban and non-urban), based on proximity to urban areas (U.S. Census Bureau 2010). The urban criteria are applied to park units that have at least 90% of the park property *within* an urban area. The non-urban criteria were applied to units that have at least 90% of the park property *outside* an Urban Area. Parks that are distant from urban areas possess lower sound levels, and they exhibit less divergence between existing sound levels and predicted



natural sound levels. These quiet areas are more susceptible to subtle noise intrusions than urban areas. Visitors and wildlife have a greater expectation for noise-free environments. Accordingly, the thresholds for the amber and red condition ratings are lower for these park units than for units near urban areas. Urban areas tend to have higher ambient sound levels than non-urban areas (U.S. EPA 1971, Schomer *et al.* 2011). Higher thresholds are used for parks in urban areas. However, acoustical environments are important in all parks: units in urban areas may seek to preserve or restore low ambient sound levels to offer respite for visitors.

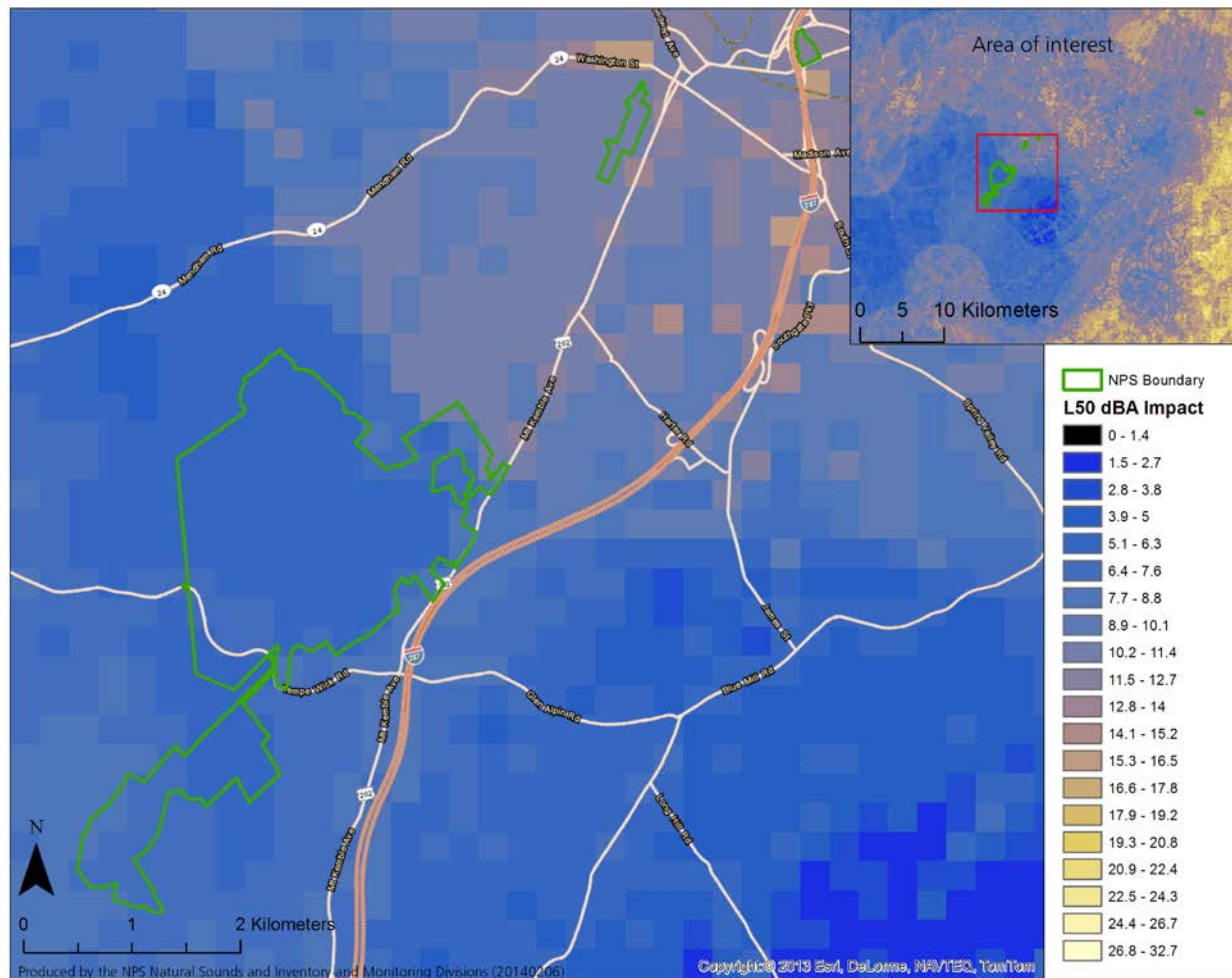
### **Condition and Trend**

#### Acoustical Conditions

Baseline acoustical monitoring has not been conducted in MORR, and therefore the condition and trend of the acoustic environment are unknown. In cases where ability to collect acoustical data on site is limited, such as in MORR, alternatives for assessing condition and trend are also available. Using acoustic data collected at 244 sites and 109 spatial explanatory layers (such as location, landcover, hydrology, wind speed, and proximity to noise sources such as roads, railroads, and airports), NSNSD has developed a geospatial sound model which predicts natural and existing sound levels with 270 meter resolution (see Figure 4.39) (Mennitt *et al.* 2013). In addition to predicting these two ambient sound levels, the model also calculates the difference between the two metrics, providing a measure of impact to the natural acoustic environment from anthropogenic sources. The resulting metric (L<sub>50</sub> dBA impact) indicates how much anthropogenic noise raises the existing sound pressure levels in a given location. The resulting metric (mean L<sub>50</sub> dBA impact) indicates how much anthropogenic noise raises the existing sound pressure levels in a given location. The mean L<sub>50</sub> impact measure for MORR was calculated at 6.3 dBA, categorizing the park as *Warrants Significant Concern* (Table 4.31, 4.32).

**Table 4.31.** Condition thresholds for non-urban and urban parks and the acoustical condition assessment for MORR.

Measure	Condition Categories	Threshold for non-urban parks (dBA)	Threshold for urban parks (dBA)	Result
Mean L <sub>50</sub> impact (dBA)	Warrants Significant Concern	3.0 < Threshold <i>Listening area reduced by &gt; 50%</i>	12 < Threshold <i>Listening area reduced by &gt; 94%</i>	6.3 dBA
Calculated as difference between existing ambient and natural ambient models	Warrants Moderate Concern	1.5 < Threshold ≤ 3.0 <i>Listening area reduced by 30 - 50%</i>	6.0 < Threshold ≤ 12 <i>Listening area reduced by 75 - 94%</i>	
	Resource is in Good Condition	Threshold ≤ 1.5 <i>Listening area reduced by ≤ 30%</i>	Threshold ≤ 6.0 <i>Listening area reduced by ≤ 75%</i>	



**Figure 4.39.** Map displaying modeled L50 dBA impact levels in MORR.

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

**Table 4.32.** Modeled dBA for Existing, Natural and Impact level in MORR. Impact metric indicates how much anthropogenic noise raises the existing sound pressure levels in a given location. Data provided by NPS Natural Sounds and Night Sky Division.

Metric	Minimum (dBA)	Median (dBA)	Mean (dBA)	3rd Quartile (dBA)	Maximum (dBA)
Existing	38.9	39.9	40.4	40.7	48.0
Natural	33.1	34.1	34.0	34.2	35.9
Impact	5.1	5.9	6.3	6.6	12.1

To assess the condition of the acoustic environment, it is also useful to consider the functional effects that increases in sound level might produce. For instance, the *listening area*, the area in which a sound can be perceived by an organism, will be reduced when background sound levels increase. The failure to perceive a sound because other sounds are present is called *masking*. Masking interferes with wildlife communication, reproductive and territorial advertisement, and acoustical location of prey or predators (Barber, Crooks, & Fristrup, 2010). However, the effects of masking are not limited to wildlife. Masking also inhibits human communication and visitor detection of wildlife sounds. In urban settings, masking can prevent people from hearing important sounds like approaching people or vehicles, and interfere with the way visitors experience cultural sounds or interpretive programs. Keep in mind that seemingly small increases in sound level can have substantial effects, particularly when quantified in terms of loss of listening area (Payne & Webb, 1971; Barber, Crooks, & Fristrup, 2010). Each 3 dB increase in the background sound level will reduce a given listening area by half. See Table 4.33 for additional information.

**Table 4.33.** Increases in background sound level (dB) with resulting decreases in listening area.

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

## Trends

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

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

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

## **Data Gaps and Confidence in Assessment**

Confidence in the assessment for MORR’s soundscape was medium due to a lack of baseline data and trend analysis was not applicable. Baseline acoustical ambient data collection will clarify existing conditions and provide greater confidence in resource condition trends. Wherever possible, baseline ambient data collection should be conducted. In addition to providing site specific information, this information can also strengthen the national noise model.

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

to differentiate between impacts to wildlife that result from the noise itself or the presence of the noise source.

### **Sources of Expertise**

Several statements in this text were provided by the NPS Natural Sounds and Night Skies Division in order to serve as a template within NRCA reports. These scientists help parks manage sounds in a way that balances the various expectations of park visitors with the protection of park resources. They provide technical assistance to parks in the form of acoustical monitoring, data collection and analysis, and in developing acoustical baselines for planning and reporting purposes. For more information, see <http://www.nature.nps.gov/sound/>.

## **Lightscape-Dark Night Sky**

### **Relevance and Context**

The NPS uses the term *natural lightscape* to describe resources and values that exist in the absence of human-caused light at night (NPS 2006). *Photoc environment* is the totality of the pattern of light at night at all wavelengths. The photoc environment affects a broad range of species, is integral to ecosystems, and is a natural physical process. Light that is undesirable in a landscape is often called *light pollution*. Light pollution is the introduction of artificial light, either directly or indirectly, into the natural environment. Light pollution exists in two forms: 1) sky glow, the brightening of the night sky from human-caused light scattered in the atmosphere and 2) glare, or the direct shining of light. Light pollution tends to be most acute in urban environments, has pronounced ecological effects and potentially influences human circadian rhythms. An examination of North American light emissions shows a roughly six percent annual increase from 1947 to 2000 (Cinzano and Elvidge 2003). These increases exceed the population growth rate, indicating that the increase in light pollution is primarily due more light emitted per capita and a greater percentage of uplight from light fixtures (NPS 2013).

Natural lightscapes are critical for nighttime scenery, such as viewing a starry sky, but are also critical for maintaining nocturnal habitat. Adding artificial light to habitats may result in substantial impact to certain species (Rich and Longcore 2006). Research into the ecological consequences of artificial night lighting is revealing numerous connections between light pollution and species disruption. Many wildlife species rely on natural patterns of light and dark for navigation, to cue behaviors or to hide from predators. Light is vital to organisms as an energy resource and as an information source. As a source of information, patterns of light and darkness are used to regulate circadian cycles of activity, cue behaviors and are used for navigation. A wide diversity of ecological impacts from light pollution exists (Rich and Longcore 2006, Bruce-White and Shardlow 2011). Impacts from light pollution include: influences on organismal movements, foraging, interspecific interactions, communication, reproduction and mortality (Svensson and Rydell 1998, Black 2005, Miller 2006, Boldogh *et al.* 2007, Lorne and Salmon 2007, Stone *et al.* 2009, Santos *et al.* 2010). Furthermore, air pollution exacerbates the scattering of light and dims the stars. The NPS considers night skies an important part of visibility, which is considered an air quality related value under the 1977 Clean Air Act Amendments.



Lightscares can be cultural as well, and it may be integral to the historical content of the park. Human-caused light may be obtrusive in the same manner that noise can disrupt a contemplative or peaceful scene. A naturally dark surrounding is part of the historic aspect of many national parks, such as MORR. Just as the National Park Service strives to keep historic structures intact and the surrounding landscape looking as it did during the time of historic significance, the park should also conserve the lightscape during the period of significance. However, the growth of urban areas surrounding MORR makes this objective difficult to obtain.

Measuring of the intensity, spectra and periodicity of artificial light is important to understanding the status and trends of the lightscape in MORR. Additional studies on the ecological effects of light pollution on specific species are needed to identify critical wavelengths and thresholds in terms of timing and duration (season and lit period during the night) and spatial extent that trigger effects. Few studies have attempted to quantify the thresholds in terms of the size of the unlit area and the light intensity below which an area is effectively unlit in ecological terms and thresholds (Gaston *et al.* 2012).

It has been recommended by the NPS Natural Sounds & Night Skies Division that MORR be categorized as a Level 1 (more sensitive) park based on the non-urban character of the park and its natural resources. Level 1 parks include those which have been designated by the NPS I & M Program as having significant natural resources. These areas include parks in which the nighttime photic environment has a greater influence on natural resources and ecological systems. These parks often have higher quality night sky conditions and less anthropogenic light levels. Thus, these parks tend to be more sensitive to the effects of light pollution (see Moore *et al.* 2013 for further discussion on Level 1 vs. Level 2 parks).

### ***Data and Methods***

For this NRCA, the parameter to characterize the quality of the photic environment and lightscape is the *average anthropogenic sky luminance presented as a ratio of natural conditions (ALR)*. It was selected because it is a robust and descriptive metric that can be modeled relatively easily (Moore *et al.* 2013). The amount of anthropogenic light averaged over the entire sky, measured in the green (human visual) spectral band is a single parameter useful for assessing the quality of a park's nighttime environment. Average anthropogenic light is calculated by using the total observed sky brightness and removing the natural night sky component from the observed conditions. A natural night sky has an average brightness across the entire sky of 78 nL (nanolambers). This is expressed as a ratio of anthropogenic to natural light (ALR). Therefore, a ratio of 1.0 would signify that the anthropogenic light was 100% brighter than the natural light from the night sky. This would equate to an anthropogenic component of 78 nL and natural component of 78 nL. Average anthropogenic sky luminance is calculated from ground based measurements or from a GIS model when in-park measure are not available. Data for MORR was provided by the NPS Natural Sounds & Night Skies Division.

The NPS Natural Sounds and Night Skies Division has been collecting data within national parks. Sites were selected that have a good view of the horizon with minimal obstructions, with data being collected for 1–8 hours per night, and often on multiple nights (NPS 2013). Weather conditions

constrain data collection and only nights with no moon are suitable. In addition to the photometric measures, field technicians make observations of the nighttime environment and sky quality. This enables the NPS to identify relationships between numerical data and visual features of the night and better understand human visual perception of the natural lightscape. Several methods can be used to assess the lightscape within the park. Qualitative methods, such as the Bortle Dark Sky Scale, rates sky quality in intervals from 1 to 9, where 1 is pristine and 9 represents a sky dominated by anthropogenic light in which only the very brightest dozen or so stars and planets may be seen. Quantitative methods involve digitized cameras and software. The current state of the NPS methodology features rapidly capturing the night sky in a high resolution mosaic, gathering precise measurements of sky brightness and glare across the entire celestial hemisphere, identifying light pollution sources and analyzing data to separate natural and human-caused sky brightness. Images captured on a computer choreographed digital camera are later individually calibrated and then stitched together to form a mosaic of the entire sky that can be displayed in either a panoramic or hemispheric (i.e., fish-eye) view. Data is displayed in various measures of sky brightness (luminance) as well as ground illuminance as a result of human-caused light. Images of the entire hemisphere of the sky may also be used to quantify the amount of anthropogenic (human-caused) skyglow present at any given location and time.

#### **Reference Condition/Threshold Values Utilized**

For Level 1 parks, the threshold separating *Resource is in Good Condition* from *Warrants Significant Concern* is set at an ALR of 0.33 or 1/3<sup>rd</sup> brighter than natural conditions (Table 4.44). This value corresponds with the point at which portions of the sky typically become bright enough that humans are unable to fully adapt to the dark when looking toward them. This attribute of human ‘night vision’ is likely similar in other mammals, although certain mammals may be more or less sensitive. The threshold separating *Warrants Moderate Condition* with *Warrants Significant Condition* is set at an ALR of 2.0. This value corresponds with a point at which portions of the sky typically cast shadows at which the Milky Way can no longer be seen in its entirety, at which Zodiacal lights are seldom seen and full dark adaptation is not possible (Table 4.44).

#### **Condition and Trend**

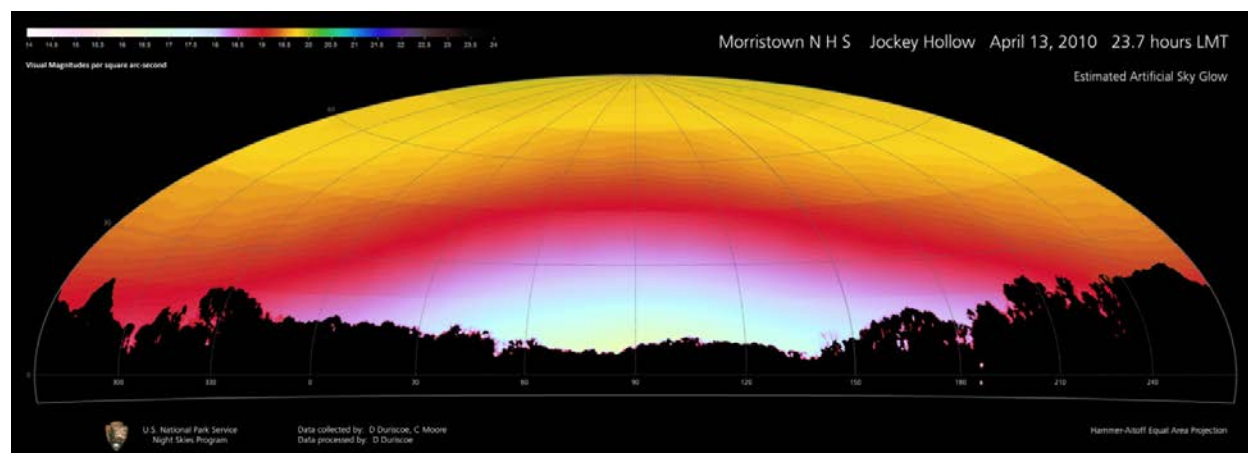
The ground based Anthropogenic Light Ratio (ALR) in MORR’s Jockey Hollow Unit is 15.00 and is considered *Warrants Significant Concern* (Table 4.44). The sky glow produced by the scattering of light from nearby sources around MORR does degrade the view of the night sky for the Jockey Hollow Unit, as depicted in Figure 4.40. Figure 4.41 displays the Regional ALR near Morristown National Historic Site. To the east of MORR lies the urban cities of Newark, Jersey City and New York City, all which emit great amounts of light pollution. The trend for ALR was categorized as *unchanging*. The trend was based on the population growth rate of towns near MORR. The park lies adjacent to Morristown, NJ which had a five year growth rate of 0.2%. Additionally the New York Metro area also had a slow growth rate of less than 4% over the last 5 years (U.S. Census Bureau).

### Data Gaps and Confidence in Assessment

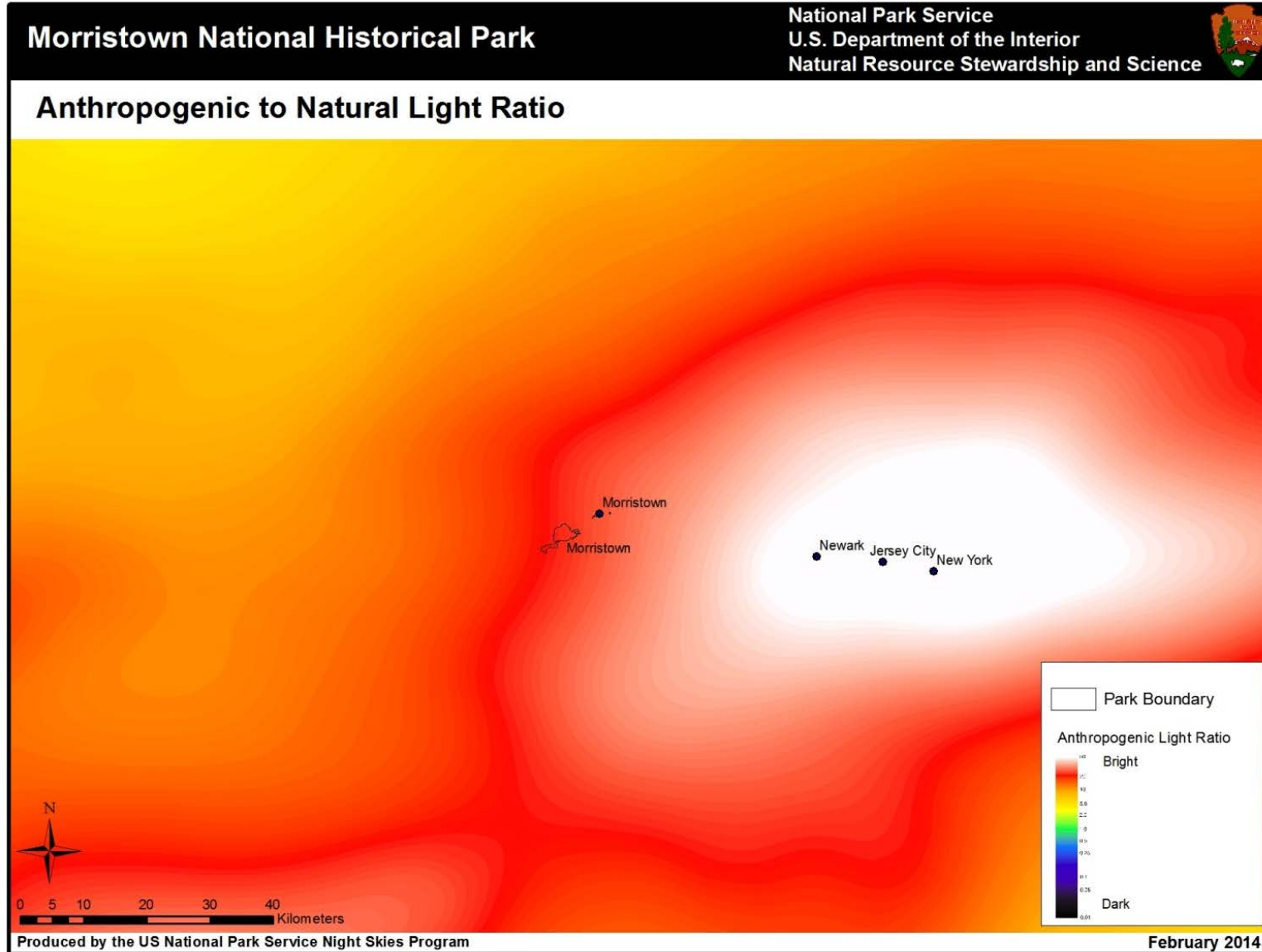
Confidence in the assessment was medium and confidence in the trend was medium. The ALR metric provides a relatively coarse description of overall resource conditions and limits the ability to fully describe and manage the variations in resource quality that often exist within the park. Park management actions for lightscape conditions, if warranted, would require additional lightscape measures (e.g., maximum vertical illuminance, horizontal illuminance, impacts to wildlife species of concern, qualitative indices) that capture other important characteristics of the resources within the park. Additionally, management actions would need to take into account relevant park information, such as park significance, desired condition, presence of sensitive species, and other factors.

**Table 4.34.** Anthropogenic Light Ratio threshold categories for assessing the night sky conditions in Level 1 parks.

Measure	Condition Categories		Result
Anthropogenic Light Ratio (ALR)  (Average anthropogenic all-sky luminance: average natural all-sky luminance)  Light flux is totaled above the horizon (the terrain is omitted) and the anthropogenic and natural components are expressed as a unitless ratio. The average natural sky luminance is 78 nL	Warrants Significant Concern	ALR > 2.00 (>156 nL average anthropogenic light in sky). At least half of park area should meet this criteria.	<div>15.00</div> (for Jockey Hollow Unit)
	Warrants Moderate Concern	ALR 0.33-2.00 (26-156 nL average anthropogenic light in sky). At least half of park area should meet this criteria.	
	Resource is in Good Condition	ALR <0.33 (<26 nL average anthropogenic light in sky). At least half of park area should meet this criteria.	



**Figure 4.40.** Estimated anthropogenic sky glow from Jockey Hollow in MORR.



**Figure 4.41.** Regional anthropogenic light ratio (ALR) for the landscape surrounding MORR.

## Superstorm Sandy: Ecological Implications

### **Background**

Superstorm Sandy, a combination of a hurricane and nor'easter, brought about catastrophic damage in the mid-Atlantic region in October 2012. This extreme weather event caused damage to several of the Nation's national parks, including MORR. MORR began park closures on October 29, 2012 due to the imminent arrival of the storm. In order to respond to the major impacts from the storm, crews needed to clear debris at MORR due to safety hazards on the ground, trails and parking areas in the park. The park reopened completely on November 22, 2012. Restoring historical and cultural systems to the National Parks has already begun with archeological investigations by NPS, but ecosystem restoration remains a challenge for the parks due to the complexity and cost associated with this type of storm recovery effort. Although extreme storm events can be beneficial for some ecological measures, they often cause or magnify disturbances. These disturbances make plant and animal communities more susceptible to negative impacts such as diseases, invasive plant establishment and pest infestations. Additionally, extreme weather events create habitat fragmentation in areas that are already significantly fragmented by human uses.



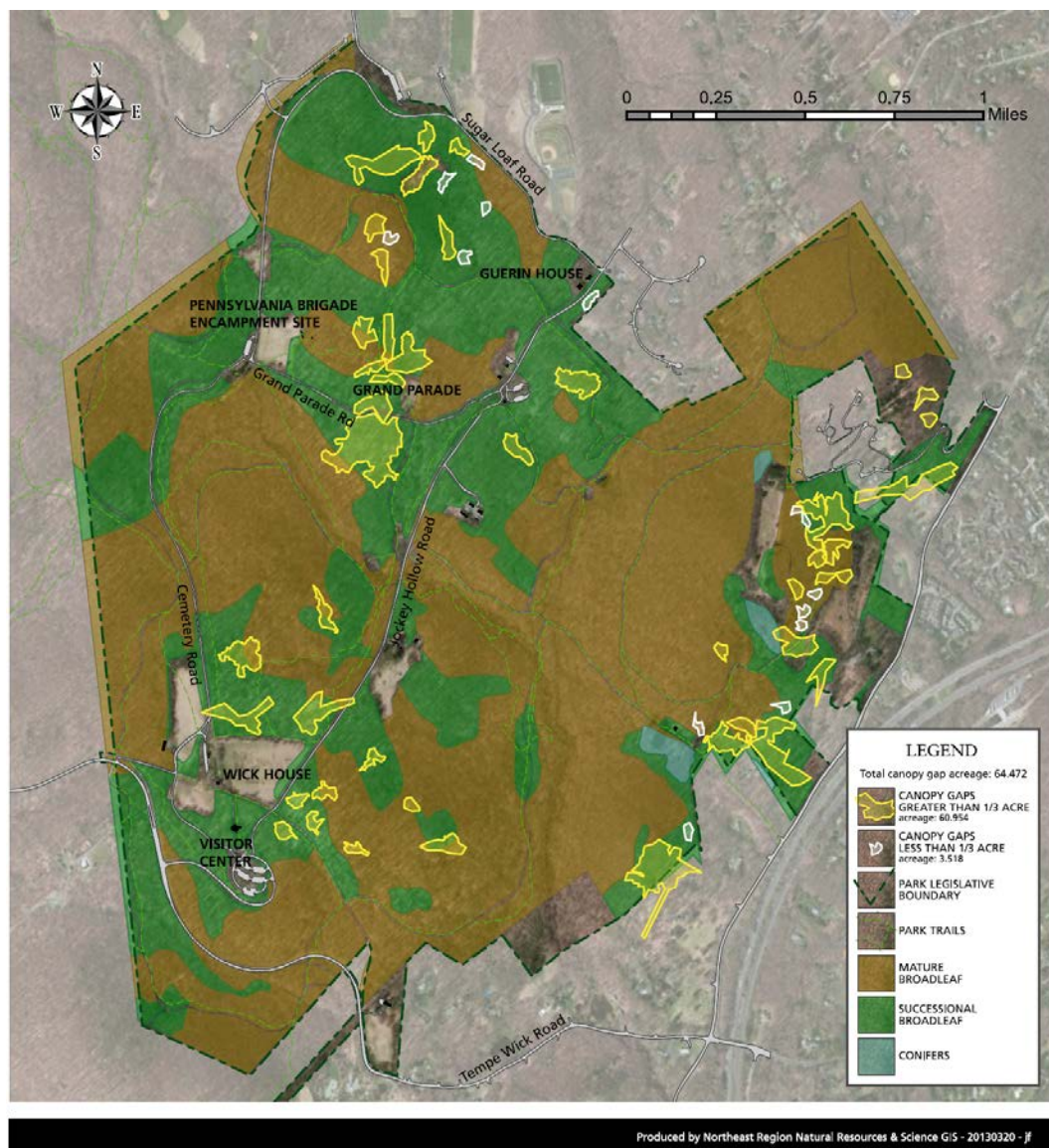
*Examples of tree damage in MORR post Superstorm Sandy. Photos courtesy of R. Masson, NPS.*

### **Ecological Disturbances**

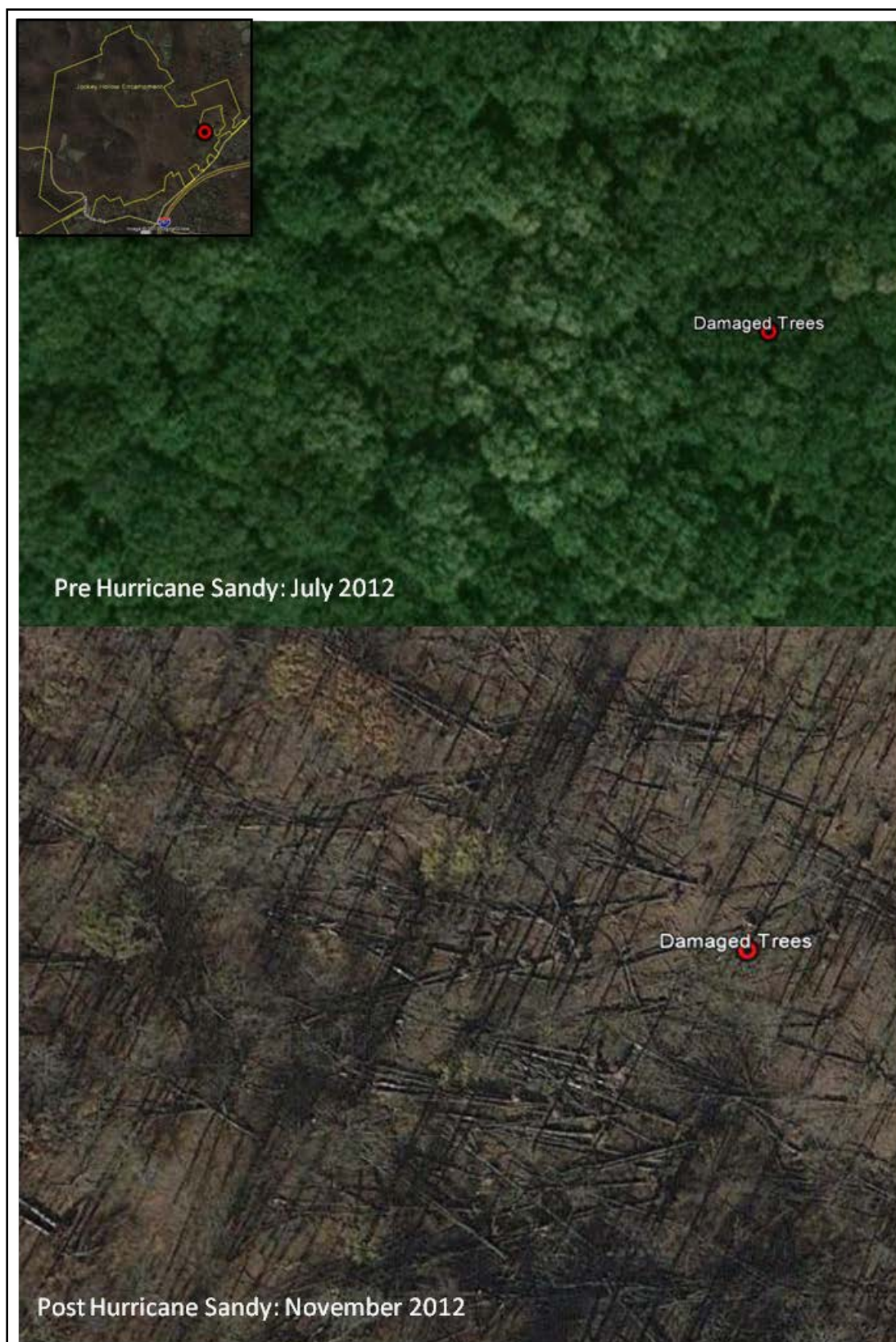
Trees are most vulnerable during hurricanes and in MORR, trees not only hold a historical significance as living landmarks, but possess ecological services as well (see Chapters 2 and 4). Extreme weather events significantly alter the structure and composition of the forests in the NETN (Boose *et al.* 2001). The effects of hurricanes on vegetation include immediate and substantial tree mortality, delayed tree mortality (months to years) and altered forest regeneration configurations (Lugo and Scatena 1996, Lugo 2000). These alterations can lead to successional shifts, higher rates of species turnover and opportunities for species change in forests. Furthermore, these changes can increase landscape heterogeneity, result in lower aboveground biomass in mature vegetation and produce greater biomass turnover (Lugo and Scatena 1995). MORR's canopy gaps were mapped after the storm and the forest canopy gap acreage was approximately 65 acres (per communication Robert



Masson, NPS). The Jockey Hollow Unit was the forested area most impacted by the hurricane, while the New Jersey Brigade Unit had only one gap resulting from the storm. Most of the damage from the hurricane appeared to be on the southeast facing slopes in the park, with the southeast facing slope of Mt. Kemble receiving some of the greatest tree damage (Figure 4.39, 4.40). Destructive winds were prevalent along the edges of forest patches, as seen in Figure 4.39, 4.40. Some of the damaged trail systems have been repaired, but other tree related activities, such as removing tree root balls or replacing some damaged trees in specific areas in the park, have not been completed at this time. The NETN forest monitoring plots may have seen extensive damage as well and these alterations could lead to the creation of new research and monitoring questions for the NETN program.



**Figure 4.42.** Post-Superstorm Sandy forest canopy gaps (data collected 01/13/2012) in the Jockey Hollow Encampment Area of MORR.



**Figure 4.43.** Example of a forested section in MORR's Jockey Hollow Encampment Area, pre-(July 2012) and post-Superstorm (November 2012) Sandy. Imagery from NOAA.



Unit had only one gap resulting from the storm. Most of the damage from the hurricane appeared to be on the southeast facing slopes in the park, with the southeast facing slope of Mt. Kemble receiving some of the greatest tree damage (Figure 4.39, 4.40). Destructive winds were prevalent along the edges of forest patches, as seen in Figure 4.39, 4.40. Some of the damaged trail systems have been repaired, but other tree related activities, such as removing tree root balls or replacing some damaged trees in specific areas in the park, have not been completed at this time. The NETN forest



*Damaged trees in MORR due to Superstorm Sandy. Photo: NPS.gov*

monitoring plots may have seen extensive damage as well and these alterations could lead to the creation of new research and monitoring questions for the NETN program.

The spread of invasive plants species in MORR's forest is also a concern due to the increased sunlight penetrating the forest floor from the expanded open canopy. This is especially a concern for the weed, mile-a-minute (*Polygonum perfoliatum*), which was discovered in the park in 2013 and tends to proliferate in open sunny areas. A benefit to the creation of canopy gaps is that the gaps will allow for more native plant regeneration, which was recommended as a management strategy by MORR's Vegetation and Deer Plan's Science Team (per communication, R. Masson, NPS).

Although the creation of forest gaps is beneficial for native plants, these areas will have to be monitored to prevent invasive plants from establishing in these areas as well. Additionally, many of the forest gaps in MORR contain large downed trees with root balls attached, creating a shaded environment on the forest floor. Although coarse woody debris is a beneficial forest floor attribute for several ecological reasons, some downed trees will have to be removed in order to maximize the amount of light reaching the forest floor.

Extreme weather events can generate or exacerbate water quality issues. Excess nutrients and organic material introduced by storm runoff can fuel algal blooms, leading to low dissolved oxygen conditions, thereby affecting aquatic biota. Superstorm Sandy occurred late in October when low dissolved oxygen is not normally an issue and algal blooms are less likely to develop in MORR's streams. However, the water quality impacts of Superstorm Sandy particularly due to erosion activity, such as sediment mobilization and deposition, may be more lasting impacts that require attention by the park. Erosion events, such as landslides, are natural components of terrestrial and aquatic ecosystems. Yet, erosion activity in forest landscapes can damage aquatic resources and threaten public safety. During extreme weather events, slow and rapid movements of soil, rock and associated vegetation are triggered. The frequency and extent of erosion activity are influenced by factors such as precipitation amount and intensity, snow melting rates and land use (e.g., percentage of impervious surface). MORR's topography consists of varying degrees of slope, and the potential for erosion events in the park is influenced by slope steepness, geological properties and hydrologic factors (see Chapter 2 and Chapter 4, section 4.2). Additionally, vegetation influences the likelihood

of erosion through the stabilizing effects of root systems and therefore, preservation of vegetation and seed banks along steep embankments in MORR is an important management goal.

### ***Future Implications and Monitoring***

Several studies have identified an increase in hurricane frequency as well as increases in the intensity and possibly duration of individual storms (Emanuel 1987, Royer *et al.* 1998, Walsh and Pittock 1998, Groisman *et al.* 2000). Such climate changes are expected to have substantial long-term impacts at all NETN park units (Davey *et al.* 2006). Although research is limited on the mitigation of hurricane impacts (i.e., how to reduce hurricane impacts to landscapes and ways to design protected areas), it is important to begin discussions on ways in which impacts to landscapes, such as MORR's historical forests, can be mitigated under extreme weather disturbances (Dale *et al.* 2001). Forest management objectives for MORR could include discussion on extreme weather events and climate variability should be factored into future scenarios regarding MORR's ecological restoration. Furthermore, MORR can begin monitoring the effects and variability associated with forest disturbances from extreme weather events. Monitoring (whether for invasive plants landbirds, mammals, etc...) can be developed by establishing post-storm ecological questions using the currently established NETN forest plots in conjunction with forested areas which are not currently monitored but have been damaged by Superstorm Sandy. Other previously gathered data, such as park vegetation maps, may be used to determine specific tree species which were impacted from the hurricane. One of the more beneficial data tools for MORR to acquire is higher resolution post-Superstorm Sandy aerial imagery and mapping of MORR, which would enable more accurate assessments of the overall ecological damage within the park.

## Chapter 5. Discussion

Morristown National Historical Park, the first national historical park in the national park system, was established in 1933 with the mission of preserving the lands and features associated with the winter encampments of the Continental Army during the War for Independence. Although MORR is a small cultural park, it operates as a biological refuge near an expanding suburban/urban environment for many resident and migratory species. The preservation of the natural environment, viewshed and historic structures within all units composing MORR is vital in order to sustain the park's culturally driven purpose. External impacts, such as population growth, housing expansion, construction of roads and other infrastructure, disruption of hydrology and habitat conversion can significantly affect natural resources through pressures on terrestrial and aquatic habitats. MORR's landscape of fields, mature forested areas, wetlands and streams are not exempt from these impacts.

Table 5.1 provides a summary of MORR's natural resources and their status and trend assessment. The park's location and size can present challenges to park personnel as to what they can do to help maintain and manage the natural resources within park boundaries. The adjacent threats and stressors to MORR become a challenge when managing the park's natural resources. Furthermore, a lack of baseline data in relation to natural resources limits the evaluation of trend statistics and reduces the overall number of ecological integrity assessments within the park. These limitations restrict the ability of park personnel to determine proper management actions and thus, park personnel cannot properly manage natural resources. The lack of natural resource data is not uncommon for parks which primarily serve as historical and cultural areas. It is important to assess the status and trends of natural resources in MORR not only for their ecological value but for their historical significance (e.g., MORR's forests are part of the park's historic encampment structure). Any recommendations about additional indicators must be evaluated by NPS managers with respect to how additional monitoring efforts would meet objectives. Management and monitoring objectives should be explicitly linked (Wagner *et al.* 2013). In addition, any evaluation can take into account tradeoffs between information provided by additional indicators, costs, and the ability to make inferences about status and trends of park resources. Therefore, our recommendations should be used as a first step in this decision making process.

One of the more difficult aspects for the park to manage is its air quality since impacts to air quality occur largely outside of park boundaries. Park personnel can, however, continue to work towards increasing air quality monitoring activities within the park. Specifically, the park could work towards developing an air quality monitoring station (e.g., ozone, visibility) within its boundaries. Secondarily, a monitoring program for wet deposition of sulfur and nitrogen, as well as mercury would also be beneficial for investigating these contaminants on natural resources in the park. Such efforts should be coordinated with NPS regional air quality support and nationally with the air resources division. Regional colleges and universities could also be approached to better leverage both funds and personnel.

Soils are impacted within MORR, likely from increased levels of acid precipitation. The impacts to MORR come from off-site and park personnel are limited in their ability to respond. Continuous



monitoring of soils and forest vegetation structure and function will allow trend detection and the understanding of long term impacts of acid deposition on forest health in MORR. Additionally, MORR's topography contains severely constrained slopes which can affect seed bank retention along riparian habitats in MORR and increase sedimentation in streams. Assessing of the riparian vegetation structure in the park can assist managers in evaluating the need for proactive management or restoration of these habitats.

Impacts to water resources are more of a local issue compared to air resources, and thus it is more likely that MORR personnel can respond to changes in water quality in the park. MORR has a diverse hydrological system of streams, wetlands and springs. The determination of stream quantity needs or identifying a stream quantity threshold for MORR should consider the management objectives for MORR's surface waters (e.g., to maintain fish and macroinvertebrate communities, conserve a threatened species, recreational value, cultural restoration). The scarcity of long-term gaging records for hydrologic parameters, including baseflow measurements within MORR, is a limiting factor for assessing stream water quantity condition for the park. The long-term collection of baseline stream flow and storm flow data are important variables in identifying critical minimum baseflow needs for stream flow preservation and assessing how anthropogenic activities are influencing surface and ground water quantities which in turn, may affect biological community composition. MORR could work with the USGS, NETN and local conservation entities and universities to instate a gaging monitoring program within the park.

In addition to a gaging station, the park should attempt to increase water quality sampling within park boundaries, as this is key to understanding impacts from disturbances, either internal or external to the park. Sampling seasonally and collecting multiple samples will be important to understanding park water quality and for assessing the trends of physical and chemical parameters in surface waters. Since the park's streams are prone to high coliform counts, sampling should include a microbial component for assessing MORR's water quality. Depending on the objective, continuously monitoring multi-parameter sondes can also be used for recording water measurements on a finer temporal scale. Water quality is often tied to water quantity and the synchronization of monitoring quality and quantity variables will provide managers with an improved understanding of water quantity/quality relationships in MORR. Monitoring of waters should not be limited to streams, and the NPS should continue to utilize habitats such as vernal pools to assess ecological integrity. Any wetland complexes adjacent to park boundaries should be proactively conserved as these environments benefit the park's wildlife community and enhance landscape connectivity.

Sampling for aquatic invasive species also needs to be increased to at least an annual cycle. There are a number of problem species within the region, making MORR vulnerable to invasion, yet sampling frequency is too low to make a quantitative assessment of the problem. Data needs include continued surveys, population estimates and mapping to determine the extent and trend of non-indigenous invasive aquatic species within MORR's watersheds. MORR would benefit from early detection strategy lists for aquatic environments, similar to what has been created for forested systems. Also, continued sampling for invasive species in MORR's terrestrial ecosystems will provide valuable

temporal data useful for management actions. At the present, areas such as wetlands within MORR are unassessed while forest systems within MORR are systematically sampled for invasive species.

MORR is unique in that the forest habitats in the park not only serve as a natural resource but as a cultural resource. Forest health issues in MORR are present, as pests and abundances of snags, coarse wood debris and tree mortality and growth rates remain some of the issues in the park. Continued forest plot assessment is planned and will aid in the long-term planning of forest management and trend detection of forest health metrics. Supplementary forest monitoring plots should be considered in vegetation associations of significant or rare occurrence. Canopy gaps from Superstorm Sandy are evident in MORR and the storm's aftermath presents new natural resource management issues and monitoring questions for MORR and the NETN.

MORR contains a diverse wildlife community due to a landscape matrix of streams, wetlands, and forests. MORR's fish community data was sparse and trend analysis was thereby limited. Fish communities need to be sampled on a 5-year basis in order to develop some understanding of trends. Several streams in the park scored *Warrants Moderate Concern* and these streams should be further assessed to investigate if stream restoration efforts are needed. The fish community survey is especially important for the evaluation of the native brook trout population in the watershed. This species of fish is sensitive to water quality degradation and thus can be used as an indicator species to assess stream habitats.

MORR provides important forest habitat for birds that are Neotropical migrants and also resident species. Management should focus on maintaining the health of the forest and ensuring an understory for mid-canopy nesters. Additionally, management of nonnative invasive plant species (that prevents native tree regeneration) and maintaining deer numbers at levels where effects of deer on regeneration are minimal are important management objectives to continue within the park. Overall, the forest avian rankings for MORR are very good given the urban landscape that surrounds the park. However, parks (such as MORR) that have relatively small areas of forest habitat or forest that is fragmented by roads, managed landscapes, and open habitat will tend to have lower ecological assessment scores just by virtue of the fact that the forest patches are small with relatively large amounts of edge habitat. The avian index used by NETN can still be useful in terms of monitoring direction of change. The goal should be to maintain or improve the score instead of a goal of obtaining a score of good in all categories. This goal may be unattainable given the configuration of the park and the other management mandates.

Since MORR currently contains a highly palatable vegetation structure for deer, the current quantification of deer densities within the park and adjacent areas would assist in assessing the effects of white-tailed deer on herbivory. Tree regeneration in MORR is a significant concern and data collected in MORR illustrated that seedling and sapling densities were below levels required to adequately restock the forest canopy in MORR (Miller *et al.* 2012). Since there is a lack of seedlings that survive for more than a few year in MORR, these areas should be monitored to find out why seedlings are not surviving (i.e., soil chemistry, canopy density). Tulip poplar regeneration was absent in the park and oak was rare in MORR. Deer browsing is frequently cited as a reason for failure of regeneration in oak communities of eastern parks (e.g., Storm *et al.* 1989, Healy 1997).

The park contains amphibian and reptiles species which have been identified as declining or are 'listed' at the State level (e.g., wood turtle and eastern box turtle are NJ State listed species). Therefore, it is important to consider the long-term preservation and connectivity of upland and wetland areas in order to protect the sustainability of populations. For example, the wood turtle (*Clemmys insculpta*) not only utilizes NPS property but also the property of the Scherman-Hoffman Sanctuary of the NJ Audubon Society, located south of MORR's New Jersey Brigade Unit and therefore working to preserve the integrity of this connectivity is vital to sustaining this population. MORR's aquatic systems which serve as habitats for several amphibians were rated as *Warrants Moderate Concern*. Cat Swamp Pond contains most pond breeding amphibian activity and preservation of this habitat is important in order to maintain successful reproduction for amphibian species. Several factors have been identified as contributing to the regional decline of amphibian and reptile species and park personnel are limited in their ability to control most of these factors. Factors such as continued suburban development and population expansion create unpolluted habitats and thus those habitats are at risk of declining, with the avenues for safe immigration or emigration decreasing. However within the park, activities such as mowing during periods of high turtle nesting prevalence in fields can reduce the survival of these species and park personnel can reassess such activities while still maintaining both the cultural integrity and biological integrity of the park.

Finally, MORR is located in a setting where development will continue to expand towards the park and within the park's viewshed. It is possible that as the population increases in areas around MORR, the demand for recreational space will increase, creating further pressure on MORR's natural and cultural resources. It is imperative for park personnel to continue their interactions with the local and surrounding communities, especially in areas where the possibility exists for increasing buffers and enhancing habitat connectivity around the park. Soundscape and lightscape analyses will provide further information regarding how external developments may be affecting MORR's natural and cultural resources. Keeping external impacts secluded from MORR is challenging, but it is the most important management action the park can enact in order to protect the natural and cultural resources of this national historical park.

### **Potential Natural Resource Indicators to Assess in MORR**

Natural resource vital signs monitoring is a long-term survey and analysis of data are used to predict/detect natural or human-induced changes in resource conditions. The data collected for these indicators are then used to determine if natural resource condition objectives within the park are being achieved. Additionally, they provide a rationale for management actions within the park. NETN vital sign indicators have been used in this NRCA to characterize the status and determine trends of MORR's natural resources and to provide early warning of impending threats. Several indicators are possible to assess the status and trends due to the unique natural resources within MORR. Although many indicators have been used in this NRCA to assess the park's natural resource conditions, other indicators may provide further information on the status and trends of MORR's natural resources. Below is a listing of natural resource indicators (listed in no particular priority) which may be beneficial to the park's future management of its natural and cultural resources. We have also noted some of these indicators in the *Data Gaps and Confidence in Assessment* sub-sections of this report. It is recognized that the NPS NETN has 'Protocols in Development' or have

written 'Protocol Development Summaries' for several indicators which the authors feel are important in assessing MORR's natural resources but are not listed below since they have been recognized by the NETN staff. These indicators include: Visitor Use, Landscape Dynamics, Phenology and Weather and Climate ([http://science.nature.nps.gov/im/units/netn/monitor/monitoringprotocols\\_vital.cfm](http://science.nature.nps.gov/im/units/netn/monitor/monitoringprotocols_vital.cfm)).

## ***Soils and Geology***

### Geomorphology

#### *Stream Morphology and Characteristics*

The physical characteristics of stream channels, along with water quality, shape the biological assemblages in streams. Thus, status and trends in biological integrity of stream systems requires information on stream characteristics and therefore stream geomorphology should be considered

along with any stream faunal groups selected for monitoring. Physical habitat requirements and preferences vary among individual species and the life stages of species. Stream morphology and characteristics affect biological communities through their influence on energy flow. Variables such as bed roughness, pool-riffle ratios and the amount of organic matter within the channel are primary factors of carbon and nutrient flow and retention for lotic systems (Brookshire and Dwire 2003). Channel geomorphologic measures change due to both natural and anthropogenic factors. In undisturbed watersheds, climate, geology and topography determine stream characteristics (Gordon *et al.* 2004). Increases in impervious surface due to urbanization within a watershed may cause higher storm flows which leads to changes in stream size due to bank erosion and increased sedimentation, thus increasing substrate embeddedness for riffle areas and creating less complex pool habitats (Richards *et al.* 1996, Snyder *et al.* 2003). From a natural resource management perspective for the park, it would be important to evaluate threats to stream habitat and assess the needs for restoration efforts.

The NETN collects annual stream hydrogeomorphic data at various monitoring sites in MORR. Although the park follows the U.S. EPA protocol for collecting these types of data, several other stream characteristics can be measured, depending on the overall objective(s) of the NETN's Vital Signs. Identification of stream characteristics allows for better design in monitoring programs and can be monitored on a periodic or infrequent basis or can be guided by changes occurring in the watershed around MORR. Stream characteristic measurements can be collected in conjunction with water quantity and water chemistry parameters. Measures of stream characteristics include, but are not limited to: channel width, substratum size distributions, substrate embeddedness, amount of coarse woody debris, pool-riffle ratios, bank stability measures and stream canopy coverage. However, questions remain as to the frequency of monitoring for some metrics such as substrate composition because changes in substrate composition are related to the frequency of high flow events. Methods of assessment include a quantitative assessment that involve detailed measurements of stream channel and bank characteristics and a qualitative visual-based rapid assessment that involves relative rankings of important stream habitat features.

## **Water**

### Water Quantity

#### *Groundwater inputs and levels*

Watersheds consist of a network of streams, riparian zones and wetlands that are supported by various combinations of precipitation, surface water and groundwater. MORR currently has surface water quantity and quality data collected from its aquatic habitats. Assessing the groundwater inputs and levels enables an assessment of the hydrological alterations and external land use or development occurring in the watershed. MORR contains six groundwater monitoring wells, but these wells were last sampled in 2003 by USGS. Groundwater measures become important if extraction of water resources increases due to industrial development, agricultural uses or population growth.

Groundwater measurements are important to diagnosing stressors in watersheds and documenting deviations from reference hydrologic conditions is critical for identifying hydrologic stressors. From a park management objective, it is important to understand changes in local groundwater hydrology in relation to natural processes and land use change. Quantifying the status and trends of groundwater measures typically are taken from wells and piezometers placed at various depths into soil and geologic strata. Strategic consideration should be given to the locations of sampling stations. The sampling regime for hydrologic measurements should be coordinated with surface hydrological measurements and water quality data collection to allow the computation of loadings and to increase efficiency.

### Water Quality

#### *Aquatic Macroinvertebrates*

Aquatic macroinvertebrates are aquatic and semi-aquatic invertebrates that inhabit the benthic (bottom) region of the stream. They are important links in stream food webs and are instrumental in nutrient and carbon dynamics (Webster 1983). Aquatic macroinvertebrates are sensitive to a wide range of instream, riparian and landscape features that vary naturally and are altered by human disturbance. Stream channel characteristics, water quality, water quantity, aquatic vegetation assemblages and landscape changes are linked to aquatic macroinvertebrate assemblage patterns. Macroinvertebrate communities would be ideal species to monitor since MORR experiences stream bank erosion and deposition. Currently, only the confluence of East and West Primrose Brook are sampled annually by the NJDEP volunteer monitoring program. Because MORR has smaller tributaries present representing several different gradients, other biological indicators such as fish and periphyton may not serve as the best biological indicator species due to their low abundances. Benthic macroinvertebrates are good indicators of local conditions because most benthic species are either sessile or are limited in migration. Additionally, they exhibit wide variation in tolerance among species and life stages to environmental stresses. Furthermore, many species have long life cycles relative to other groups which allow inferences to be made regarding temporal trends. For example, most invertebrate life cycles are accomplished in a single year and thus macroinvertebrates can integrate the physical, chemical and biological environment in a short time period. Most biological monitoring programs that use aquatic macroinvertebrates derive a suite of Index of Biological Integrity (IBI) metrics from field samples that are based on the structure and function of the entire



assemblage to infer the ecological condition of a habitat. Sampling aquatic macroinvertebrate assemblages is relatively easy and inexpensive and has minimal effects on resident biota (Rosenberg and Resh 1992, Barbour *et al.* 1999). Numerous individual assemblage response metrics can be calculated from macroinvertebrate sample data but variation of accuracy occurs among metrics. Several State and Federal agencies use aquatic macroinvertebrates in their biological monitoring programs. Rapid bioassessment protocols for sampling stream macroinvertebrates have been developed by the U.S. EPA (Barbour *et al.* 1999). Timing of aquatic macroinvertebrate sampling is critical for obtaining comparable data (seasonality) and regional taxonomic experience is required to identify organisms to levels beyond the Order stage in the field. Generic or species level identifications normally require laboratory processing.

## ***Biological Integrity***

### Focal Species/Communities

#### *Fish Communities*

Fish are important components of most healthy streams and the condition of fish populations is commonly of interest to the public due to their importance in terms of recreation and food. Fish assemblages are influenced by a wide range of instream, riparian and landscape features that vary naturally as well as being altered by human disturbance. The composition of the fish community in MORR may be altered due to changes in water chemistry from surrounding development, invasive species colonization or sedimentation. Thus, it is important to assess changes in fish communities, especially native brook trout populations, and determine the need for management and restoration efforts since. Streams in MORR have been classified as trout production streams, which include streams where young of the year trout may be found, indicating a nursery or spawning site. Trout reproduction is desired in cool waters of high quality, a rating granted to less than 5% of streams in NJ (Hudy 2005). Specifically, trout production streams in MORR are classified as Fresh Water Two, Category One (FW2-C1) waters by NJDEP. The C1 categorization is designated to waters of exceptional values based on water quality, scenic setting, recreational significance, ecological significance, water supply or fisheries resources. Additionally, Indian Grove Brook and a section of Passaic River have been designated as “Wild Trout Streams” by the NJ Division of Fish, Game and Wildlife. This designation identifies a viable wild trout population and regulates stocking and fishing. The Eastern brook trout (*Salvelinus fontinalis*)-New Jersey’s official state fish, the only trout species native to New Jersey waters, and resident to MORR’s streams-is a highly valued sport fish, along with being an important water quality indicator. However, brook trout populations have been dramatically impacted over the years in New Jersey due to degraded habitats and poor quality waters. Conservation and restoration strategies are needed in order to maintain existing brook trout populations in New Jersey waters.

Fish have several characteristics that are advantageous from a biological monitoring and assessment perspective, including being relatively easy to collect and identify. Their longevity in stream and mobility make fish species good indicators of long-term effects and broad habitat conditions and their life histories and environmental requirements of most species are well documented (Karr 1986, Barbour *et al.* 1999). Fish populations (excluding young-of-year) tend to be stable throughout the

year because most species reproduce only once a year. Thus, a single sampling during the relatively long period of base flow conditions is generally all that is required to adequately assess fish assemblages within a stream reach. Electrofishing has been shown to be the most effective sampling technique for collecting information on the broad fish community. Multivariate analyses and multi-metric approaches (i.e., index of biotic integrity [IBI]), are commonly used to analyze fish community data. Fish community measures can be an excellent indicator of ecological condition in streams, but fish sampling is more expensive and labor intensive than periphyton and macroinvertebrate sampling. However, because they are longer lived, fish assemblage metrics provide a better indicator of long-term trends in ecological condition than other groups. The Park should take advantage of collaborations with State, Federal and academic research entities in order to reduce costs associated with sampling. Additionally, monitoring only brook trout populations can also reduce costs, as these fish serve as water quality indicators and are an important native recreational fish.

### *Herpetofauna*

Herpetofauna refers to the amphibian and reptile populations of a specific region, such as frogs, toads, turtles, salamanders, snakes, terrapins and lizards. Herpetofauna have been reported to be in decline worldwide and have been identified as indicators of ecosystem stress (Welsh and Ollivier 1998). Impacts of global climate change, atmospheric deposition and air pollution would most likely be apparent in herpetofaunal communities before they would in other sectors of the terrestrial ecosystem. Therefore, the health and diversity of herpetofauna in MORR could be monitored in order to provide indications of ecosystem changes. Additionally, amphibians are sensitive to changes occurring in the environment. Amphibians are experiencing extinctions and population declines due to habitat destruction, changing climate, disease and contaminants (Blaustein and Wake 1990, Beattie and Tyler-Jones 1992, Rohr and Madison 2003). For example, streamside salamanders appear to be responsive to multiple stressors and because of its high sensitivity to anthropogenic perturbations, the red-backed salamander has been widely used as indicator for monitoring forest ecosystems (Patrick *et al.* 2006). Vernal pool amphibians can be viewed as indicators of the condition of a larger forested ecosystem since they require un-degraded aquatic and terrestrial habitats to successfully complete their life cycles and need intact corridors between two habitats for migration. The extreme sensitivity of amphibians to environmental stressors and their ubiquitous distribution make this group an important focal species to be included in the park's monitoring program.

Relative density and diversity are the commonly-used measures to describe herpetofauna in forested ecosystems and an Index of Biotic Integrity for amphibians has been created for wetland habitats in some states (Micacchion 2004). Because of the difficulty of sampling, it may be hard to find certain species, especially at times of the year when they are inactive or hibernating, so sampling should focus on areas of prime habitat and should be conducted at times when target species are active. There are a variety of sampling methods used to collect and inventory herpetofauna and include drift fences for snakes and terrapins, funnel traps for frogs, toads and newts and coverboards for inventorying salamanders. Even different life stages can be enumerated such as counting the number of egg masses laid in vernal pools. Since there are several species of herpetofauna to inventory, it

may be difficult, time-consuming and expensive to attempt to inventory them all each year and a staggered schedule would allow monitoring a proportion of the species each year.

#### *Non-vascular plants*

Non-vascular plants species (mosses, lichens, liverworts, and fungi) are a poorly known component of MORR despite their ecological and aesthetic importance. Non-vascular plants play a role in forest ecosystems by providing habitat for a variety of insects and small vertebrates. Many non-vascular plants live as epiphytes, or in exposed locations such as cliffs, rocks and dead logs. They are exposed to extreme weather conditions and rely on nutrients dissolved in rainwater, or deposited in particulate matter from the atmosphere. Due to this reason, these plants are vulnerable to changes in the chemistry of the atmosphere and precipitation. They are known to be sensitive to precipitation chemistry and air quality such as sulfates or heavy metals (Hawksworth and Hill 1984, Bates *et al.* 1996, Insarov *et al.* 1999). Therefore, these species may be useful indicators of ecosystem health. Declining abundance and diversity on non-vascular plants should raise concerns regarding the health of the Park's ecosystem. However, prior to identifying key species for long-term monitoring and the development of monitoring protocols, MORR needs a better inventory of non-vascular plants and estimates of their abundances. Development of species lists, surveys of abundance and distribution and identification of key species for future research and long-term monitoring is needed. An initial inventory of species density and diversity would serve as a baseline for subsequent samples. Any changes observed over time may correlate with known changes in the environment. Long term stability of populations of non-vascular plants would be one indicator of ecosystem stability. Sampling could be stratified by types of ecosystems in MORR and the method of sampling would depend on the organism being inventoried (e.g., mosses would have a fixed area plot where epiphytic lichens would be counted on individual trees). Changes in non-vascular communities would be expected since forests are continuously changing due to succession and natural disturbance. However, if the rate of change of non-vascular plant communities is inconsistent with a natural process, then the change may be a cause for concern.

#### *Terrestrial Invertebrates*

Terrestrial invertebrates include species such as insects and arachnids, among others. These invertebrates perform ecosystem functions such as the breakdown of litter and woody debris, serve in the pollination, seed dispersal and spore distribution of plants and fungi and are food sources for higher level trophic organisms. Invertebrates also promote soil aeration, thereby reducing soil compaction. Invertebrates may serve as indirect indicators of ecosystem health, as their diversity and ubiquitous occurrence and abundance is determined by the health and abundance of their food sources (Kermen *et al.* 1993; Taylor and Doran 2001). Specific species such as ground beetles and tiger beetles have been shown to be indicators of ecosystem health (Pearson and Cassola 1992, Rainio and Niemela 2003). Invertebrate populations may be affected by atmospheric pollution or they may indicate changes in the weather and climate. Diversity of species like butterflies can serve as indicators of ecosystem changes, such as global warming and rainfall patterns (Pollard 1998). Additionally, mowing and habitat alterations within MORR can affect invertebrate species breeding habitats. For example, frequent mowing during the breeding season can have detrimental effects on Lepidoptera species due to a direct result of mowing or as an indirect effect on host plant availability

(Wynhoff 1998). Habitat alterations may impact wetland habitats, allowing invasive vegetation to become established, thus creating an unsuitable habitat for the breeding of Odonata species (dragonflies and damselflies).

Assessing the status and trends of the community structure and composition of certain terrestrial invertebrates species serve as an index to changes in ecosystem health and will alert park managers to changing conditions of MORR's habitats. Sampling these populations can be a time consuming and costly task due to the diversity of terrestrial invertebrates. Therefore, the monitoring of selected indicator species located in various forest cover types and wetlands in MORR would be needed in order to maximize information gained while minimizing efforts needed for inventories (Oliver and Beattie 1996). Baseline inventory information would be needed for MORR and metrics such as density, distribution and diversity of the indicator species can be measured over time to compare with baseline data. Monitoring can be conducted on an annual basis for assessing changes in the indicator invertebrate species in order to track changes to MORR's ecosystem.

### *Mammals*

Mammal assessments focus on target species including mesocarnivores (e.g., raccoon, striped skunk, bear), small mammals (e.g., mice, shrews, squirrels) and volant mammals (bats). Because carnivores have a high trophic level and require large habitat ranges, mammal conservation can be indicative of healthy ecosystem functioning which will benefit other species. Mammals are susceptible to habitat fragmentation within and surrounding the park because of their need for large area requirements and the degree of fragmentation can reduce genetic diversity of a species (Turner 1996, van Manen *et al.* 2001). Additionally, habitat structure can be altered by encroachment of invasive exotic species, shifts in understory structure due to deer overgrazing or changes in overstory canopy from pests and pathogens, all factors which are occurring in MORR (Mahan and Yahner 1999, Muzika *et al.* 2004, Rooney *et al.* 2004). Furthermore, climate change may also influence mammals that are less mobile (Burns *et al.* 2003). Because of the variation in mobility, habitat requirements and size of many different mammals, monitoring may be more effective by selecting target species in order to assess changes in mammal communities. Evaluation of current community structure, composition and distribution of mammals in MORR can be accomplished using a variety of methods including visual and scat surveys, camera traps, and scent postings. Small mammals can be surveyed using live and pitfall traps in multiple habitat types, while mistnetting, acoustic surveys, direct counts, density of guano deposits and harp traps may be used for surveying bat populations. The last mammal inventory in MORR was conducted in 2004 by USGS.

### *Wetland and Riparian Communities*

Riparian and wetland communities include vegetation and animals that inhabit areas along rivers, streams and seasonally flooded inland areas such as vernal pools. NETN has identified wetlands as a key "Vital Sign" or indicator of ecological condition for long-term monitoring in NETN parks, yet monitoring freshwater wetlands is a low priority for the National Historical Parks and Sites in NETN. Furthermore, vernal pools are present in most, if not all NETN parks, but are not mapped as part of the National Wetland Inventory. Climate, hydrology, water chemistry, species composition, landuse/landcover, invasive exotic species, acid deposition and stress, contamination and nutrient

enrichment have been identified as key wetland indicators to monitor by NETN. Wetlands and riparian zones represent important community types within Morristown National Historical Park. Ecologically, they provide habitat for a diversity of flora and fauna. At the local and regional levels, the park's wetlands provide for landscape diversity. In terms of water quality, wetlands can improve or maintain water quality by nutrient removal and retention, chemical and microbial processing of some organic constituents, and by trapping and reducing suspended sediment loads. Additionally, the issue of flooding is particularly relevant in the lower Passaic River watershed and wetlands play a particular role in natural flood control in this region.

Riparian plant communities are particularly vulnerable to invasive species because their linear nature exposes them to large areas containing potential invaders (Simberloff *et al.* 2005). Most plant species classified as invasive tend to concentrate along forest edges other areas of disturbance that may include wetlands and riparian areas (Woods 1997, Walker and Smith 1997). *Microstegium vimineum* (Japanese stiltgrass) is a grass can become particularly abundant in along stream banks and in floodplains. This species is a NETN indicator species and is also present in MORR. It is shade tolerant, readily disperses and suppresses other herbaceous species.


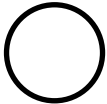


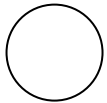





Animals have been identified as potential indicator species for wetland and riparian habitats. Most amphibian species require both terrestrial and aquatic habitats at various times of their life cycles, although some species spend considerably more time in truly aquatic habitats. Vernal ponds host breeding frogs and salamanders and streamside salamanders have been identified as potential indicator species. Concern over the status of amphibians has increased in recent years due to evidence of global and regional population declines, range reductions and extinctions and losses have been reported in fairly pristine areas (i.e., National Parks) (Blaustein and Wake 1990, Wyman 1990). Additionally, a variety of bird species use riparian areas as habitat, and several species and selected guilds have been shown to respond to degradation of these ecosystems (Croonquist and Brooks 1993, Brooks *et al.* 1998).

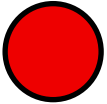

Generally, monitoring of wetland and riparian communities will enable park managers to assess changes in wetland and riparian communities and determine the need for management and restoration efforts. Assessing the impacts of wetland surface and ground water levels due to adjacent development activities as well as investigating the response of vegetation composition, structure and wetland boundaries to changing hydrological, water quality and climatic factors can be addressed through monitoring of the parks wetland and riparian communities. Metrics proposed for wetland and riparian communities would incorporate those already established or proposed for other Vital Signs, such as metrics for hydrological characteristics (surface and ground water levels), soils, plant species composition and vegetation structure of various wetland types, small mammal surveys and herpetofaunal surveys. Particular attention to rare species occurrences and notation of critical habitat characteristics is recommended.



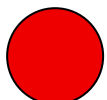

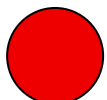
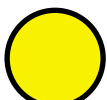
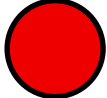








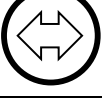
**Table 5.1.** MORR natural resource condition status for selected measurements. See legend at bottom for condition status symbol definitions.





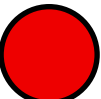

**Key to Symbol Definitions**

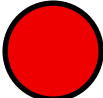
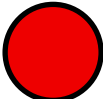
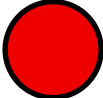


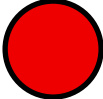

Condition Status		Confidence in Data		Trend	
	Warrants Significant Concern		High		Condition is Improving
	Warrants Moderate Concern		Medium		Condition is Deteriorating
	Resource is in Good Condition		Low		Condition is Unchanging
	An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence				

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Air & Climate	Air Quality	Ozone		NPS ARD calculations from 2006-2010 indicated park ozone level was 79.4 ppb. (1)	Exceeds regulatory threshold of 75 ppb and the NPS ARD <i>Resource is in Good Condition</i> rating of 60 ppb.(1)	Data for trend not available. (2)
Air & Climate	Air Quality	Wet Nitrogen Deposition		NPS ARD calculations from 2006-2010 indicated park level was 5.2 kg/ha/yr. (1)	Exceeds NPS ARD <i>Resource is in Good Condition</i> rating of <1 kg/ha/yr. (1)	No statistical trend detected.(3)







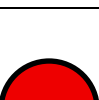
Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Air & Climate	Air Quality	Wet Sulfur Deposition		NPS ARD calculations from 2006-2010 indicated park level was 5.6 kg/ha/yr. (1)	Exceeds NPS ARD <i>Resource is in Good Condition</i> rating of <1 kg/ha/yr.(1)	Statistically decreasing for NJ99 station.(3)
Air & Climate	Air Quality	Mercury (Hg)		Hg levels were 9.4±8.3 ng/L at neighboring Hg monitoring station from 2006-2009. (4)	Equated a 2 ng/L threshold to 0.5 MeHg mg/kg wet weight in freshwater fish. (5)	Trend not assessed for park although eastern U.S. trend is decreasing for Hg in wet deposition. (6)
Air & Climate	Air Quality	Visibility		NPS ARD calculation from 2006-2010 indicated park levels was 11.0 dv. (1)	Exceeds NPS ARD <i>Resource is in Good Condition</i> rating of ≤2 dv. (1)	Trend not assessed for MORR. (1)
Geology & Soils	Forest Soil Dynamics	Ca:Al		NPS NETN sampling Ca:Al median 5.35. (7)	NPS NETN <i>Resource is in Good Condition</i> categorical rating of median Ca:Al >4. (7)	Statistical trend not assessed
Geology & Soils	Forest Soils Dynamics	C:N		NPS NETN sampling C:N median 14.34. (7)	NPS NETN <i>Resource is in Good Condition</i> categorical rating of median C:N>25. (7)	Statistical trend not assessed.
Geology & Soils	Soil Feature	Slope Constraints	 	Moderate (all non-Riparian Area lands having a slope of 15% to less than 20% which are forested) and severe (all land >20% slope and riparian areas ≥10% slope) slope constraints in all 4 park units which can increase soil and water runoff. (9)	Limited slope constraints: 15-20% slope in non-forested areas. (9)	Statistical trend not assessed.

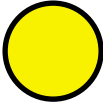

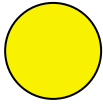
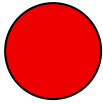
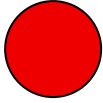

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Water	Stream Water Quantity	Quantity/Flow		No in park long term water quantity data available. NRCA discusses short term stream discharge in MORR and the impact of water consumption in the county.	Lack of park baseline data to serve as reference condition for park.	Statistical trend not assessed.
Water	Stream Water Chemistry (E. Primrose, Primrose confluence, Indian Grove, Passaic, W. Primrose)	Temperature		NPS NETN sampled streams and average temperatures were calculated. (10,11,12)	NJ State standard is $\leq 22^{\circ}\text{C}$ for FW2-TP streams(10,13)	No statistical trend detected. (11,12)
Water	Stream Water Chemistry (E. Primrose, Passaic River)	Dissolved Oxygen		NPS NETN sampled streams 2006-2012. Average value for streams ranged from 9.7-10.8 mg/L. (10,11,12)	NJ State water standards: FW2-TP streams shall not be $< 7.0$ mg/L. (10,13)	No statistical trend detected. (11,12)
Water	Stream Water Chemistry (Primrose confluence, Indian Grove, W. Primrose)	Dissolved Oxygen		NPS NETN sampled streams 2006-2012. Average values for streams ranged from 9.5-9.7 mg/L. (10,11,12)	NJ State water standards: FW2-TP streams shall not be $< 7.0$ mg/L. (10,13)	Decreasing trend. (11,12)
Water	Stream Water Chemistry (Indian Grove, Passaic River)	pH		NPS NETN sampled streams 2006-2012. Average values for streams ranged from 7.3-7.4. (10,11,12)	NJ State water standards: $6.5 \leq \text{pH} \leq 8.5$ . (10,13)	No statistical trend detected. (11,12)
Water	Stream Water Chemistry (East Primrose, West Primrose, Primrose confluence,.)	pH		NPS NETN sampled streams 2006-2012. Average values for streams ranged from 7.1-7.4. (10,11,12)	NJ State water standards: $6.5 \leq \text{pH} \leq 8.5$ . (10,13)	Increasing trend. (11,12)
Water	Stream Water Chemistry (Passaic)	Specific Conductance		NPS NETN sampled streams 2006-2012. Average values for stream was 226 ( $\mu\text{S}/\text{cm}$ ). (10,11,12)	Due to its natural variability, no criterion is recommended.	No trend detected. (11,13)

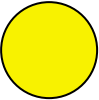




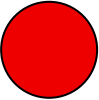

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Water	Stream Water Chemistry (E. Primrose, Primrose confluence, Indian Grove, W. Primrose)	Specific Conductance		NPS NETN sampled streams 2006-2012. Average values for streams ranged from 111-234 ( $\mu\text{S}/\text{cm}$ ). (10,11,12)	Due to its natural variability, no criterion is recommended.	Increasing trend. (11,13)
Water	Stream Water Chemistry (E. Primrose, Primrose confluence, Indian Grove, Passaic, W. Primrose)	Acid Neutralizing Capacity		NPS NETN sampled streams 2006-2012. Average values for streams ranged from 452-685 (mg/L), with 86.7-100% of individual samples within criteria. (10,11,12)	Criteria includes ANC > 5 (mg/L) (100 $\mu\text{eq}/\text{L}$ ). (10,13,14)	Statistical trend not assessed.
Water	Stream Water Chemistry (E. Primrose, Primrose confluence, Indian Grove, Passaic, W. Primrose)	Chloride		From samples collected in 2001-2004, average values ranged from 17-46 mg/L. (12,13)	New Jersey criteria for aquatic life for FW2 streams is 230 mg/L (chronic) and 860 mg/L (acute). (13)	Increasing trend.
Water	Stream Water Chemistry (Primrose confluence, Passaic)	Total Nitrogen		NPS NETN sampled streams 2006-2012. Average values for streams ranged from 0.43-0.68 (mg/L). (10,11,12)	0.69 mg/L (streams). (10,15)	Statistical trend not assessed.
Water	Stream Water Chemistry (E. Primrose, Indian Grove, W. Primrose)	Total Nitrogen		NPS NETN sampled streams 2006-2012. Average value for stream ranged from 0.76-1.21 (mg/L). (10,11,12)	0.69 mg/L (streams). (10,15)	Statistical trend not assessed.
Water	Stream Water Chemistry (Primrose confluence, Indian Grove, Passaic,)	Total Phosphorus		NPS NETN sampled streams 2006-2012. Average value for stream ranged from 21.33-30.35 ( $\mu\text{g}/\text{L}$ ). (10,11,12)	36.56 $\mu\text{g}/\text{L}$ (streams). (10,15)	Statistical trend not assessed.


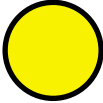
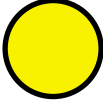
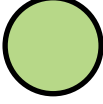
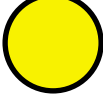
Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Water	Stream Water Chemistry (E. Primrose, W. Primrose)	Total Phosphorus		NPS NETN sampled streams 2006-2012. Average values for streams ranged from 59.77-195.09 (µg/L). (10,11,12)	36.56 µg/L (streams). (10,15)	Statistical trend not assessed.
Water	Stream Water Chemistry (E. Primrose, Primrose confluence, Indian Grove, Passaic, W. Primrose)	NO <sub>2</sub> +NO <sub>3</sub>		NPS NETN sampled streams 2006-2011. Average values for streams ranged from 0.200-0.920 (mg/L). (10,11,12)	0.125 mg/L (streams). (10,15)	Statistical trend not assessed.
Water	Stream Water Chemistry (Primrose Brook)	<i>E.coli</i>		Sampled streams 2006-2008. Average values for stream was 182 counts. (12,13)	Counts of 126/100 mL geometric mean (FW2 streams). (13)	Statistical trend not assessed.
Water	Stream Water Chemistry (Indian Grove, Passaic)	Total Dissolved Solids		Sampled streams 2006-2009. Average values for stream ranged from 106-115 mg/L. (12,13)	No increase in background or >500 mg/L. (13)	Statistically increasing.
Water	Stream Water Chemistry (E. Primrose, Primrose confluence, W. Primrose)	Total Dissolved Solids		Sampled streams 2006-2009. Average values for stream ranged from 52-55 mg/L. (12,13)	No increase in background or >500 mg/L. (13)	No statistical trend detected.
Biological Integrity	Invasive Exotic Plants-Forest	Key Species Per Plot		5.54 key indicator species per plot were detected in overall forest, 4.05 in mature and 8.67 in successional forest. (16)	<0.5 key indicator species per plot rates NETN parks in <i>Resource is in Good Condition</i> condition (16).	Statistical trend not assessed.
Biological Integrity	Invasive Exotic Plants-Aquatic	Present or Absent in HUC 8 and HUC 14 Watersheds	 <b>HUC8</b>	Invasive exotic plants are present in HUC 8 watersheds surrounding MORR and absent in HUC 14 based on USGS invasive plant	Absence of invasive species in habitats ideal reference condition.	Statistical trend not assessed.

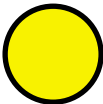

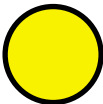
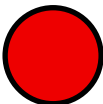
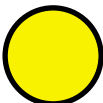


Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
			 HUC14	mapping. (17,18,19 20)		
Biological Integrity	Invasive Exotic Animals/Disease-Tree Species	Priority Pests Present		Using 2007, 2009 and 2011 data, it was assessed that approximately 60% of plots were <i>Resource is in Good Condition</i> . (16,21)	For NETN parks, foliage problem < 10% and no priority 1 or 2 pests and BBD ≤ 2. (16).	Statistical trend not assessed.
Biological Integrity	Invasive Exotic Animals/Disease-Aquatic	Present or Absent in HUC 8 and HUC 14 Watersheds		Invasive exotic animals are present in watersheds surrounding MORR. (17)	Absence of invasive species in habitats ideal reference condition.	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Anthropogenic Land Use		Averaged 5.3% based on 2007 and 2009 data analyses.(22)	<10% Anthropogenic land use around park considered <i>Resource is in Good Condition</i> by NETN criteria. (22)	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Forest Patch		2 large patches of 609.62 ha and 818.37 ha in MORR. (22)	>50 ha around park considered <i>Resource is in Good Condition</i> by NETN criteria. (22)	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Structural Stage Distribution		68% late successional, 100% mature and late successional. (21)	≥ 25% late-successional structure in park considered <i>Resource is in Good Condition</i> by NETN criteria. (21)	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Snag Abundance		1.79 (# of medium-large snags/ha). (16)	≥10% standing trees as snags and ≥ 10% medium-large trees as snags in park considered <i>Resource is in Good Condition</i> by NETN criteria. (16)	Statistical trend not assessed.


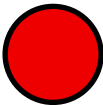
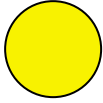

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Biological Integrity	Forest Vegetation	Coarse Woody Debris		6.66 % (overall) and 6,82% (mature) live tree volume. (16)	> 15% live tree volume in park considered <i>Resource is in Good Condition</i> by NETN criteria. (16)	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Biotic Homogenization		Unrated. NETN refining metric. However, plots present with non-native earthworms and Jaccard Similarity Index was 0.24. (22)	Metric being refined by NETN. (22)	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Tree Growth and Mortality Rates		Mean growth rate <60% and mean % mortality rate=1.50.(16)	Mean growth rate ≥60% of regional mean or mean mortality rate ≤1.6%. (16)	Statistical trend not assessed.
Biological Integrity	White-Tailed Deer Herbivory	Tree Regeneration		Seedling ratio range was - 1.00-0.61 and stocking index ranged from 11.37-13.15 for MORR. (16)	Seedling ratio ≥ 0 , stocking index >25 defined as <i>Resource is in Good Condition</i> by NPS NETN. (16,23,24)	Statistical trend not assessed.
Biological Integrity	White-Tailed Deer Herbivory	Deer Browse Index		Deer browse index calculated at 4.39, indicating browse evidence common and browse preferred species rare to absent. (16)	Plot located inside deer exclosure and no browse present. (16).	Statistical trend not assessed.
Biological Integrity	Fish Community (Indian Grove Brook, Passaic River)	NJ Fish IBI		Data was incomplete from survey to calculate true overall IBI score (25). Final range of potential scores for streams were 40-44 for Indian Grove Brook and 38-42 for Passaic River.	IBI used reference streams in NJ Fish IBI for Northern NJ streams to create Fish IBI ratings.(26)	Statistical trend not assessed.

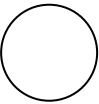
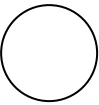
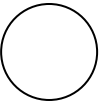
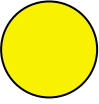
Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Biological Integrity	Fish Community (Jersey Brook)	NJ Fish IBI	 	Data was incomplete from survey to calculate true overall IBI score (25). Final range of potential scores for this stream was 26-30.	IBI used reference streams in NJ Fish IBI for Northern NJ streams to create Fish IBI ratings.(26)	Statistical trend not assessed.
Biological Integrity	Fish Community (West Primrose Brook)	NJ Fish IBI		Data was incomplete from survey to calculate true overall IBI score (25). Final range scores for this stream was 32-36.	IBI used reference streams in NJ Fish IBI for Northern NJ streams to create Fish IBI ratings.(26)	Statistical trend not assessed.
Biological Integrity	Fish Community (E. Primrose, Primrose Brook)	NJ Fish IBI	 	Data was incomplete from survey to calculate true overall IBI score (25). Final range of potential scores for streams were 34-38 for E. Primrose and 34-38 for Primrose Brook.	IBI used reference streams in NJ Fish IBI for Northern NJ streams to create Fish IBI ratings.(26)	Statistical trend not assessed.
Biological Integrity	Fish Community	Conservation Success Index (CSI)		Loantaka Brook scored a CSI of 48, with other subwatersheds around MORR scoring <i>extirpated</i> . (27,28,29)	CSI scores ranged from 20-100, with 100 representing the best reference condition.(27,29)	Statistical trend not assessed.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-exotic species (%)		0% based on data from 2006-2012. (30)	0% rates this IBI metric as <i>Resource is in Good Condition</i> . (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.




Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-nest predator/brood parasites (%)		8% based on data from 2006-2012.(30)	<10% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-residents (%)		29% based on data from 2006-2012. (30)	<28% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-single brood (%)		56% based on data from 2006-2012. (30)	>68% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-bark prober (%)		12% based on data from 2006-2012. (30)	>11% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-ground cleaner (%)		8% based on data from 2006-2012. (30)	>9% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-high canopy forager (%)		10% based on data from 2006-2012.(30)	>12% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-low canopy forager (%)		23% based on data from 2006-2012.(30)	>22% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-omnivore (%)		37% based on data from 2006-2012.(30)	<30% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-canopy nester (%)		29% based on data from 2006-2012.(30)	>35% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-forest ground nester (%)		15% based on data from 2006-2012.(30)	>18% rates this IBI metric as <i>Resource is in Good Condition.</i> (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.



Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-interior forest obligate (%)		35% based on data from 2006-2012.(30)	>35% rates this IBI metric as <i>Resource is in Good Condition</i> . (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-shrub nester (%)		25% based on data from 2006-2012.(30)	<18% rates this IBI metric as <i>Resource is in Good Condition</i> . (30,31,32,33)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Amphibians & Reptiles	Amphibian IBI & Population Trend		Average IBI score for MORR's habitats was 17 (IBI score of <i>fair</i> , thus <i>Warrants Moderate Concern</i> ) (34).	AmphIBI contains 5 metrics used to calculate IBI. Overall score of 30-50 rates waterbodies with IBI score of <i>excellent</i> . (35)	Statistical trend not assessed. Subjective trend analysis indicated more species stable, although some declining or unknown.
Human Use	Visitor Usage	Visitor Statistics & Characteristics		Environmental impacts from visitors unknown, but visitor trend statistics and population growth models indicate potential stress on resources.(36)	Increasing trend since park has been established indicate a 1.6% increase in visitation, with population growth in the region.(36)	Visitation increasing from 1941-2010 and decreasing from 2000-2010. Population growth in county increasing.

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Landscape Dynamics	Landscapes	Housing		Projected increase in number of housing units/km <sup>2</sup> within a 30 km <sup>2</sup> area around park.(37)(38)(39)	Condition categories not established. Modeled historic and future population projections from1970-2010 using a 30 km <sup>2</sup> buffer around park. (37)(38)(39)	Projected increasing trend.
Landscape Dynamics	Landscapes	Land Cover Change (acreage)-Urban		11% increase within park and 5km surrounding buffer.(40)	Condition categories not established.Compared historical land cover from 1988-2002 within park and adjacent 5 km buffer. (40)	Increased acreage.
Landscape Dynamics	Landscapes	Land Cover Change (acreage)-Mixed, Coniferous, Deciduous		19% and 61% decrease for mixed and coniferous and 35% increase for deciduous within park and 5km surrounding buffer. (40)	Condition categories not established.Compared historical land cover from 1988-2002 within park and adjacent 5 km buffer. (40)	Decreased acreage for mixed and coniferous, Increase acreage deciduous.
Landscape Dynamics	Landscapes	100 m buffers from roads and Patch Area from Roads > 500 m		Spatial analyses indicate that habitats and streams exist within 100 m of roads. Two patch areas exist from major roads with areas of 9.3 and 8.9 km <sup>2</sup> . These patches decrease with the presence of all roads in park to 0.32 and 0.40 km <sup>2</sup> (36)(40). These small patch areas are at a higher vulnerability to anthropogenic impacts. (37, 41, 42)	Ecological studies have suggested habitats <100 m away from roads may be affected. (37, 41, 42) (36)(40)	Statistical trend not assessed.

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Landscape Dynamics	Landscapes	% Impervious Coverage		MORR averaged < 10% of highly developed impervious coverage in park boundaries, with some areas near major roads containing up to 46% impervious coverage. (37, 39, 41)	Studies have found water and habitat quality is ' <i>Resource is in Good Condition</i> ' when impervious coverage is <10% . (43,44)	Statistical trend not assessed.
Landscape Dynamics	Soundscapes	Mean L <sub>50</sub> (dBA) Impact Level		Mean L <sub>50</sub> (dBA) impact Level for park was 6.3. (45)	Mean L <sub>50</sub> (dBA) impact threshold ≤ 1.5. Listening area reduced by ≤ 30% (45)	Statistical trend not assessed.
Landscape Dynamics	Lightscape	Anthropogenic Light Ratio (ALR)		ALR calculated at 15.00. (46)	ALR <0.33 (<26 nL average anthropogenic light in sky). At least half of park area should meet this criteria. (46)	Trend unchanging due to population stability around park.

### References and Data Sources

- (1) National Parks Service (NPS). 2013a. Methods for Determining Air Quality Conditions and Trends for Park Planning and Assessments Available from [http://www.nature.nps.gov/air/Planning/docs/AQ\\_ConditionsTrends\\_Methods\\_2013.pdf](http://www.nature.nps.gov/air/Planning/docs/AQ_ConditionsTrends_Methods_2013.pdf)
- (2) National Park Service, Air Resources Division (NPS). 2013b. Air quality in national parks: trends (2000–2009) and conditions (2005–2009). Natural Resource Report NPS/NRSS/ARD/NRR—2013/683. National Park Service, Denver, Colorado.
- (3) National Atmospheric Deposition Program (NADP). <http://nadp.sws.uiuc.edu/>.
- (4) Mercury Deposition Network (MDN). <http://nadp.sws.uiuc.edu/mdn/>
- (5) Meili, M., K. Bishop, L. Bringmark, K. Johansson, J. Muthe, H. Sverdrup, and W. deVries. 2003. Critical levels of atmospheric pollution: Criteria and concepts for operational modeling of mercury in forest and lake ecosystems. *The Science of the Total Environment* 304: 83-106.
- (6) Butler, T. J., M. D. Cohen, F. M. Vermeulen, G. E. Likens, D. Schmeltz, and R. S. Artz. 2007. Regional precipitation mercury trends in the eastern USA, 1998-2005: Declines in the Northeast and Midwest, no trend in the Southeast. *Atmospheric Environment* 42: 1582-1592.
- (7) Miller, K. M., G. L. Tierney, and B. R. Mitchell. 2010. Northeast Temperate Network forest health monitoring report: 2006-2009. Natural Resource Report NPS/NETN/NRR—2010/206. National Park Service, Fort Collins, Colorado.
- (8) Natural Resources Conservation Service (NRCS), United States Department of Agriculture (USDA). Web Soil Survey. Available online at <http://websoilsurvey.nrcs.usda.gov/>. Accessed January 16, 2013.
- (9) New Jersey Highlands Council. <http://www.highlands.state.nj.us/njhighlands/actmaps/maps/>. Accessed January 16, 2013.

- (10) Lombard, P., W. Gawley, J. Caldwell. 2006. Freshwater Vital Signs Monitoring Plan for National Parks in the Northeast Temperate Network (NETN) Phase III: Water Quality Monitoring Protocols in Lakes, Ponds and Streams: USGS, Augusta, ME, 222p.
- (11) NPS Northeast Temperate Network (NETN) raw stream data collected by NETN biologists.
- (12) United States Environmental Protection Agency (EPA). 2012. STORET/WQX Data Warehouse. [http://www.epa.gov/storet/dw\\_home.html](http://www.epa.gov/storet/dw_home.html). Accessed: February 1, 2012.
- (13) New Jersey Department of Environmental Protection (NJDEP). [Surface Water Quality Standards \(SWQS\), N.J.A.C. 7:9B](http://www.nj.gov/dep/wms/bwqsa/swqs.htm). Available from <http://www.nj.gov/dep/wms/bwqsa/swqs.htm> (accessed 30 March 2011).
- (14) Stoddard, J., J. S. Kahl, F. Deviney, D. DeWalle, C. Driscoll, A. Herlihy, J. Kellogg, P. U. Murdoch, J. Webb, and K. Webster. 2003. Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990. EPA/620/R-03/001. Washington, D.C.: U.S. EPA.
- (15) United States Environmental Protection Agency (USEPA). 2000. Ambient water quality criteria recommendations. Information supporting the development of state and tribal nutrient criteria for rivers and streams in nutrient ecoregion IX. EPA 822-B-00-019. December 2000.
- (16) Miller, K. M., B. R. Mitchell, and J. S. Wheeler. 2012. Forest health monitoring in the Northeast Temperate Network: 2011 summary report. Natural Resource Technical Report NPS/NETN/NRTR—2012/604. National Park Service, Fort Collins, Colorado.
- (17) United States Geological Survey (USGS). 2004. Nonindigenous Aquatic Species Database, Gainesville, FL. Retrieved from <http://nas.er.usgs.gov>, March 3, 2010.
- (18) NJISST. 2011. New Jersey Invasive Species Strike Team. 2011 Target Plant List. <http://www.njisst.org> (accessed 30 January 2012).
- (19) EDDMapS. 2012. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available at <http://www.eddmaps.org/>. (accessed 25 January 2012).
- (20) Sneddon, L., R.E. Zaremba, E. Largay, G. Podniesinski, S. Perles and J. Thompson. April 2008. Vegetation Classification and Mapping of Morristown National Historical Park. Technical Report NPS/NER/NRTR—2008/116. National Park Service. Philadelphia, PA.
- (21) Miller, K. M., G. L. Tierney, and B. R. Mitchell. 2010. Northeast Temperate Network forest health monitoring report: 2006-2009. Natural Resource Report NPS/NETN/NRR—2010/206. National Park Service, Fort Collins, Colorado.
- (22) Miller, K. M., B. R. Mitchell, G. L. Tierney, and J. S. Wheeler. 2011. Northeast Temperate Network forest health monitoring report: 2010. Natural Resource Report NPS/NETN/NRR—2011/399. National Park Service, Fort Collins, Colorado.
- (23) Brose, P.H., K.W. Gottschalk, S.B. Horsley, P.D. Knopp, J.N. Kochenderfer, B.J. McGuinness, G.W. Miller, T.E. Ristau, S.H. Stoleson, S.L. Stout. 2008. Prescribing regeneration treatments for mixed-oak forests in the Mid-Atlantic region. General Technical Report NRS-33. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station, 100p.
- (24) Perles, S., J. Finley, M. Marshall. 2010. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network., Version 2. Natural Resource Report NPS/ERMN/NRR-2010/183. National Park Service. Fort Collins, Colorado.
- (25) Mather, M. E., A.J. Norris, M.P. Carey. March 2003. Freshwater Fish Inventory: Northeast Temperate Network, 1999-2001. Technical Report NPS/NER/NRTR—2005/16. National Park Service. Woodstock, VT.
- (26) Vile, J. 2010. *Fish IBI Report 2008 Sampling Round 2, Year 4 of 5. Volume 1-Summary*. NJ Department of Environmental Protection. Water Monitoring and Standards. Bureau of Freshwater and Biological Monitoring.
- (27) Trout Unlimited. 2007. Conservation Success Index. [www.tu.org/science/conservation-success-index](http://www.tu.org/science/conservation-success-index) (accessed 12 March 2012).
- (28) Trout Unlimited. 2009. Subwatershed Conservation Strategies. June 2009. [Tucsi.tu.org/Documents/CSI\\_Framework/ConservationStrategies.pdf](http://Tucsi.tu.org/Documents/CSI_Framework/ConservationStrategies.pdf) (accessed 19 March 2012).
- (29) Williams, J.E., A.L. Haak, N.G. Gillespies and W.T. Colyer. 2007. The Conservation Success Index: Synthesizing and Communicating Salmonid Condition and Management Needs. *Fisheries*. 32 (10): 477-493.

- (30) Faccio, S. D. and B. R. Mitchell. 2013. Breeding landbird monitoring in the Northeast Temperate Network: 2012 summary report. Natural Resource Data Series NPS/NETN/NRDS—2013/468. National Park Service, Fort Collins, Colorado.
- (31) Faccio, S. D., and B. R. Mitchell. 2009. Breeding landbird monitoring. Northeast Temperate Network 2008 Annual Report. Natural Resource Report NPS/NETN/NRR—2009/105. USDI, NPS, Fort Collins, CO.
- (32) Glennon, M. J. and W. F. Porter. 2005. Effects of land use management on biotic integrity: An investigation of bird communities. *Biological Conservation* 126: 499-511.
- (33) O'Connell, T. J., L. E. Jackson and R. P. Brooks. 2000. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Application* 10:1706-1721.
- (34) Brotherton, D.K., J.L. Behler, L. Williamson, and R.P. Cook. March 2005. Morristown National Historical Park Amphibian and Reptile Inventory March-September 2000. Technical Report NPS/NER/NRTR-2005/013. National Park Service. Woodstock, VT.
- (35) Micacchion, M. 2004. Integrated Wetland Assessment Program. Part 7: Amphibian index of biotic integrity (AmphIBI) for Ohio wetlands. Ohio EPA Technical Report WET/2004-7. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water. Columbus, OH. [http://www.epa.state.oh.us/dsw/wetlands/Integrated\\_Wetland\\_Assessment\\_Program\\_Part7\\_AmphIBI\\_formatted.pdf](http://www.epa.state.oh.us/dsw/wetlands/Integrated_Wetland_Assessment_Program_Part7_AmphIBI_formatted.pdf).
- (36) National Park Service NPS Stats-Public Use Statistics Office. 2011. Web Access: <http://www.nature.nps.gov/stats/>.
- (37) National Park Service NPScape data. 2012. <http://science.nature.nps.gov/im/monitor/npscape/> (accessed 12 January 2013).
- (38) United States Census Bureau. 2012. United States Census. <http://www.census.gov/> (accessed 12 September 2012).
- (39) Svancara, L., P. Budde, and J. Gross. 2009a. Measure Development Summary: Population and Housing. Office of Inventory, Monitoring, and Evaluation. National Park Service, Fort Collins, Colorado, USA.
- (40) Wang, Y. Q., and J. Nugranad-Marzilli. 2009. Land cover change in Northeast Temperate Network parks 1973-2002. Natural Resource Technical Report NPS/NETN/NRTR—2009/238. National Park Service, Fort Collins, Colorado.
- (41) Svancara, L. and M. Story. 2009b. Measure Development Summary: Land Cover / Land Use. Office of Inventory, Monitoring, and Evaluation, National Park Service, Fort Collins, Colorado, USA.
- (42) Gross, J.E., and L. Svancara. 2009. Measure Description Summary: Landscape Pattern. Office of Inventory, Monitoring, and Evaluation, National Park Service, Fort Collins, Colorado, USA.
- (43) Goetz, S. J., R. Wright, A. J. Smith, E. Zinecker, and E. Schaub, Ikonos imagery for resource management: tree cover, impervious surfaces and riparian buffer analyses in the mid-Atlantic region. *Remote Sensing of Environment* 88, 195–208, 2003.
- (44) Schiff R. and G. Benoit. 2007. Effects of impervious cover at multiple spatial scales on coastal watershed streams. *Journal of the American Water Resources Association* 43(3):712-730.
- (45) National Park Service Natural Sounds and Night Sky Division (per communication E. Lynch).
- (46) Data provided by the National Park Service Natural Sounds and Night Sky Division.



## Literature Cited

- Aber, J. D., K. J. Nadelhoffer, P. Steudler, and J. M. Melillo. 1989. Nitrogen saturation in northern forest ecosystems. *BioScience* 39: 378–386.
- Aber, J. D., C. L. Goodale, S. V. Ollinger, M. L. Smith, A. Magill, M. Martin, R. Hallett, and J. Stoddard. 2003. Is nitrogen deposition altering the nitrogen status of northeastern forests? *BioScience* 53:375–389.
- Alverson, W. S., D. W. Waller and S. L. Solheim. 1988. Forests to deer: edge effects in northern Wisconsin. *Conservation Biology* 2:348–358.
- Anderssen, S. H., R. B. Nicolaisen, and G. W. Gabrielsen. 1993. Autonomic response to auditory stimulation. *Acta Paediatrica* 82:913–918.
- Bank, M. S., C. S. Loftin, R. E. Jung. 2005. Mercury bioaccumulation in northern two-lined salamanders from streams in the northeastern United States. *Ecotoxicology* 14:181–191.
- Barno, L. 2008. Eastern Brook Trout: Species in Peril. New Jersey Fish and Wildlife Digest. Freshwater Fishing Issue. January 2008.
- Bates, J. W., P. J. Mcnee and A. R. Mcleod. 1996. Effects of sulphur dioxide and ozone on lichen colonization of conifers in the Liphook Forest Fumigation Project. *New Phytologist* 132(4): 653–660.
- Beattie, R. C. and R. Tyler-Jones. 1992. The effects of low pH and aluminum on breeding success in the frog *Rana temporaria*. *Journal of Herpetology* 26:353–360.
- Black, A. 2005. Light induced seabird mortality on vessels operating in the Southern Ocean: incidents and mitigation measures. *Antarctic Science* 17:67–68.
- Blaustein, A. R. and D. B. Wake. 1990. Declining amphibian populations: A global phenomenon? *Trends in Ecology and Evolution* 5:203–204.
- Boldogh, S., D. Dobrosi and P. Samu. 2007. The effects of the illumination of buildings on house-dwelling bats and its conservation consequences. *Acta Chiropterologica* 9:527–534.
- Boose, E. R., K. E. Chamberlin and D. R. Foster. 2001. Landscape and regional impacts of hurricanes in New England. *Ecological Monographs* 71:27–48.
- Bringmark, L. and E. Bringmark. 2001. Soil respiration to small-scale patterns of lead and mercury in mor layers of southern Swedish forest sites. *Water, Air and Soil Pollution* 1:395–408.
- Brooks, R. P., T. J. O'Connell, D. H. Wardrop and L. E. Jackson. 1998. Towards a regional index of biological integrity: The example of forested riparian ecosystems. *Environmental Monitoring and Assessment* 51:131–143.

- Brookshire, E. N. J. and K. A. Dwire. 2003. Controls on patterns of coarse organic particle retention in headwater streams. *Journal of the North American Benthological Society* 22:17–34.
- Brose, P. H., K. W. Gottschalk, S. B. Horsley, P. D. Knopp, J. N. Kochenderfer, B. J. McGuinness, G. W. Miller, T. E. Ristau, S. H. Stoleson, S. L. Stout. 2008. Prescribing regeneration treatments for mixed-oak forests in the Mid-Atlantic region. General Technical Report NRS-33. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.
- Brotherton, D. K., J. L. Behler, L. Williamson and R. P. Cook. March 2005. Morristown National Historical Park Amphibian and Reptile Inventory March-September 2000. Technical Report NPS/NER/NRTR-2005/013. National Park Service. Woodstock, VT.
- Bruce-White, C. and M. Shardlow. 2011. A Review of the Impact of Artificial Light on Invertebrates. *Buglife*, Peterborough.
- Bugler, A. J., B. J. Cosby and R. J. Webb. 2000. Current, reconstructed past and projected future status of brook trout (*Salvelinus fontinalis*) streams in Virginia. *Canadian Journal of Fisheries and Aquatic Sciences* 57: 1515–1523.
- Bullen, T. D. and S. W. Bailey. 2005. Identifying calcium sources at an acid deposition-impacted spruce forest: a strontium isotope, alkaline earth element multi-tracer approach: *Biogeochemistry* 74(1):63–99.
- Burns, C. E., K. M. Johnston and O. J. Schmitz. 2003. Global climate change and mammalian species diversity in U.S. national parks. *Proceedings of the National Academy of Sciences* 100(20):11474–11477.
- Butler, T. J., M. D. Cohen, F. M. Vermeulen, G. E. Likens, D. Schmeltz and R. S. Artz. 2007. Regional precipitation mercury trends in the eastern USA, 1998-2005: Declines in the Northeast and Midwest, no trend in the Southeast. *Atmospheric Environment* 42:1582–1592.
- Campbell, J. L., C. T. Driscoll, A. Pourmokhtarian and K. Hayhoe. 2011. Stream flow responses to past and projected future changes in climate at the Hubbard Brook Experimental Forest, New Hampshire, United States, *Water Resou. Res.*, 47, W02512, doi:10.1029/2010WR009438.
- Charles, E. G., C. Behroozi, J. Schooley and J. L. Hoffman. 1993. GSR 32 - A method for Evaluating Ground-Water-Recharge Areas in New Jersey. New Jersey Department of Environmental Protection and Energy. Division of Science and Research, Geological Survey. Trenton, NJ.
- Christie, R. G. and M. W. Sayre. 1989. White-tailed deer management study, Morristown National Historical Park. Final Report to the National Park Service, Boston, MA.
- Cinzano P., and C. Elvidge. 2003. Night sky brightness at sites from satellite data. *Memorie Societa Astronomica Italiana* 74:456–457.

- Clark, K. L. and R. J. Hall. 1985. Effects of elevated hydrogen ion and aluminum concentrations on the survival of amphibians embryos and larvae. *Canadian Journal of Zoology* 63:116–123.
- Clough, G. 1982. Environmental effects on animals used in biomedical research. *Biological Reviews* 57:487–523.
- Conant, R. and J. T. Collins. 1998. A Field Guide to Reptile and Amphibians: Eastern and Central North America. 3<sup>rd</sup> Edition Expanded. Boston: Houghton Mifflin Co.
- Cornett, M. W., L. E. Frelich, K. J. Puettmann and P. D. Reich. 2000. Conservation implications of browsing by *Odocoileus virginianus* in remnant upland *Thuja occidentalis* forests. *Biological Conservation* 93:359–369.
- Cronan, C. S., and D. F. Grigal. 1995. Use of calcium/aluminum ratios as indicators of stress in forest ecosystems. *Journal of Environmental Quality* 24:209–226.
- Croonquist, M. J. and R. P. Brooks. 1993. Effects of Habitat Disturbance on Bird Communities in Riparian Corridors. *Journal of Soil and Water Conservation JSWCA* 3, p 65-70, 23 ref.
- Davey, C. A., K. T. Redmond and D. B. Simeral. 2006. Weather and Climate Inventory, National Park Service, Northeast Temperate Network. Natural Resource Technical Report NPS/NETN/NRTR—2006/011. National Park Service, Fort Collins, CO.
- Driscoll, C. T., G. B. Lawrence, A. J. Bulger, C. S. Cronan, C. Eagar, K. F. Lambert, G. E. Likens, J. L. Stoddard and K. C. Weathers. 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem effects, and management strategies. *Bioscience* 51:180–198.
- Driscoll, C. T., D. Whitall, J. Aber, E. Boyer, M. Castro, C. Cronan, C. Goodale, P. Groffman, C. Hopkinson, K. Lambert, G. Lawrence and S. Ollinger. 2003. Nitrogen pollution in the northeastern United States: Sources, effects and management options. *BioScience* 3:357–374.
- Driscoll, C. T., Y.-J. Han, C. Y. Chen, D. C. Evers, K. F. Lambert, T. M. Holsen, N. C. Kamman and R. K. Munson. 2007. Mercury contamination in forest and freshwater ecosystems in the Northeastern United States. *BioScience* 57:17–28.
- Dumyahn, S. L. and B. C. Pinjanowski. 2011. Soundscape conservation. *Landscape Ecology* 26:1327–1344.
- Dunning, J. B., B. J. Danielson and H. R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. *Oikos* 65:169–175.
- Dupont, J., T. A. Clair C., Gagnon, D. S. Jefferies, J. S. Kahl, S. J. Nelson and J. M. Pechenham. 2005. Estimation of critical loads of acidity for lakes in northeastern United States and eastern Canada. *Environmental Monitoring and Assessment* 109:275–291.

- Duron, M. D. C. Evers, D. Yates and C. Niven. 2009. Assessing mercury in the Delaware, Croton and Upper Hudson watersheds, 2007. Report BRI 2009-06 submitted to New York State Department of Environmental Conservation. Biodiversity Research Institute, Gorham, ME.
- EDDMapS. 2012. Early Detection & Distribution Mapping System. The University of Georgia - Center for Invasive Species and Ecosystem Health. Available at <http://www.eddmaps.org/> (accessed 5 September 2014).
- Ehrenfeld, J. G. 1977. Vegetation of Morristown National Historical Park: Ecological analysis and management alternatives. Final Report. USDI National Park Service Contract No. 1600-7-0004.
- Ehrenfeld, J. G., P. Kourtev and W. Huang. 2001. Changes in soil functions following invasions of exotic understory plants in deciduous forests. *Ecological Applications* 11(5):1287–1300.
- Eigenbrod, F., S. J. Hecnar and L. Fahrig. 2009. Quantifying the road-effect zone: threshold effects of a motorway on anuran populations in Ontario, Canada. *Ecology and Society* 14(1):24.
- Emanuel, K. A. 1987. The dependence of hurricane frequency on climate. *Nature* 326:483–485.
- Ericksen, J. A., M. S. Gustin, D. E. Schorran, D. W. Johnson, S. E. Lindberg and J. S. Coleman. 2003. Accumulation of atmospheric mercury in forest foliage. *Atmospheric Environment* 37(12):1613–1622.
- Evers, D. C. 2005. Mercury Connections: The extent and effects of mercury pollution in northeastern North America. BioDiversity Research Institute. Gorham, ME.
- Evers, D. C., Y. J. Han, C. T. Driscoll, N. C. Kamman, M. W. Goodale, K. F. Lambert, T. M. Holsen, C. Y. Chen, T. A. Clair and T. Butler. 2007. Identification and Evaluation of Biological Hotspots of Mercury in the Northeastern U.S. and Eastern Canada. *Bioscience* 57:29–43.
- Faccio, S. D., and B. R. Mitchell. 2009. Breeding landbird monitoring. Northeast Temperate Network 2008 Annual Report. Natural Resource Report NPS/NETN/NRR—2009/105. USDI, NPS, Fort Collins, CO.
- Faccio, S. D. and B. R. Mitchell. 2013. Breeding landbird monitoring in the Northeast TemperateNetwork: 2012 summary report. Natural Resource Data Series NPS/NETN/NRDS—2013/468. National Park Service, Fort Collins, CO.
- Fancy, S. G., J. E. Gross and S. L. Carter. 2009. Monitoring the condition of natural resources in US national parks. *Environmental Monitoring and Assessment* 151:161–174.
- Fausch, K. D. and R. J. White. 1981. Competition between brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) for positions in a Michigan Stream. *Canadian Journal of Fisheries and Aquatic Sciences* 38:1220–1227.

- Flory, S. L. and K. Clay. 2006. Invasive shrub distribution varies with distance to roads and stand age in eastern deciduous forests in Indiana, USA. *Plant Ecology* 184:131–141.
- Forman, R. T. T. and L. E. Alexander. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29:207–231.
- Forman, R. T. T. and R. D. Deblinger. 2000. The ecological road effect zone of a Massachusetts (U.S.A.) suburban highway. *Conservation Biology* 14:36–46.
- Forman, R. T. T., B. Reineking and A. Hersperger. 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. *Environmental Management* 29(6):782–800.
- Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine and T. C. Winter. 2003. *Road Ecology: Science and Solutions*, Island Press, Washington.
- Gaston, K. J., T. W. Davies, J. Bennie and J. Hopkins. 2012. Reducing the ecological consequences of night-time light pollution: options and developments. *Journal of Applied Ecology* 49:1256–1266.
- Gates J. E. and J. B. Johnson. 2012. Bat Inventories of Eight National Park Service Units in the Northeast Region of the United States. Natural Resource Technical Report. NPS/NER/NRTR—2012/599. National Park Service. Fort Collins, CO.
- Gilbert, A. T., A. F. O’Connell Jr., E. M. Annand, N. W. Talancy, J. R. Sauer and J. D. Nichols. 2008. An inventory of terrestrial mammals at National Parks in the Northeast Temperate Network and Sagamore Hill National Historic Site: U.S. Geological Survey Scientific Investigations Report 2007–5247, 158 p.
- Glennon, M. J. and W. F. Porter. 2005. Effects of land use management on biotic integrity: An investigation of bird communities. *Biological Conservation* 126:499–511.
- Goetz, S. J., R. Wright, A. J. Smith, E. Zinecker, and E. Schaub. 2003. Ikonos imagery for resource management: tree cover, impervious surfaces and riparian buffer analyses in the mid-Atlantic region. *Remote Sensing of Environment* 88:195–208.
- Gordon, N. D., T. A. McMahon and B. L. Finlayson. 2004: Stream hydrology : An introduction for ecologists. Vol. 1. 2nd ed. Wiley, 429 pp. Kaughman, P. R., and E. G. Robinson, 1997: Physical habitat assessment. EPA. EPA/620/R-94/004, 6-1 pp.
- Grigal, D. F. 2002. Inputs and outputs of mercury from terrestrial watersheds: A review. *Environmental Review* 10:1–39.
- Grigal, D. F. 2003. Mercury sequestration in forests and peatlands: a review. *Journal of Environmental Quality*. 32:393–405.



- Groisman, P. Ya., R. W. Knight, and T. R. Karl. 2000. Heavy precipitation and high streamflow in the contiguous United States: trends in the 20th Century. *Bulletin of the American Meteorological Society* 82:219–246.
- Gross, J. E., and L. Svancara. 2009. Measure Description Summary: Landscape Pattern. Office of Inventory, Monitoring, and Evaluation, National Park Service, Fort Collins, CO.
- Haas, G., and T. Wakefield. 1998. National parks and the American public: a national public opinion survey on the national park system. National Parks and Conservation Association and Colorado State University, Washington DC and Fort Collins, CO.
- Hammerschmidt C. R. and W. F. Fitzgerald. 2005. Methylmercury in mosquitoes related to atmospheric mercury. *Environmental Science and Technology* 39:3034–3039.
- Hammerschmidt C. R. and W. F. Fitzgerald. 2006. Methylmercury in freshwater fish linked to atmospheric mercury deposition. *Environmental Science and Technology* 40:7764–7770.
- Hansen, A. J., R. P. Neilson, V. H. Dale, C. H. Flather, L. R. Iverson, D. J. Currie, S. Shafer, R. Cook, and P. J. Bartlein. 2001. Global change in forests: Responses of species, communities, and biomes. *BioScience* 51:765–779.
- Harris, C. M. (1998). *Handbook of Acoustical Measurements and Noise Control*, 3rd ed. McGraw-Hill, New York.
- Haskell, D. G. 2000. Effects of forest roads on macroinvertebrate soil fauna of the Southern Appalachian mountains. *Conservation Biology* 14:57–63.
- Hawksworth, D. L. and D. J. Hill. 1984. *The Lichen Forming Fungi*. Chapman and Hill, New York.
- Healy, W. M. 1997. Influence of deer on the structure and composition of oak forests in central Massachusetts. Pages 249–266 in W. J. McShea, H. B. Underwood, and J. H. Rappole, editors. *The science of overabundance: deer ecology and population management*. The Smithsonian Institution Press, Washington, D.C.
- Heinz Center (H. John Heinz III Center for Science, Economics and the Environment). 2008. *The State of the Nation's Ecosystems 2008: measuring the land, waters, and living resources of the United States*. Washington, DC: Island Press.
- Henriksen, J. A., J. Heasley, J. G. Kennen and S. Nieswand. 2006. Users' manual for the Hydroecological Integrity Assessment Process software (including the New Jersey Assessment Tools): U.S. Geological Survey Open-File Report 2006-1093.
- Horsley, S. B., R. P. Long, S. W. Bailey, R. A. Hallett and P. M. Wargo. 2002. Health of eastern North American sugar maple forests and factors affecting decline. *Northern Journal of Applied Forestry* 19:34–44.

- Hudy, M., T. M. Thieling, N. Gillespie and E. P. Smith. 2005. Distribution, Status and Perturbations to Brook Trout within the eastern United States. Final report to the steering committee of the Eastern Brook Trout Venture.
- Insarov, G. E., S. M. Semenov and R. D. Insarova. 1999. A system to monitor climate change with epilithic lichens. *Environmental Monitoring and Assessment* 55:279–298.
- Jensen, M. and H. Thompson. 2004. Natural sounds: an endangered species. *George Wright Forum* 21:10–13.
- Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant and I. J. Schlosser. 1986. Assessment of biotic integrity in running waters: a method and its rationale. Illinois Natural History Survey, Special Publication Number 5, Champaign.
- Karraker, N. E., J. P. Gibbs and J. R. Vonesh. 2008. Impacts of road deicing salt on the demography of vernal pool-breeding amphibians. *Ecological Applications* 18(3). doi 10.1890/07-1644.1.
- Keefer, J. S., M. R. Marshall and B. R. Mitchell. 2010. Early detection of invasive species: surveillance, monitoring, and rapid response: Eastern Rivers and Mountains Network and Northeast Temperate Network. Natural Resource Report NPS/ERMN/NRR–2010/196. National Park Service, Fort Collins, CO.
- Kenny, J. F., N. L. Barber, S. S. Hutson, K. S. Linsey, J. K. Lovelace and M. A. Maupin. 2009. Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344, 52 p.
- Kline, L. J., D. D. Davis, J. M. Skelly, J. E. Savage and J. Ferdinand. 2008. Ozone sensitivity of 28 plant selections exposed to ozone under controlled conditions. *Northeastern Naturalist* 15:57–66.
- Kohut, R. 2007. Assessing the risk of foliar injury from ozone on vegetation in parks in the U.S. National Park Service's Vital Signs Network. *Environmental Pollution* 149:348–357.
- Kourtev, P., W. Huang and J. G. Ehrenfeld. 1998. Effects of exotic plant species on soil properties in hardwood forests of New Jersey. *Water, Air and Soil Pollution* 105:493–501.
- Kremen, C., R. K. Colwell, T. L. Erwin, D. D. Murphy, R. F. Noss and M. A. Sanyjayan. 1993. Terrestrial arthropod assemblages: their use in conservation planning. *Conservation Biology* 7(4):796–808.
- Levin, S. A. 1981. The problem of pattern and scale in ecology. *Ecology* 73:1942–1968.
- Lombard, Pamela. 2004. Freshwater Vital-Signs Monitoring Plan for National Parks in the Northeast Temperate Network (NETN) PHASE I: A Scoping Report. USGS, Augusta, ME.

- Lombard, P., W. Gawley and J. Caldwell. 2006. Freshwater Vital Signs Monitoring Plan for National Parks in the Northeast Temperate Network (NETN) Phase III: Water Quality Monitoring Protocols in Lakes, Ponds and Streams: USGS, Augusta, ME.
- Lorne, J. K. and M. Salmon. 2007. Effects of exposure to artificial lighting on orientation of hatchling sea turtles on the beach and in the ocean. *Endangered Species Research* 3:23–30.
- Lovett, G. M, T. H. Tear, D. C. Evers, S. E. G. Findlay, B. J. Cosby, J. K. Dunscomb, C. T. Driscoll and K. C. Weathers. 2009. Effects of air pollution on ecosystems and biological diversity in the Eastern United States. *The Year in Ecology and Conservation Biology Ann. N.Y. Acad.Sci.* 1162: 99–135.
- Luck, G. W. 2007. A review of the relationships between human population density and biodiversity. *Biological Review* 82:607–645.
- Lugo, A. E. 2000. Effects and outcomes of Caribbean hurricanes in a climate change scenario. *Science of the Total Environment* 262:243–251.
- Lugo, A. E. and F. N. Scatena. 1995. Ecosystem-level properties of the Luquillo Experimental Forest, with emphasis of the tabonuco forest. Pages 59–108 in Lugo AE, Lowe C, eds. *Tropical Forests: Management and Ecology*. New York: Springer-Verlag.
- Lugo, A. E. and F. N. Scatena. 1996. Background and catastrophic tree mortality in tropical moist, wet, rain forests. *Biotropica* 28:585–599.
- Lynch, E., D. Joyce, and K. Fristrup. 2011. An assessment of noise audibility and sound levels in U.S. National Parks. *Landscape Ecology* 26:1297–1309.
- Mahan, C. G. and R. H. Yahner. 1999. Effects of forest fragmentation on behavior patterns in the eastern chipmunk (*Tamias striatus*). *Canadian Journal of Zoology* 77:1991–1997.
- Mather, M. E., A. J. Norris, and M. P. Carey. March 2003. Freshwater Fish Inventory: Northeast Temperate Network, 1999-2001. Technical Report NPS/NER/NRTR—2005/16. National Park Service. Woodstock, VT.
- McDonald, C. D., R. M. Baumgartner, and R. Iachan. 1995. National Park Service aircraft management studies (US Department of Interior Rep. No. 94-2). Denver, CO: National Park Service.
- Meehan, W. R. (ed.) 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society. Special Publication 19.
- Meili, M., K. Bishop, L. Bringmark, K. Johansson, J. Muthe, H. Sverdrup and W. deVries. 2003. Critical levels of atmospheric pollution: Criteria and concepts for operational modeling of mercury in forest and lake ecosystems. *The Science of the Total Environment* 304:83–106.

- Mele, J. A. and M. R. Mele. 1983. Final report: A water resources assessment and inventory of benthic invertebrates, fish, and amphibians of Morristown National Historical Park. Final Report: for the period of October 15, 1982 through October 15, 1983. Associated Ecologists.
- Mennitt, D., K. Fristrup, K. Sherrill, and L. Nelson. 2013. Mapping sound pressure levels on continental scales using a geospatial sound model. 43<sup>rd</sup> International Congress and Exposition on Noise Control Engineering, Innsbruck, Austria, Sept 15-18:1–11.
- Micacchion, M. 2002. Amphibian index of biotic integrity (AmphIBI) for wetlands. Final report to U.S. EPA Grant No. CD985875-01, Testing biological metrics and development of wetland assessment techniques using reference sites: Volume 3. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Unit. Columbus, OH. [http://web.epa.state.oh.us/dsw/wetlands/2002\\_Amphibian\\_report\\_final\\_rev.pdf](http://web.epa.state.oh.us/dsw/wetlands/2002_Amphibian_report_final_rev.pdf)
- Micacchion, M. 2004. Integrated Wetland Assessment Program. Part 7: Amphibian index of biotic integrity (AmphIBI) for Ohio wetlands. Ohio EPA Technical Report WET/2004-7. Ohio Environmental Protection Agency, Wetland Ecology Group, Division of Surface Water. Columbus, OH. [http://www.epa.state.oh.us/dsw/wetlands/Integrated\\_Wetland\\_Assessment\\_Program\\_Part7\\_AmphIBI\\_formatted.pdf](http://www.epa.state.oh.us/dsw/wetlands/Integrated_Wetland_Assessment_Program_Part7_AmphIBI_formatted.pdf)
- Miller, E. K., A. Vanarsdale, G. J. Keeler, A. Chalmers, L. Poissant, N. C. Kamman and R. Brulotte. 2005. Estimation and mapping of wet and dry mercury deposition across northeastern North America. *Ecotoxicology* 14:53–70.
- Miller, M. W. 2006. Apparent effects of light pollution on singing behavior of American robins. *The Condor* 108:130–139.
- Miller, K. M., G. L. Tierney, and B. R. Mitchell. 2010. Northeast Temperate Network forest health monitoring report: 2006-2009. Natural Resource Report NPS/NETN/NRR—2010/206. National Park Service, Fort Collins, CO.
- Miller, K. M., B. R. Mitchell, G. L. Tierney and J. S. Wheeler. 2011. Northeast Temperate Network forest health monitoring report: 2010. Natural Resource Report NPS/NETN/NRR—2011/399. National Park Service, Fort Collins, CO.
- Miller, K. M., B. R. Mitchell and J. S. Wheeler. 2012. Forest health monitoring in the Northeast Temperate Network: 2011 summary report. Natural Resource Technical Report NPS/NETN/NRTR—2012/604. National Park Service, Fort Collins, CO.
- Mitchell, M. J., C. T. Driscoll, J. S. Owen, D. Schaefer, R. Michener and D. J. Raynal. 2001. Nitrogen biogeochemistry of three hardwood ecosystems in the Adirondack Region of New York. *Biogeochemistry* 56(2):93–133.
- Mitchell, B. R., G. Shriver, F. Dieffenbach, T. Moore, D. Faber-Langendoen, P. Lombard, and J. Gibbs. 2006. Northeast Temperate Network Vital Signs monitoring plan. Technical Report NPS/NER/NRTR—2006/059. Boston, MA.

- Moore, C. M., J. M. White, F. Turina. 2013. Recommended Indicators of Night Sky Quality for NPS State of the Parks Reports. National Park Service, Fort Collins, Colorado.  
[https://irma.nps.gov/App/Reference/DownloadDigitalFile?code=468796&file=Recommended\\_Indicators\\_of\\_Night\\_Sky\\_Quality.pdf](https://irma.nps.gov/App/Reference/DownloadDigitalFile?code=468796&file=Recommended_Indicators_of_Night_Sky_Quality.pdf)
- Morfeý. 2001. Dictionary of Acoustics, Academic Press.
- Mullaney, J. R., D. L. Lorenz, and A. D. Arntson. 2009. Chloride in groundwater and surface water in areas underlain by the glacial aquifer system, northern United States: U.S. Geological Survey Scientific Investigations Report 2009–5086, 41 p. National Historical Park. Final Report to the National Park Service, Boston, MA.
- Muzika, R. M., S. T. Grushecky, A. M. Liebhold and R. L. Smith. 2004. Using thinning as a management tool for gypsy moth: the influence on small mammal abundance. *Forest Ecology and Management* 192(2-3):349–359.
- National Park Service (NPS). 1993. Morristown National Historical Park water resources scoping report. Water Resources Division, Coastal Research Center and Morristown National Historical Park. Fort Collins, CO: Technical Report: NPS/NRWRD/NRTR-93/17.
- National Park Service (NPS). 1994. Baseline water quality data inventory and analysis. Morristown National Historical Park. September 1994. Water Resources Division. Fort Collins, CO. Technical Report NPS/NRWRD/NRTN-94/29.
- National Park Service. 1994b. Report to Congress. Report on effects of aircraft overflights on the National Park System. September 12, 1994.
- National Park Service (NPS). 2001. “Management Policies”.
- National Park Service (NPS). 2003a. Morristown National Historical Park General Management Plan, Environmental Impact Statement. U.S. Dept. of the Interior, National Park Service, Northeast Region, Boston, MA.
- National Park Service (NPS). 2003b. Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Lands: Results of a June 24-25, 2003 Workshop Baltimore, Maryland. [www.nature.nps.gov/air/Pubs/pdf/BalkFinalReport1.pdf](http://www.nature.nps.gov/air/Pubs/pdf/BalkFinalReport1.pdf).
- National Park Service (NPS) 2006. Ozone Sensitive Plant Species, by Park, November 2006. Available at  
[http://www.nature.nps.gov/air/permits/aris/docs/Ozone\\_Sensitive\\_ByPark\\_3600.pdf](http://www.nature.nps.gov/air/permits/aris/docs/Ozone_Sensitive_ByPark_3600.pdf)  
(accessed 9 September 2014).
- National Park Service (NPS). 2006b. Management Policies 2006. U.S. Department of Interior, National Park Service, Washington, DC. Available at  
<http://www.nps.gov/policy/mp/policies.html#Toc157232745> (accessed 9 September 2014).



- National Parks Service (NPS-IMD). 2009. NPS Landscape Dynamics Project: Housing Metrics Processing SOP – Current Housing Density, Historic Housing Density, and Projected Housing Density Metrics. Inventory and Monitoring Division. National Park Service, Fort Collins, CO.
- National Park Service. 2011. Morristown National Historic Park-Washington’s Headquarters Unit-traffic noise level modeling preliminary report. Obtained from H. Salazer, NPS.
- National Parks Service (NPS). 2013a. Methods for Determining Air Quality Conditions and Trends for Park Planning and Assessments Available at [http://www.nature.nps.gov/air/Planning/docs/AQ\\_ConditionsTrends\\_Methods\\_2013.pdf](http://www.nature.nps.gov/air/Planning/docs/AQ_ConditionsTrends_Methods_2013.pdf) (accessed 9 September 2014).
- National Park Service (NPS). 2013b. Air quality in national parks: trends (2000–2009) and conditions (2005–2009). Natural Resource Report NPS/NRSS/ARD/NRR—2013/683. National Park Service, Denver, CO.
- National Park Service Hydrographic & Impairment Statistics (NPS HIS). 2012. Available at <http://www.nature.nps.gov/water/HIS/index.cfm> (accessed 9 September 2014).
- National Parks Service (NPS) Stats-Public Use Statistics Office. 2012. Available at <http://www.nature.nps.gov/assets/redirects/statsRedirect.cfm> (accessed 9 September 2014).
- Natural Resources Conservation Service (NRCS), United States Department of Agriculture (USDA). Web Soil Survey. Available at <http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm> (accessed 9 September 2014).
- New Jersey Audubon Society. 2003. Sherman-Hoffman Wildlife Sanctuary. Reptiles and Amphibians Checklist. 11 Hardscrabble Road. P.O. BOX 693, Bernardsville, NJ 07924.
- New Jersey Department of Environmental Protection (NJDEP). 2010. 2010 New Jersey Integrated Water Quality Monitoring and Assessment Report. New Jersey Department of Environmental Protection Division of Water Monitoring and Standards Bureau of Water Quality Standards and Assessment. June 2011. 840 p.
- New Jersey Department of Environmental Protection (NJDEP). 2011. Atmospheric Deposition: Acidity and Nutrients. 2/2011. Environmental Trend Report, NJDEP, Office of Science. Available at <http://www.state.nj.us/dep/dsr/trends/> (accessed 9 September 2014).
- New Jersey Department of Environmental Protection (NJDEP). Surface Water Quality Standards (SWQS), N.J.A.C. 7:9B. Available at <http://www.nj.gov/dep/wms/bwqsa/swqs.htm> (accessed 9 September 2014).
- New Jersey Department of Health and Senior Services and New Jersey Department of Environmental Protection. 2010. Fish Smart, Eat Smart: A guide to health advisories for eating fish and crabs caught in New Jersey waters. <http://www.state.nj.us/dep/dsr/2010FishAdvisoryBrochure.pdf>

- New Jersey Highlands Council. Digital Spatial Data.  
<http://www.highlands.state.nj.us/njhighlands/actmaps/maps/>
- New Jersey State Data Center. 2012. New Jersey Census Data. Available at  
[http://lwd.dol.state.nj.us/labor/lpa/content/njsdc\\_index.html](http://lwd.dol.state.nj.us/labor/lpa/content/njsdc_index.html) (accessed 9 September 2014).
- NJISST. 2011. New Jersey Invasive Species Strike Team. 2011 Target Plant List. Available at  
<http://www.njisst.org/> (accessed 9 September 2014).
- NOAA Coastal Services Center. 2012. Coastal Change Analysis Program Regional Land Cover. Available at <http://csc.noaa.gov/digitalcoast/coastal-change-analysis-program-regional-land-cover> (accessed 9 September 2014).
- Noss, R. F. 1999. Assessing and monitoring forest biodiversity: A suggested framework and indicators. *Forest Ecology and Management* 115:135–146.
- NPSpecies - The National Park Service Biodiversity Database. IRMA version. Available at <https://irma.nps.gov/NPSpecies/Search/> (park-species list - evidence counts; accessed 9 September 2014).
- O’Connell, T. J., L. E. Jackson and R. P. Brooks. 2000. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Application* 10:1706–1721.
- Office of Natural Lands Management (ONLM). 2001. Special plants of New Jersey (20 October 2002). Department of Environmental Protection and Energy, New Jersey.
- Ohio Environmental Protection Agency. 1987. Biological criteria for the protection of aquatic life: Vol. II. Users Manual for biological field assessment of Ohio surface waters. Ohio EPA, Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, OH.
- Oliver, I. and A. J. Beattie. 1996. Designing a cost-effective invertebrate survey: a test of methods for rapid assessment of biodiversity. *Ecological Applications* 6(2):594–607.
- Omernik, J. M. 1995. Ecoregions: A spatial framework for environmental management. In: Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Davis, W.S. and T.P. Simon (eds.), Lewis Publishers, Boca Raton, FL.
- Omernik, J. M. 2004. Perspectives on the nature and definition of ecological regions. *Environmental Management* 34 (1):S27–S38.
- Patrick, D. A., H. L. Hunter Jr., and A. J. K. Calhoun. 2006. Effects of experimental forestry treatments on a Maine amphibian community. *Forest Ecology and Management* 234:323–332.
- Pearson, D. L. and F. Cassola. 1992. World-wide species richness patterns of tiger beetles (Coleoptera: Cicindelidae): Indicator taxon for biodiversity and conservation studies. *Conservation Biology* 6(3):376–391.

- Perles, S., J. Finley and M. Marshall. 2010. Vegetation and soil monitoring protocol for the Eastern Rivers and Mountains Network, Version 2. Natural Resource Report NPS/ERMN/NRR—2010/183. National Park Service. Fort Collins, CO.
- Peters, J. C. 1967. Effects on a trout stream of sediment from agricultural practices. *Journal of Wildlife Management* 31:805–812.
- Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, D. C. 587 pp.
- Pollard, E. 1988. Temperature, rainfall, and butterfly numbers. *Journal of Applied Ecology* 25:819–828.
- Princeton Hydro, LLC. 2004. Primrose Brook Sub-Watershed Environmental Assessment. Project No. 0341.003. Prepared for Ten Towns Great Swamp Watershed Management Committee. April 2004.
- Rainio, J. and J. Niemelä. 2003. Ground beetles (Coleoptera: Carabidae) as bioindicators. *Biodiversity and Conservation* 12:487–506.
- Rich, C. and T. Longcore. (eds) 2006. Ecological Consequences of Artificial Night Lighting. *Island Press*, Washington, DC.
- Richards, C., L. Johnson and G. Host. 1996: Landscape-scale influences on stream habitats and biota. Vol. 53. National Research Council of Canada.
- Rimmer, C. C., K. P. McFarland, D. C. Evers, E. K. Miller, Y. Aubry, D. Busby and R. J. Taylor. 2005. Mercury concentrations in Bicknell's thrush and other insectivorous passerines in montane forests of northeastern North America. *Ecotoxicology* 14:223–240.
- Rohr, J. R., and D. M. Madison. 2003. Dryness increases predation risk in efts: Support for an amphibian decline hypothesis. *Oecologia* 135:657–664.
- Rooney, T. M. and D. Waller. 2003. Direct and indirect effects of white-tailed deer in forest ecosystems. *Forest Ecology and Management* 181:165–176.
- Rooney, T. P., S. M. Wiegmann, D. A. Rogers, and D. M. Waller. 2004. Biotic impoverishment and homogenization in unfragmented forest understory communities. *Conservation Biology* 18(3):787–798.
- Rosenberg, D. M. and V. H. Resh. 1992: *Freshwater biomonitoring and benthic macroinvertebrates*. Vol. 1. 1st ed. Chapman & Hall, 488 pp.
- Royer, J. F., F. Chauvin, B. Timbal, P. Araspin and D. Grimal. 1998. A GCM study of the impact of greenhouse gas increase on the frequency of occurrence of tropical cyclones. *Climatic Change* 38:307–343.

- Ruhren, S. and S. N. Handel. 2003. Herbivory constrains survival, reproduction and mutualisms when restoring nine temperate forest herbs. *Journal of the Torrey Botanical Society* 130:34–42.
- Rusek, J. and V. G. Marshall. 2000. Impacts of airborne pollutants on soil fauna. *Annual Review of Ecology, Evolution, and Systematics* 31:395–423.
- Russell, F. L., D. B. Zippin, and N. L. Fowler. 2001. Effects of white-tailed deer (*Odocoileus virginianus*) on plants, plant populations, and communities: a review. *American Midland Naturalist* 146:1–26.
- Santos, C. D., A. C. Miranda, J. P. Granadeiro, P. M. Lourenço, S. Saraiva and J. M. Palmeirim. 2010. Effects of artificial illumination on the nocturnal foraging of waders. *Acta Oecologica* 36:166–172.
- Sanzo, D. and S. J. Hecnar. 2001. Effects of road de-icing salt (NaCl) on larval wood frogs (*Rana sylvatica*). *Environmental Pollution* 140(2):247–256.
- Schiff, R. and G. Benoit. 2007. Effects of impervious cover at multiple spatial scales on coastal watershed streams. *Journal of the American Water Resources Association* 43(3):712–730.
- Schindler, D. W. 1988. Effects of acid rain on fresh water ecosystems. *Science* 239 (4836):149–157.
- Schindler, D. W., S. E. M. Kaslan and R. H. Hesslein. 1989. Biological impoverishment in lakes of the Midwestern and northeastern United States from acid rain. *Environmental Science and Technology* 23:573–80.
- Schomer, P., J. Freytag, A. Machesky, C. Luo, C. Dossin, N. Nookala, and A. Pamdighantam. (2011) A re-analysis of Day-Night Sound Level (DNL) as a function of population density in the United States. *Noise Control Engineering Journal* 59:290–301.
- Selye, H. 1956. The stress of life. New York: McGraw-Hill.
- Simberloff, D., I. M. Parker and P. N. Windle. 2005. Introduced species policy, management, and future research needs. *Frontiers in Ecology and the Environment* 3(1):12–20.
- Skelly, J. M. 2000. Tropospheric ozone and its importance to forest and natural plant communities of the northeastern United States. *Northeastern Naturalist* 7:221–236.
- Smart S., C. Evans, E. Rowe, W. Wamelink W., S. Wright, A. Scott, D. Roy, C. Preston, M. Hill, P. Rothery, J. Bullock, I. Moy, B. Emmett and L. Maskell. 2005. Atmospheric nitrogen pollution impacts on biodiversity: Phase 1 - Model development and testing. Centre for Ecology and Hydrology.  
[http://www.defra.gov.uk/science/project\\_data/DocumentLibrary/WC02008/WC02008\\_2866\\_FRP.pdf](http://www.defra.gov.uk/science/project_data/DocumentLibrary/WC02008/WC02008_2866_FRP.pdf)

- Sneddon, L., R. E. Zaremba, E. Largay, G. Podniesinski, S. Perles and J. Thompson. April 2008. Vegetation Classification and Mapping of Morristown National Historical Park. Technical Report NPS/NER/NRTR—2008/116. National Park Service. Philadelphia, PA.
- Snyder, C. D., J. A. Young, R. Vilella and D. P. Lemarie. 2003: Influences of upland and riparian land use patterns on stream biotic integrity. *Landscape Ecology* 18:647–664.
- Southgate, E. W. B. 2002. Changes in the forests of the Jockey Hollow Unit of Morristown National Historical Park over the last 5-15 years. Technical Report NPS/BSO-RNR/NRTR/2002-9. National Park Service. Boston Support Office, Boston, MA.
- Stewart, I. T., D. R. Cayan and M. D. Dettinger. 2005. Changes toward earlier streamflow timing across western North America. *Journal of Climate* 18:1136–1155.
- Stoddard, J., J. S. Kahl, F. Deviney, D. DeWalle, C. Driscoll, A. Herlihy, J. Kellogg, P. U. Murdoch, J. Webb and K. Webster. 2003. Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990. EPA/620/R-03/001. Washington, D.C.: U.S. EPA.
- Stone, E. L., G. Jones and S. Harris. 2009. Street lighting disturbs commuting bats. *Current Biology* 19:1123–1127.
- Storm, G. L., R. H. Yahner, D. F. Cottam and G. M. Vecellio. 1989. Population status, movements, habitat use and impact of white-tailed deer at Gettysburg National Military Park and Eisenhower National Historic Site, Pennsylvania. National Park Service Technical Report NPS/MAR/NRTR-89/043, Philadelphia, PA.
- Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey and D. Moore. 2011a. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: main report. Natural Resource Report NPS/NRPC/ARD/NRR—2011/349. National Park Service, Denver, CO.
- Sullivan, T. J., T. C. McDonnell, G. T. McPherson, S. D. Mackey, and D. Moore. 2011b. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: main report. Natural Resource Report NPS/NRPC/ARD/NRR—2011/313. National Park Service, Denver, CO.
- Svancara, L. K., P. Budde and J. Gross. 2009. Measure development summary: Population and housing. Office of Inventory, Monitoring, and Evaluation, National Park Service, Fort Collins, CO.
- Svancara, L., P. Budde and J. Gross. 2009a. Measure Development Summary: Population and Housing. Office of Inventory, Monitoring, and Evaluation, National Park Service, Fort Collins, CO.
- Svancara, L. and M. Story. 2009b. Measure Development Summary: Land Cover / Land Use. Office of Inventory, Monitoring, and Evaluation, National Park Service, Fort Collins, CO.



- Svensson, A. M. and J. Rydell. 1998. Mercury vapour lamps interfere with the bat defense of tympanate moths (*Operophtera* spp.; Geometridae). *Animal Behavior* 55:223–226.
- Sweetapple, P. J., and G. Nugent. 2004. Seedling ratios: a simple method for assessing ungulate impacts on forest understories. *Wildlife Society Bulletin* 32:137–147.
- Taylor, J. N., W. R. Courtenay, Jr. and J. A. McCann. 1984. Known impact of exotic fishes in the continental United States. Pages 322-373 in W. R. Courtenay, Jr., and J. R. Stauffer, editors. *Distribution, biology, and management of exotic fish*. Johns Hopkins Press, Baltimore, MD.
- Taylor, R. J. and N. Doran. 2001. Use of terrestrial invertebrates as indicators of the ecological sustainability of forest management under the Montreal Process. *Journal of Insect Conservation* 5:221–231.
- Templeton and Sacre. 1997. *Acoustics in the built environment: advice for the design team*. Architectural Press.
- Thormann, M. N. 2006. Lichens as indicators of forest health in Canada. *The Forestry Chronicle* 82:335–343.
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski and D. Faber-Langendoen. 2009. Long-term forest monitoring protocol: Northeast Temperate Network. Natural Resource Report NPS/NETN/NRR—2009/117. National Park Service, Fort Collins, CO.
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski and D. Faber-Langendoen. 2010. Northeast Temperate Network long-term forest monitoring protocol: 2010 revision. Natural Resource Report NPS/NETN/NRR—2010/195. National Park Service, Fort Collins, CO.
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski and D. Faber-Langendoen. 2011. Northeast Temperate Network long-term forest monitoring protocol: 2011 revision. Natural Resource Report NPS/NETN/NRR—2011/404. National Park Service, Fort Collins, CO.
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski and D. Faber-Langendoen. 2012. Northeast Temperate Network long-term forest monitoring protocol: 2012 revision. Natural Resource Report NPS/NETN/NRR—2012/507. National Park Service, Fort Collins, CO.
- Trama, F. B. and L. M. Galloway. 1988. Morristown National Historical Park watershed study: Phase II - Aquatic Resources. Center for Coastal and Environmental Studies. Rutgers, The State University of New Jersey, New Brunswick (Contract 4-02-8217 DI-NPS-0006).
- Trocki, C., P. Paton. December 2003. Avian Surveys in Northeast Temperate Network. Technical Report NPS/NER/NRTR—2005/004. National Park Service. Woodstock, VT.
- Trout Unlimited. 2007. Conservation Success Index. Available at <http://www.tu.org/csi> (accessed 9 September 2014).

- Trout Unlimited. 2009. Subwatershed Conservation Strategies. June 2009.  
[Tucsi.tu.org/Documents/CSI\\_Framework/ConservationStrategies.pdf](http://Tucsi.tu.org/Documents/CSI_Framework/ConservationStrategies.pdf)
- Turner, I. M. 1996. Species Loss in Fragments of Tropical Rain Forest: A Review of the Evidence . *Journal of Applied Ecology* 33(2):200–209.
- Underwood, H. B. 1997. Feasibility of a fertility control program for white-tailed deer at Morristown National Historical Park: Phase I. Report to the National Park Service, Syracuse, NY.
- Underwood, B. H. and Salmon P. A. 2007. Exploring the Feasibility of White-tailed Deer Fertility Control Programs. Technical Report NPS/NER/NRTR-2007/087. USGS-Patuxent Wildlife Research Center, State University of New York, College of Environmental Science and Forestry, Syracuse, NY.
- United States Census Bureau. 2010. *2010 Census Urban and Rural Classification*. Retrieved June 28, 2013 from <http://www2.census.gov/geo/tiger/TIGER2010/UA/2010>.
- United States Census Bureau. 2012. United States Census. Available at <http://www.census.gov/> (accessed 9 September 2014).
- United States Census Bureau. “Population Estimates”. 2013. City and Town Intercensal Estimates (2000-2010). Available at <http://www.census.gov/popest/data/intercensal/cities/cities2010.html> (accessed 9 September 2014).
- U.S. Census Bureau. "State & County QuickFacts". 2013. Available at <http://quickfacts.census.gov/qfd/states/34/3448300.html> (accessed 9 September 2014).
- U.S. Census Bureau. “Metropolitan and Micropolitan. 2013. Available at <http://www.census.gov/population/metro/data/index.html> (accessed 9 September 2014).
- United States Department of Agriculture, Forest Service. 1992. Report to Congress. Potential impacts of aircraft overflights of National Forest System wildernesses.
- United States Department of Agriculture (USDA) Forest Service. 2010. Alien Forest Pest Explorer (AFPE). <http://www.nrs.fs.fed.us/tools/afpe/3> (accessed 10 December 2010).
- United States Environmental Protection Agency (EPA). (1971) Community Noise. Washington, D.C.
- United States Environmental Protection Agency (USEPA). 1997. Volunteer Stream Monitoring: A Methods Manual, EPA 841-B-97-003. Office of Water.
- United States Environmental Protection Agency (USEPA). 2000. Ambient water quality criteria recommendations. Information supporting the development of state and tribal nutrient criteria for rivers and streams in nutrient ecoregion IX. EPA 822-B-00-019. December 2000.

- United States Environmental Protection Agency (USEPA). 2001. Water Quality Criterion for the Protection of Human Health: Methylmercury. U.S. Environmental Protection Agency , Office of Water, Washington DC, EPA-823-R-01-001.
- United States Environmental Protection Agency (USEPA). 2006. Air Quality Criteria for Ozone and Related Photochemical Oxidants. Volume I of III. U.S. Environmental Protection Agency, Washington, DC, EPA.
- United States Environmental Protection Agency (USEPA). 2009. Provisional assessment of recent studies on health and ecological effects of ozone exposure. EPA/600/R-09/101. National Center for Environmental Assessment, Research Triangle Park, NC.
- United States. Environmental Protection Agency (USEPA). 2011. STORET/WQX Data Warehouse. Available at [http://www.epa.gov/storet/dw\\_home.html](http://www.epa.gov/storet/dw_home.html) (accessed 9 September 2014).
- United States Food and Drug Administration (FDA). 2004. *What you need to know about mercury in fish and shellfish*. March 2004. EPA 823-R-04-005. [www.fda.gov](http://www.fda.gov) (accessed 11 January 2011).
- United States Forest Service (USFS). 2010. Forest Health Protection-Beech Bark Disease. Available at <http://www.na.fs.fed.us/fhp/bbd/> (accessed 9 September 2014).
- United States Geological Survey (USGS). 2004. Nonindigenous Aquatic Species Database, Gainesville, FL. Available at <http://nas.er.usgs.gov/> (accessed 9 September 2014).
- United States Geological Survey (USGS). 2011. The National Water-Use Program. Downloading water-use information for 1985 and 1990. Available at <http://water.usgs.gov/watuse/wudownload.html> (accessed 9 September 2014).
- United States Geological Survey (USGS). 2012. USGS StreamStats. Available at <http://water.usgs.gov/osw/streamstats/> (accessed 9 September 2014).
- van Abs, D. J. 1983. The hydrogeology of the buried valley aquifer system. Passaic River Coalition. Basking Ridge. 137 pp.
- van Bohemen, H. D. and W. H. Janssen van de Laak. 2003. The influence of road infrastructure and traffic on soil, water, and air quality. *Environmental Management* 31:50–68.
- van Manen, F. T., M. D. Jones, J. L. Kindall, L. M. Thompson and B. K. Scheick. 2001. Determining the potential mitigation effects of wildlife passageways on black bears. Road Ecology Center: Paper Manen 2001a.
- Vile, J. 2010. *Fish IBI Report 2008 Sampling Round 2, Year 4 of 5. Volume 1-Summary*. NJ Department of Environmental Protection. Water Monitoring and Standards. Bureau of Freshwater and Biological Monitoring.

- Wade, T. G., K. H. Riitters, J. D. Wickham and K. B. Jones. 2003. Distribution and causes of global forest fragmentation. *Conservation Ecology*, 7, 7. Available at <http://www.consecol.org/vol7/iss2/art7> (accessed 9 September 2014).
- Wagner, T. B. J. Irwin, J. R. Bence, and D. B. Hayes. 2013. Detecting temporal trends in freshwater fisheries surveys: statistical power and the important linkages between management questions and monitoring objectives. *Fisheries* 38:309–319.
- Wallace, Z. P., G. M. Lovett, J. E. Hart, B. Machona. 2007. Effects of nitrogen saturation on tree growth and death in a mixed-oak forest. *Forest Ecology and Management* 243:210–218.
- Walker, L. R. and S. D. Smith. 1997. Community response to plant invasion. Pages 69-86 in J. O. Luken and J. W. Thieret, editors. *Assessment and Management of Plant Invasions*. Springer, New York, NY.
- Walsh, J., V. Elia, R. Kane and T. Halliwell. 1999. *Birds of New Jersey*. Bernardsville, New Jersey Audubon Society.
- Walsh, K. and A. B. Pittock. 1998. Potential changes in tropical storms, hurricanes, and extreme rainfall events as a result of climate change. *Climatic Change* 39:199–213.
- Wang, Y. Q., and J. Nugranad-Marzilli. 2009. Land cover change in Northeast Temperate Network parks 1973-2002. Natural Resource Technical Report NPS/NETN/NRTR—2009/238. National Park Service, Fort Collins, CO.
- Webster, J. R. 1983: The role of benthic macroinvertebrates in detritus dynamics of streams: A computer simulation. *Ecological Monographs* 53:383–404.
- Welsh, H., and L. Ollivier. 1998. Stream amphibians as indicators of ecosystem stress: a case study from California's redwoods. *Ecological Applications* 8:1118–1132.
- White, M. A. 2012. Long-term effects of deer browsing: competition, structure and productivity in a northeastern Minnesota old-growth forest. *Forest Ecology and Management* 269:222–228.
- Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips and E. Losos. 1998. Quantifying threats to imperiled species in the United States. *BioScience* 48:607–615.
- Williams, J. E, A. L. Haak, N. G. Gillespies and W. T. Colyer. 2007. The Conservation Success Index: Synthesizing and Communicating Salmonid Condition and Management Needs. *Fisheries* 32(10):477–493.
- Woods, K. D. 1997. Community response to plant invasion. Pages 56-68 in J. O. Luken and J. W. Thieret, editors. *Assessment and Management of Plant Invasions*. Springer, New York, NY.
- Wyman, R. L. 1990. What's happening to the amphibians? *Conservation Biology* 4:350–352.

- Wynhoff, I. 1998. Lessons from the reintroduction of *Maculinea teleius* and *M. nausithous* in the Netherlands. *Journal of Insect Conservation* 2:47–57.
- Yanai, R. D., R. P. Phillips, M. A. Arthur, T. G. Siccama and E. N.Hane. 2005. Spatial and temporal variation in calcium and aluminum in northern hardwood forest floors. *Water Air and Soil Pollution* 160:109–118.
- Yates, D. E., D. T. Mayack, K. Munney, D. C. Evers, A. Major, T. Kaur, R. J. Taylor. 2005. Mercury levels in mink (*Mustela vison*) and River Otter (*Lontra canadensis*) from northeastern North America. *Ecotoxicology* 14:263–274.



Appendix A. Plant species identified as bioindicators for ozone foliar injury and their distribution among MORR (NPS 2003b and NPS 2006).

Scientific Name	Common Name	MORR
<i>Ailanthus altissima</i>	Tree-of-heaven	X
<i>Alnus rubra</i>	Red alder	
<i>Alnus rugosa</i>	Speckled alder	X
<i>Apios americana</i>	Groundnut	X
<i>Apocynum androsaemifolium</i>	Spreading dogbane	X
<i>Artemisia douglasiana</i>	Mugwort	
<i>Artemisia ludoviciana</i>	Silver wormwood	
<i>Asclepias exaltata</i>	Tall milkweed	X
<i>Asclepias syriaca</i>	Common milkweed	X
<i>Aster acuminatus</i>	Whorled aster	
<i>Aster macrophyllus</i>	Big-leaf aster	X
<i>Cercis canadensis</i>	Redbud	X
<i>Corylus americana</i>	American hazelnut	X
<i>Eupatorium rugosum</i>	White snakeroot	X
<i>Fraxinus americana</i>	White ash	X
<i>Gaylussacia baccata</i>	Black huckleberry	X
<i>Liriodendron tulipifera</i>	Yellow-poplar	X
<i>Lyonia ligustrina</i>	Maleberry	X
<i>Oenothera elata</i>	Evening primrose	
<i>Physocarpus capitatus</i>	Ninebark	
<i>Physocarpus malvaceum</i>	Pacific ninebark	
<i>Pinus jeffreyi</i>	Jeffrey pine	
<i>Pinus ponderosa</i>	Ponderosa pine	
<i>Platanus occidentalis</i>	American sycamore	X
<i>Populus tremuloides</i>	Quaking aspen	X
<i>Prunus serotina</i>	Black cherry	X
<i>Rhus trilobata</i>	Skunkbush	
<i>Rubus allegheniensis</i>	Allegheny blackberry	X
<i>Rubus canadensis</i>	Thornless blackberry	
<i>Rudbeckia laciniata</i>	Cutleaf coneflower	
<i>Salix scouleriana</i>	Scouler's willow	
<i>Sambucus canadensis</i>	American elder	X
<i>Sambucus mexicana</i>	Blue elderberry	
<i>Sambucus racemosa</i>	Red elderberry	

Scientific Name	Common Name	MORR
Sapium sebiferum	Chinese tallowtree	
Symphoricarpos albus	Common snowberry	
Vaccinium membranaceum	Huckleberry	
Verbesina occidentalis	Crownbeard	
Vitis labrusca	Northern fox grape	X
Vitus vinifera	European wine grape	

Appendix B. Listings of soil unit symbol, name and properties featured in Figure 4.5 for Morristown National Historical Park. United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) [www.nrcs.usda.gov/](http://www.nrcs.usda.gov/).

- CakB Califon loam, 3 to 8 percent slopes
- CakBb Califon loam, 0 to 8 percent slopes, very stony
- CapfB Califon variant loam, 3 to 8 percent slopes
- CoaBc Cokesbury loam, 0 to 8 percent slopes, extremely stony
- CobA Cokesbury gravelly loam, 0 to 3 percent slopes
- CobB Cokesbury gravelly loam, 3 to 8 percent slopes
- CobBb Cokesbury gravelly loam, 0 to 8 percent, slopes, very stony
- FNAT Fluvaquents and udifluvents, 0 to 3 percent slopes, frequently flooded
- GkaoB Gladstone gravelly loam, 3 to 8 percent slopes
- GkaoC Gladstone gravelly loam, 8 to 15 percent slopes
- GkaoD Gladstone gravelly loam, 15 to 25 percent slopes
- MenB Meckesville moderately well drained, gravelly loam, 2 to 6 percent slopes
- PaoC Parker gravelly sandy loam, 3 to 15 percent slopes
- PapC Parker very gravelly sandy loam, 3 to 15 percent slopes
- PapD Parker very gravelly sandy loam, 15 to 25 percent slopes
- PapFg Parker very gravelly sandy loam, 25 to 45 percent slopes, rocky
- PauCc Parker-Gladstone complex, 0 to 15 percent slopes, extremely stony
- PauDb Parker-Gladstone complex, 15 to 25 percent slopes, very stony
- PauDc Parker-Gladstone complex, 15 to 25 percent slopes, extremely stony (SSURGO1)
- PawE Parker-Rock outcrop complex, 25 to 45 percent slopes
- PbpAt Parsippany silt loam, 0 to 3 percent slopes, frequently flooded
- PbphAt Parsippany silt loam, sandy loam substratum, 0 to 3 percent slopes, frequently flooded
- RerB7 Reaville deep variant channery silt loam, 0 to 6 percent slopes
- UCFat Udifluvents and Udepts, 0 to 3 percent slopes, frequently flooded
- USGKAC Urban land-Gladstone complex, 8 to 15 percent slopes
- USRHVB Urban land-Riverhead complex, 3 to 8 percent slopes



Appendix C. USGS listing of non-indigenous species observed in HUC 8 basin 02030103 Hackensack-Passaic.

Group	Family	Scientific Name	Common Name	Native_Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Coelenterates-Hydrozoans	Olindiidae	<i>Craspedacusta sowerbyi</i>	freshwater jellyfish	Exotic
Crustaceans-Crayfish	Cambaridae	<i>Orconectes rusticus</i>	rusty crayfish	Native
Crustaceans-Crayfish	Cambaridae	<i>Orconectes rusticus</i>	rusty crayfish	Native
Crustaceans-Crayfish	Cambaridae	<i>Orconectes rusticus</i>	rusty crayfish	Native
Fishes	Centrarchidae	<i>Lepomis macrochirus</i>	bluegill	Native
Fishes	Centrarchidae	<i>Micropterus dolomieu</i>	smallmouth bass	Native
Fishes	Centrarchidae	<i>Micropterus salmoides</i>	largemouth bass	Native
Fishes	Centrarchidae	<i>Pomoxis annularis</i>	white crappie	Native
Fishes	Centrarchidae	<i>Pomoxis nigromaculatus</i>	black crappie	Native
Fishes	Cobitidae	<i>Misgurnus anguillicaudatus</i>	Oriental weatherfish	Exotic
Fishes	Cyprinidae	<i>Ctenopharyngodon idella</i>	grass carp	Exotic
Fishes	Cyprinidae	<i>Cyprinus carpio</i>	common carp	Exotic
Fishes	Esocidae	<i>Esox masquinongy</i>	muskellunge	Native



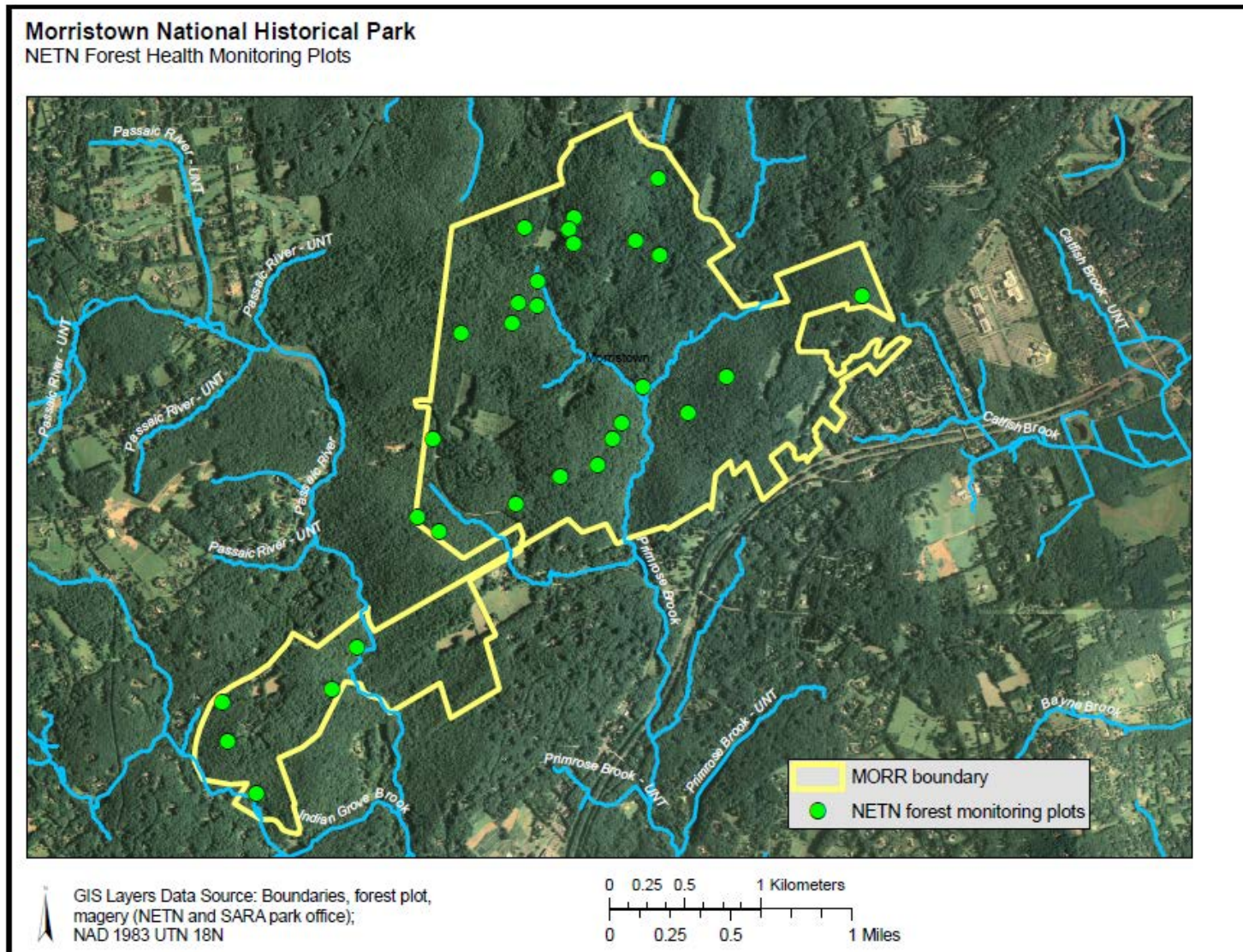
Group	Family	Scientific Name	Common Name	Native_Exotic
Fishes	Esocidae	<i>Esox masquinongy</i>	muskellunge	Native
Fishes	Esocidae	<i>Esox masquinongy</i>	muskellunge	Native
Fishes	Esocidae	<i>Esox masquinongy</i>	muskellunge	Native
Fishes	Fundulidae	<i>Lucania parva</i>	rainwater killifish	Native
Fishes	Fundulidae	<i>Lucania parva</i>	rainwater killifish	Native
Fishes	Gasterosteidae	<i>Apeltes quadracus</i>	fourspine stickleback	Native
Fishes	Gasterosteidae	<i>Apeltes quadracus</i>	fourspine stickleback	Native
Fishes	Ictaluridae	<i>Ictalurus furcatus</i>	blue catfish	Native
Fishes	Ictaluridae	<i>Ictalurus punctatus</i>	channel catfish	Native
Fishes	Moronidae	<i>Morone chrysops</i>	white bass	Native
Fishes	Percidae	<i>Sander vitreus</i>	walleye	Native
Fishes	Percidae	<i>Sander vitreus</i>	walleye	Native
Fishes	Salmonidae	<i>Oncorhynchus mykiss</i>	rainbow trout	Native
Fishes	Salmonidae	<i>Salmo salar</i>	Atlantic salmon	Native
Fishes	Salmonidae	<i>Salmo trutta</i>	brown trout	Exotic
Fishes	Salmonidae	<i>Salmo trutta</i>	brown trout	Exotic
Fishes	Salmonidae	<i>Salmo trutta</i>	brown trout	Exotic
Fishes	Salmonidae	<i>Salvelinus alpinus</i>	Arctic char	Exotic
Fishes	Salmonidae	<i>Salvelinus alpinus</i>	Arctic char	Exotic
Fishes	Synbranchidae	<i>Monopterus sp.</i>	Asian swamp eel	Exotic
Mollusks-Bivalves	Corbiculidae	<i>Corbicula fluminea</i>	Asian clam	Exotic
Mollusks-Bivalves	Corbiculidae	<i>Corbicula fluminea</i>	Asian clam	Exotic
Mollusks-Bivalves	Corbiculidae	<i>Corbicula fluminea</i>	Asian clam	Exotic
Mollusks-Gastropods	Lymnaeidae	<i>Radix auricularia</i>	European ear snail	Exotic
Mollusks-Gastropods	Lymnaeidae	<i>Radix auricularia</i>	European ear snail	Exotic
Mollusks-Gastropods	Lymnaeidae	<i>Radix auricularia</i>	European ear snail	Exotic
Mollusks-Gastropods	Lymnaeidae	<i>Radix auricularia</i>	European ear snail	Exotic
Mollusks-Gastropods	Viviparidae	<i>Cipangopaludina chinensis malleata</i>	Chinese mysterysnail	Exotic
Plants	Cabombaceae	<i>Cabomba caroliniana</i>	Carolina fanwort	Native
Plants	Callitrichaceae	<i>Callitriche stagnalis</i>	pond water-starwort	Exotic

Group	Family	Scientific Name	Common Name	Native_Exotic
Plants	Haloragaceae	<i>Myriophyllum spicatum</i>	Eurasian water-milfoil	Exotic
Plants	Haloragaceae	<i>Myriophyllum spicatum</i>	Eurasian water-milfoil	Exotic
Plants	Haloragaceae	<i>Myriophyllum spicatum</i>	Eurasian water-milfoil	Exotic
Plants	Lentibulariaceae	<i>Utricularia inflata</i>	swollen bladderwort	Native
Plants	Marsileaceae	<i>Marsilea quadrifolia</i>	European water-clover	Exotic
Plants	Potamogetonaceae	<i>Potamogeton crispus</i>	curly pondweed	Exotic
Plants	Potamogetonaceae	<i>Potamogeton crispus</i>	curly pondweed	Exotic
Reptiles-Turtles	Emydidae	<i>Trachemys scripta elegans</i>	Red-eared Slider	Native



Appendix D. NETN forest monitoring plots established from 2007 and 2009 in MORR.

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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**National Park Service**  
**U.S. Department of the Interior**



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