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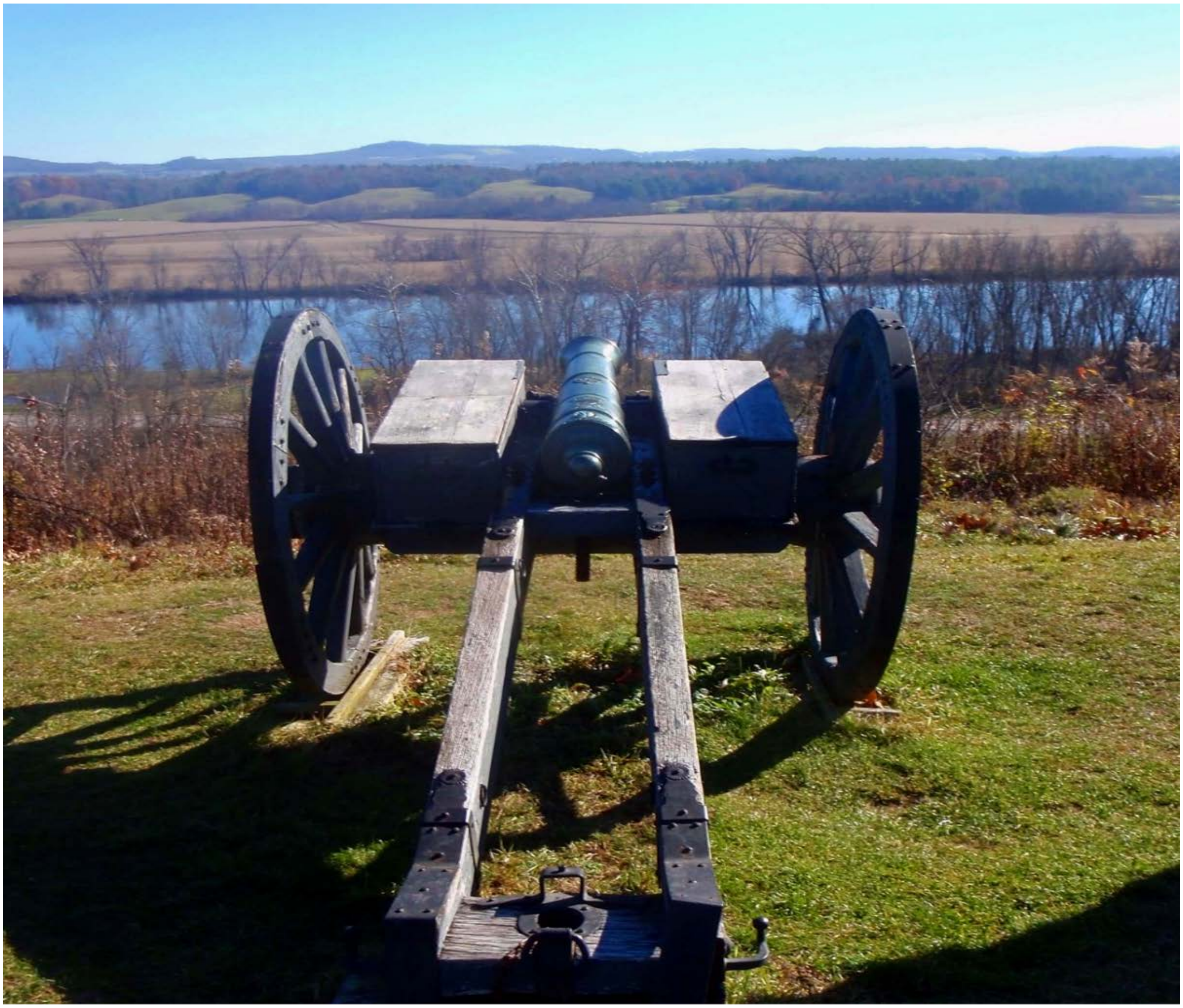
Natural Resource Stewardship and Science

Saratoga National Historical Park Natural Resource Condition Assessment

Natural Resource Report NPS/NETN/NRR—2014/751



ON THE COVER
A Revolutionary War replica cannon overlooking the Hudson River at Saratoga National Historical Park, New York.
Photograph by: Rebecca Wagner

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Natural Resource Condition Assessment

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Executive Summary

Background and Context

The Saratoga National Historical Park (SARA) includes over 3,400 acres along the historic Hudson River. The park is located in Saratoga County, NY, and is distributed within the towns of Stillwater and Saratoga. SARA's mosaic landscape integrates undulating fields, grassland habitat, mature forested areas and streams, ponds, rivers and floodplains, all which played a significant role in the defeat of British forces during the American Revolution. The battlefield at Saratoga was established as a US National Historical Park on June 1, 1938 under authorization of the United States Congress (52 Stat. 608; 16 U.S.C, secs. 159-159c) in order to commemorate the first significant American military victory during the American Revolution, specifically the 1777 Battle of Saratoga. Saratoga National Historical Park's purpose has been designated as follows:

"Saratoga National Historical Park preserves and protects sites associated with the battles, siege, and surrender of British forces at Saratoga, which were decisive events in the winning of American independence. The park interprets these and other sites, events, and people associated with the 1777 military campaign in the Champlain-Hudson and Mohawk valleys (also known as the Burgoyne Campaign)" (SARA General Management Plan 2004).

SARA preserves and interprets four non-contiguous units associated with the American Revolution: the Battlefield Unit (Stillwater, NY), the General Philip Schuyler House (Schuylerville, NY), the Saratoga Monument (Victory, NY) and Victory Woods (Village of Victory, NY). The Battlefield Unit, the largest contiguous parcel of SARA (approximately 4 square miles), is bounded by Route 4 to the east and Route 32 to the west and south. General Philip Schuyler House, Saratoga Monument and Victory Woods are commonly referred to as Old Saratoga Unit. The Schuyler House is the restored home of American General Philip Schuyler located near Fish Creek and the Hudson River while the Saratoga Monument commemorates the American victory in the Battle of Saratoga. Victory Woods is a22 acre woodland which was used by the British as their final defensive position before surrendering. The cultural aspects of SARA are well documented but the natural resources that compose the park are less well known. The preservation of the natural environment, viewshed and historic structures within all units composing SARA 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 SARA'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 Temperature Network (NETN) as the baseline and developed the local data sets to compare with those values. The majority of natural resource data was collected for the Battlefield Unit, with a lesser quantity of data available for the Old Saratoga Unit. Each evaluated natural resource in this NRCA begins with a brief description of the relevance and context of the resource to the general environment and SARA. 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 and NPS Air Resources Division categories. 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 generally included three categories: *good*, *caution* (*moderate* for air quality ratings) and *significant concern.* The exception to this language was for the assessment of PCB contamination from the Hudson River which included only *present* versus *absent* language. Best professional judgment was used to assign a condition category in the Visitor Usage section.Trend analysis was assigned a condition of *improving*, *deteriorating* or *unchanging* after statistical analyses of quantitative historical and current data. Data gaps and confidence in assessment were discussed after each metric was assessed. Confidence in the assessment and trend was identified as *high*, *medium*, *low* or *not applicable*. *High* confidence included extensive spatial and temporal quantitative data in the assessment; *medium* indicated data were from some studies that were quantitative and/or qualitative in nature; *low* indicated data were from limited studies that collected qualitative or quantitative spatial and temporal data; *not applicable* indicated no reliable trend analysis was possible with the data available or temporal data were absent. Finally, the authors recommend in Chapter 5 potential indicators which may be useful for monitoring natural resource conditions in SARA other than those indicators analyzed in this report.

Threats to SARA

Although SARA fundamentally serves as a historical cultural park, its matrix of forest, agriculture and grasslands serve as a unique biological refuge within an increasingly urban environment. External development around SARA is a concern due to negative pressures which may be inflicted on 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 lightscapes of the park. As population increases in the surrounding environment there may be an increase in demand for recreational space, thereby increasing stress on SARA's environment from increased visitor usage. Contaminants in soil, air and water resources threaten the environmental integrity of SARA. Atmospheric conditions such as high ozone, degraded visibility and elevated atmospheric deposition have been shown to stress vegetation, pose toxicity to terrestrial and aquatic systems and degrade the visibility of SARA's culturally important viewshed. The neighboring Hudson River and its floodplain along SARA's eastern boundary bear the legacy of detrimental chemicals, particularly PCBs, due to their release from industrial facilities. This part of the river is a federal PCB Superfund site and poses a threat to the SARA's wildlife which uses the Hudson River and floodplain as a resource for habitat, breeding and food resources. Invasive plant and animal species continue to threaten SARA'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 SARA's mature forests.

Current Condition of Natural Resources in SARA

Air Quality

Air quality can affect visitor health and use, animal and vegetation communities, water quality and the cultural viewshed in SARA. Parameters of interest for SARA's air quality included ozone, wet nitrogen deposition, wet sulfur deposition, mercury deposition, and visibility. Based upon NPS guidance, SARA's air quality for wet nitrogen and sulfur deposition is considered a *significant concern*. NPS has no current guidance for mercury, although values are higher than a peer-reviewed threshold used for this assessment. SARA's ozone and visibility rated *moderate* based upon NPS guidance.

Forest Soil Dynamics

Soil monitoring is used to understand the effects of acidic deposition on forest health. Using condition ratings developed by the NPS NETN, SARA Ca:Al ratio rated *good*, whereas the C:N ratio rated *significant concern*. The results from samples collected in SARA indicate that the park may be experiencing excess N saturation.

Water Quantity and Stream Water Chemistry

SARA 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 baseline data within SARA, we were unable to assess surface water quantity condition, thereby rating it as *unknown*. With continued growth in the region, water availability and its quality will likely be stressed and it is recommended that the park monitor surface and groundwater availability. SARA's stream surface water chemistry depended upon the parameter measured and the stream sampled. Several water quality parameters sampled, such as dissolved oxygen, specific conductance, pH and acid neutralizing capacity were compliant with New York water quality standards or recommended thresholds based upon peer-reviewed research. Nutrient parameters such as total nitrogen, total phosphorus and NO_2+NO_3 exceeded EPA criteria for Kroma Kill, sections of Mill Creek and American's Creek.

PCB Contamination

The neighboring Hudson River and the adjacent floodplain of SARA have had a legacy of polychlorinated biphenyls (PCBs) contamination for several decades. PCBs have been detected in various habitats and organisms at sites located within or near SARA, including: surface water samples, soils and tissues and blood samples of insects, amphibians and reptiles, fish, birds and small mammals. In order to reduce PCB exposure, visitor use near the Hudson River is discouraged but is not prohibited. Additionally, park management and staff interactions in floodplain areas are limited in SARA. For example, park management has altered vegetation management techniques in order to address safety concerns of staff working in the floodplain.

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 SARA's grassland, forest and aquatic habitats. Common buckthorn (*Rhamnus cathartica*) and exotic bush honeysuckle (*Lonicera* spp.) are the most relatively abundant invasive species surveyed in forest plots. SARA contains 3.26 key indicator species per forest plot, rating the park as *caution* for invasive, exotic forest species under the NETN rating methods. Spatial distribution of invasive plant species in SARA has shown several species are a concern for grassland fields, particularly *Centaurea* sp. (knapweed), which was found established in over 69% of fields in SARA. The documentation of invasive, emergent vegetation species in and near waterbodies within HUC 12 boundaries of SARA resulted in a condition assessment of *significant concern*.

Invasive exotic animals and diseases in forest and aquatic habitats are present in SARA. From 2008-2010 approximately 90% of forest plots were rated *good* for the tree condition and forest pest measure which included measuring foliage problems and presence of pests. T he remaining forest plots were rated *caution* in SARA under NETN rating methods. Although many of the forest plots in SARA were considered *good*, the impact of exotic invasive animals and disease had been observed in several plots in the park. Many trees have been affected from defoliation and beech bark disease, threatening the tree species which were vital to the historic significance of the 1777 Battle of Saratoga and the ecosystem integrity of SARA's forests. Invasive fishes, mollusks and crustaceans are present in the adjoining Hudson River, endangering the tributaries flowing through SARA to the

Hudson River. Based on a HUC 8 spatial assessment, the Upper Hudson Basin condition for invasive animals was assessed as significant concern. SARA's HUC12 subwatershed, Fish Creek, was categorized as *significant concern* due the presence of common carp. McAuley Brook and Mill Hollow Brook subwatersheds were categorized as *caution* based upon the potential risk of invasion in SARA's waters due to non-indigenous species establishment in adjacent tributaries.

Forest Vegetation

SARA contains a forested landscape which is vital to the cultural significance of the park and serves as important biological habitat. Forest health metrics in SARA were rated as *good* or *caution* based on NETN established ratings. Forest patch and structural stage distribution rated *good* while anthropogenic land use, snag abundance and coarse woody debris rated *caution* for forest plots sampled in SARA. Biotic homogenization remains unrated due to current refinement of the metric.

White-tailed Deer Herbivory

Deer populations in SARA have been growing slowly since the 1960's and exceeding densities which may degrade vegetation regeneration due to herbivory (Underwood *et al.* 1994). Two tree regeneration indicators, seedling ratio and deer browse index, were measured in SARA forest plots by NETN and used to assess deer impacts on vegetation. The seedling ratio measured -0.32±0.10 and was categorized as *caution* using the NETN rating system. Seedlings less than 30 cm tall were abundant in SARA; seedlings in height classes over 1 m were less common and sapling density was low. SARA also contained the lowest seedling ratio of all NETN parks. The deer browse index was 3.07±0.12, which rated *moderate.* The *moderate* category indicated browse preferred regeneration was present in SARA and had little height variability, with non-preferred and browse resistant species common. These two indicators suggest that deer browse pressure may be impacting forest regeneration in SARA.

Fish Community

There is no recognized Index of Biotic Integrity (IBI) for fish in New York, necessitating the use of an IBI developed for the Northern Mid-Atlantic Slope Drainage. Kroma Kill rated *caution-good* and Mill Creek's main, middle and south branch rated *significant concern-caution*. Additionally, the analysis of individual metrics provides value in the assessment of structural composition and function of the fish community. Kroma Kill and three sections of Mill Creek were assessed using individual metrics. These streams contained metric ratings of *good*, *caution* and *significant concern* for nine individual metrics measuring species richness and composition and trophic composition.

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 *good* while structural and functional metrics were dominated by *caution* or *significant concern*. These results indicate that the forest bird community at SARA may be affected by the generally fragmented landscape consisting of small forest blocks broken up by fields and early successional habitats, plus effects of deer on understory vegetation structure. 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 assessment scores just by virtue of the fact that the forest patches are small with relatively large amounts of edge habitat. The assessment can still be useful in terms of monitoring direction of change.

The grassland avian ecological integrity assessment consisted of four *caution* ratings. The grassland bird assessment is new and will probably be adjusted over the coming years to better reflect condition. At a regional level SARA grasslands are considered a high priority because of the number of grassland obligates it supports and the high abundance of some of the grassland obligates. As such, in terms of the bird community, grasslands are the most important habitat type and should be managed to maximize the value of this habitat. Additionally, continued monitoring of grassland birds, knapweed management, and maintaining management records will improve the management of grassland habitats and the grassland bird community.

Amphibians and Reptiles

Historical documentation indicates that 30 species of amphibians and reptiles have been observed throughout SARA and Saratoga County. Species of special concern under NY legislation Section 182.2(i) of 6NYCRR Part 182 are present in SARA. Thirty-nine sites (stream, woodland and wetland habitats) within SARA's Battlefield Unit, Victory Woods, and Schuyler House property were assessed for the presence of amphibians and reptiles by Cook *et al.* (2011). The State of New York currently does not have an amphibian index of biotic integrity, thus the Amphibian Index of Biotic Integrity (AmphIBI) was utilized to assess the amphibian community (Micacchion 2004). Based on the AmphIBI calculations, SARA rated *fair*. Additionally, Cook *et al.* (2011) determined that 18 of the 28 amphibian and reptile species that occurred historically at or in the area around SARA appeared to be stable in terms of their population status, three species-northern leopard frog, Jefferson salamander and eastern box turtle- have declined or have disappeared and seven species lack information for trend assessment. For these species identified as declining, truly "historic" data are lacking and it is impossible to know how common or rare they were at SARA, except in recent decades. Their decline in SARA however, may be due to a broader global or regional decline, along with a variety of potential stressors.

Visitor Usage

Based on NPS Public Use Office annual park visitation data, from 1941-2010 SARA hosted over 7,000,000 recreational visitors, with nearly 20% of visitors having been to the park 10 or more times (Vana-Miller *et al*. 2001, NPS Stats 2011). Visitors to SARA engage in many activities during their visits such as tour road visits, hiking, biking, horseback riding, skiing and snowshoeing. Little quantitative data are available regarding impacts to natural resources due to visitor use. Best professional judgment based on visitation statistics and the region's population and housing growth was used to assess visitor usage impacts on SARA's natural resources. Based on the examination of available data, visitor usage and its impact to SARA's natural resources was assessed as *caution.* 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, wildlife impacts, trampling, litter, and many other stresses.

Landscape Dynamics

Evaluating landscape patterns around the park is crucial to assessing natural resource conditions within SARA. Population and housing density within 30 km of the park were spatially modeled and have been projected to increase within the next few decades. For SARA, urban land cover within 5 km of the park increased 26% from 1986-2001, while forested cover of all types has decreased from 10-26% depending on the forest type (see Wang *et al.* 2009 for potential caveats of Landsat sensor data). Assessments of impervious surface within SARA rated the park *good.* Buffer analysis of 100 m around roads within and surrounding SARA rated the park *caution* due to the stressors roads can pose on the park's habitats. Additionally, decreases in forested patch area due to road development threaten the terrestrial and aquatic habitat integrity of SARA. Lastly, the surrounding cultural viewshed of SARA, although moderately preserved due to proactive efforts by NPS and conservation groups, still remains highly vulnerable to alterations (e.g., cell phone tower installations, changes to the surrounding lightscapes). Based on the available land use spatial data, long-term development trends will continue to increase pressure on SARA's natural resources and our evaluation of this issue is that SARA is under cautionary threat at this time.

Acknowledgments

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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". For these condition analyses they also report on trends (as possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list 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. Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures ⇨ conditions for indicators ⇨ condition summaries by broader topics and park areas
- identify or develop logical reference conditions/values to compare current 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 a 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

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 and help parks report to government accountability measures

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

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.

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

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

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)

Chapter 2 Introduction and Resource Setting

2.1 Introduction

2.1.1 History & Enabling Legislation

Acquisition of battlefield lands in New York State began due to the formation of a 1926 State law. The battlefield at Saratoga was established as a U.S. National Historical Park on June 1, 1938 under authorization of the United States Congress (52 Stat. 608; 16 U.S.C, secs. 159-159c) in order to commemorate the first significant American military victory during the American Revolution, specifically the 1777 Battle of Saratoga.

"*An Act To provide for the creation of the Saratoga National Historical Park in the State of New York and for other purposes, approved June 1, 1938 (52 Stat. 608)…Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That when title to all the lands, structures, and other property in the area at Saratoga, New York, whereon was fought the Battle of Saratoga during the War of the Revolution, shall have been vested in the United States, such area shall be, and it is hereby, established, dedicated, and set apart as a public park for the benefit and inspiration of the people and shall be known as the Saratoga National Historical Park: Provided, That such area shall include that part of the Saratoga Battlefield now belonging to the State of New York and any additional lands in the immediate vicinity thereof which the Secretary of the Interior may, within six months, after the approval of this Act, designate as necessary or desirable for the purposes of this Act. (16 U.S.C. sec. 159.).*"

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

"Saratoga National Historical Park preserves and protects sites associated with the battles, siege, and surrender of British forces at Saratoga, which were decisive events in the winning of American independence. The park interprets these and other sites, events, and people associated with the 1777 military campaign in the Champlain-Hudson and Mohawk valleys (also known as the Burgoyne Campaign)" (SARA General Management Plan 2004).

Legislation for the revision of park boundaries and land acquisition (16 U.S.C. 159d-g) was enacted in later years for SARA. Since 1938, The Saratoga National Historical Park Battlefield Unit was joined with three sites: General Philip Schuyler Estate in the village of Schuylerville, Saratoga Monument and Victory Woods in the village of Victory. Land acquisition and boundary alteration was to, "… preserve certain lands historically associated with the Battle of Saratoga and to facilitate the administration and interpretation of the Saratoga National Historical Park (96 STAT. 2520, Public Law 97-460, 16 USC 159f, 1983)".

Overall, Saratoga National Historical Park (SARA General Management Plan 2004):

- Honors the participants and preserves the battlegrounds where a major British military offensive in 1777 ended in a surrender that heartened the patriot cause and brought about the international recognition and aid essential to securing our nation's freedom.

- Contains the Saratoga estate of General Philip Schuyler, an outstanding figure during the revolutionary period and commander of the northern theater of operations between June 1775 and August 1777.
- Presents a richly monumented landscape reflective of a commemorative movement, which culminated in the establishment of the national historical park in 1938.

2.1.2 Geographic Setting

Saratoga National Historical Park (SARA) 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). SARA is located near the southern extent of the Adirondack Mountain region in New York's upper Hudson River Valley. This park is situated in Saratoga County, NY and is distributed within the towns of Stillwater and Saratoga (Figure 2.2). The 3406 acre park is positioned along the historic Hudson River, approximately 30 miles (48 km) north of Albany, NY, 10 miles southeast of the City of Saratoga Springs and 17 miles (27 km) west of the Vermont boundary. Regionally, SARA is within an area which is growing rapidly in population, facilitated by Interstate 87 (The Northway). Many development pressures are shielded by Saratoga Lake located to the west of the SARA's main battlefield. Lands surrounding the park are rural/agricultural in character, but may change in land usage due to population growth.

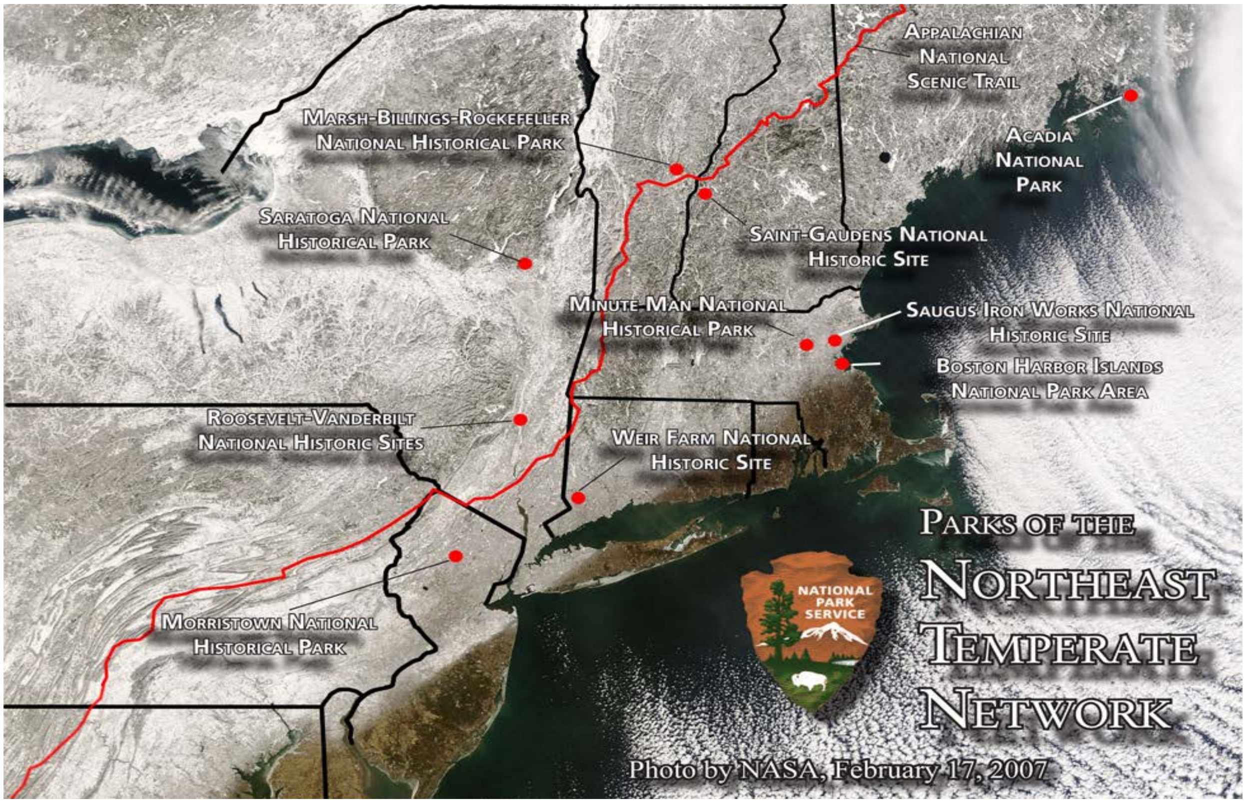


Figure 2.1. NPS Northeast Temperate Network (NETN). From NPS NETN webpage. Accessed: http://science.nature.nps.gov/im/units/NETN/index.cfm.

SARA's mosaic landscape integrates undulating fields, grassland habitat, mature forested areas, streams, ponds, rivers and floodplains, all which played a significant role in the defeat of British forces during the American Revolution. The 1992 Resource Management Plan for SARA notes that the vegetation of the historical/cultural landscape is the park's primary natural feature, as topography and vegetation played an important role during the Battle. SARA preserves and interprets four non-contiguous units associated with the American Revolution: the Battlefield Unit (Stillwater, NY), the General Philip Schuyler House (Schuylerville, NY), the Saratoga Monument (Schuylerville, NY) and Victory Woods (Village of Victory, NY) (Figure 2.2), all which are within USGS 7.5 minute topographic quadrangles Quaker Springs, Schuylerville, Mechanicville, and Schaghticoke. The Battlefield Unit, the largest contiguous parcel of SARA (approximately 4 square miles (about 10 km^2)), is bounded by Route 4 to the east and Route 32 to the west and south. General Philip Schuyler House, Saratoga Monument and Victory Woods are commonly referred to as Old Saratoga Unit. The Schuyler House is the restored home of American General Philip Schuyler located near Fish Creek and the Hudson River while the Saratoga Monument commemorates the American victory in the Battle of Saratoga. Victory Woods is a 22 acre (9 ha) woodland which was used by the British as their final defensive position before surrendering. The preservation of the natural environment, viewshed and historic structures within all units composing SARA is vital in order to sustain the park's culturally driven purpose.


The Philip Schuyler House (left) and the Saratoga Monument (right) are important cultural features located at Saratoga National Historical Park. Photos: C. A. Cole and R. Wagner (November 12, 2010).

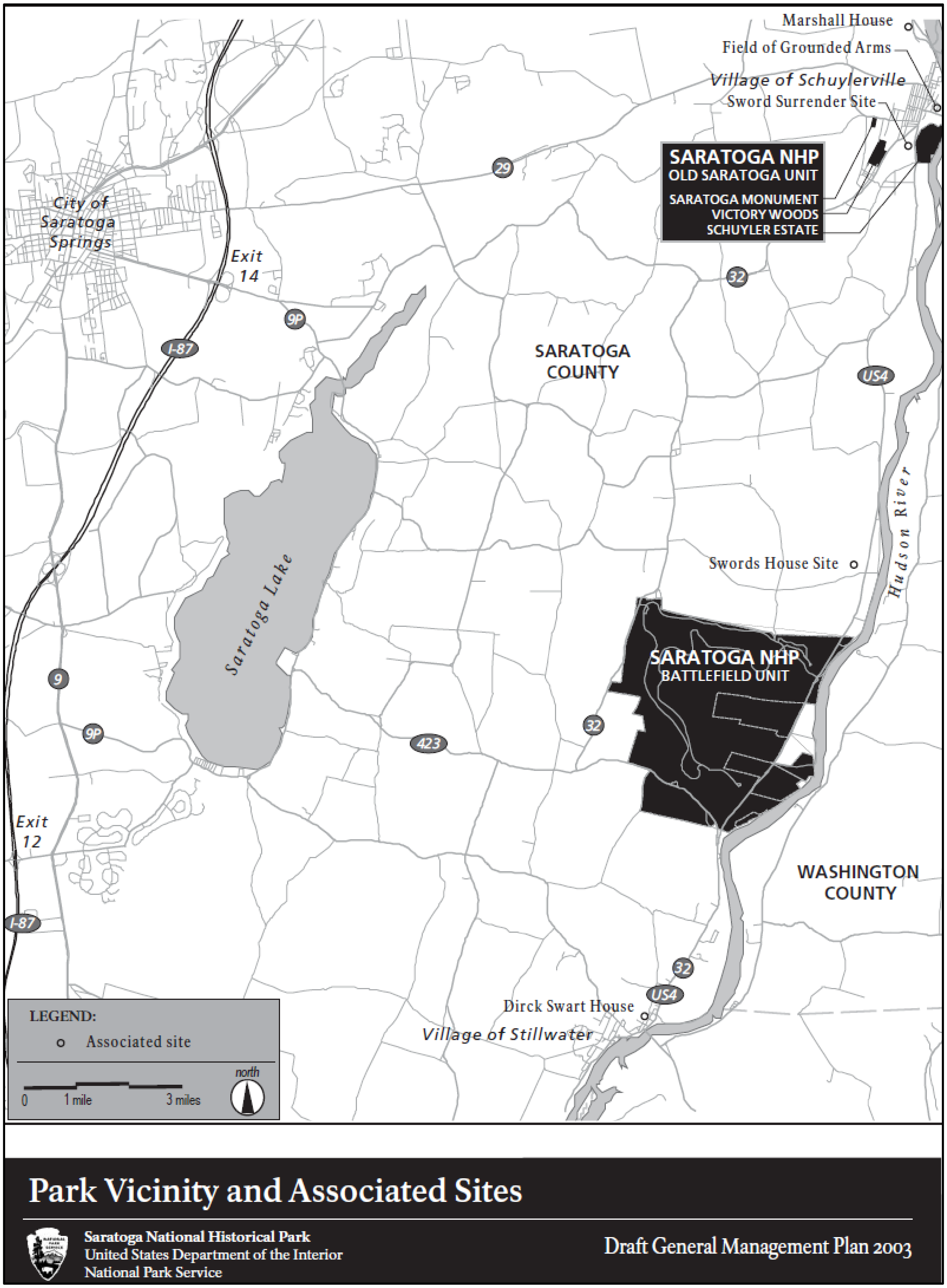


Figure 2.2. Location of Saratoga National Historical Park units (from SARA General Management Plan 2004).

2.1.3 Visitation Statistics

Based on annual visitation data, SARA averaged 111,000 recreational visitors per year from 1941-2010 , with 45% of all visitors from local communities and nearly 20% of visitors having been to the park 10 or more times (Vana-Miller *et al.* 2001, NPS Stats 2011). SARA's highest visitation months are generally from May through September (NPS Stats 2011). In 2010, SARA recorded 63,719 visitors for the year, with the month of July hosting the most number of visitors at 9,980 people (NPS Stats 2011). Recreational activities such as hiking, horseback riding, snow activities, wildlife and scenic viewing, cycling and historical education are experienced at SARA. Several monuments and markers and ten historical tour stops exist within the Battlefield Unit of SARA (Figure 2.3). In recent years, SARA has incorporated the use of digital technology (i.e., audio tours via MP3 downloads and cell phones, interactive ancestor database) to enhance the historical experience and education for visitors at SARA.

The Battlefield Unit is open to pedestrian traffic seven days a week, and the tour road is accessible April-November, weather permitting. Schuyler House and Saratoga Monument are open from Memorial Day through Labor Day, and then are only accessible on the weekends through October. Foot trails, horse trails and tour roads are means of transportation within SARA. Approximately 96% of visitors to SARA arrive in private auto and 67% tour the park by private auto (SARA General Management Plan 2004). The Battlefield tour road drive time ranges from 30 minutes to 2 hours, depending on the number of tour road stops. It has been identified by the SARA General Management Plan (2004) that traffic congestion could increase within the park, causing delays, noise and air pollution that could distract from visitor's experience and affect natural resources.

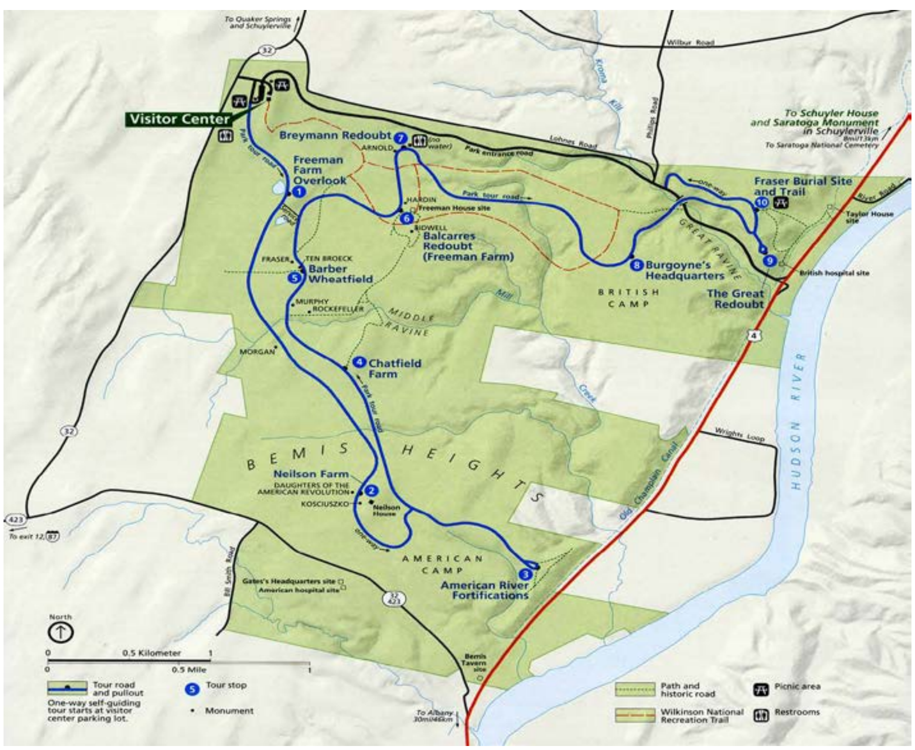


Figure 2.3. Tour road and tour stops in SARA Battlefield Unit. From: www.nps.gov/sara.

2.2 Natural Resources

2.2.1 Ecological Units and Watersheds

Climate

Climate in the region which encompasses SARA is characterized by lengthy cold winters, short warm summers and moderately heavy precipitation. Climate data analyzed from 1961-1990 indicate that SARA has a mean annual temperature ranging from 44.7-46.4°F (7.1-8.0°C). Minimum temperatures for January ranged from 7.0-53.6° F (-13.9-12.0°C) and maximum temperatures in July averaged a range from 82.6-84.2° F (28.1-29.0°C). Mean annual precipitation from 1961-1990 ranged from 35-39 in/yr (901-1000 mm/yr) and mean annual snowfall ranged from 39-79 in/yr (1001-2000 mm/yr) (Davey *et al.* 2006). These precipitation values make SARA one of the driest parks in the NETN (Figure 2.4).

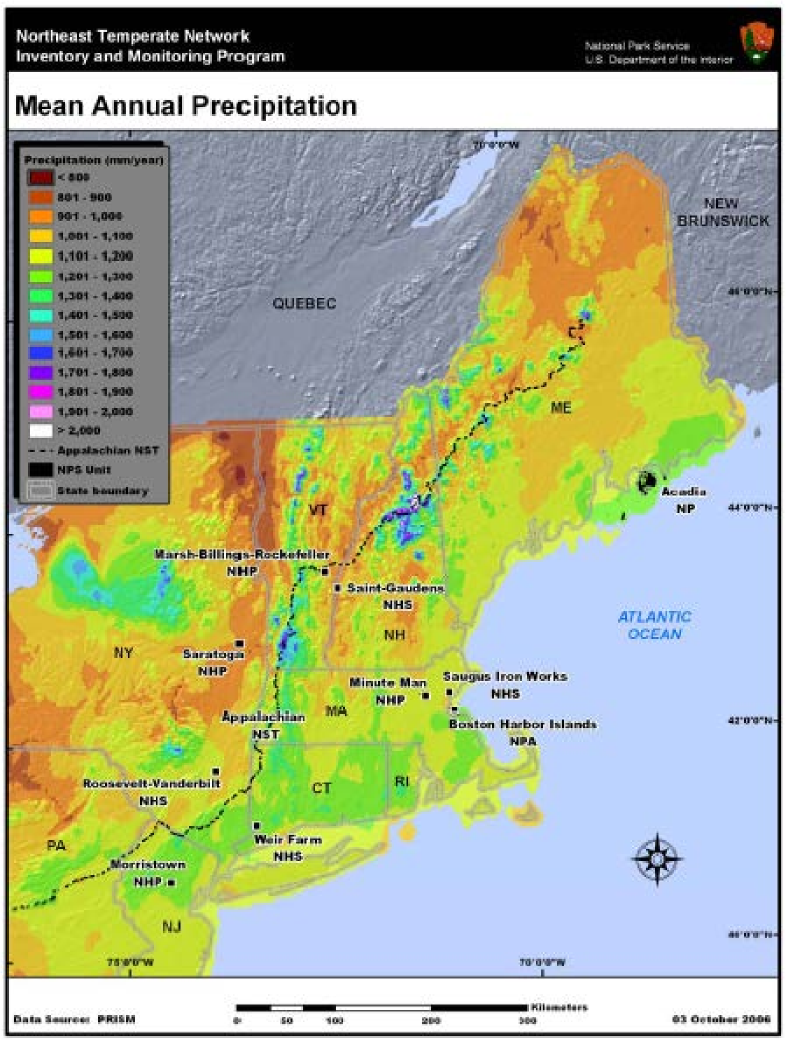


Figure 2.4. Mean annual precipitation (mm/year) for the Northeast Temperate Network parks (from Davey *et al.* 2006).

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. SARA is within the Level III ecoregion 59 *Northeastern Coastal Zone* and Level IV ecoregion 59i *Hudson Valley* as derived by Omernik (1995, 2004) (Figure 2.5)**.** The Northeastern Coastal Zone ecoregion contains considerably less surface irregularity and much greater concentrations of human population. Landforms include irregular plains, and plains with high hills. Appalachian oak forests and northeastern oak-pine forests are the natural vegetation types. SARA is also recognized as part of The Nature Conservancy terrestrial ecoregion classification of Hudson Glacial Lake Plains Subsection of the Lower New England/Northern Piedmont Ecoregion and the U.S. National Vegetation ecoregional classification of Eastern broadleaf forest (oceanic).

Watersheds

SARA is situated in the Upper Hudson basin, lying within the Hudson-Hoosic watershed (HUC8 02020003) (Figure 2.6). SARA's legislative boundary is located within four subwatersheds (HUC 12): Mill Hollow Brook-Hudson River, McAuley Brook-Hudson River, Slocum Creek-Hudson River and Fish Creek (Figure 2.6). The Upper Hudson River watershed originates in the Adirondack Mountains and flows south toward the Hudson River confluence with the Mohawk River at the Troy Dam. The Upper Hudson has a drainage basin area of 4,590 square miles (11,888 square km) and lies primarily in New York State but also drains a portion of southwestern Vermont and Massachusetts. 7,140 miles (11,490 km) of freshwater rivers and streams and 229 significant freshwater lakes, ponds and reservoirs (76,940 acres (31,136 ha)) are within the watershed (NYSDEC, http://www.dec.ny.gov/lands/48019.html). Major water quality concerns in the Upper Hudson watershed include:

- Impacts from legacy industrial PCB releases to the Upper Hudson which are currently being remediated. Sections of the Hudson River have been deemed a PCB Superfund Site by the U.S. EPA.
- Acid rain which limits the fish community and aquatic life.
- Mercury atmospheric deposition which restricts fish consumption.

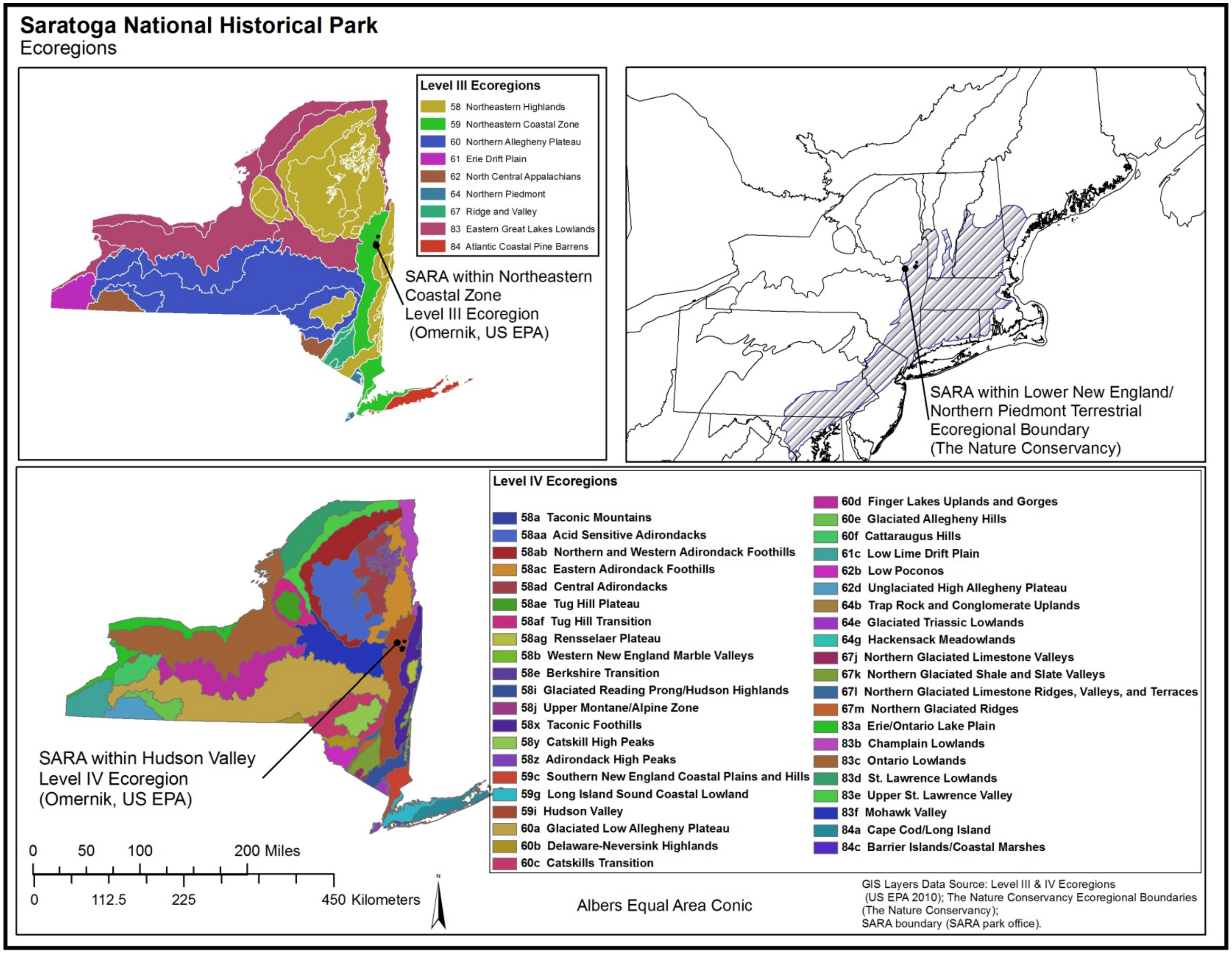


Figure 2.5. Multiple spatial scale ecoregions of SARA.

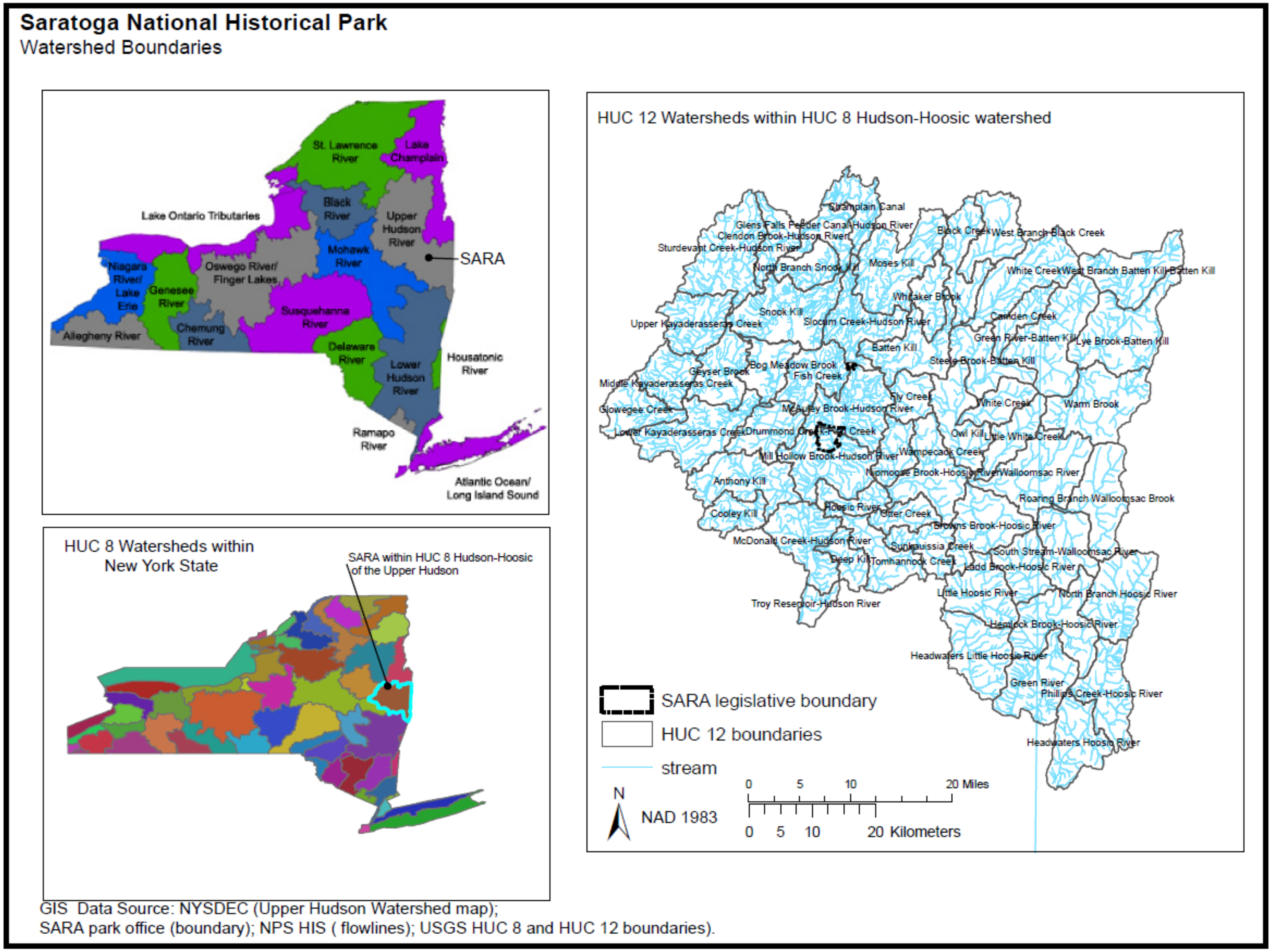


Figure 2.6. Basin, subbasin and subwatershed boundaries of SARA.

2.2.2 Resource Descriptions

Topography and Geology

Topography played a major role in battle strategy due to the ridges, gorges, bluffs and hydrology that compose SARA's environment. Thus, topography is of great cultural significance and interpretation for SARA. Two topographically distinct areas divide the park (Health *et al.* 1963) (Figure 2.7). West of Route 32, low hills transverse in a northeast-southwest direction, alternating with flat-bottomed valleys. Hill altitudes in the northwestern corner of SARA range from 400 ft (123 m) above sea level to more than 600 ft (163 m) outside of the western boundary of SARA. Valley basins range from 300 ft (91 m) near Route 32 to 450 ft (137 m) west of the park (Vana-Miller *et al.* 2001). East of Route 32 are two terraces and the Hudson River floodplain. An upper and lower terrace has been influenced by stream erosion, with the lower terrace being separated from the floodplain by a steep scarp more than 100 ft (30 m) high. The floodplain ranges from 525 to 2756 ft (160-804 m) in width and 90 to 100 ft (27-30 m) in altitude on the western part of the river, from Kroma Kill south to Mill Creek (Vana-Miller *et al.* 2001).

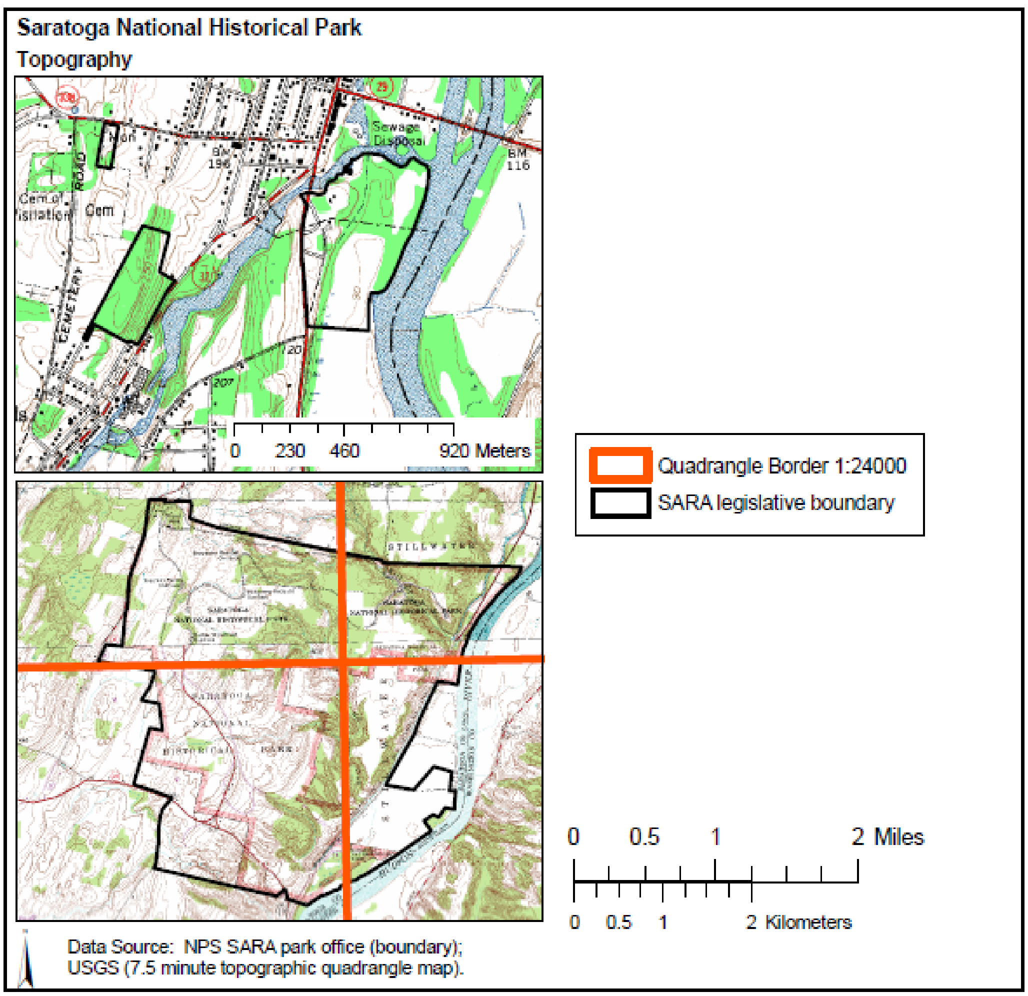


Figure 2.7. Topography features of SARA park units

SARA lies in the Appalachian Basin which is composed of the Devonian, Marcellus and Utica Shales. The Marcellus shale layer is situated above the Utica layer, and the Devonian layer is the shallowest and youngest geological layer within the basin. The Utica shale, which SARA overlays, is the deepest and oldest shale play. These geologic formations are currently being utilized in isolated areas for their oil and gas resources.

Generally, bedrock geology in SARA is composed of Ordovician to Cambrian age sedimentary rock (i.e., sandstone, siltstone, shale). In the Battlefield Unit, three bands of underlying bedrock run parallel to the Hudson River (Figure 2.8). Along the Hudson River, the first and largest bedrock formation in SARA is the geological band Canojoharie Shale (sandstone and shale). The next band is the Mount Merino Formation, composed of shale, siltstone and minimal sandstone. The final formation is the Austin Glen Formation, which is also composed of shale, siltstone and minimal sandstone. Mount Merino Formations composes all of the Old Saratoga Unit (Fisher *et al.* 1970).

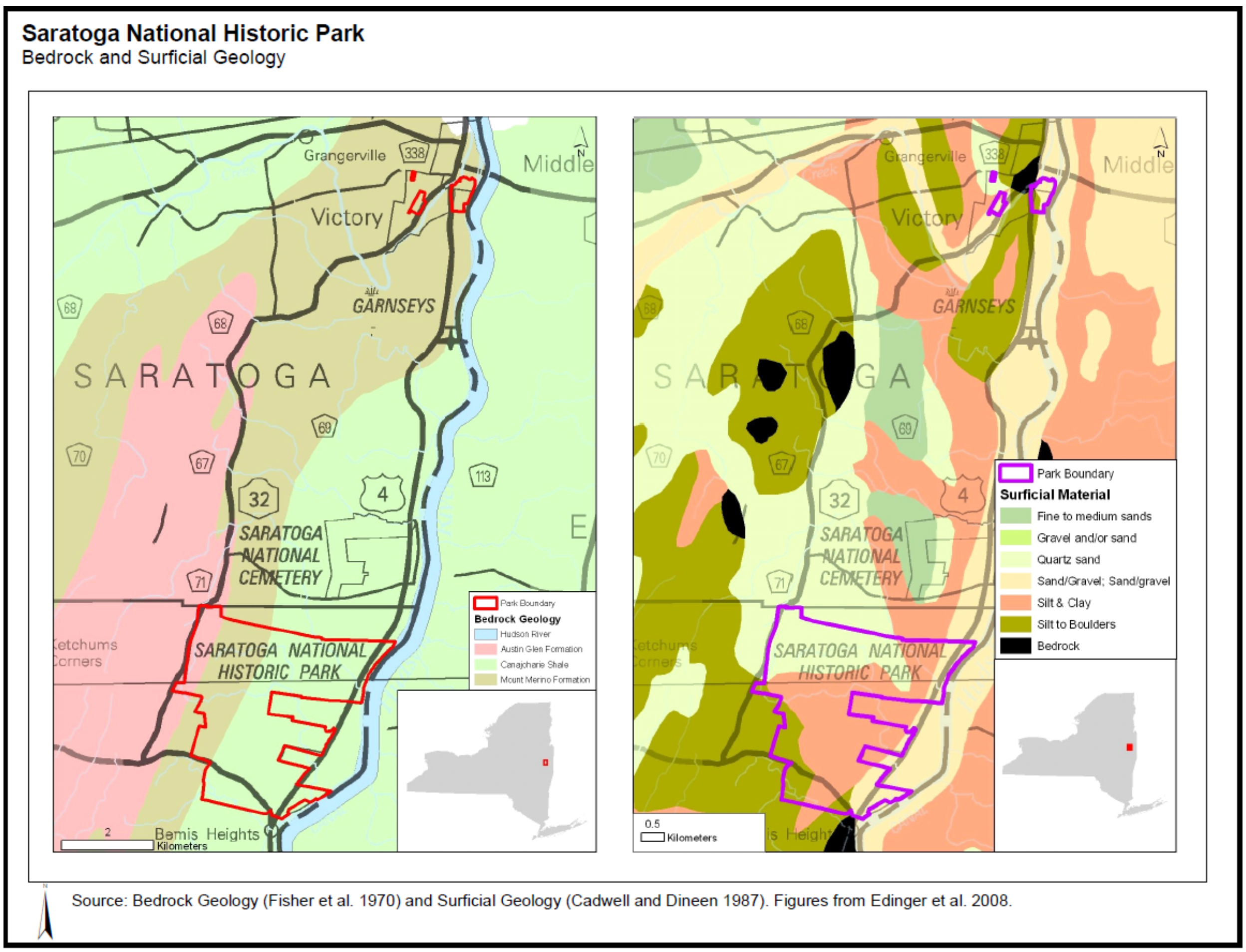


Figure 2.8. Bedrock and surficial geology of SARA (from Fisher et al. 1970 and Edinger et al. 2008).

Surficial geology of SARA's Battlefield Unit is similar in pattern to the bedrock, running parallel to the Hudson River. Recent alluvium (sand and gravel) grades into lacustrine silt and clay to the west. Northward, the park contains lacustrine quartz sand, grading into glacial till (silt to boulders) to the west. Old Saratoga Unit is primarily alluvium along the rivers near Schuyler Estate which grades westerly into glacial till. Victory Woods contains alluvium and lacustrine silt and clay (Cadwell and Dineen 1987). A unique geological feature to the area is Devil's Hollow, a shale gorge deeply eroded near the southern edge of SARA. The gorge depth ranges from 5 to 80 feet, emitting shale-based waterfalls from an intermittent stream. Geologic disturbance produced by anthropogenic activity has not occurred in SARA since the late 1930s to 1940s when surface sand mining was active within park boundaries (Vana-Miller *et al.* 2001).

Soils

Soils in Saratoga County have been shaped by retreating glaciers and lacustrine deposits which have influenced the strong agricultural tradition in the Hudson Region (USDA NRCS 2004). Soils in SARA are generally alluvial clays and loams, producing site-specific variations in park vegetation. The soils along the Hudson are alluvial clays and loams which produced moist and flooded areas. Hills rising from the river flats are composed of gravel and sand components. Many sandy areas near the Hudson River have been underlain with clay, creating poor, deep drainage. Toward the western park of SARA, the soils are rocky and fairly well drained. Major soil associations for SARA include (Appendix A):

- Rhinebeck Silt Loam (0-15% slopes)
- Hudson silt loam, hilly
- Bernardston-Manlius-Nassau complex, undulating
- Manlius-Nassau complex, hilly, rocky
- Oakville loamy fine sand, nearly level
- Bernardston silt loam, 3 to 8 % slope
- Pittstown silt loam, 3 to 8 % slope
- Limerick-saco complex
- Madalin mucky silty clay loam
- Nassau-Rock outcrop complex
- Sun silt loam
- Mosherville-Hornell complex, undulating

Many soil types found at SARA are subject to slumping and erosion as documented by landslide incidents in SARA in the late 1980's early 1990's (Vana-Miller *et al.* 2001). Potential soil loss through erosion was calculated and erosion hazards were categorized as *slight, moderate, severe/very severe* for SARA based on the USDA NRCS 2004 Saratoga County soil survey. GIS mapping indicated that the majority of SARA has a slight hazard rating while the most severe erosion hazard is near streams which flow through the park (Figure 2.9). Proper conservation procedures can reduce the rate of erosion for areas in SARA containing severe erosion hazards.

Soils which constitute *prime farmland* and *farmland of statewide importance* are found within SARA and surround the park (Figure 2.10). The best and most productive soils are classified by the Natural Resources Conservation Service (NRCS) as prime soils. These soils are suited to a wide variety of farm crops with few limitations and are an irreplaceable resource but are not protected at the county level. Their gentle topography and even-texture characteristics make these soils easy to develop for residential and commercial uses. Statewide important soils support crop fields but have limitations that require conservation measures and are suited to a smaller variety of crops. The loss of prime soils and important agricultural soils is a common trend seen over time due to sustained development activities in Saratoga County.

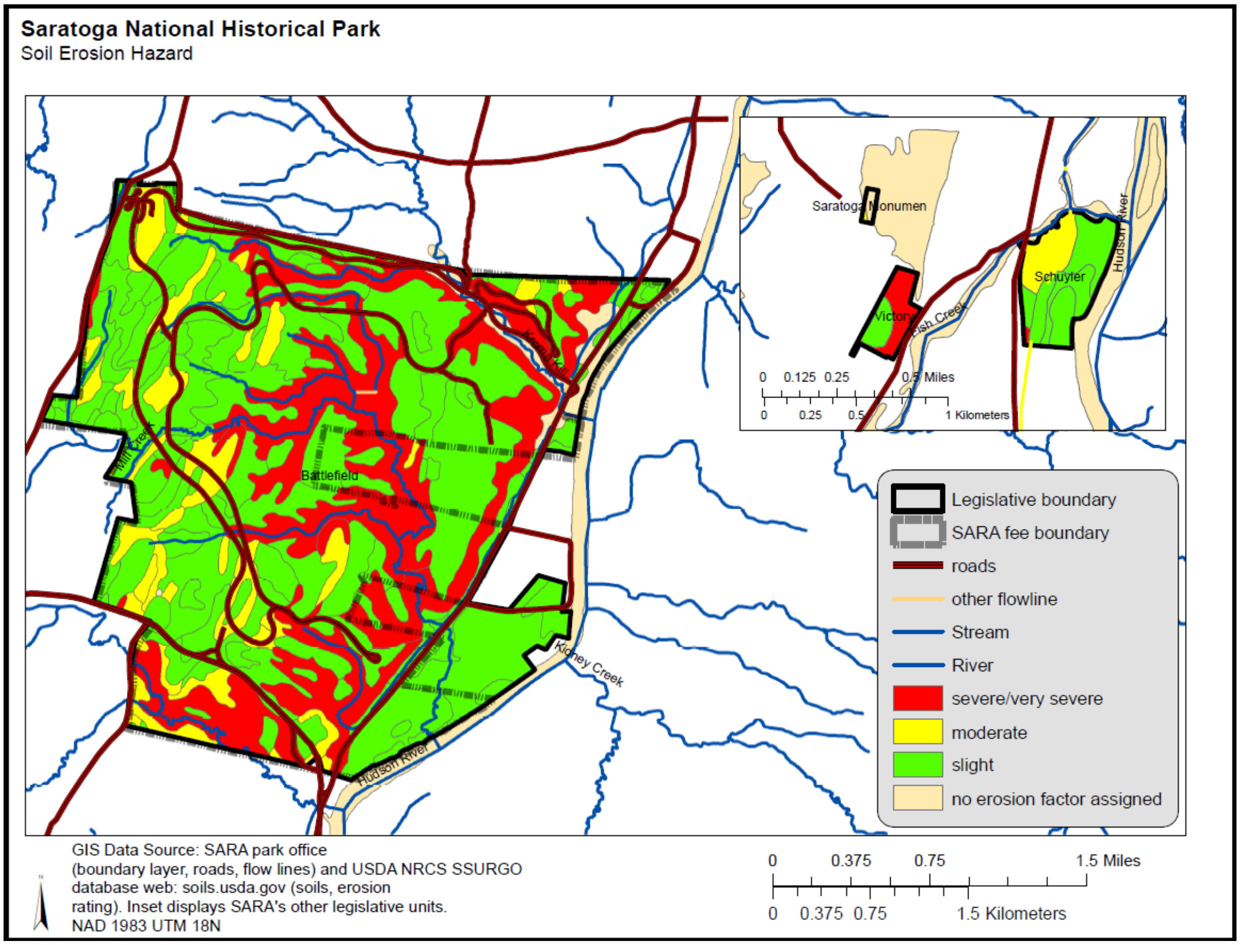


Figure 2.9. Soil erosion hazard ratings for SARA based on USDA NRCS (2004) Saratoga County, NY soil survey in releation to streams and roads.

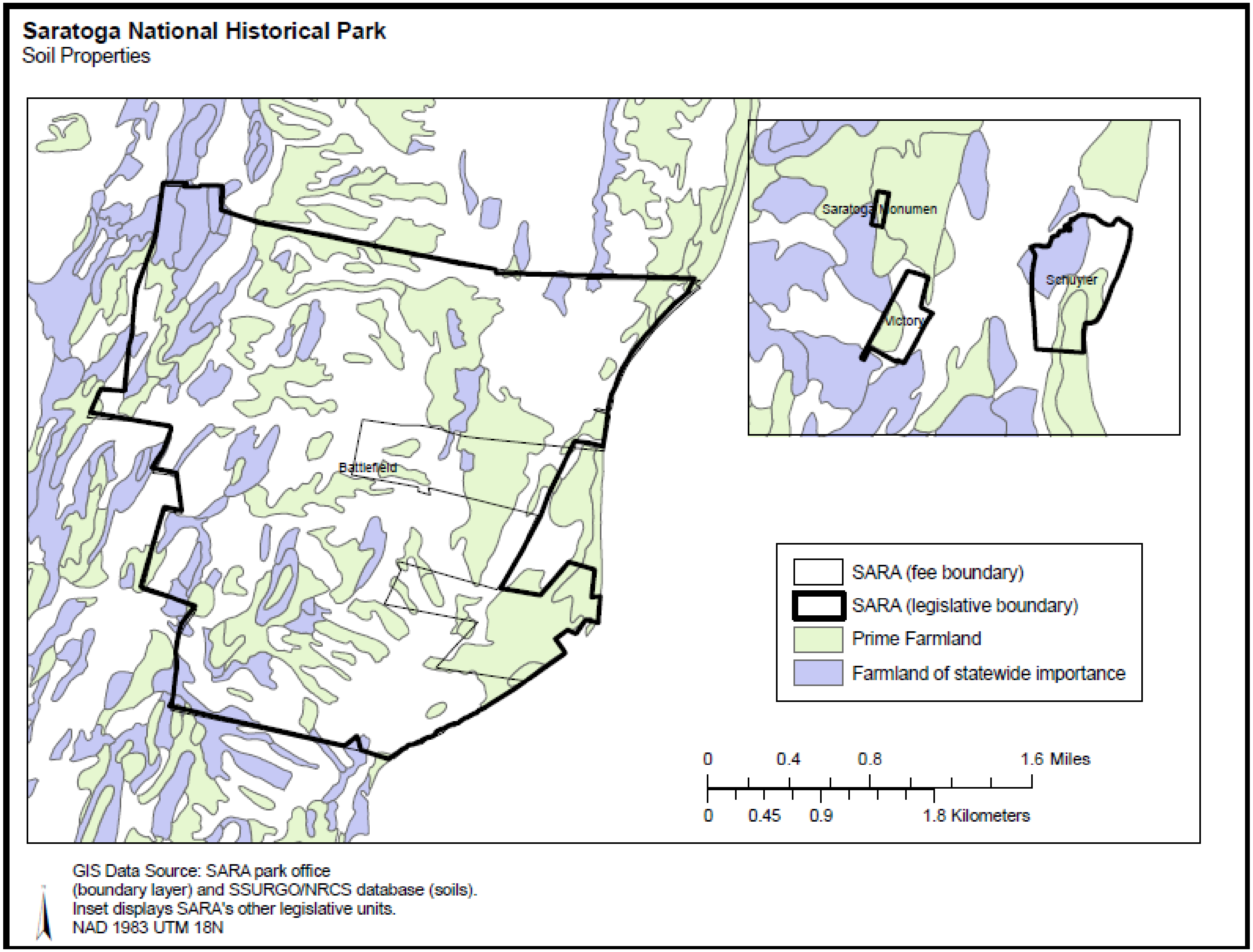


Figure 2.10. Soil properties designating areas as prime farmland and farmland of statewide importance in SARA.

Vegetation

SARA's vegetation community is comprised of a mosaic of grass fields, shrubland and forests which has changed in size and composition since 1777 (Figure 2.11). The park is situated within an Appalachian oak region and hemlock-white pine-northern hardwood transition zone. Forests cover the largest percentage of the park (2,145 acres (868 ha)), with deciduous trees abundant in the mature forests of SARA and hemlocks common on steep ravines in the park. Grasslands, which are of significant ecological occurrence and vital habitat for birds in SARA, comprise almost one-third of the park, with the largest area of grassland roughly 100 acres (40 ha) near the southern portion of SARA (Figure 2.12). Each grassland field has a unique management history in SARA and has been subjected to prescribed burning (Figure 2.13), mowing or haying practices due to an agricultural lease program SARA has engaged in with local farmers. Shrub and wetlands comprise the rest of SARA's vegetative landscape.

Open fields and forests compose the vegetative landscape in the park. Photo: R. Wagner (November 12, 2010).

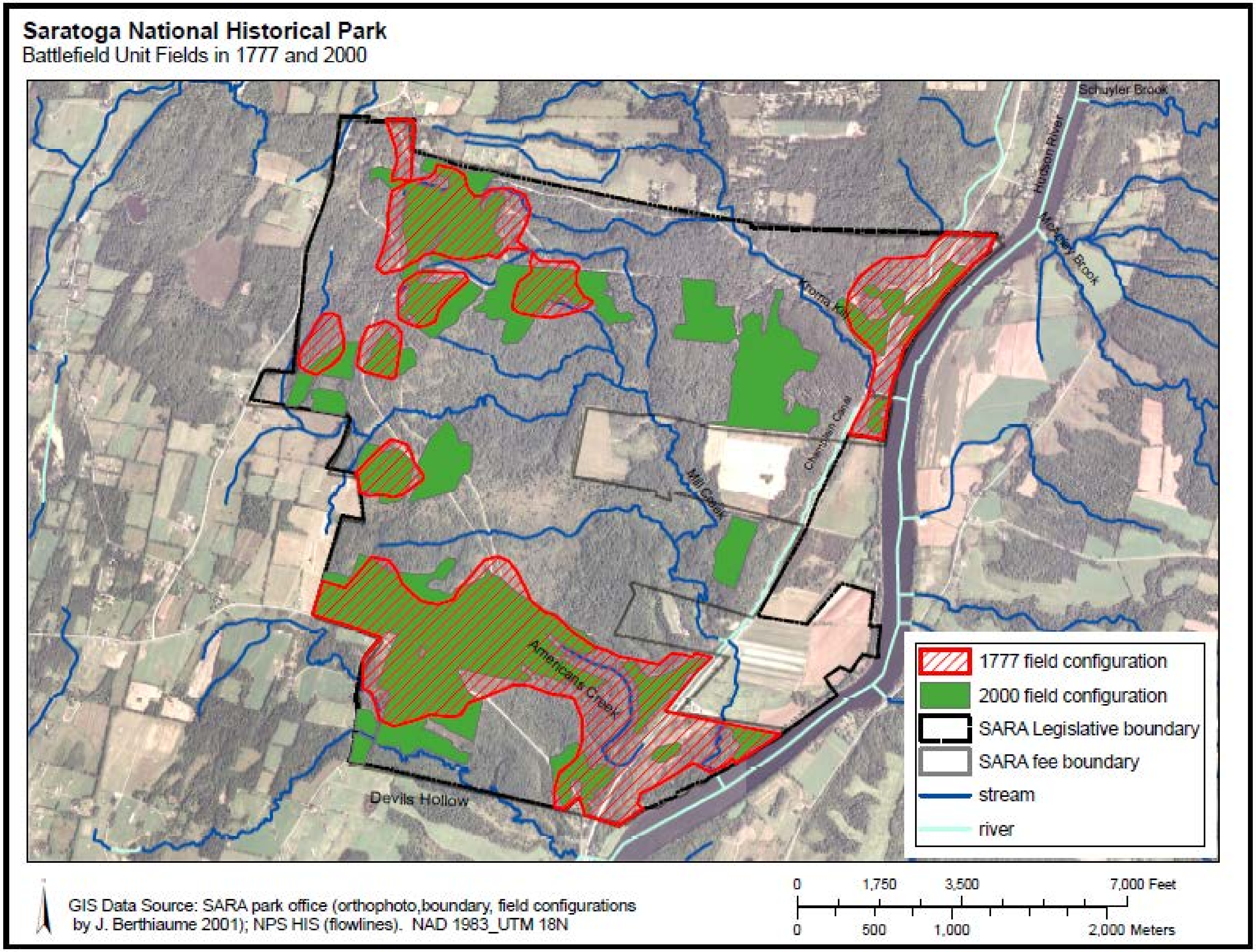


Figure 2.11. Field configurations in SARA's battlefield unit in 1777 and 2000 (Berthiaume 2001).

The terrestrial vegetative habitat of SARA consists of the following (Mitchell *et al.* 2006):

- Hemlock northern hardwood forest: 1067 acres (432 ha)
- Northern hardwood forest:83 acres (34 ha)
- Successional northern hardwood: 593 acres (240)
- Successional shrubland: 90 acres (36 ha)
- Old field: 301 acres (122 ha)
- Agricultural fields: 508 acres (206 ha)
- Landscaped: 13 acres (5 ha)

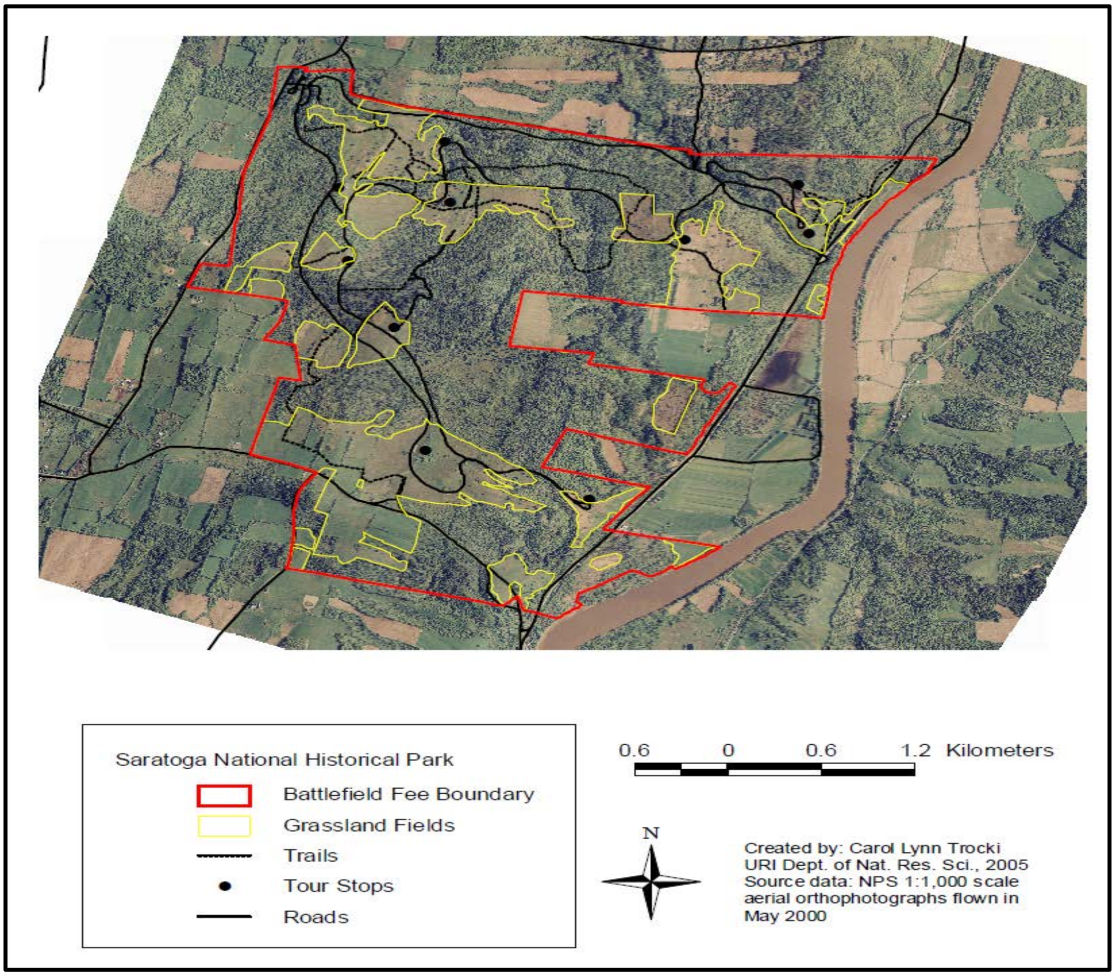


Figure 2.12. Human disturbance features such as roads and trails in relation to grassland fields within SARA. Figure from Trocki and Paton (2005).

SARA contains 823 known species of plants representing 116 different families (SARA GMP 2004). Stalter *et al.* (1993) conducted a vascular flora survey in SARA from 1987-1990. In this survey, 525 vascular plant species representing 302 genera and 106 families were documented. The largest families were Asteraceae and Poaceae and the most abundant genera were *Carex*, *Solidago* and *Aster*. One hundred thirty-four species indentified in SARA were considered non-native to the U.S.

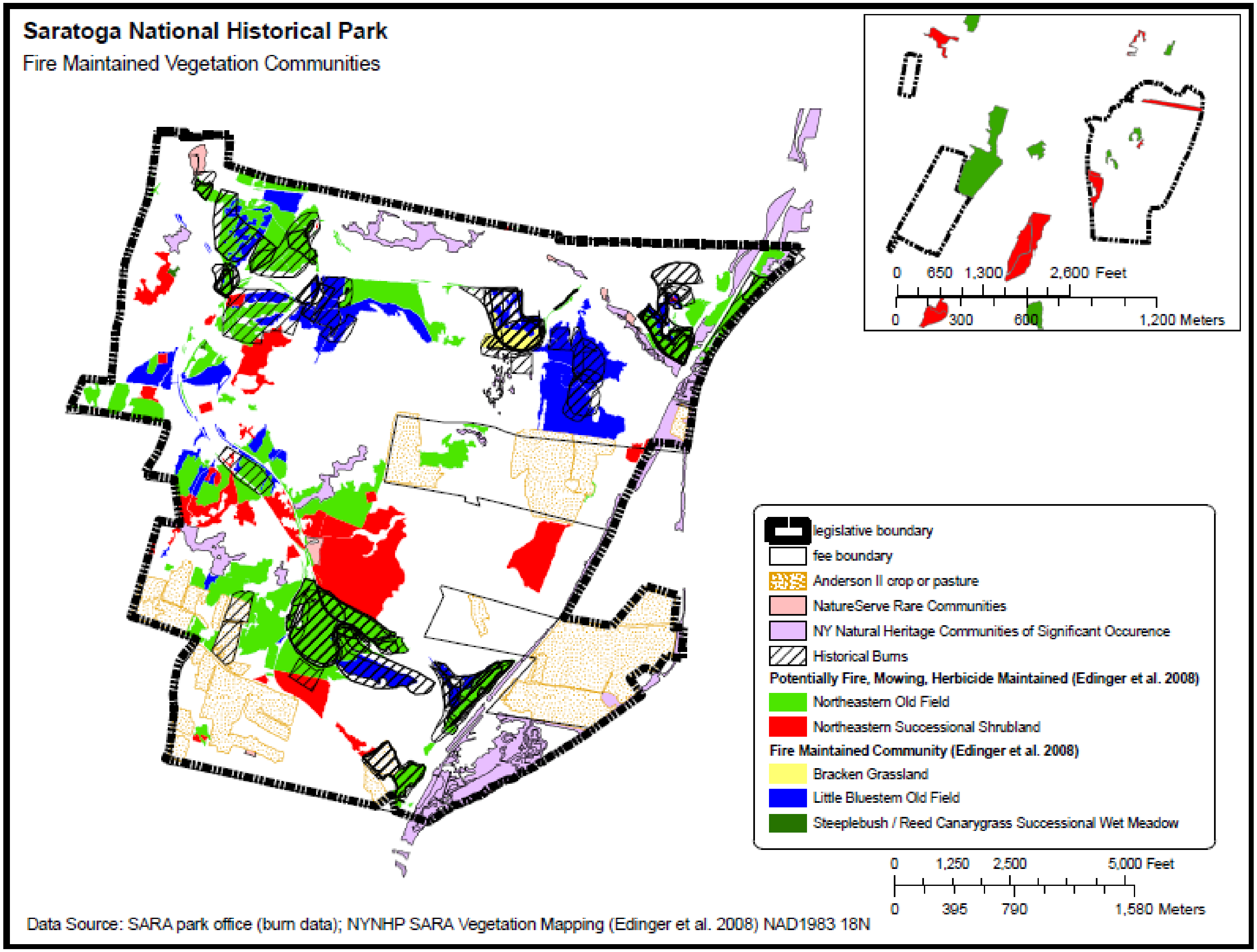


Figure 2.13. Fire maintained vegetation communities in SARA, including historical burns and communities maintained by fire, mowing and herbicide treatment.

Vegetation classification and mapping of vegetation associations were conducted at the Saratoga National Historical Park beginning in 2003 (Edinger *et al.* 2008) (Appendix B, C). Fifty-four vegetation associations were identified in SARA and described in detail by Edinger *et al.* (2008). Of the 54 associations, ten are successional types that become established after forest clearings or cessation of agricultural activities. Six associations are a result of anthropogenic activity: Black Locust Successional Forest, Common Reed Marsh, Norway Spruce Plantation, Purple Loosestrife Wetland, Reed Canarygrass Eastern Marsh, and Eastern White Pine Plantation (Figure 2.14).

Saratoga National Historical Park has vegetation associations considered to be of global rarity by NatureServe: American Beech – Maple Glaciated Forest, Hairyfruit Sedge Wetland, Wild Rice Marsh, and Shale Talus Slope Woodland. Three NY Natural Heritage natural communities at SARA are considered significant occurrences from a statewide perspective: floodplain forest (combination of seven floodplain vegetation associations), vernal pool (Eastern Woodland Vernal Pool association), and successional fern meadow (Bracken Grassland association) (Figure 2.15) (Edinger *et al.* 2008). The floodplain forest along the Hudson River near Bemis Heights was the first significant occurrence of floodplain forest to be surveyed and documented by NY Natural Heritage on this stretch of the Hudson River north of Troy, NY (Edinger *et al.* 2008).

Twenty-four State listed threatened, species of special concern and exploitably vulnerable native plant species have been documented in SARA (NPSpecies 2011). Threatened species meet Section 182.2(h) of 6NYCRR Part 182, which are likely to become endangered within the foreseeable future. Species of special concern as defined in Section 182.2(i) of 6NYCRR Part 182 warrant attention and consideration but current information does not justify listing these species as either endangered or threatened. Native plants likely to become threatened in the near future throughout all or a significant portion of their ranges if causal factors continue unchecked are categorized as exploitably vulnerable (EV) species.

Exotic and invasive plant species are present within SARA and are a major management issue for the park. Inventories have been conducted to assess the spatial distribution of invasive plants in SARA (e.g., Canham, 2003). Knapweed (*Centaurea* sp.) is one of the greatest invasive threats to SARA's grassland habitats as its encroachment has the potential to influence grassland bird species composition and abundance.

The cultural significance of vegetation at SARA remains an important factor in the interpretation of the park due to its role in strategic battle planning during the American Revolution. Vegetation patterns in SARA have changed since the historic battles, including land conversion from forest to agriculture and the acquisition of surrounding lands by NPS. Complex native plant communities which have developed over hundreds of years are at risk due to invasion of exotic plants and human –caused disturbances that foster their establishment. Fire has remained an important role in the ecology of forests and grasslands in and around the vicinity of SARA. Fire is hypothesized to have been implemented by Native Americans in the region based evidence of pine regeneration (Gordon 1987) and today prescribed fire is implemented in SARA to maintain grasslands of the Revolutionary War era.

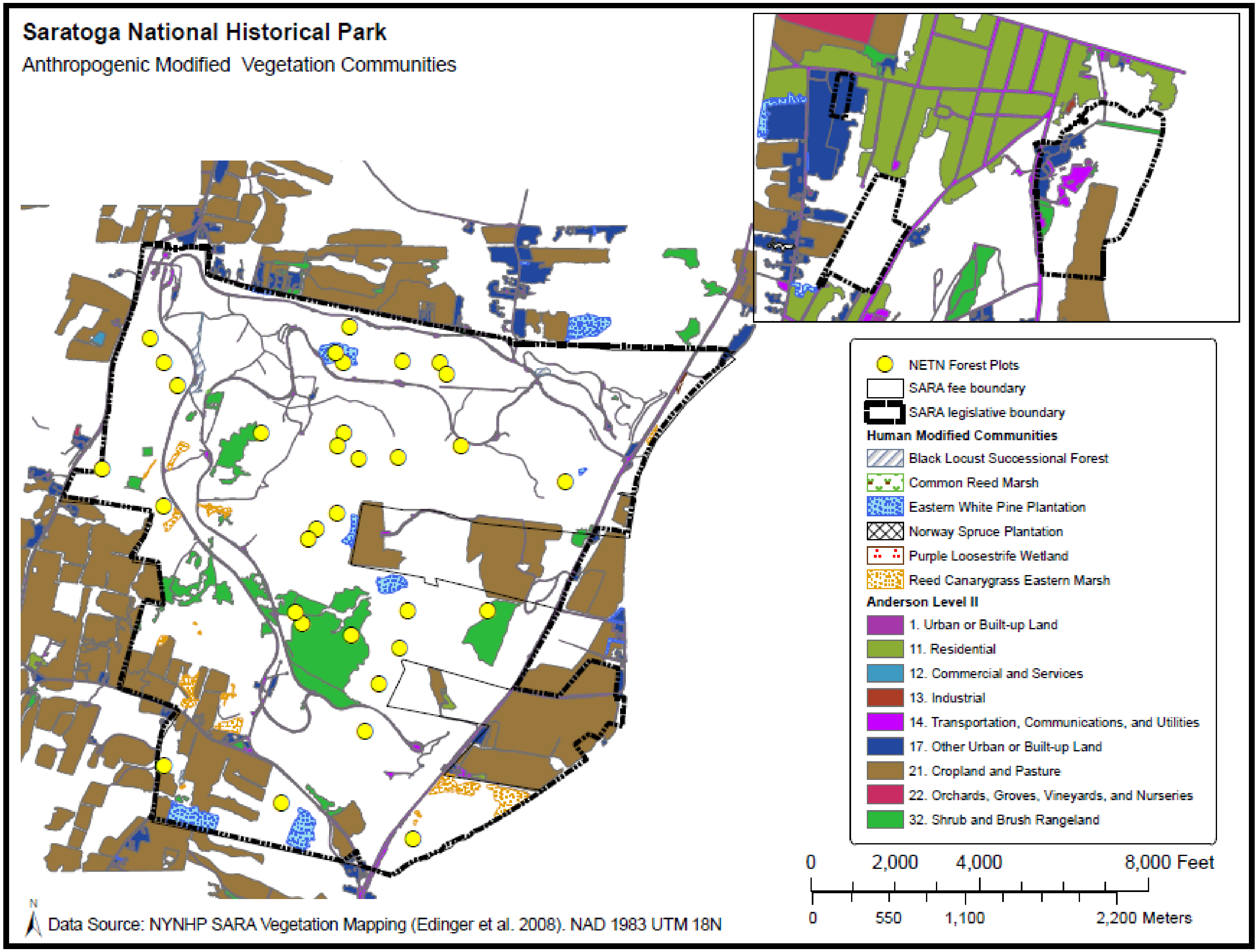


Figure 2.14. Anthropogenic modified vegetation communities in SARA park unit.

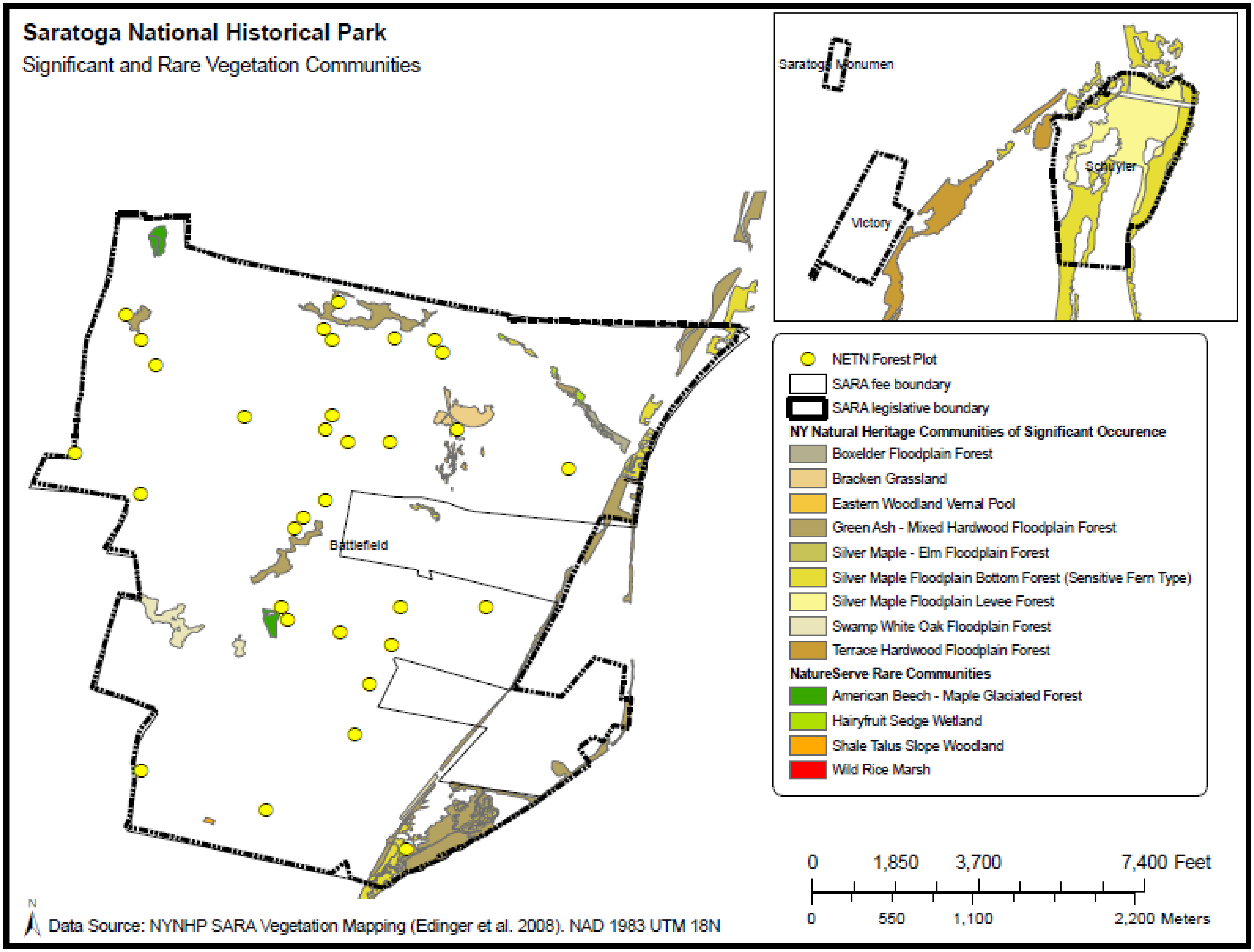


Figure 2.15. Vegetation associations considered rare and of significant occurrence in SARA park units.

Hydrology

The hydrology in SARA is not only of environmental significance, but also of cultural significance due to its importance during the American Revolution. The neighboring Hudson River along the eastern side of SARA was used as a transportation corridor by armies for supplies and communication, and spring seeps within the Battlefield Unit may have provided water to soldiers in the American encampment. SARA's aquatic environment supports unique habitat for plant and wildlife species, including state listed threatened and special concern species and serves as breeding ground for numerous herpetofauna, invertebrate and fish species.

SARA is comprised of tributaries flowing to the Hudson River, which has been partially designated as a federal Superfund site due to chemical contamination, particularly with polychlorinated biphenyls (PCBs). Approximately 8 mi (13 km) of perennial streams, 4 mi (7 km) of intermittent streams and 1.7 mi (2.7 km) of canals flow through SARA, with 1.7 mi (2.7 km) of 303(d) impaired streams that are adjacent to the park boundary (NPS HIS 2011). Streams in SARA include: American's Creek, Devil's Hollow, Kroma Kill and Mill Creek (Figure 2.16). These are designated as Class C streams which support fisheries and are suitable for non-contact activities under the New York State Department of Conservation classification system. Stream discharge for these systems typically increases from October through December, decreases in January to February, peaks in March and April and declines again through the summer months. The historic Champlain Canal flows through sections the Schuyler Estate and the Battlefield Unit.

Additional aquatic environments in SARA include several acres of forested, palustrine and mixed forest-scrub shrub wetlands. A National Wetland Inventory (NWI) in SARA by Tiner (2000) delineated approximately 176 acres (71 ha) of wetlands in the park. Additional mapping of wetlands by vegetation type in SARA was performed by Edinger *et al.* (2008) (Figure 2.16). Forested wetlands predominate within the park, followed by palustrine and mixed forest scrub-shrub wetland types (Tiner 2000). In New York, wetlands smaller than 12.5 acres (5 ha) are not protected by The Freshwater Wetlands Act (Article 24 of the Environmental Conservation Law, 1975) unless they are determined to be of *Unusual Local Importance* by NYSDEC. Based on Tiner (2000) wetland delineations and inventory, the majority of wetlands (87.5%, N=49 wetlands inventoried) in SARA are smaller than the regulatory 5 ha size wetlands (Figure 2.17). These smaller wetlands are noted as some of the most ecologically valuable habitats in terms of ecosystem services (Blackwell and Pilgrim 2011). Additionally, wetland researchers have suggested that wetlands as small as 0.5 acres (0.2 ha) be protected due to their unique features and importance to the connectivity with other regional wetlands (Semlitsch and Bodie 1998), especially within the Hudson Valley. If using the suggested 0.2 ha regulation, approximately 81% of wetlands would be regulated in SARA versus only 12.5% of wetlands protected under the current NY State regulations. Regardless of size or hydrological connectivity, the NPS regulates all wetlands within park boundaries under the NPS Director's Order #77.1.

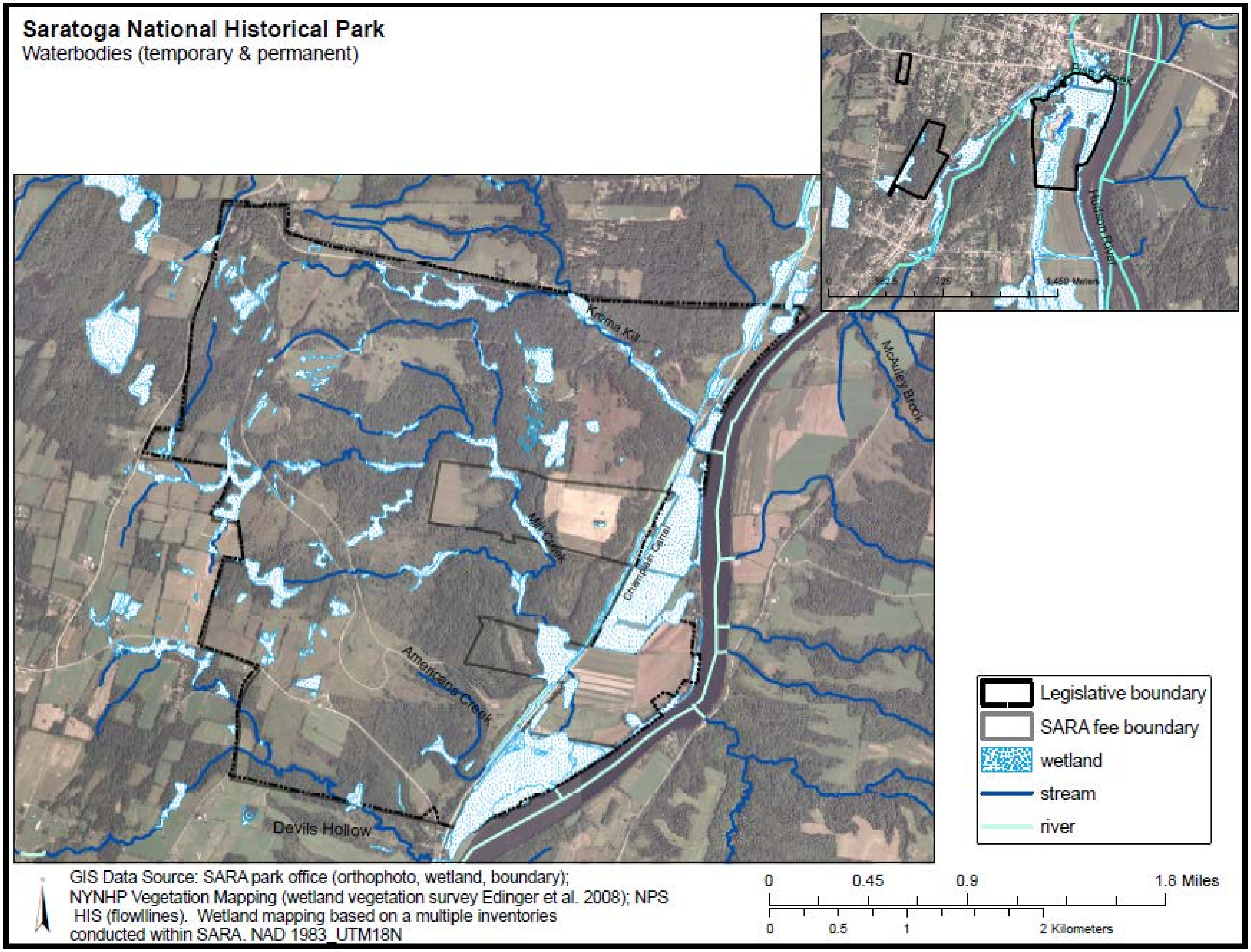


Figure 2.16. Temporary and permanent waterbodies of SARA park units.

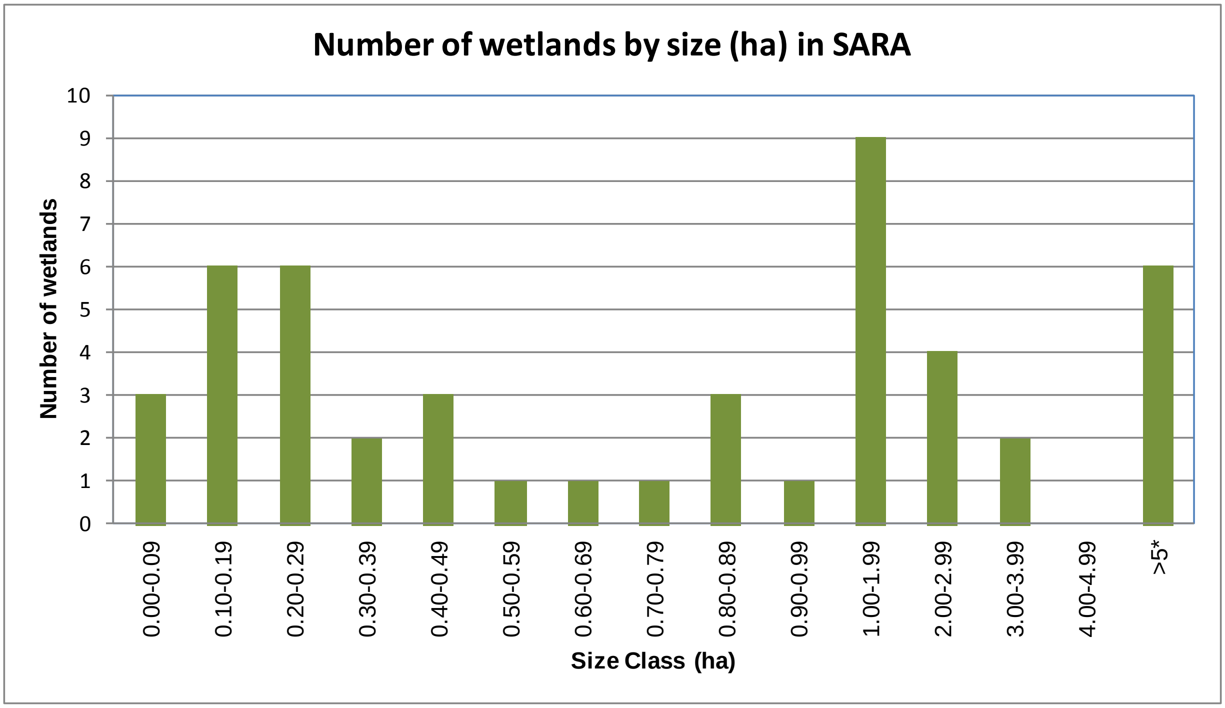
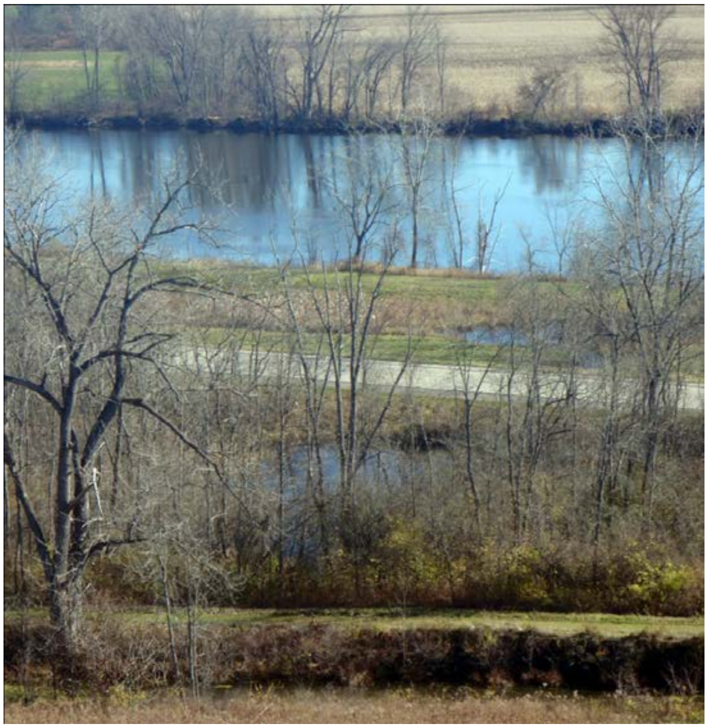


Figure 2.17. Distribution of wetlands by size (ha) inventoried in SARA by Tiner (2000). *Denotes wetland size (5 ha) regulated under The Freshwater Wetlands Act (1975) of New York.

Two artificial ponds and spring seeps, including numerous abandoned wells dug prior to 1900 are within the Battlefield Unit. Ground water quantity has been investigated by Heath *et al.* (1963) in the park, but ground water quality information is temporally and spatially limited. Aquifer recharge area is within sand deposits in the Battlefield Unit. Approximately 12% of total parkland is in floodplain areas, with the 100 year Hudson River floodplain located along the eastern side of the park and ranging from 0.2 to 0.5 miles (0.32 km-0.80 km) in width. The Water Resource Management Plan for SARA contains further information on the historical studies and management of SARA's hydrology (Vana-Miller *et al.* 2001).



Small wetlands which serve as habitat for park fauna dot the landscape along the Champlain Canal and Hudson River. Photo: R. Wagner (November 12, 2010).

Wildlife

Forty three species of mammals, 181 species of birds, 20 species of fish, 19 species of reptiles, and 19 species of amphibians are listed as *present* or *probably present* in SARA (NPSpecies). Several species in SARA have conservation rankings listed, including 24 wildlife species which are considered endangered, threatened, or of special concern under NY State law. Indiana bats (*Myotis sodalis*) are Federally and State listed as endangered and are found hibernating to the north and south of Saratoga County but have not been found wintering in the county. It is possible that hibernacula will be found in the future in Saratoga County, allowing bats to feed or establish colonies within SARA since the park provides an abundance of the preferred roosting trees for Indiana bats (Gilbert *et al.* 2008). SARA also provides important habitat for the bald eagle (*Haliaeetus leucocephalus)*, which is Federally delisted but is listed as threated in NY. White-tailed deer (*Odocoileus virginianus*) are commonly observed at SARA, while other larger mammals such as black bear (Ursus americanus) and moose (Alces alces) have been reported but are not regular inhabitants of SARA (Gilbert *et al.* 2008). SARA is also designated as an Important Bird Area (IBA) and provides critical breeding habitat for amphibians and reptiles.

Various wildlife disease studies have been conducted in SARA. Hantavirus, a disease spread by rodents, was studied in populations of small mammals in 1994. No individuals at SARA tested positive for hantavirus antibody reactivity (Mills *et al.* 1998). West Nile virus (WNV), a mosquito-borne flavivirus that affects both humans and birds, was assessed in SARA in 2001. Although WNV was negative in vector mosquito species collected in SARA, *Culex restuans* and *Culex pipiens,* both species that are enzootic vectors for WNV, were abundant in SARA (Lussier *et al.* 2006). Tick-borne Lyme disease (*Lyme borreliosis*) remains a concern due to the wooded areas, tall grass fields and the presence of mice and deer in SARA. Chronic wasting disease (CWD), a rare neurological disease found in cervids (members of the deer family), has not been detected in SARA but was found in NY in 2005. A statewide surveillance program has not detected CWD since 2005 (NYDEC, www.dec.ny.gov/animals/33220.html). White-nose syndrome (WNS), a fungal disease affecting bats, was first discovered in Albany, NY in 2006. Northern myotis (*Myotis septentrionalis*), a bat species which is susceptible to WNS was not documented recently in SARA, which was part of a bat inventory conducted in eight national parks from 2009-2011 (Gates and Johnson 2012). However, this species had been documented in the park in the past and the little brown bat (*Myotis lucifugus*), another bat species susceptible to WNS was recorded acoustically (Gates and Johnson 2012). Due to the devastation that WNS may cause to bat populations, the northern myotis is currently proprosed for listing under the Endangered Species Act.

2.2.3 Resource Issues Overview

Examples of Past Activities That Influence Current Park Conditions

Hudson River Contamination
The Hudson River, which has been partially deemed a federal Superfund site, contains a legacy of chemical contamination particularly from polychlorinated biphenyls (PCB). During a 30-year period ending in 1977, 209,000 to 1.3 million pounds (589, 670 kg) of PCBs and several other chemicals were released into the river from various industrial facilities located in Fort Edward and Hudson Falls, New York (USEPA, http://www.epa.gov/superfund/accomp/success/hudson.htm). The contamination of the Hudson River has influenced park condition and use for several decades. It has restricted visitor use of the river, including fishing for consumption along the shores of SARA in order to minimize the public's exposure to PCBs. The contamination has also altered SARA's vegetation management techniques in order to address safety concern of staff working along the floodplain (NPS 2010c). This environmental contamination has raised concern regarding the welfare of SARA's wildlife population which utilizes the Hudson River and surrounding floodplain.

Grassland and Agricultural Field Maintenance
Mowing and burning practices have been used to maintain grassland areas in SARA as a management tool as early as the 1970's. These practices have been altered over the years to protect and enhance grassland bird habitats. Burning and mowing are on a rotational schedule and mowing is limited during grassland bird breeding months. In order to reduce establishment of invasive knapweed, mowing and burning have been rescheduled to limit seeding proliferation of the plant. Agricultural practices have become increasingly incompatible with nesting success of grassland birds in the region. As a result, agricultural practices permitted in SARA (under a leasing program implemented by NPS) are being designed to be compatible with grassland habitat conservation and cultural landscape objectives.

Examples of Threats or Stressors Identified as Being "Of Concern" in Terms of Potential Risk/Harm to Important Park Resources

Development
Threats and stressors to resources within SARA, especially sensitive resource areas (Figure 2.18), include risk from external developments, visitor impacts, environmental contaminants and natural disasters. Natural resource threats were identified through discussions with SARA park staff, technical reports and park and regional data. External development around SARA 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 2.19). Present and future development efforts threaten the park's viewshed, as buildings and utilities such as cell towers become established around the park. Additionally, natural soundscapes and lightscapes within SARA become altered by development projects, potentially affecting wildlife behavior and visitor experience. 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.

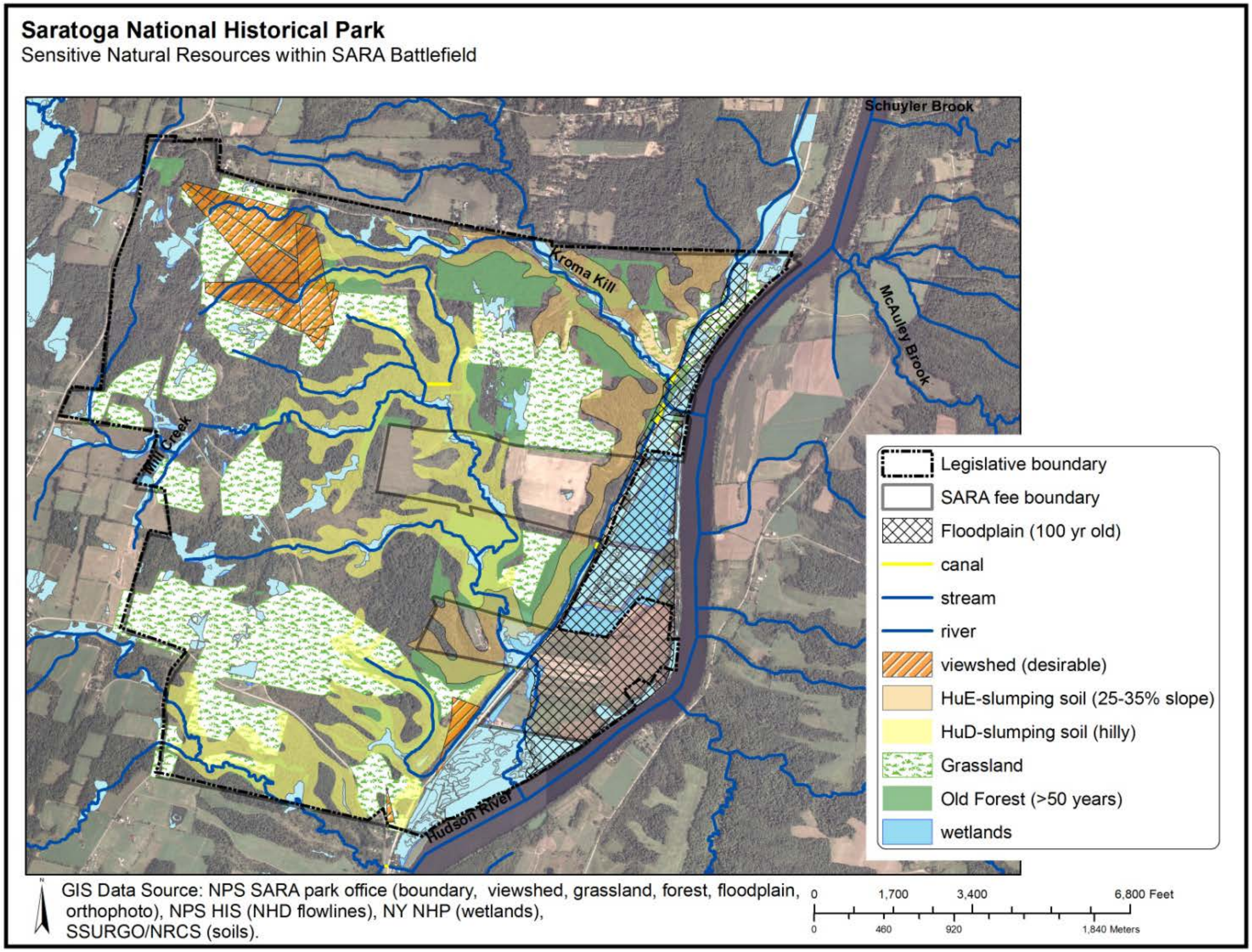


Figure 2.18. Areas in SARA's Battlefield Unit containing sensitive natural resources, as designated in the SARA General Management Plan (NPS 2004).

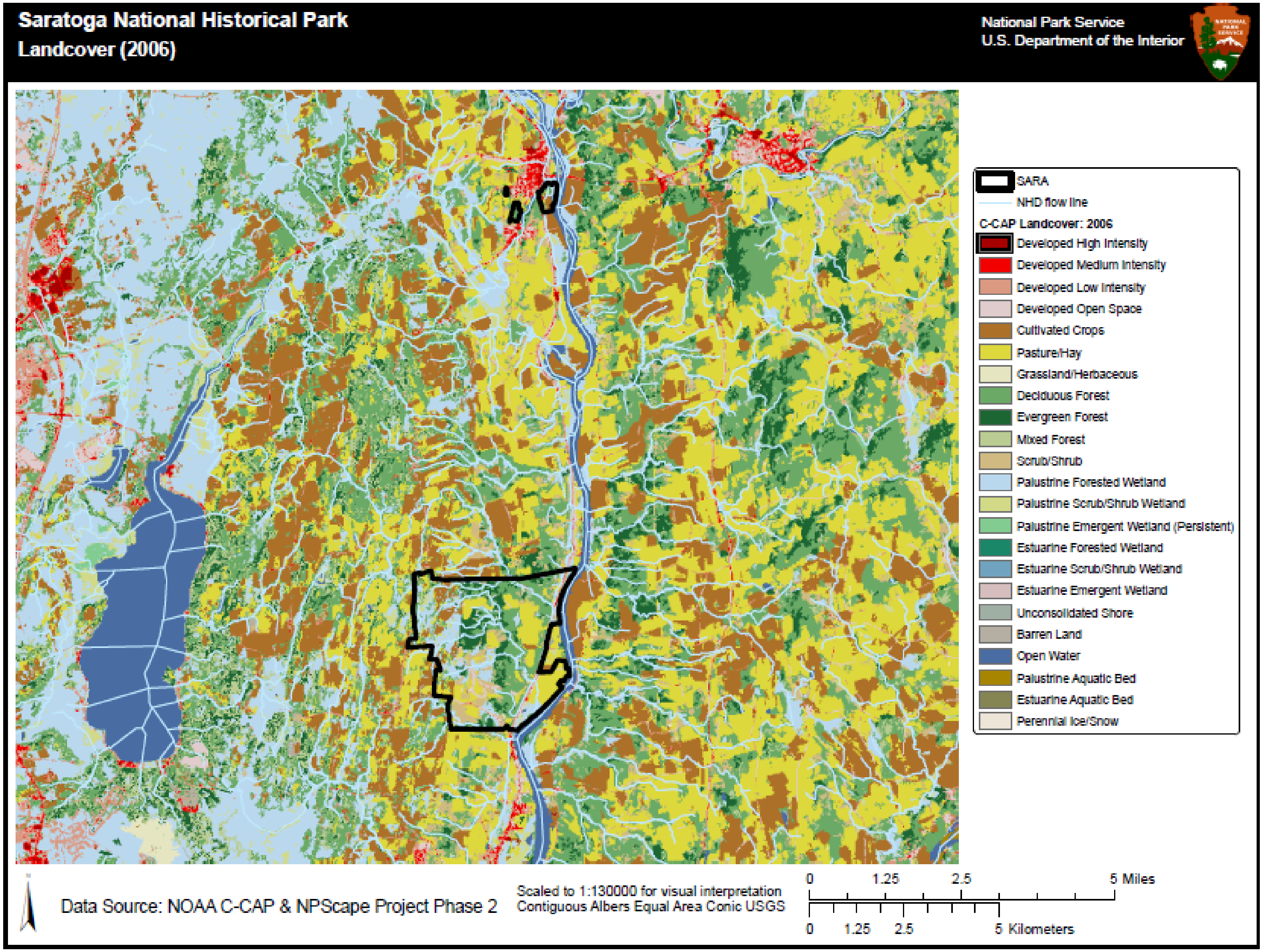


Figure 2.19. Land cover characteristics within and surrounding SARA (C-CAP 2006).

Contaminants

Contaminants in air and water resources threaten the environmental integrity of SARA, with sources of contamination currently surrounding the park (Figure 2.20). Atmospheric conditions such as high ozone, degraded visibility and elevated atmospheric deposition (e.g., SO_x, NO_x, and Hg) from industrial emissions have been shown to stress vegetation, pose toxicity to terrestrial and aquatic systems and degrade the visibility of SARA's culturally important viewshed. The neighboring Hudson River along SARA's eastern boundary bears the legacy of detrimental chemicals such as PCB, lead and cadmium due to their release from various industrial facilities. This federal Superfund site continues to pose a threat to SARA's wildlife which uses the Hudson River and floodplain as a resource for habitat, breeding and food resources. As a result of the contamination, park staff discourages some visitor activities in SARA, such as fishing for consumption and spending time along the floodplain and shore of the Hudson River. "Emerging contaminants" in waterways which include pharmaceuticals, personal care products and endocrine-disrupting compounds may be a threat to SARA's waterways, although their presence in SARA's waters is unknown and their effects to aquatic systems are scarce (Ellsworth 2011).

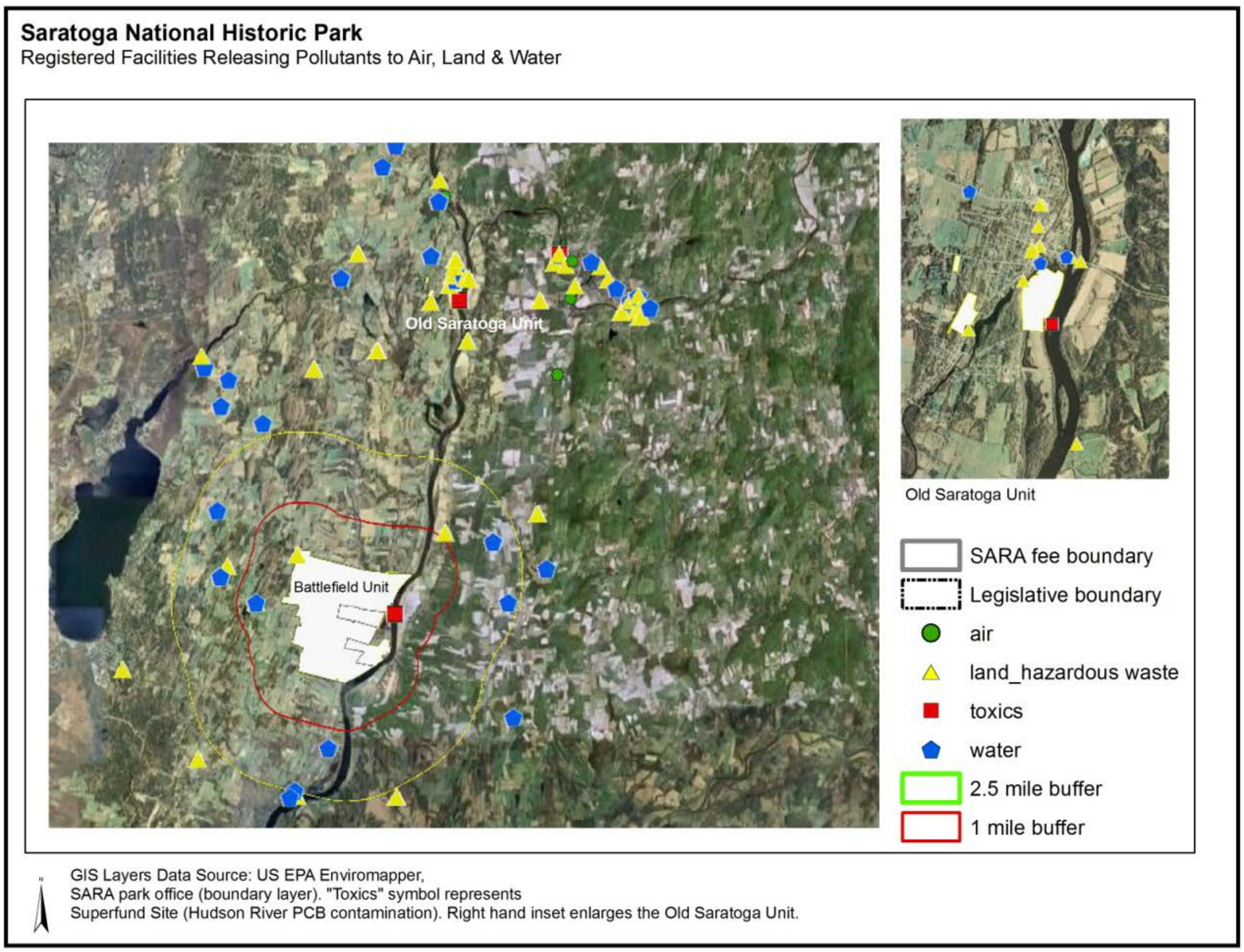


Figure 2.20. Facilities registered to release pollutants to air, water, and land within a 1 mile and 2.5 mile buffer around the SARA Battlefield Unit.

Invasive Species & Diseases
Invasive plant and animal species continue to threaten SARA's terrestrial and aquatic environment. Invasive species are currently established in the park and continue to be recruited due to development activities, anthropogenic transmittal and changes in climate patterns. SARA's aquatic resources are subjected to the establishment of invasive plants and animals, which threaten the native composition and ecological balance of these systems. The sources of invasion of aquatic species are from neighboring tributaries within the watershed (e.g., SARA's streams connect to the presently invaded Hudson River), transportation by anthropogenic means (e.g., attachment to waders) and seedling recruitment (e.g., purple loosestrife in wetlands).

Within SARA's terrestrial environment, invasive plants and insects have been confirmed and management programs have been implemented to treat their occurrence. However, invasive species continue to threaten the natural and cultural environment due to new species becoming established, species range and populations expanding within the region and treatment methods becoming costly or less effective over time. Additionally, diseases to vegetation pose an even greater threat to SARA's mature forests. Parasitic diseases (e.g., canker) and non-parasitic disorders (e.g., root disturbance from construction, air pollution injury) can cause outbreaks affecting isolated species or a variety of tree species.

Visitor Use
Visitor usage activities may stress SARA's environment and its resources. 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.

Natural Disasters
Effects from natural disasters range from threatening wildlife habitat and historic structures to being a source of regeneration for the natural environment. The environmental and cultural integrity of SARA can be reshaped by natural occurrences such as wildfires, floods or droughts. Natural disasters also create indirect stress to natural resources in the park, magnifying other issues. For example, certain tree species suffering from the effects of drought are more susceptible to epidemic occurrence. SARA is unique in that its vegetation composition is part of its historic structure, thus making both the natural and historic landscapes vulnerable to a natural disaster.

Natural Gas Extraction
Extraction of natural gas from the Marcellus and Utica shales may create numerous environmental and socioeconomic impacts for SARA. The potentially large amount of industrial activity resulting from shale-gas development around SARA may include environmental impacts to air quality, water quantity and quality (e.g., surface water withdrawals, groundwater contamination,), soundscapes, lightscapes and viewshed alteration. Recently, a 2011 earthquake occurring in Oklahoma was linked to injection wells used by the oil and gas industry (Keranen *et al.* 2013). Visitor use conflicts may occur with the potentially large amount of drilling-related industrial activity occurring around SARA, including degradation of the visitor experience and posing safety risks due to the large amount of drilling support traffic.

2.3 Resource Stewardship

2.3.1 Management Directives and Planning Guidance

SARA is fundamentally a cultural park, though each management unit has significant natural resources that deserve attention. The General Management Plan (NPS 2004, pg. ii) states that one of the resource management goals is to, "Contribute to the accumulation of knowledge and understanding of cultural and natural resources related to the site's historical significance and to its ecological importance in the upper Hudson River Valley." The presence of key types of habitat near an area of rapid development in the State of New York argue for the potentially important role that SARA can play in maintaining natural resources along the Hudson River.

2.3.2 Status of the Supporting Science

Our approach to a natural resources assessment for SARA was based on indicators developed by the Northeast Temperate Network (NETN) of the NPS Vital Signs program. This program conducts long-term monitoring 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 2.1 lists the high priority vital signs defined by the NETN which are applicable to SARA and may or may not have been assessed based on data availability (Mitchell *et al.* 2006). Data for these analyses was requested or queried from the 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 2.2.

Table 2.1. NETN Vital Signs potentially applicable to SARA (Mitchell et al. 2006).

Level 1	Level 2	Level 3	Vital Sign	Potential measure
Air and climate	Air quality	Ozone	Ozone	Atmospheric ozone concentration, foliar injury to indicator species
		Wet and dry deposition	Atmospheric deposition and stress	Wet and dry deposition rates, streamwater ANC, streamwater nitrate concentration
			Contaminants	Heavy metal deposition
	Weather and climate	Weather and climate	Climate	Air temperature, precipitation by type, relative humidity, solar radiation, wind speed and direction, snow water equivalent, snow depth
Geology and soils	Soil quality	Soil function and dynamics	Forest soil condition	Ratios of carbon to nitrogen and calcium to aluminum
Water	Hydrology	Surface water dynamics	Water quantity	Water depth, water duration, streamflow, groundwater levels/inputs, spring/ seep volume
	Water quality	Water chemistry	Water chemistry	Stream water nitrate, stream alkalinity/ANC,water temperature, % dissolved oxygen, specific conductance, pH, color, salinity

Level 1	Level 2	Level 3	Vital Sign	Potential measure
		Aquatic macroinvertebrates	Streams-macroinvertebrates	Diversity of selected communities and subcommunities
Biological integrity	Invasive species	Invasive/exotic plants	Invasive/exotic plants-early detection	Presence/absence
		Invasive/exotic animals	Invasive/exotic animals-early detection	Presence/absence
	Focal species or communities	Wetland communities	Wetland vegetation	Diversity of community and subcommunities, exotic species extent, beaver activity
		Forest vegetation	Forest vegetation	Community diversity (all layers), tree species, rates of mortality and regeneration, stand structural dynamics, tree basal area by species, canopy condition, snag density, coarse woody debris volume, percent exotic species
			White-tailed deer herbivory	Browse intensity in forests
		Fishes	Fishes	Diversity of community and subcommunities,percent exotic species
		Birds	Breeding birds	Diversity of forest, high elevation, grassland/ old-field, and subcommunities
		Amphibians and reptiles	Amphibians and reptiles	Diversity of wetland/vernal pool communities and subcommunities, red-backed salamander abundance in forests
Human use	Visitor and recreation use	Visitor usage	Visitor usage	Number of visitors by location and activity, trampling impacts, soil erosion
Landscapes	Landscape Dynamics	Landscape Dynamics	Land use	Road network extent, nearby housing development permits, proportion of nearby lands in various categories of human uses, % impervious surface in watershed, nearby human population density, landscape buffers
			Land cover/ecosystem cover	Change in area and distribution of ecological systems (including intertidal communities) within park and adjacent landscape, patch size distribution, patch connectivity, patch fragmentation, extent of major disturbance, ecological integrity index by ecological system

Table 2.2. Monitoring data collected for the NRCA of Saratoga National Historical Park, New York.

Level 1	Level 2	Level 3	Vital Sign	Period of data for SARA condition assessment and/or trend analysis	Reference/source
Air and climate	Air quality	Ozone	Ozone	1998-2010	NPS Air Resources Division
		Wet and dry deposition	Atmospheric deposition and stress	1981-2010	NPS Air Resources Division; NADP database; Sullivan *et al.* (2011)
			Contaminants	1999-2009 (Hg) 2005-2010 (visibility)	NPS Air Resources Division; MDN database
Geology and soils	Soil quality	Soil function and dynamics	Forest soil condition	2006, 2008, 2010	NETN forest monitoring reports
Water	Hydrology	Surface water dynamics	Water quantity	2005; 2006-2011	USGS consumption data; NETN water monitoring;
	Water quality	Water chemistry	Water chemistry	1987-2011	NPS data reports; US EPA STORET database; NETN monitoring data
Biological integrity	Invasive species	Invasive/exotic plants	Invasive/exotic plants-early detection	Historical presence/absence data; 2006, 2008, 2010	USGS; NETN monitoring reports; NPS surveillance reports
		Invasive/exotic animals	Invasive/exotic animals-early detection	Historical presence/absence data; 2006, 2008, 2010	USGS NAS database; NETN monitoring reports; NY State Dept. of Conservation surveillance; USDA risk assessments; peer-reviewed research articles
	Focal species or communities	Forest vegetation	Forest vegetation	2006, 2008, 2010	NETN monitoring reports; SARA vegetation mapping (Edinger *et al.* 2008)
			White-tailed deer herbivory	2003, 2010	SARA vegetation mapping (Edinger *et al.* 2008); NETN monitoring reports;
		Fishes	Fishes	2000	NPS report (Mather *et al.*, 2003)
		Birds	Breeding birds	2006-2010	NETN monitoring reports (Faccio and Mitchell 2011)
		Amphibians and reptiles	Amphibians and reptiles	2001	Historical inventory data for the region; NPS survey data (Cook *et al.* 2011)
Human use	Visitor and recreation use	Visitor usage	Visitor usage	1941-2010 (visitation); 1991-2010 (traffic counts)	NPS Stats
Landscapes	Landscape dynamics	Landscape dynamics	Land cover/ecosystem cover Land use	Historical data collection and projected models for landscape variables from 1950-2050	NETN forest monitoring reports; Wang *et al.* 2006, 2009; NPScape historical and projected data; NLCD data 1992-2006; US census data (2010); The LA Group (2006); Saratoga P.L.A.N. (2009), Wang *et al*. (2009).

Chapter 3 Study Scoping and Design

3.1 Preliminary Scoping

Preliminary scoping efforts for the NRCA of SARA began in 2010 with a meeting of SARA's park staff and NPS coordinators for discussions and a tour of the park's grounds. Historical reports, photographs, geospatial data (GIS), and data from current sampling efforts were collected through several meetings and communication exchanges with SARA personnel, NPS Northeast Temperate Network biologists (NETN) and the NPS Air Resources Division (ARD). Pennsylvania State University (PSU) continued to collect data from federal (e.g., USGS) and state (e.g., NYSDEC) agency databases and local watershed committees in New York. 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 SARA and the surrounding area, current data collection protocols and efforts for SARA, and Vital Signs metric development. These communication efforts were essential to understanding the natural resources in SARA, as NPS staff invests significant time inventorying, monitoring, and interpreting data for the park.

National Park Service staff and The Pennsylvania State University researchers meet to discuss natural resource issues and tour the park. Photo: R. Wagner (November 12, 2010).

3.2 Study Design

3.2.1 Indicator Framework, Focal Study Resources and Indicators

Although SARA is a historic cultural park, information regarding the natural resources in SARA and the surrounding vicinity was abundant. The framework used for SARA's assessment is organized by broad ecosystem resources following the Northeast Temperate Network (NETN) Vital Signs approach (Mitchell *et al.* 2006, Fancy *et al.* 2009). The use of the Vital Signs indicators 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 SARA's natural resources was limited in terms of quantitative measures as well as spatial and temporal sample sizes. Thus, the confidence of the historical and present data collected for SARA determined which Vital Sign indicators were included in SARA's NRCA assessment, as well as determining the framework for the condition categories used for assessing SARA's natural resources. Additionally, a special subsection under Chapter 4 "Water", titled "Hudson River Contamination", was added to the NRCA due to the environmental significance PCB contamination has had on SARA's flora and fauna communities.

3.2.2 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, Visitor Usage and Landscapes. Vital Sign indicators in each of the above categories were used in the SARA NRCA and evaluated as whether the metrics for each indicator were relevant to SARA based on environmental occurrence, management objectives or data availability. A list of Vital Signs to be evaluated for the NRCA was finalized by the PSU team (Table 2.2). SARA has separate management units-the Battlefield Unit and Old Saratoga Unit (containing Saratoga Monument, Victory Woods and Schuyler Estate) - comprise the park. The metrics were assessed for each park unit unless data availability limited the assessment to a broader scale. 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.

3.2.3 General Approach and Methods

Chapter 4 provides discussion on general background, approach and justification for the indicators and their subsequent metrics. Each evaluated natural resource begins with a brief description of the relevance and context of the resource to the general environment and SARA. 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 and NPS Air Resources Division categories. Further, analysis of data resulted in each evaluated natural resource being given a condition category rating and assessment of trend of the natural resource condition. Condition category language followed the NPS State of the Parks terminology and included three categories: *good, caution (moderate* for air quality data*),* and *significant concern.* The exception to this language was for the assessment of PCB contamination from the Hudson River which included only *present* versus *absent* language. Best professional judgment was used to assign a condition category in the Visitor Usage section. Trend analysis was assigned a condition of *improving*, *deteriorating*, *unchanging* or *not applicable* after statistical analyses of quantitative historical and current data. Data gaps and confidence in assessment were discussed after each indicator was assessed. Confidence in the assessment and trend was identified as *high*, *medium* or *low*. *High* confidence included extensive spatial and temporal quantitative data in the assessment; *medium* indicated data were from some studies that were quantitative and/or qualitative in nature; *low* indicated data were from limited studies that collected qualitative or quantitative spatial and temporal data; *not applicable* indicated no reliable trend analysis was possible with the data available or temporal data was absent.

The Hudson River, a historically significant waterway during the Revolutionary War, flows adjacent to Saratoga National Historical Park. Photo: C. A. Cole (November 12, 2010).

Chapter 4 Natural Resource Conditions

4.1 Air Quality

Air quality parameters were assessed using data collected from various air quality monitoring stations near SARA in conjunction with NPS Air Resource Division analyses (Figure 4.1). Four broad air quality categories were individually assessed: ozone, atmospheric deposition and stress, mercury contamination, and visibility. To attain the goals of this report, the NPS Air Resources Division (ARD) air quality data and classification systems were used to assess air quality (NPS 2010a). The NPS Air Resources Division (ARD) developed this approach to assess overall air quality conditions within all NPS parks. Parameters of assessment included *total wet deposition of sulfur (S) and nitrogen (N)*, *mercury (Hg)*, *ozone* and *visibility*. The ARD used air quality monitoring data from national, state, and local stations averaged over five-year periods to generate interpolations to derive estimates of air quality parameters at all NPS units. Interpolation condition categories of 1) *good* 2) *moderate* and 3) *significant concern* were then assigned to assess each air quality parameter. The creation of these categories was based on regulatory standards/ and criteria and peer-reviewed literature which investigated the effects of air quality parameters on ecological systems. However, gaps in air pollution impacts upon the environment exist and this lack of knowledge may be underestimating 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 and should be considered in any long-term environmental conservation strategy. Although most pollution sources are outside NPS park boundaries, the park's ecological resources continue to be affected by air pollutants.

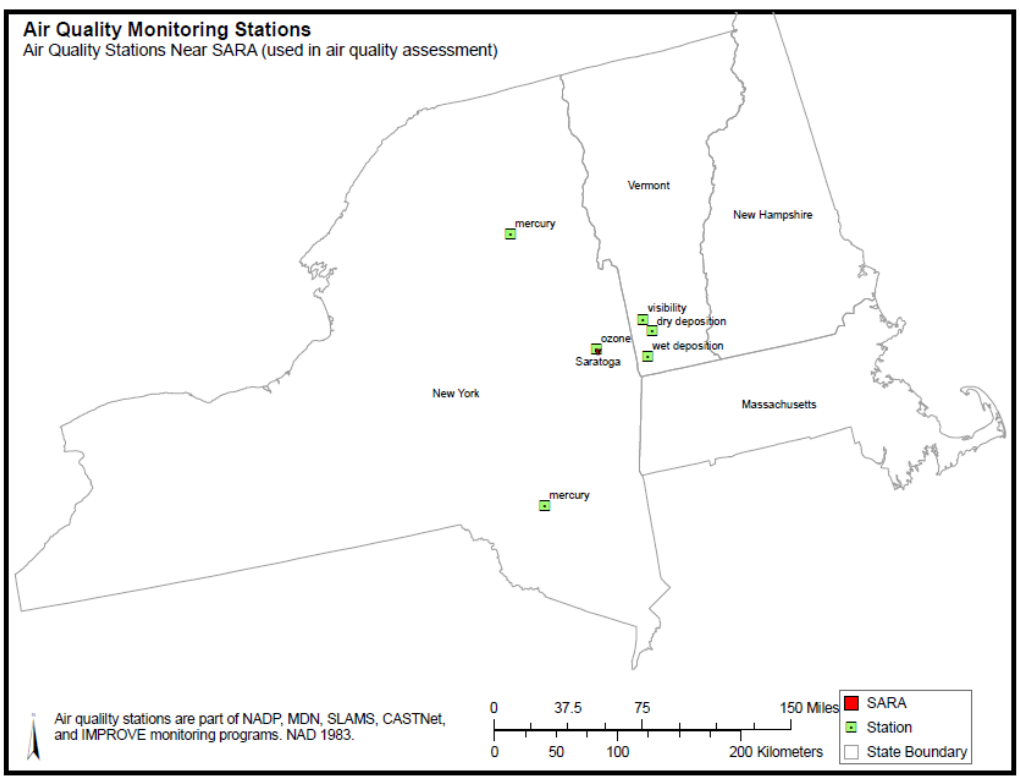


Figure 4.1. Air quality monitoring stations near SARA and used in the NRCA.

4.1.1 Ozone

Relevance and Context

Sunlight and chemical reactions between volatile organic compounds (VOCs) and oxides from nitrogen produces 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 lower than the federal standards can still lead to a negative impact on 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. Ozone-sensitive plants have been identified for SARA (Appendix D). A qualitative assessment of foliar injury risk for SARA by Kohut (2007) resulted in SARA receiving a *low* risk rating, indicating SARA's vegetation is not likely to experience injury because of low levels of ozone exposure and soil moisture. However, this does not mean foliar injury will not occur, as injury is dependent on high ozone coinciding with soil moisture levels, both of which can change over time.

Data and Methods

The evaluation of condition and trends for ozone levels was based on data collected from monitoring stations nearest to SARA, in conjunction with NPS ARD data and their guidance establishing condition categories for assessing ozone. The most recent interpolated ozone data was collected from 2006-2010 (Table 4.1). Using annual fourth-highest daily maximum 8-hour ozone concentrations, five year average values were calculated using interpolated values derived from all available monitoring data from NPS ARD (NPS 2010a). Trend assessments were based on NPS ARD regional data from 1999-2008 (NPS 2010b).

Reference Condition/Threshold Values Utilized

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

"To derive an estimate of the current ozone condition at parks, the five-year average of the annual 4th-highest 8-hour ozone concentration is determined for each park from the interpolated values... If the resulting five-year average is greater than or equal to 76 ppb then the condition Significant Concern is assigned to that park. Moderate condition for ozone is assigned to parks with average five-year 4th-highest 8-hour ozone concentrations from 61 to 75 ppb (concentrations greater than 80 percent of the standard). Good condition for ozone is assigned to parks with average five-year ozone concentrations less than 61 ppb (concentrations less than 80 percent of the standard)." (NPS 2010a).

Condition and Trend

Interpolated ozone values for SARA from 2006-2010 were calculated to be 70.7 ppb. This value does not exceed a regulatory threshold of 75 ppb. Based on NPS ARD condition categories of *good*, *moderate* and *significant concern*, SARA's air quality for ozone was considered *moderate,* as ozone was between 61- 75 ppb (0% attainment for reference values) (Table 4.1). Five year interpolation values obtained from NPS ARD and calculated since 1995 for ozone have consistently been categorized as either *moderate* or *significant concern*, with interpolated values ranging from 70.7-80.6 ppb (Table 4.1). Trend assessment of ozone levels for national parks throughout the U.S. from 1999-2008 resulted in no significant trend and therefore was *unchanging* (p=0.05) for SARA. Several other eastern parks also showed no significant trend in ozone levels during this time period (NPS 2010b).

Table 4.1. NPS Air Resources Division 5-Year Interpolated Ozone Values for SARA.

Parameter	NPR ARD Threshold		SARA 5-Year ARD Values						
	Condition Category	Value	1995-1999	1999-2003	2001-2005	2003-2007	2004-2008	2005-2009	2006-2010
Ozone (ppb)	Good	≤60	79.0	80.6	80.3	75.1	74.0	72.5	70.7
	Moderate	61-75							
	Significant Concern	≥76							

Data Gaps and Confidence in Assessment

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

4.1.2 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

ARD has set a criteria of >3 kg/ha/yr of total wet sulfur (S) or nitrogen (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 2010a). The Northeast region of the U.S., including New York, has experienced elevated wet sulfate and nitrate deposition inputs to its ecosystems compared to the rest of the U.S., specifically in the Adirondack and Catskill regions which have experienced acidification and N saturation to its ecosystems (Aber *et al.* 1989, Driscoll *et al.* 2003). Dry and wet sulfur and nitrogen deposition can directly enter the ecosystem and have direct implications to 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). 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 (Aber *et al.* 2003, Schindler 1988, Dupont *et al.* 2005). Acid neutralizing capacity (ANC) and the 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

In order to evaluate the temporal and spatial trends of deposition, data were collected from monitoring stations nearest to SARA, in conjunction with using NPS ARD data and their guidance establishing condition categories for assessing wet S and N deposition from 2006-2010 (condition assessment) and from 1981-2008 (trend analysis). Park resources sensitive to acidification were measured at a national scale based on a risk assessment by Sullivan *et al.* (2011a). These measures incorporated acidification related risk ratings for 271 I & M parks, including SARA. This risk assessment considered three factors that influence acidification risk to park 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 Appendices E, F 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 (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 (Title 42, Chapter 85) for wet S and N deposition. The NPS is creating a critical load approach for wet deposition of S and N to protect and manage its parks' ecosystems (NPS 2010a). The NPS ARD has produced conditional assessment categories based on ecological responses documented in scientific literature (see 'Relevance and Context' section above, NPS 2010a). The NPS ARD values for SARA for wet S and N deposition were based on interpolated values over a five year average from NADP/NTN data collected from stations operating nearby. 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 was calculated in order to minimize variation in data caused by interannual variation in precipitation. The condition categories established by NPS ARD for wet deposition of S and N have been stated as the following: "*Monitoring evidence indicating that wet deposition amounts less than 1 kg/ha/yr cause ecosystem harm is not currently available. Therefore, parks with wet deposition less than 1 kg/ha/yr were considered to be in good condition for deposition; parks with 1-3 kg/ha/yr were considered to be in moderate condition; and parks with greater than 3 kg/ha/yr were considered to have a significant concern for deposition.*" (NPS 2010a).

Risk assessments produced for national parks were used as supplemental information to assess SARA's air quality and natural resources. As a coarse introduction to the risk assessment of acidification due to S and N deposition on SARA'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 (kg/ha/yr) were used to understand the risk SARA 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

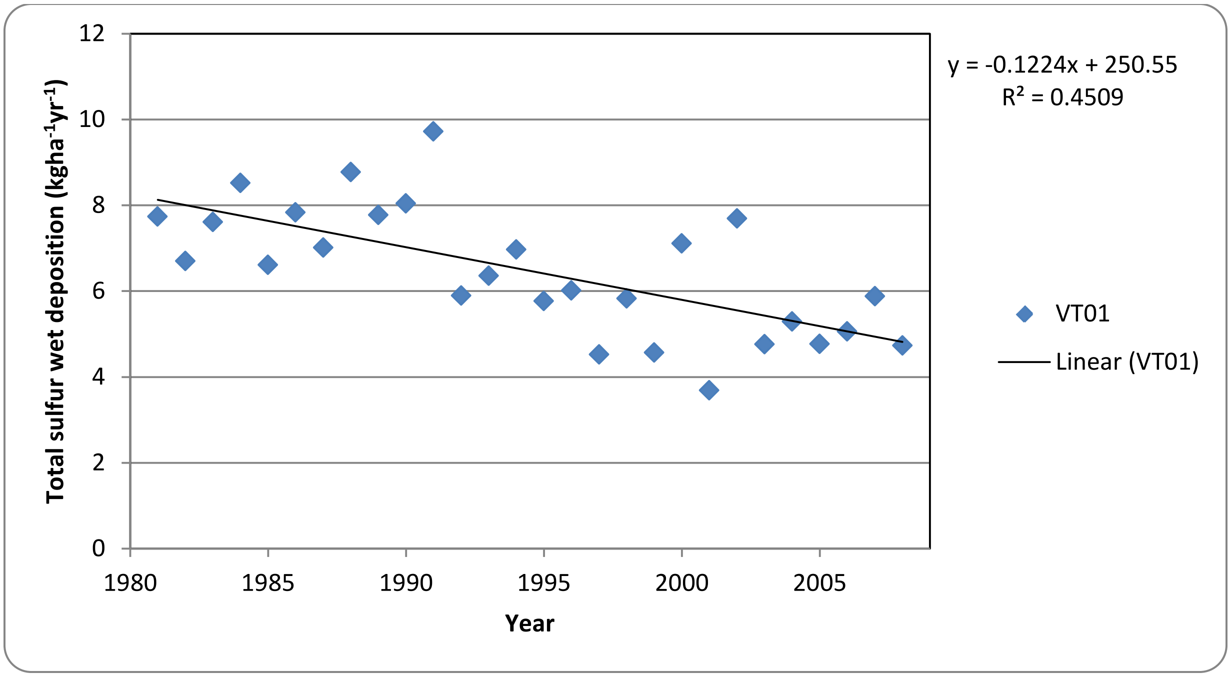
Interpolated wet S and N values for SARA from 2006-2010 were 3.6 and 3.5 kg/ha/yr, respectively. These values do not meet an ecological threshold of 1 kg/ha/yr. Based on NPS ARD condition categories of *good*, *moderate* and *significant concern*, SARA's air quality for wet S and N deposition was considered a *significant concern,* as it was >3 kg/ha/yr (0% attainment) (Table 4.2, NPS 2010a).

Sulfur wet deposition levels collected at station VT01 near SARA have significantly decreased from 1981-2008 based on linear regression results and therefore was assessed as *improving* (n=1 station, $p<0.05$, Figure 4.2). Nitrogen wet deposition trend data collected from station VT01 was not statistically significant ($p>0.05$, Figure 4.2) and was assessed as *unchanging*. Trends for sulfur wet deposition levels seem to be decreasing for SARA while nitrogen wet deposition levels are slower to decrease within the region and are more variable. These trends are supported by peer-reviewed literature that has studied 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 SARA are still well above the NPS ARD *good* condition threshold of 1 kg/ha/yr and therefore, natural resources may still experience negative impacts from higher wet deposition levels.

Table 4.2. NPS Air Resources Division 5-Year Interpolated Atmospheric Wet N and S Deposition Values for SARA.

Parameter	NPR ARD Threshold		SARA 5-Year ARD Values						
	Condition Category	Value	1995-1999	1999-2003	2001-2005	2003-2007	2004-2008	2005-2009	2006-2010
Wet N Deposition (kg/ha/yr)	Good	<1							
	Moderate	1-3	4.04	4.31	4.18	3.87	3.8	3.31	3.5
	Significant Concern	> 3							
Wet S Deposition (kg/ha/yr)	Good	<1							
	Moderate	1-3	4.39	4.57	4.42	4.51	4.2	3.53	3.6
	Significant Concern	> 3							

The NPS risk assessment which evaluated the sensitivity of national parks to acidification effects from S and N deposition included an assessment for SARA (Sullivan *et al.* 2011a). Based on pollutant exposure, ecosystem sensitivity and park protection measures, SARA rated moderate (score=3.00) (Table 4.3). SARA 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, SARA rated *low* (ranking 117.83) (Table 4.3).



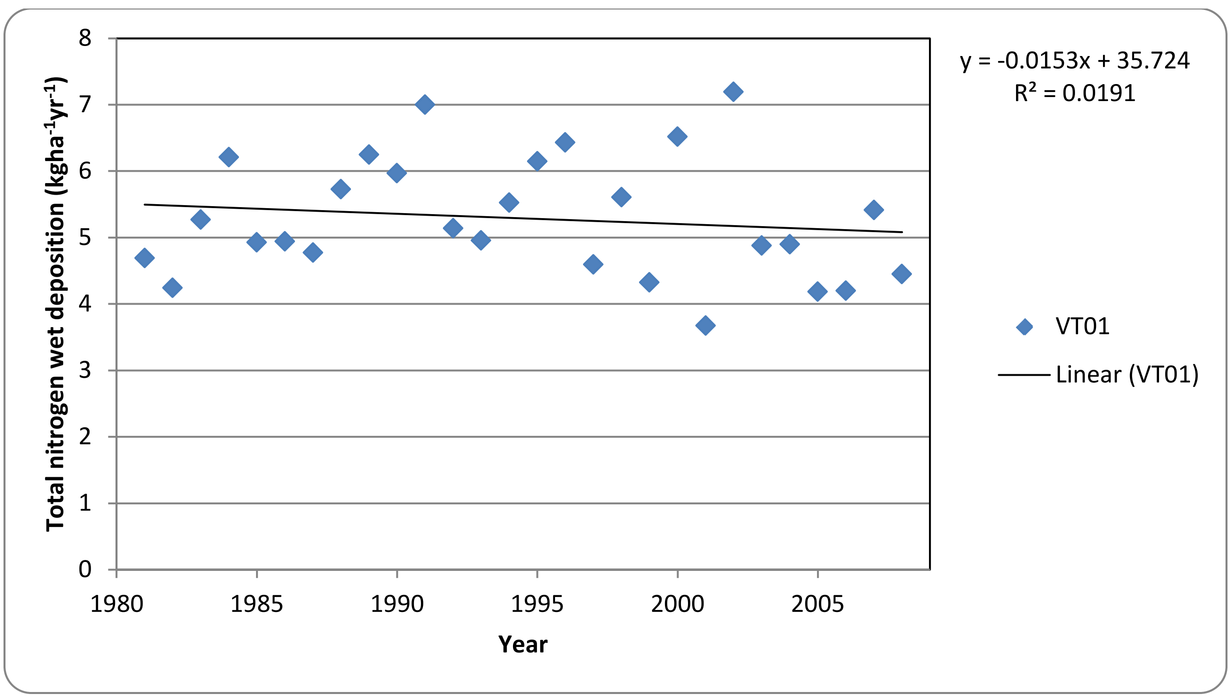


Figure 4.2. Trend of total sulfur wet deposition (top) and total nitrogen wet deposition (bottom) levels (kg/ha/yr) measured at NADP station VT01 near SARA from 1981-2008.

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

Relative Ranking of Parks to Acidification Sensitivity				
Measure	*Avg. of Pollutant Exposure (numerical rank)*	*Avg. of Ecosystem Sensitivity (numerical rank)*	*Avg. of Park Protection (numerical rank)*	*Summary Risk (average numerical rank)*
Acidification	Moderate (173.25)	Moderate (112.92)	Moderate (97)	Moderate (3.00)
Nutrient Enrichment	Moderate (149)	Low (107.5)	Moderate (97)	Low (117.83)

Data Gaps and Confidence in Assessment

The NPS ARD has not included SARA in a NPS-wide trend analysis of wet deposition but has interpolated wet deposition values for SARA. Confidence in the condition assessment of sulfur and nitrogen wet deposition is *high* and confidence in the trend assessment was *medium*. 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 (Sullivan et al 2011a, b) and should increase as scientific knowledge of the factors increases and spatial and temporal data collection efforts improve.

4.1.3 Contaminants

Mercury (Hg)

Relevance and Context

Heavy metal contaminants such as mercury (Hg) 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 (MeHg) 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 streams with low-productivity (Grigal 2003, Miller *et al.* 2005). Wetlands are net sinks for Hg and serve as sources of methylmercury as these waterbodies support bacteria which are responsible for methylation of mercury (Grigal 2003). SARA contains approximately 175 acres (70 ha) of freshwater wetlands, making methylmercury bioaccumulation in these habitats a concern for the park's ecosystem health. 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 to be four times higher than atmospheric deposition by precipitation. Forests may provide ideal 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).

Sections of New York have been identified as "biological hotspots" for mercury contamination based on mercury blood levels of common loon data (Evers *et al.* 2007). Studies have shown that songbirds near the Upper Hudson in New York have some of the highest blood Hg levels in the nation (Duron *et al.* 2009). Although mercury concentrations may be decreasing in certain fish species in New York, the New York Department of Health still establishes advisories for consuming sportfish deemed unsafe for human consumption due to mercury contamination (New York Department of Health 2010). The U.S. EPA, under the Clean Water Act 304(a) (1970, 1990), has established a fish tissue criterion for human consumption that should not exceed 0.3 MeHg mg/kg (U.S. EPA 2001). Additional studies have investigated mercury contamination in fish. 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 the two mercury deposition monitoring stations closest to SARA. Station NY68 in Biscuit Brook, NY (Ulster Co.) and station NY20 in Huntington Wildlife, NY (Essex Co.) are located approximately 80 miles from SARA. Annual mean Hg concentrations (ng/L) were calculated for each station from 2004-2010 (NY68) and 1999-2009 (NY20). Trend analysis for mercury deposition for SARA was only reported for station NY20 and not NY68 due to the lack of long term data.

Reference Conditions/Threshold Values Utilized

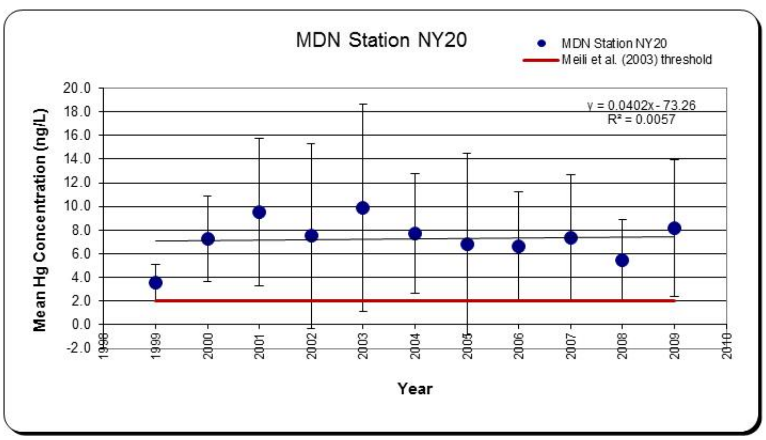
At this time, the NPS is currently working on guidance for mercury that would include condition categories (personal communication, Holly Salazer, NPS air resources coordinator for NE region). Ecological data representing modeled Hg levels by Meili *et al.* (2003) suggested that 2 ng/L of mercury in 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 assessed as *significant concern* if exceeding the 2 ng/L threshold and categorized as *good* if below this threshold for mercury deposition. Trend for mercury deposition at station NY20 was either *improving*, *unchanging* or *deteriorating*.

Condition and Trend

Annual mean Hg concentrations from data collected at monitoring stations near SARA exceeded the 2 ng/L threshold established by Meili *et al.* (2003) and therefore was assessed as a *significant concern* (Figure 4.3). From 1999-2009, Hg mean deposition values and standard deviations were 7.5±6.1 (ng/L) (NY20) and from 7.4±4.8 (ng/L) for station NY68 from 2004-2010. Trend for mercury deposition at station NY20 based on ten years of data was *unchanging* ($p>0.05$). 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

A condition category was not established for SARA due to lack of scientific threshold data for mercury deposition for several types of ecological systems. Although 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. Confidence in the condition assessment of mercury deposition was *low* and trend assessment was *low*.



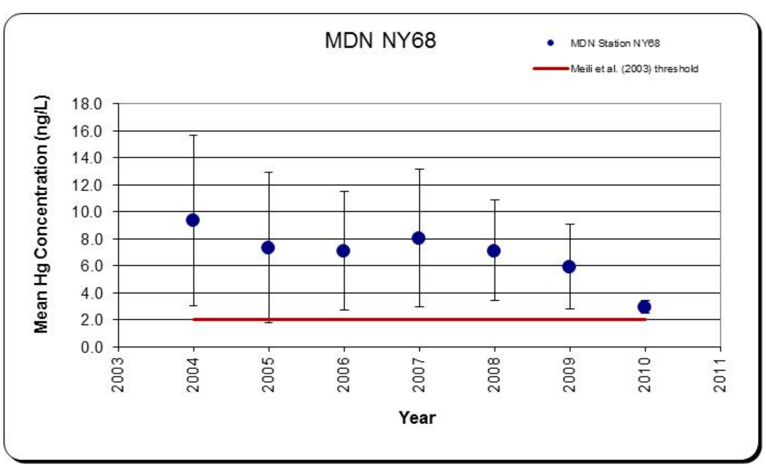


Figure 4.3. Mean yearly mercury concentrations (ng/L) ± standard deviation for MDN station NY20 (N=458) and NY68 (N=274). Note NY68 2010 sample readings were incomplete when assessing this station.

4.1.4 Visibility

Reference and Context

Contaminants within the atmosphere 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. Recognizing the importance of visibility, the Clean Air Act (1977) was approved to include visibility as an indicator of emissions and air quality. This type of atmospheric impairment, which is commonly caused by human-induced activities (e.g., industrial emissions) vs. natural occurrences (e.g., fire), has resulted in the monitoring of visibility at a number of national parks and wilderness areas, specifically Class I areas (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.

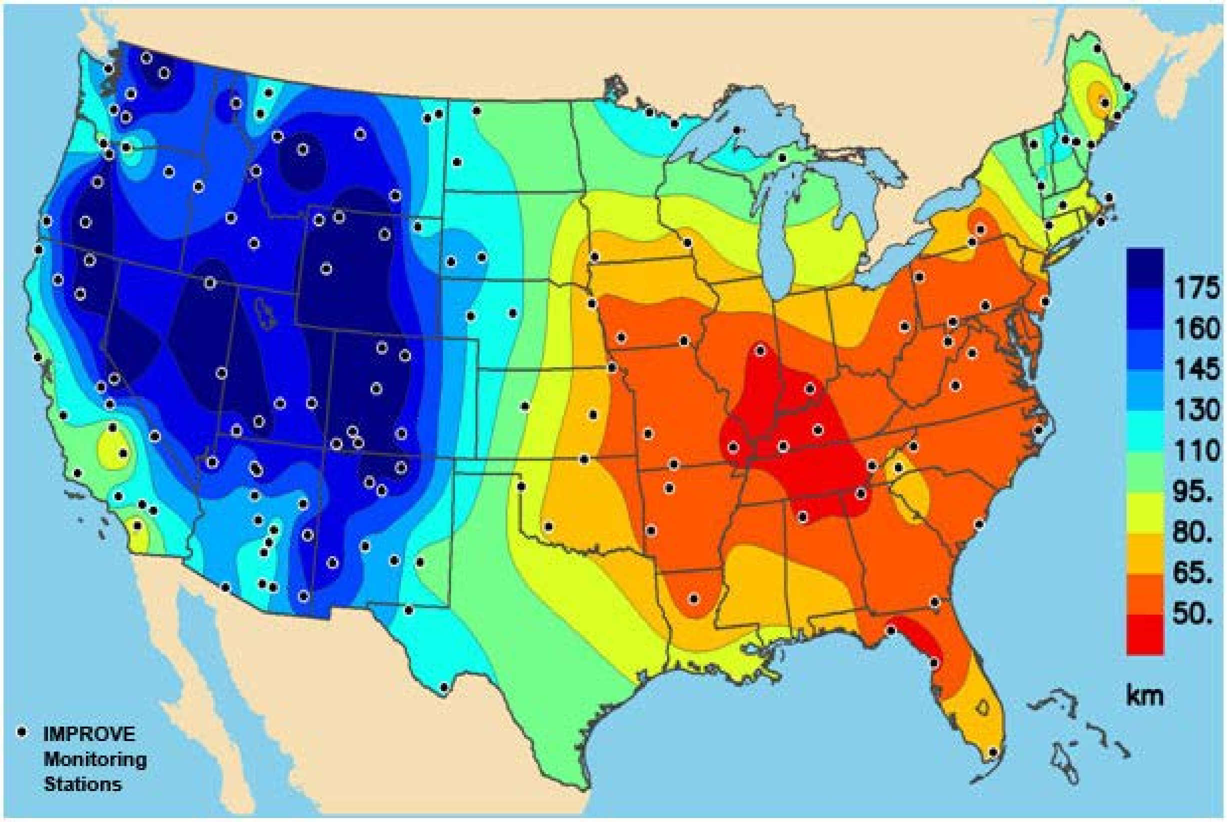


Figure 4.4. Location of IMPROVE monitoring stations within the U.S. and the annual average visual range (in kilometers) based on data collected from 2005-2007. From NPS Air Resources Division. www.nature.nps.gov/air/monitoring/vismonresults.cfm.

Data and Methods
The evaluation of condition and trends for visibility was based on data collected from monitoring stations closest to SARA, in conjunction with NPS ARD data and their established condition categories for assessing visibility (Table 4.4). The closest IMPROVE site to SARA is Lye Brook Wilderness, VT (LYBR1) which is located 35 miles southeast of the park. The most recent NPS ARD interpolated visibility measures for SARA 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 resulted from the difference between current group 50 (mean of the 40^{th}-60^{th} percentile data) visibility and the natural group 50 visibility (estimated visibility in the absence of human caused visibility impairment) (NPS 2010a).

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 *good* has been established by NPS ARD of ≤2 (dv). NPS ARD has established the following categories for assessing visibility and these categories were used in the condition assessment for SARA:

The visibility condition is expressed as:

Visibility Condition = current Group 50 visibility – estimated Group 50 visibility under natural conditions*. Good condition is assigned to parks with a visibility condition estimate of less than two dv above estimated natural conditions. Parks with visibility condition estimates ranging two to eight dv above natural conditions are considered to be in Moderate condition and parks with visibility condition estimates greater than eight dv above natural conditions are considered to have a Significant Concern. The dv ranges of these categories, while somewhat subjective, were chosen to reflect as nearly as possible the variation in visibility conditions across the monitoring network* (NPS 2010a).

Condition and Trend
Interpolated visibility value for SARA from 2006-2010 was 6.0 dv. Based on NPS ARD condition categories of *good*, *moderate* and *significant concern*, SARA's air quality for visibility is considered a *moderate,* as it is greater than the *good* condition level of <2 dv (0% attainment) (Table 4.4, NPS ARD 2010). Trend assessment of visibility data based on the haziest days for national parks within the U.S. from 1999-2008 resulted in many eastern U.S. parks showing 'no significant trend' or 'possible improvement'. A few areas south of New York did have a statistically significant improving trend for visibility measures ($p<0.05$) (NPS ARD 2010).

Data Gaps and Confidence in Assessment
Visibility trend analyses for SARA are not yet available from the NPS ARD's nation-wide trend calculations. Confidence in the current assessment of condition was *high* and the current assessment of trend was *medium*.

Table 4.4. NPS Air Resources Division 5-Year Interpolated Visibility Values for SARA.

Parameter	NPR ARD Threshold		SARA 5-Year ARD Values			
	Condition Category	Value	2001-2005	2003-2007	2005-2009	2006-2010
Visibility (dv) [Current group 50-Est. Group 50 natural]	Good	<2	7.5	7.5	6.6	6.0
	Moderate	2-8				
	Significant Concern	>8				

4.2 Soils

4.2.1 Forest Soil Condition

Relevance and Context

In order to understand the effects acid deposition may have on the health of SARA's forests, soil chemistry has been monitored within the park since 2006 as part of the Vital Signs program. Acidic deposition affects soil chemistry by depleting nutrients such as calcium (Ca), magnesium (Mg), and potassium (K) while mobilizing toxins such as aluminum. These changes influence 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 excess 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.* 1998). Nitrogen also affects carbon cycling by impacting forest ground flora due to a lack of leaf letter and influx of non-native species that thrive on N-rich soils.

Data and Methods

The monitoring of soil chemistry variables congruent with 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 SARA during NETN forest monitoring efforts (Tierney 2009, 2011, Miller *et al.* 2011). Composite soil samples from 32 NETN forest monitoring plots in SARA collected in 2008 and 2010 were analyzed in the laboratory for Ca:Al and C:N. Non-metric Multidimensional Scaling (NMDS) ordinations performed by Miller *et al.* (2011) were also included in this assessment to discuss how SARA's forest soil chemistry compares to eight other NETN parks. Trend analyses were not performed for these indicators due to no 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. 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., Cronan and Grigal 1995, Aber *et al.* 2003). Ca:Al condition categories included the following: median Ca:Al ratio >4 was rated *good*, a ratio of Ca:Al from 1-4 rated *caution*, and a ratio <1 was considered *significant concern* (Table 4.5). Nitrogen saturation was assessed using a C:N soil ratio with the following condition categories: a *good* rating included C:N >25, a *caution* rating was between C:N 20-25, and a *significant concern* rating fell below C:N of 20 (Table 4.5).

Condition and Trend

NETN soil sampling in SARA resulted in an overall median Ca:Al value of 31.5, thus being rated as *good* for SARA (Table 4.5). The median C:N value for SARA was 13.2, falling into the *significant concern* category. Even though C:N rated *significant concern*, the higher levels of N in SARA may not have yet affected Ca:Al values (Miller *et al.* 2009). Long term trend data for SARA's soil chemistry is not available. Since acid deposition is a regional problem, there are few management activities that may be implemented at the park level to reduce it. However, 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 SARA. Furthermore, if treatment of forest soils with Ca, Mg, or K due to elemental deficiencies is needed, SARA staff can formulate a comprehensive soil treatment program as cost effective methods exist for treating forest soils.

Table 4.5. Condition assessment ratings for SARA soil chemistry.

Measure	Condition Category	Result
Ca:Al	Significant Concern: ratio < 1 Caution: ratio 1 - 4 Good: ratio > 4	Median Ca:Al 31.52
C:N	Significant Concern: ratio < 20 Caution: ratio 20 - 25 Good: ratio > 25	Median C:N 13.22

NETN monitors soil chemistry in order to understand the effects of atmospheric deposition on forest health. This is of particular concern for forests in this region because soils here tend to have low soil buffering capacity. Miller *et al.* (2011) used Non-metric Multidimensional Scaling (NMDS) ordinations to examine major gradients in forest soil chemistry across NETN parks and related these gradients to stressors (e.g., acid deposition, N saturation, and invasive species), land-use history, environmental gradients, and forest condition. To examine potential relationships between soil chemistry and other gradients, a matrix of environmental variables was assembled to include values derived for each permanent monitoring plot or park, depending on the data source. Based on ordination plots, the A horizon of soils in SARA had high base saturation and base concentration, higher pH and lower C and N content. When compared to eight other NETN parks, SARA tended to have the lowest average C:N ratio, and contained the only average stream NO_3 concentration above a 20 μeq/L threshold. This ordination may suggest that soils in SARA are vulnerable to N saturation, and it is possible that N saturation and NO_3 leaching are occurring in SARA. However, Miller *et al.* (2011) noted that SARA is surrounded by agricultural lands, and NO_3 inputs from agriculture cannot easily be differentiated from those of soil leaching activity.

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, trend analyses will provide a comprehensive understanding of regional soil acidification and nutrient saturation. 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 SARA. Spatial variability of individual cations is highly dependent upon local site conditions, and temporal variability in cation concentrations can be high, reflecting conditions such as 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. 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. This information can be used at a site level to assess the risk to forest structure from acidification (Smart *et al.*, 2005).

4.3 Stream Water

4.3.1 Stream Water Quantity

Relevance and Context

Over eight miles (13 km) of perennial streams within four watersheds in SARA flow into the bordering Hudson River. Kroma Kill, Mill Creek, American’s Creek and Devil’s Hollow, in addition to the Champlain Canal, serve as aquatic habitat in SARA, along with the approximately 6% of wetlands comprising the parkland (NPS 2004). Prior to the implementation of NETN Vital Signs program in 2006, SARA’s surface waters were not regularly monitored for water quantity parameters. The USGS station which had been previously used to conduct a seasonal analysis of SARA water quantity conditions was the Hudson River at Stillwater (gage 01331095). Based on the Hudson River at Stillwater hydrograph, hydrologic seasons for SARA are: September 20 to February 28, March 1 -to April 30, May 1 to June 30, and July 1 to September 19 (NPS 1997) (Figure 4.5). Stream discharge patterns tend to increase from October-December due to temperature decreases and rainfall accumulation. January to February stream discharges are lower than December due to continuous temperature decline and snow precipitation. March and April begin peaks in discharge from snow melting and from May through August discharge begins to decline again.

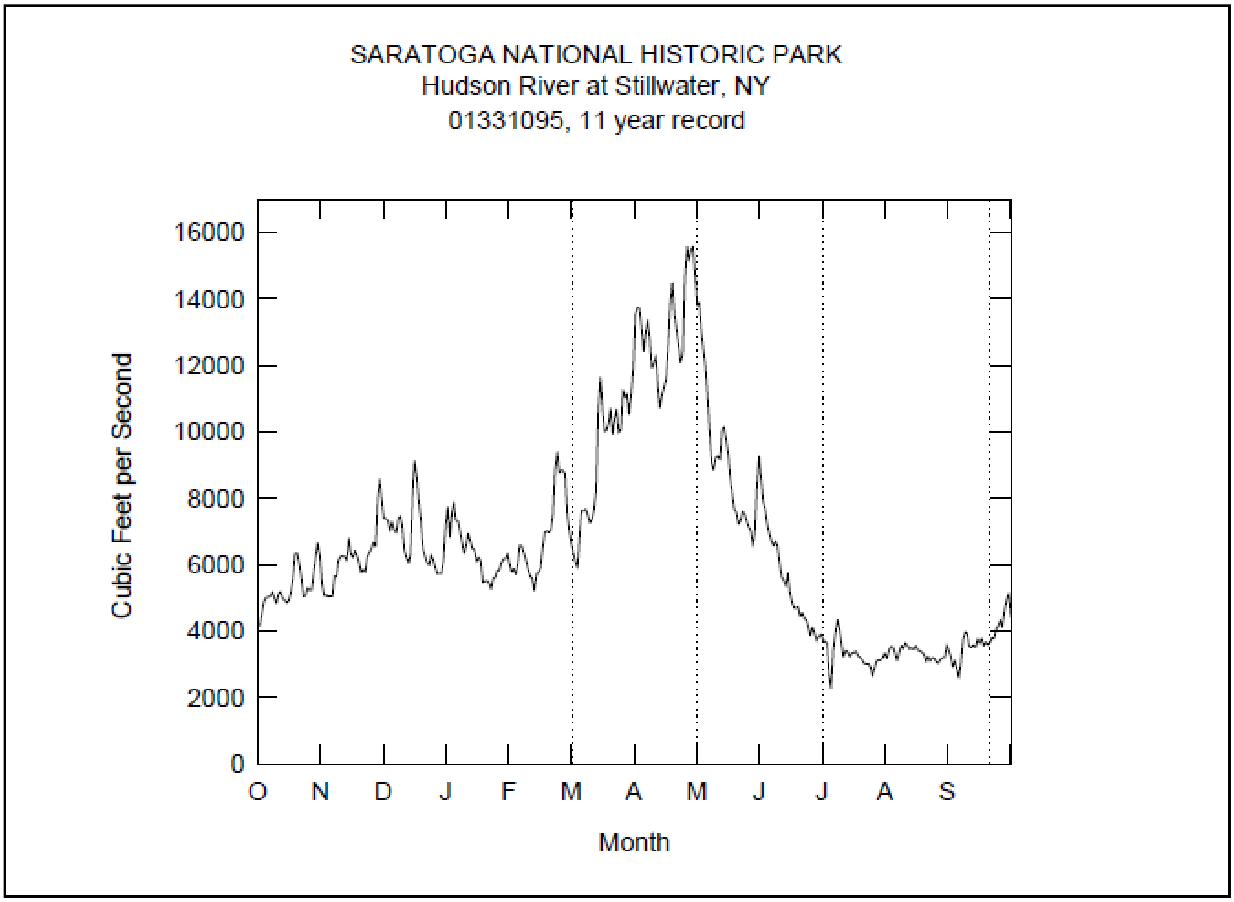


Figure 4.5. Mean annual hydrograph for the Hudson River at Stillwater, NY (NPS 1997). Hydrologic seasons for SARA based on the annual hydrograph are: Sep.20 to Feb.28, Mar.1 to Apr.30, May 1 to Jun.30, and Jul.1 to Sep.19.

Low stream flows can lead to high water temperatures, inadequate dissolved oxygen levels, and restrictions on movements of fish and other aquatic organisms. Low water quantity can limit SARA fish production due to reduced fish passage, spawning habitat, and rearing habitat. Water quantity variables most useful for identifying changes in aquatic communities have been modeled and these models have been suggested as tools for water quantity assessments. A study by Carlisle et al. (2011) identified that diminished flow magnitude models can be used as a general predictor of biological integrity for fish and macroinvertebrate communities, as streams with diminished flow magnitudes tend to increase common fish and macroinvertebrate taxa that possess traits characteristic of lentic habitats. However, the authors noted that streamflow alteration and a complete understanding of ecological consequences remain unresolved to due to a lack of basic accounting and a quantitative understanding of relationships between ecological integrity and stream flow alterations. Efforts to establish minimal environmental flows have resulted in procedures to determine how much water must be left in a specific channel to ensure 'good' habitat value and ecological functioning. New York has not established minimal environmental flows to date, although research is being pursued to establish scientific information that will inform flow recommendations for the State (NY Coop News 2010).

Data and Methods

Data from stream discharge measurements (n=4 stream locations, 2006-2011) in SARA from NETN Vital Signs monitoring efforts were used for assessing SARA's surface water quantity. Average stream discharge and variability for SARA streams were analyzed from May through October (Lombard *et al.* 2006). Information on human population dynamics surrounding SARA and data from Saratoga County water consumption uses were also used to supplement the condition assessment of SARA's water quantity.

Reference Condition/Threshold Values Utilized

A threshold value could not be established for surface water quantity in SARA. Although the New York State Section 703.2 flow regulations cites, "…no alteration that will impair the waters for their best usages…" the scarcity of long-term gauging records for hydrologic parameters within SARA is a limiting factor for assessing stream water quantity condition for the park, as well as the lack of routine biological monitoring data for SARA streams.

Condition and Trend

SARA's surface water quantity condition was rated *unknown.* The hydrological record for SARA's streams was insufficient to assess the condition or document any statistical trends for water quantity variables. Boxplots of discharge data from four SARA streams demonstrate that although discharge generally declines in May versus August, some streams, such as American Creek and Upper Mill Creek, are similar in median discharge rates for these months based on 2006-2011 data (Figure 4.6). Stream discharge declined after May in most of SARA streams due to decreased snow melt and rainfall. However, these temporal snow melt patterns may change based on projected climate changes (Campbell *et al.* 2011). Increasing summer temperatures related to periods of low stream quantity is when competition for water is greatest for public supply, agricultural and domestic needs, and may not be sufficient for supporting the future needs of SARA's habitats. Housing density is projected to expand around SARA (Svancara *et al.* 2009), thus increasing pressure on surface water quantity for consumption uses and threatening biological integrity. The continuation of monitoring efforts in SARA will be critical in explaining the flow regimes of SARA's streams and determining future water management strategies for the park. Management of aquatic environments should consider public water consumption demands during low water quantity periods (e.g., summer months) (Figure 4.7), the increasing human population and housing density near SARA, the annual and seasonal variability of stream measurements (Figure 4.6) and aquatic biota water quantity requirements.

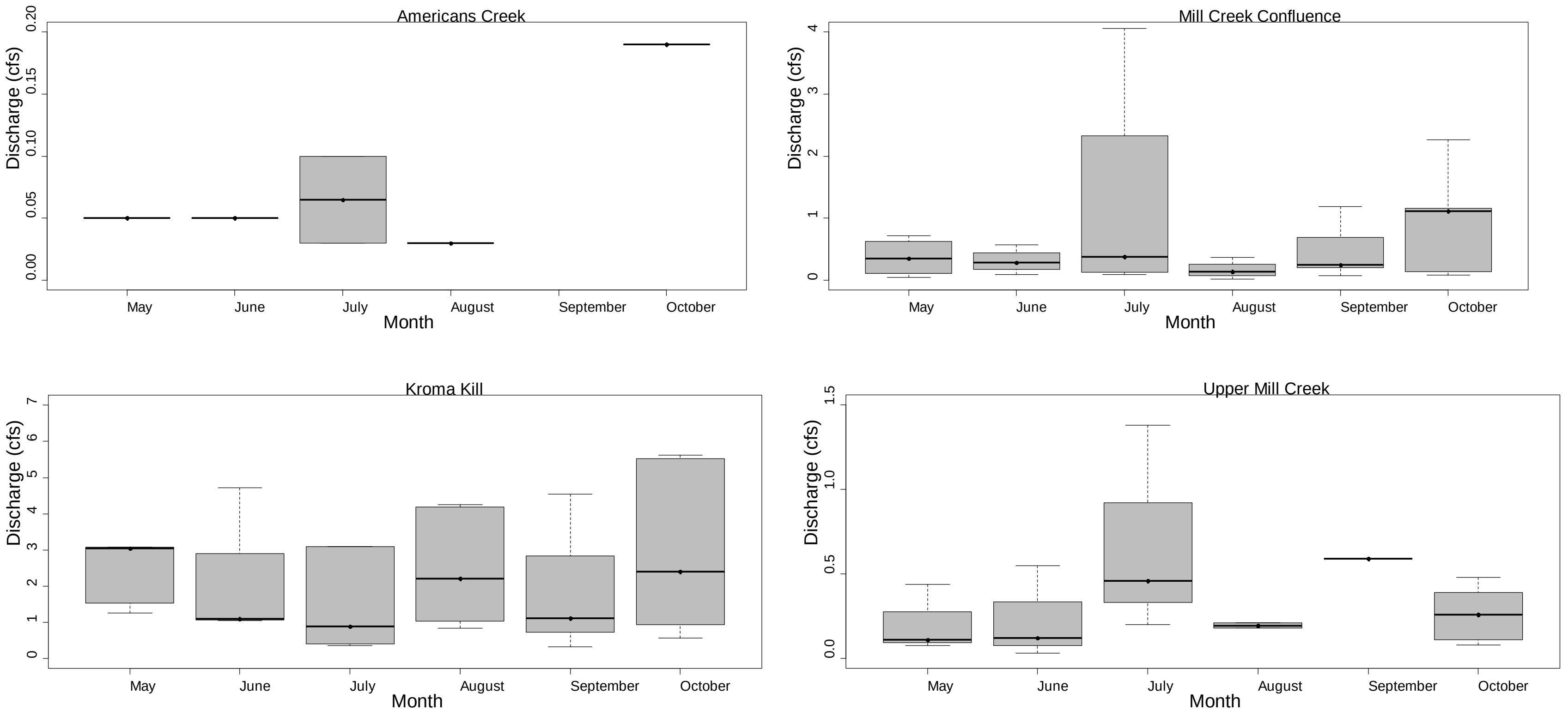


Figure 4.6. Discharge (cfs) measurements collected in May and August 2006-2011 from four streams in SARA. The boundary of the box closest to zero indicates the 25th percentile, a line within the box marks the median, the dot in the middle is the mean and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers above and below the box indicate the minimum and maximum data, respectively.

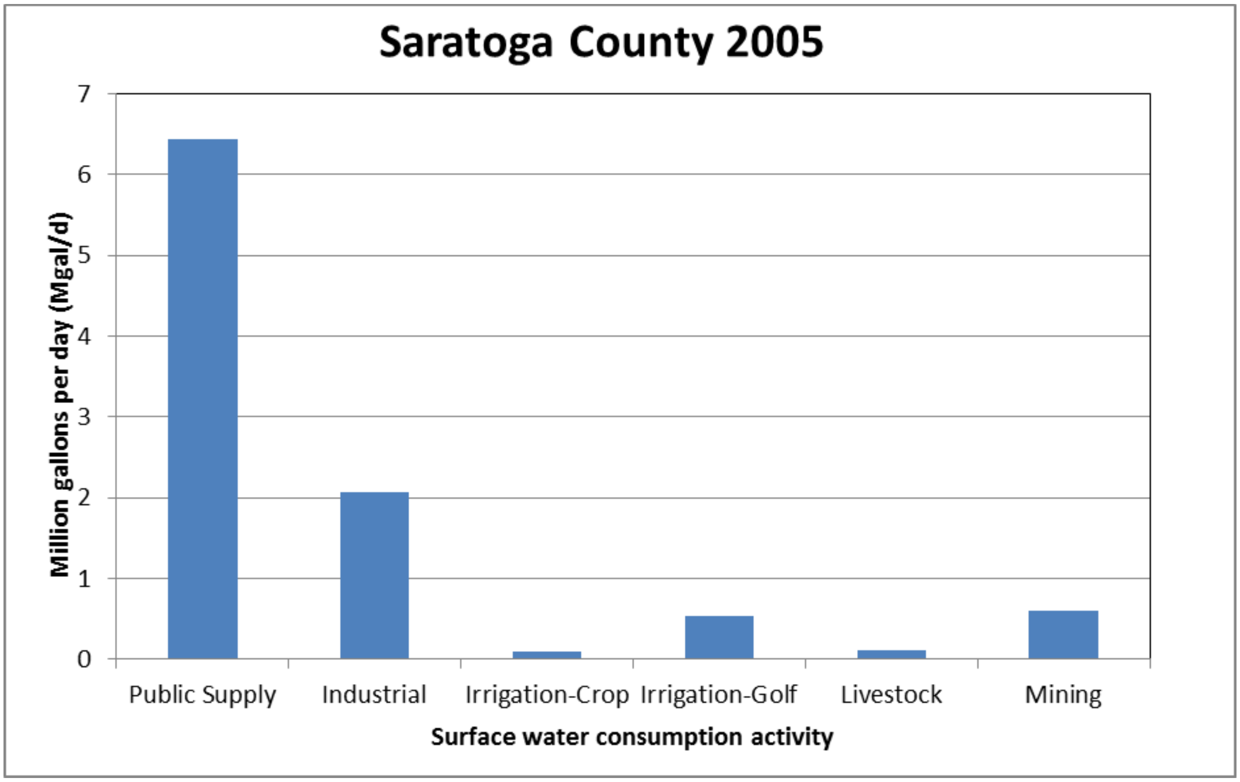


Figure 4.7. Estimated surface water consumption use by activity (Mgal/d) in Saratoga County, 2005 (USGS http://water.usgs.gov/watuse).

Data Gaps and Confidence in Assessment

Confidence in the condition assessment of stream surface water quantity was *low* and confidence in the trend assessment was *not applicable*. The current data availability and quality hinders analyzing water quantity data for SARA's surface water due to the infancy of the NETN Vital Signs Program and the lack of 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). 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. The determination of stream quantity needs or identifying a stream quantity threshold for SARA should consider the management objectives for SARA' s surface waters (i.e., maintain fish and macroinvertebrate communities, conserve a threatened species, recreational value, cultural restoration), and identify what SARA streams' "best usages" are in accordance with NY State flow regulations. An analysis of stage to discharge relationships would be beneficial to estimate measures such as nutrient loading to streams; however, numerous discharge measurements are needed to estimate this relationship. 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 SARA.

4.3.2 Stream Water Chemistry

Relevance and Context

Understanding the physical, chemical and biological components of water is vital to assessing overall water quality conditions. New York State's surface water quality standards (NYCRR Part 703) identify Class AA as the most restrictive classification for stream water quality, and the park's streams are held to New York's highest classification standards as well as to the Federal Water Pollution Control Act (Clean Water Act) (Lombard *et al.* 2006, Mitchell *et al.* 2006). Physical and chemical assessments of SARA's waters have been historically conducted on SARA's streams, but are lacking for other surface waters, such as SARA's wetland systems. Streams located in SARA include Kroma Kill, Mill Creek, American's Creek and Devil's Hollow, and The Champlain Canal (Figure 4.8). From 1987-1990, 16 water quality monitoring stations were established within SARA to measure stream surface water chemistry (Vana-Miller *et al.* 2001). Water quality monitoring resumed at SARA in 2006 as part of the NETN Vital Signs program, with monthly sampling occurring from May through October in Kroma Kill, upper Mill Creek, Mill Creek confluence, and American's Creek (Lombard *et al.* 2006). These sites are located near some of the original stream sites that were monitored from 1987-1990 (Figure 4.8).

Data and Methods

Monthly parameters collected by NETN and used in this NRCA report included temperature, dissolved oxygen, pH and specific conductance. Biannual collections in May and August included total phosphorus, total nitrogen, NO_2+NO_3 and acid neutralizing capacity (ANC) (Lombard *et al.* 2006). These parameters were then used to calculate averages from 2006-2010 to assess water quality standards for SARA's streams (Table 4.6). Additionally, a percentage of individual samples which were compliant with water quality standards or criteria were calculated for each stream (Table 4.6). Trend analyses were included in the assessment of water chemistry parameters for SARA, with data from 1987-2010 queried from the U.S. EPA STORET database (2011) and requested from NETN (Table 4.6). These data were queried to include only NPS stream data from roughly the same stream sites based on latitude and longitude coordinates. Additionally, we used water quality data which was only collected by NPS programs. Linear regression of water quality variables was used to assess trends in water quality data collected from waterbodies in SARA 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 (α=0.05).

Reference Condition/Threshold Values Utilized

The condition categories for water quality variables were rated *good* if compliant with agency standards/criteria and *significant concern* if exceeding those standards and criteria (Table 4.6). A *caution* rating was not applied due to the binary nature of the data. Surface water quality was assessed using standards and criteria set forth by the New York Department of Environmental Conservation (NYCRR Part 703), U.S. EPA ecoregional nutrient criteria for region VII (U.S. EPA 2000, 822-B-00-018) and technical reports (U.S. EPA 1997, Stoddard *et al.* 2003). New York State's surface water quality standards (NYCRR Part 703) identify Class AA as the most restrictive classification for stream water quality, and the park's streams are held to New York's highest classification standards (for standards see: www.dec.ny.gov/regulations/regulations.html). Certain water quality parameters, such as acid neutralizing capacity, do not have numerical criteria under State or Federal standards. In cases where water parameters lack a standard or criteria, water quality thresholds were identified through peer reviewed 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 York State has not established a standard for stream temperature. Changes in temperature can affect the 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 York standards vary according to trout vs. non-trout streams. Non-trout waters shall not be less than 5.0 mg/L (as a minimum average daily concentration and never below 4.0 mg/L), while trout waters shall not be less than 6.0 mg/L and trout spawning waters shall not be less than 7.0 mg/L.

• *pH*

A range of 6.5 to 8.5 is the current New York State standard. Changes in pH can result from metal contamination or increases in aquatic plant growth.

• *Specific Conductivity*

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, phenol and alcohol 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 specific conductance levels in water. For example, failing sewage systems or agricultural runoff can 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 µS/cm (US EPA 1997).

• *Acid Neutralizing Capacity (ANC)*

ANC measures the ability of water to neutralize strong acid. New York does not have a numerical criterion for their water quality standards. 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 York State has not established numerical values for nutrient standards. New York has set standards which indicate, "*…there shall be no nitrogen or phosphorus that will result in growth of algae or impair the water for their best usage* (NYCRR Part 703.2)*.*" The U.S. EPA has established ecoregional nutrient criteria to represent conditions of surface waters that may be affected by anthropogenic activities (US EPA, 2000):

-Total Nitrogen: 0.54 mg/L (streams), 0.66 mg/L (lakes and reservoirs)

-Total Phosphorus: 33 µg/L (streams)

-NO_2+NO_3: 0.30 mg/L (streams)

Condition and Trend

Table 4.6 provides a summary of the condition assessment for water quality parameters of SARA's streams. Dissolved oxygen (mg/L), pH, specific conductance (µS/cm), and acid neutralizing capacity (mg/L) levels were rated *good* when based on regulatory standards or criteria. Attainment of standards for each individual water sample ranged from 52%-100% for these parameters. Total nitrogen (mg/L) exceeded U.S. EPA ecoregional VII criteria for Kroma Kill, upper Mill Creek and Mill Creek confluence when based on the mean results and thus were rated *significant concern* and American's Creek rated *good*. Based on total phosphorus (µg/L) levels a *significant concern* rating was applied to Kroma Kill, American's Creek, and Mill Creek Confluence while Upper Mill Creek rated *good*. NO_2+NO_3 (mg/L) levels in water samples exceeded criteria in Kroma Kill and Mill Creek Confluence and therefore these streams were rated *significant concern* and American's Creek and Upper Mill Creek rated *good*. Table 4.6 lists the percent of water samples which attained water quality standards for nutrient parameters. Regression trend analysis for data collected from July-September 1987-2011 was performed for dissolved oxygen, pH, and specific conductance measurements. No statistically significant trend was detected in pH levels for the four streams sampled ($p>0.05$) and therefore the trend was rated as *unchanging*. Specific conductance significantly increased in all four streams, thus the trend was assessed as *deteriorating*. Trends for dissolved oxygen were statistically increasing or no statistical change was detected in various streams in SARA based on the 1987-2011 dataset ($p<0.05$) (Table 4.6) and therefore trends were rated as *improving* or *unchanging*.

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* for pH, specific conductance and dissolved oxygen and *low* for all other parameters due to the lack of long term temporal data and low sample sizes collected for SARA streams from 1987-2011. 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 SARA. 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 SARA. Depending on the objective(s) established for monitoring water quality in SARA, the park may benefit from switching to the installation of continuously operating multi-parameter sondes in order to address the natural variability which occurs in water quality parameters.

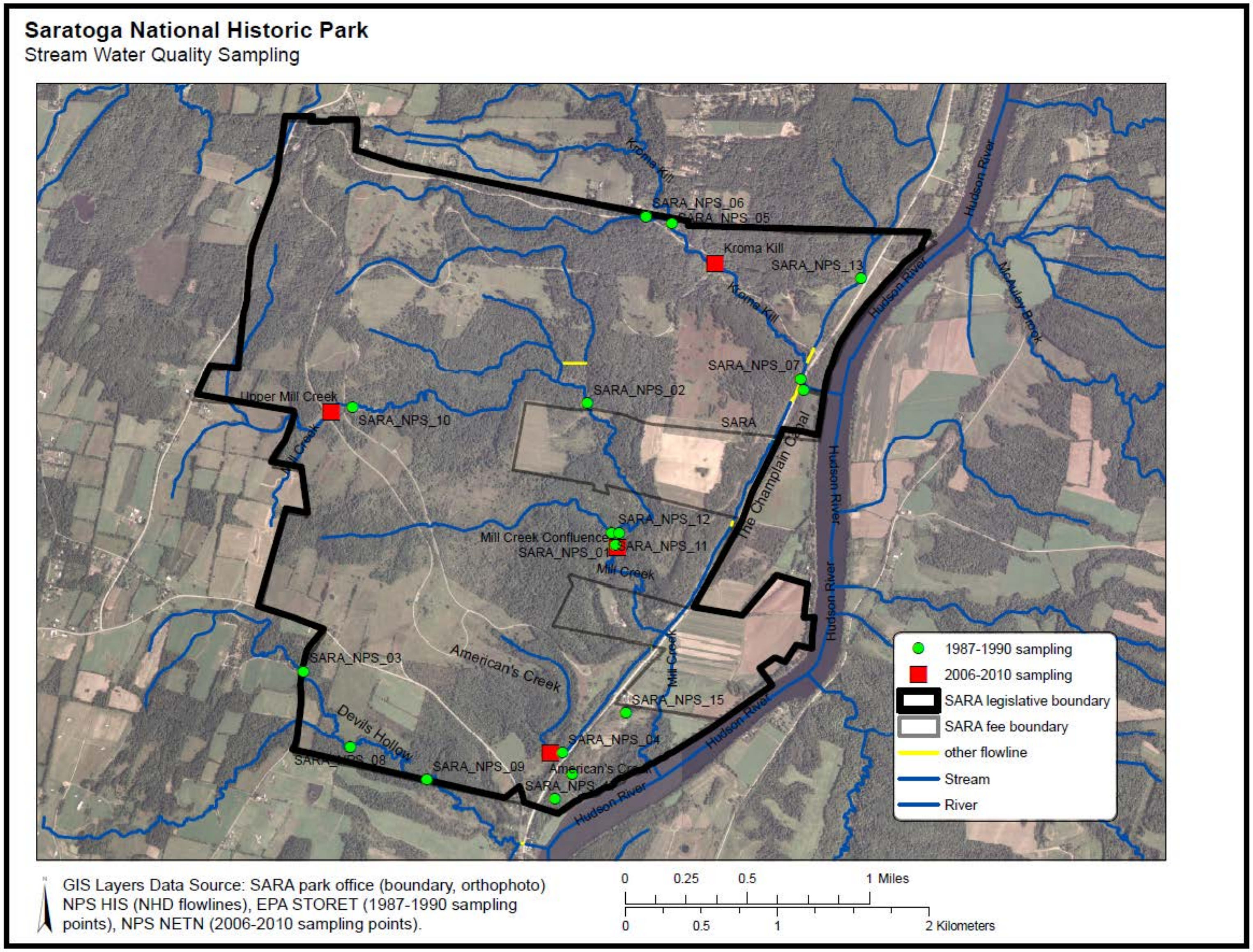


Figure 4.8. Stream water quality sampling locations in SARA's Battlefield Unit in 1987-1990 and 2006-2011.

Table 4.6. Condition assessment scores for SARA water quality parameters.

Measure	Standards	Waterbody	Results (Mean±St.Dev) (N)	Assessment (% samples compliant)	Trend
Temperature (ºC)	No threshold	Kroma Kill	16.4±4.3 (38)		
		American's Creek	16.4±4.6 (36)		
		Upper Mill Creek	16.3±5.0 (33)		
		Mill Creek Confluence	16.1±3.9 (35)		
Dissolved Oxygen (mg/L)	5.0 mg/L-non-trout waters [1] 6.0 mg/L-lakes and ponds [1] 6.0 mg/L-trout waters [1] 7.0 mg/L- cold water trout spawning[1]	Kroma Kill	10.2±1.1 (38)	Good (100%)	Improving
		American's Creek	9.0±1.4 (36)	Good (97%)	Unchanging
		Upper Mill Creek	7.7±2.4 (33)	Good (82%)	Unchanging
		Mill Creek Confluence	10.0±1.3 (35)	Good (100%)	Improving
pH	6.5≤pH≤8.5 [1]	Kroma Kill	8.5±1.0 (38)	Good (79%)	Unchanging
		American's Creek	8.1±0.3 (36)	Good (97%)	Unchanging
		Upper Mill Creek	7.9±0.6(33)	Good (97%)	Unchanging
		Mill Creek Confluence	8.2±0.6(35)	Good (91%)	Unchanging
Specific conductance (µS/cm)	150<conductivity<500 (µS/cm) [2]	Kroma Kill	380±99 (38)	Good (89%)	Deteriorating
		American's Creek	447±91 (36)	Good (75%)	Deteriorating
		Upper Mill Creek	493±112 (33)	Good (52%)	Deteriorating
		Mill Creek Confluence	355±63 (35)	Good (97%)	Deteriorating
Acid Neutralizing Capacity (mg/L)	ANC> 5 (mg/L) (100 µeq/L) [3]	Kroma Kill	3008±252 (13)	Good (100%)	
		American's Creek	3423±1658 (12)	Good (100%)	
		Upper Mill Creek	3512±483 (12)	Good (100%)	
		Mill Creek Confluence	2349±1080 (12)	Good (100%)	
Total Nitrogen (mg/L)	0.54 mg/L (streams) [4] Cannot be at levels that will result in growths of algae or impair water for best usage.[1]	Kroma Kill	4.00±2.56 (13)	Significant Concern (0%)	
		American's Creek	0.34±0.21(12)	Good (83%)	
		Upper Mill Creek	0.61±0.23(12)	Significant Concern (42%)	
		Mill Creek Confluence	3.59±1.96 (12)	Significant Concern (0%)	
Total Phosphorus (µg/L)	33 µg/L (streams)[4] Cannot be at levels that will result in growths of algae or impair water for best usage.[1]	Kroma Kill	39±22(13)	Significant Concern (38%)	
		American's Creek	41±65(12)	Significant Concern (58%)	
		Upper Mill Creek	31±13 (12)	Good (58%)	
		Mill Creek Confluence	38±11(12)	Significant Concern (33%)	
NO_2+NO_3 (mg/L)	0.30 mg/L (streams)[4]	Kroma Kill	3.49±2.68 (13)	Significant Concern (0%)	
		American's Creek	0.06±0.05 (12)	Good (100%)	
		Upper Mill Creek	0.12±0.12(12)	Good (92%)	
		Mill Creek Confluence	3.15±2.13(12)	Significant Concern (8%)	

[1]New York State standards for AA streams (NYCRR Part 703); [2]U.S. EPA (1997): Range for good fisheries mix; [3]Stoddard *et al.* (2003); [4]U.S. EPA ecoregional nutrient criteria for region VII (U.S. EPA 2000, 822-B-00-018). Data queried from NPS Northeast Temperate Network Vital Signs Monitoring Program and U.S. EPA STORET Database.

4.3.3 Hudson River Contamination

Relevance and Context

In 1984, 200 miles (322 km) of the Hudson River extending from Hudson Falls to the Battery in New York City was declared a Superfund site primarily due to extensive PCB contamination in the river. SARA, which lies within Region 2 of the Hudson River between river mile 170 and 180, has experienced cultural and natural resource impacts due to legacy contamination (Figure 4.9). The sources of PCB contamination were generated from two General Electric facilities located in Fort Edward and Hudson Falls, New York, which discharged approximately 1.3 million pounds of PCBs in to the river. PCBs are synthetic compounds consisting of 209 individual chlorinated biphenyls called congeners and have been shown to cause reproductive and developmental effects in animals according to the U.S. EPA and peer-reviewed studies. Ecological exposures to PCBs in the Hudson River are through bioaccumulation mechanisms such as 1) *bioconcentrating* (PCBs are absorbed from water and accumulated in tissue) and 2) *biomagnification* (PCBs increase in tissue concentrations as they travel up the food chain through two or more trophic levels).

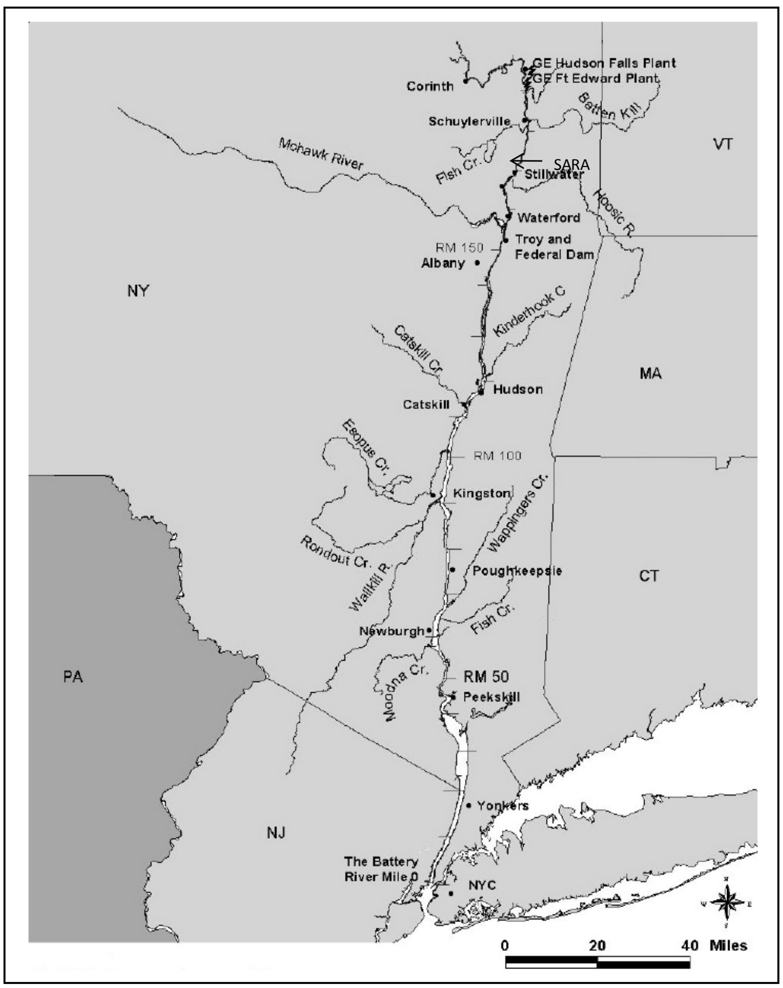


Figure 4.9. The Hudson River and river mile marker locations. SARA is located between river mile 170 and 180 (From HRNRT 2008).

Due to historic discharges and the continuous release of PCBs from bedrock and contaminated sediments, the surface water, floodplains, fish, wildlife, and other biota near and within SARA are continuously vulnerable to PCB contamination (Figure 4.10). The release of PCBs into the Hudson River resulted in these contaminants adhering to the river sediments and slowly being released back into the river. During high flow events, contaminated sediments are deposited to the floodplain, serving as a pathway into the terrestrial food chain. Additionally, bioavailability of PCBs to aquatic organisms increases, affecting animals and plants living in or near the river, such as invertebrates, fish, amphibians, reptiles, birds and mammals. Exposure to PCBs is from contaminated sediments, river water, air, or indirectly through ingestion of food or prey containing levels of PCBs.

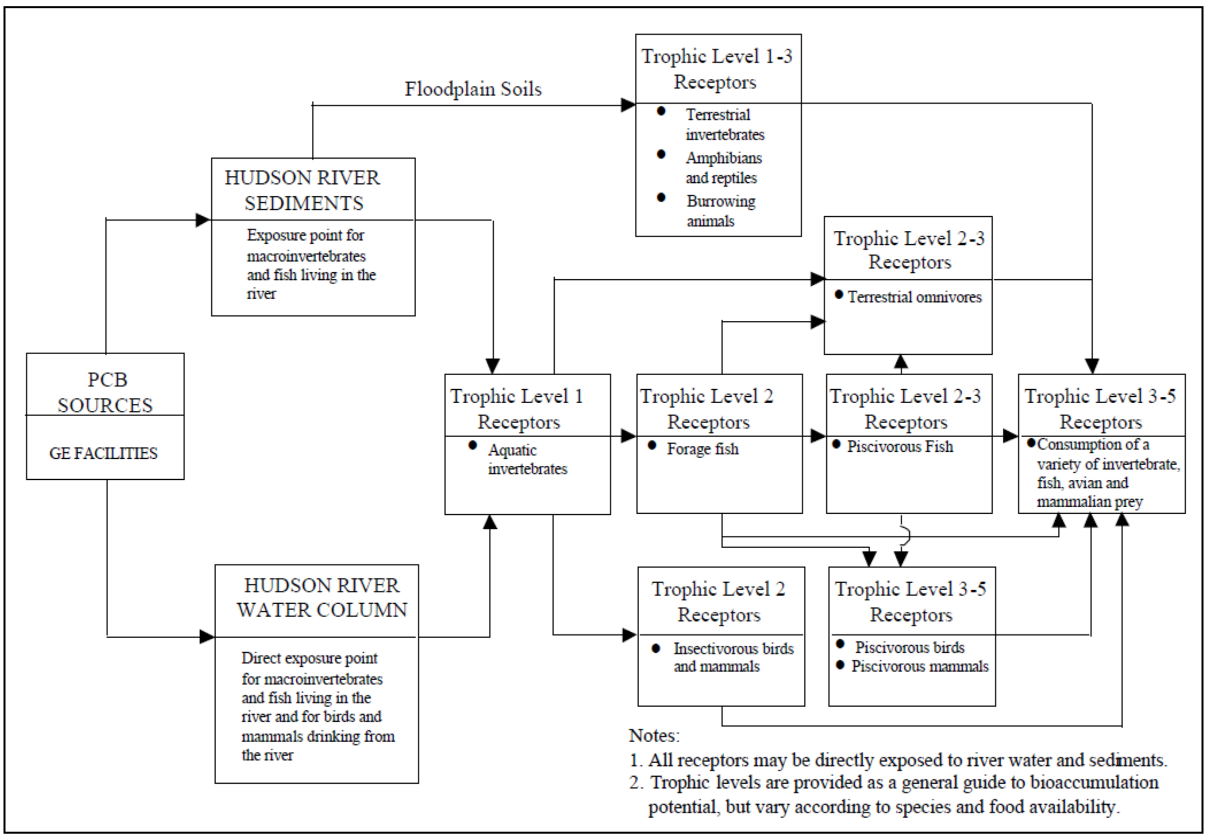


Figure 4.10. Hudson River Pathway Conceptual Model of PCB Contamination (From U.S. EPA 2000).

The following summarizes how the environment within and surrounding SARA may be affected by PCB contamination within the Hudson River:

- *Surface water*
  Water quality guidance criteria and standards have been used to evaluate whether injury to surface water resources exist near SARA. The quality of surface water is critical to the survival, health and reproduction of the diversity of species that occupy the Hudson River. Additionally, human uses of the river for recreational uses and navigation rely on water quality meeting Federal and State water quality criteria. Levels of applicable PCB guidance

criteria and regulatory standards have changed over the years, with Table 4.7 representing the present criteria and standards for PCBs in surface water.

- *Sediment and soil*
  When PCBs entered the Hudson River, they were deposited and combined with sediments on the river bottom and at locations along the shoreline. Sediment dwelling organisms may be exposed to PCBs particles bound to sediment and PCBs that are dissolved in the water column. During flooding events, contaminated sediments mix with floodplain soils, threatening the welfare of SARA's floodplain vegetation and wildlife communities. As a result of PCB contamination, floodplain soils, amphibian breeding habitat and near shore sediments have been sampled in and near SARA (Appendix G). Theoretical and empirical approaches have been created for sediment quality guidelines for PCBs in various aquatic habitats and Hudson River sediment screening guidelines for PCB concentrations have been calculated by NOAA and NYSDEC (Table 4.7).

- *Invertebrates (earthworms and adult aquatic insects)*
  Earthworms are common soil dwelling organisms which serve as an important pathway for PCBs to enter the foodweb. While in water, insects are living in direct contact with the Hudson River's contaminated sediment and serve as food for fish and wildlife. Emerging adult aquatic insects, which have spent the majority of their life cycle in the aquatic habitat, serve as a pathway for moving contaminants from the aquatic environment to terrestrial systems (Fairchild et al. 1992).

- *Fish*
  The Hudson River supports a diversity of resident, anadromous and marine species of fish which serve as food for birds and mammals located in the Hudson Valley (Hetling et al., 1978). PCB contamination may adversely affect the survival, growth and reproduction of these species. Monitoring of PCBs in fish has been measured regularly throughout the Hudson River since 1975 by the NYSDEC monitoring program, with the Stillwater/Coveville section being the closest area to SARA with available PCB data for fish (HRNRT 2001) (Appendix G). Due to the presence of high concentrations of PCBs measured in these fish, restricted fishing and consumption of fish in the Hudson River has been in effect since 1975 in New York. The Great Lakes risk-based PCB advisory has been set at >2 ppm (do not eat advisory) and at <0.05 ppm (no advisory) for fish consumption (Great Lakes Sport Fish Advisory Task Force 1993). The Food and Drug Administration (FDA) tolerance level for PCBs in fish is set at 2 ppm (Reference 21 CFR 109.30) for a "market basket" approach (i.e., assumes people eat a variety of fish from a variety of places" (www.fda.gov)). The US EPA has developed and proposed a risk-based concentration of 0.05 ppm as a goal for PCBs in fish as a protection level for people who regularly eat fish from the Hudson River (US EPA, www.epa.gove/region2/superfund/Hudson/fact_sheet.htm). Additional PCB concentrations in fish body tissue have been identified which include reproductive impairment in fish at 0.4 ppm total PCB (USEPA 1980) and hazards to fish-eating wildlife at 0.13 ppm total PCB (Newell et al. 1987).

- *Amphibians*
  The Hudson River and surrounding habitat supports several species of amphibians. Amphibians spend most of their lives in contact with potentially contaminated water and sediment and subsequently may be consumed as prey. Many amphibian species provide a mechanism of transfer for PCBs from the aquatic into the terrestrial food web due to their life cycle beginning in water and metamorphosing toward land. Bullfrogs (Rana catesbeiana) are common amphibians in the Hudson River which have been sampled and tested for PCB contamination (HRNRT 2005a, HRNRT 2007a). These frogs eat a variety of foods and are an important link between trophic levels, as they are consumed by larger predatory organisms.

- *Reptiles*
  Reptiles, such as turtles, have been evaluated for PCB contamination due to their contact with Hudson River sediments. Specifically, snapping turtle eggs (Chelydra serpentine serpentine) and Midland painted turtles (Chrysemys picta) have been sampled to assess potential PCB impacts and whether eggs are a pathway for PCB contamination to other wildlife (HRNRT 2005b). Snapping turtles retain contaminants in their fat, liver, eggs and, to a lesser extent, muscle. These long-living reptiles consume a variety of animal matter and vegetation in their diet, while snapping turtle eggs are prey for skunks, snakes, birds and other wildlife. Kiviat (1980) noted foraging home range for Hudson River snapping turtles of 22 acres (8.9 hectares (adult males)) and 18 acres (7.2 hectares (nonbreeding adult females)). Additionally, females may need to travel outside of their foraging home range for locating a suitable nesting site. New York State has issued a statewide consumption advisory of snapping turtles due to PCB contamination in the Hudson River.

- *Birds*
  Birds have the potential to be exposed to PCBs due to feeding from the river and floodplain systems. The Hudson River supports over 150 species of birds, which may be exposed to PCBs through ingestion of contaminated water, sediment, soil and prey items. Regional PCB contamination has been screened for a diversity of avian eggs, waterfowl and tree swallows. The representative sampling of birds provides information for species which use various types of habitats common in the Hudson River valley, consume assorted food types and overall represent different ecological guilds.

- *Bats*
  The Hudson River supports nine species of bats which are at risk for PCB mobilization due to fat cycles associated with hibernation and migration patterns. Their low reproductive rates slow recovery for affected bat populations and their long life span allows for greater contact with emerging insects from the river, thus increasing the accumulation of PCBs in their bodies (Clark and Shore 2001, Harvey 1992).

- *Small mammals (short-tailed shrew, meadow vole, mouse)*
  Small mammals are common along the floodplain of the Hudson River. These mammals tend to have close habitat associations with floodplain sediments and prey on floodplain flora and fauna. For example, the short-tailed shrew (Blarina brevicauda) has a high food consumption

rate, consuming earthworms, slugs, and insects, though spiders, mollusks, and some vertebrates (other shrews, snakes, salamanders, and voles) are also consumed (Hamilton 1941, Whitaker and Ferraro 1963, Whitaker and Mumford 1972,). Due to its diet and habitat, the short-tailed shrew would likely exhibit bioaccumulation of PCBs if these contaminants were present in floodplain soils.

- *River otters and minks*
  Numerous studies have assessed the health and reproductive impairment from PCB contamination in river otters (Lontra canadensis) and minks (Mustela vison). Leonards et al. (1994) summarized toxicological studies of mink and developed a model of PCB toxicity for mink based on reproductive success. Smit et al. (1996) examined a variety of potential toxicological responses of European otter to PCBs. The following criteria of Leonards et al. (1994) and Smit et al. (1996) were applied in a preliminary evaluation of potential toxicological responses in Hudson River mink and otter (Mayack and Loukmas 2001):
  1) *<9 µg total PCB's/g lipid is considered a proposed safe level for mink and otters based on an EC1 for body burdens in European otter affecting hepatic retinol level.*
  2) *≥ 21 µg total PCB's/g lipid is considered a critical level for health impairment in mink and otters based on an EC90 for body burdens in European otter affecting hepatic retinol level.*
  3) *≥50 µg total PCB's/g lipid is considered a critical level for reproductive impairment in mink and otters based on EC50 for reduction in litter size in mink. Critical levels for reduction in litter size and reduction in kit survival were 40 to 60 and 79 to 118 µg total PCB's/g lipid, respectively.*

- *Other Activities*
  In order to reduce PCB exposure, visitor use near the Hudson River is discouraged but is not prohibited. Additionally, park management and staff interactions in floodplain areas are limited in SARA. For example, park management has altered vegetation management techniques in order to address safety concerns of staff working in the floodplain (NPS 2010c).

Data and Methods

Since PCBs have known bioaccumulation properties, SARA was assessed for evidence of indirect PCB exposure at various levels of the food chain based on data collected and publically released by the Trustees of the Hudson River Natural Resource Damage Assessment (HRNRT). The Trustees, which act on the public's behalf to assess natural resources, include the New York State Department of Environmental Conservation, the National Oceanic and Atmospheric Administration and the U.S. Department of the Interior. HRNRT studies were primarily used in the assessment for SARA due to consistent sampling technique and chemical methodology in addition to documented QA/QC procedures. Additionally, peer-reviewed publications have listed the effects of PCBs on wildlife within the Hudson River. These studies were used to supplement areas which have either not been investigated or where data has not been publically released from HRNRT studies. Total PCB concentrations were the primary reported values in this report, although individual PCB congener analysis were available in some of the HRNRT reports (and are not reported here). PCB receptors of concern which have been sampled in or near SARA include: surface water, sediment, floodplain and amphibian breeding habitat, earthworms, aquatic macroinvertebrates, fish, amphibians, reptiles, birds, and mammals. Sampling dates for these receptors analyzed in this condition assessment for SARA are located in Table 4.8. Sampling site locations of the reported results (in the Condition and Trend) section below can be found in Appendix G.

Signs posted along the Hudson River at Saratoga National Historical Park indicating the presence of PCB contamination in fish and providing consumption warnings. Photo: R. Wagner (November 12, 2010).

Table 4.7. Summary of selected thresholds (standards, criteria, and guidance levels) for total PCB concentrations measured for a variety of environmental receptors in SARA.

Receptor	Description of Threshold	Threshold (Total PCB)	Authority establishing threshold
Surface water	Freshwater and marine aquatic life and consumer thereof	0.001 µg/l	41 FR 32947 (August 6, 1976) U.S. Environmental Protection Agency. Guidance Criterion Quality Criteria for Water ("Red Book"). EPA 440/9-76-023, PB 263 943 July, 1976
	Human Health	0.000064 µg /l	Environmental Protection Agency. National Recommended Water Quality Criteria: 2002. Office of Water. EPA-822-R02-047. November, 2002. 45 FR 79318 (November 28, 1980)
	Aquatic Life (freshwater)	0.014 µg /l	45 FR 79318 (November 28, 1980) U.S. Environmental Protection Agency. Ambient Water Quality Criteria for Polychlorinated Biphenyls. Office of Water Regulations and Standards. EPA 440/5-80¬ 068. November, 1980
	Piscivorous Wildlife	0.00012 µg /l	6 NYCRR § 703.5
	Human-fish consumption	0.000001 µg /l	6 NYCRR § 703.5
	Human-sources of drinking water	0.09 µg /l	6 NYCRR § 703.5
Sediments	Threshold effect concentration -adverse population level effects unlikely to be observed on sediment-dwelling organisms	Total PCB concentration: 0.04 (mg/kg or ppm)	Hudson River Sediment Effect Concentration (NOAA 1999)
	Mid-range effect concentration-adverse effects on sediment-dwelling organism expected to be frequently observed	Total PCB concentration: 0.4 (mg/kg or ppm)	Hudson River Sediment Effect Concentration (NOAA 1999)
	Extreme effect concentration -adverse effects are expected to usually or always observed	Total PCB concentration: 1.7 (mg/kg or ppm)	Hudson River Sediment Effect Concentration (NOAA 1999)
	Benthic aquatic life acute toxicity	Total PCB concentration: 2760.8 (mg/kg organic carbon)	New York Dept. Environmental Conservation-freshwater (1998)

Receptor	Description of Threshold	Threshold (Total PCB)	Authority establishing threshold
	Benthic aquatic life chronic toxicity	Total PCB concentration: 19.3 (mg/kg organic carbon)	New York Dept. Environmental Conservation-freshwater (1998)
Sediments	Wildlife bioaccumulation	Total PCB concentration: 1.4 (mg/kg organic carbon)	New York Dept. Environmental Conservation-freshwater (1998)
	Risk-based concentration for protection level of people who eat fish regularly from Hudson River	0.05 ppm	U.S. Environmental Protection Agency
	Risk-based level of “Do not consume”. Set by consortium of eight Great Lakes states	>2 ppm	The Great Lakes protocol risk-based PCB advisory
Fish	Tolerance level of PCBs in fish for a market basket approach (assume fish are from a variety of places-interstate commerce)	2 ppm	U.S. Food and Drug Administration (Ref. 21 CFR 109.30)
	Reproductive impairment in fish	0.4 ppm (body tissue)	U.S. EPA 1980
	Hazard to fish-eating wildlife	0.13 ppm (body tissue)	Newell *et al.* 1987
Earthworms	Levels compared to upstream-downstream sites		
Emerging Adult Aquatic Insects	Levels compared to upstream-downstream sites		
Amphibians and Reptiles	Levels compared to reference sites sampled		
Birds	Levels compared to reference sites and upstream-downstream sites sampled		
Bats	Levels compared to reference sites and upstream-downstream sites sampled		
Small Mammals	Levels compared to reference sites sampled		

Receptor	Description of Threshold	Threshold (Total PCB)	Authority establishing threshold
River Otters and Minks	Considered a proposed safe level for mink and otters based on an EC1 for body burdens in European otter affecting hepatic retinol level.	<9 µg total PCB's/g lipid	Leonards *et al.* 1994; Smit *et al.* 1996; Mayack and Loukmas 2001.
	Considered a critical level for health impairment in mink and otters based on an EC90 for body burdens in European otter affecting hepatic retinol level.	≥ 21 µg total PCB's/g lipid	Leonards *et al.* 1994; Smit *et al.* 1996; Mayack and Loukmas 2001.
	Considered a critical level for reproductive impairment in mink and otters based on EC50 for reduction in litter size in mink. Critical levels for reduction in litter size and reduction in kit survival were 40 to 60 and 79 to 118 µg total PCB's/g lipid, respectively.	≥50 µg total PCB's/g lipid	Leonards *et al.* 1994; Smit *et al.* 1996; Mayack and Loukmas 2001.

Reference Condition/Threshold Values Utilized
Each environmental receptor assessed for PCB impacts in SARA was categorized as *PCBs detected* or *PCBs not detected*. Historical PCB levels, reference habitats, regulatory standards, guidance levels and laboratory threshold studies were then used for comparing total PCB concentrations for each receptor (if available and/or established). An extensive listing of threshold values for each environmental receptor assessed for this report is located in Table 4.7.

Condition and Trend
The following assessment includes each environmental level receptor (Figure 4.10) which has been tested for total PCB contamination within SARA boundaries or surrounding SARA. Based on data collected by the Trustees, PCB contamination has been documented in SARA's foodweb and does exceed regulatory criteria, guidelines or PCB concentrations tested at reference locations for many trophic level receptors (Table 4.8).

- *Surface water*
  PCBs detected. Based on water samples collected from 1997-2007, PCB concentrations between river mile 170 and 180 have consistently exceeded surface water guidance criteria or regulatory standards (Figure 4.11). Total PCB concentrations between river mile 170 to 180 ranged from approximately 0.01-0.10 ppb. Standards that protect human consumers of fish, protect wildlife that eat fish, and criterion to protect humans and wildlife were all exceeded between river mile markers 170 and 180 (Table 4.7, 4.8). Drinking water standards are not applicable to water classes at these river miles.

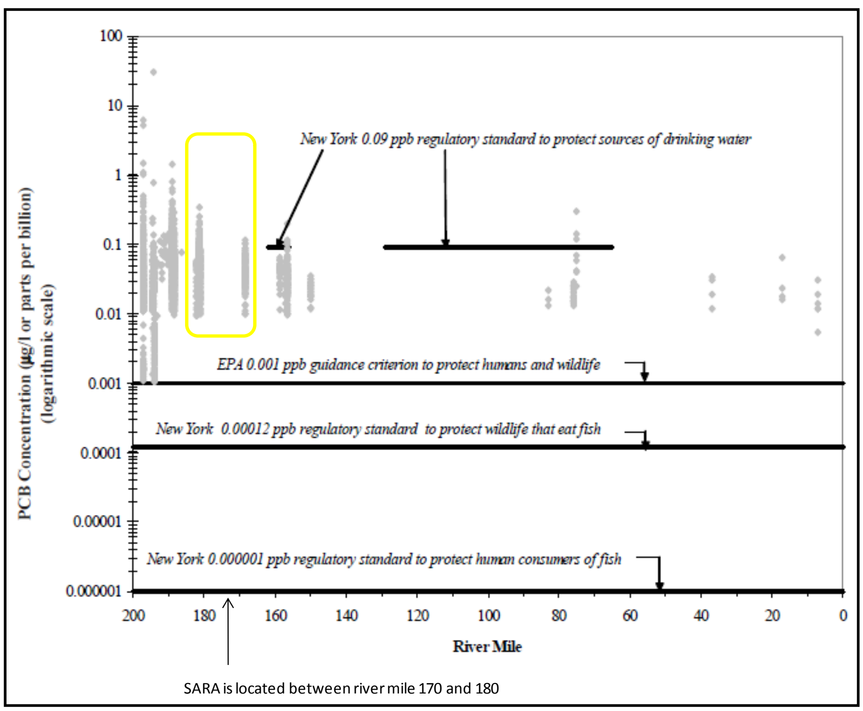


Figure 4.11. Hudson River PCB concentrations collected from 1975-2007 and regulatory standards for PCB concentration in surface waters. SARA is located between river mile 170 and 180 (Modified from HRNRT 2008b).

Table 4.8. Summarized results of total PCB concentration sampling for a collection of environmental receptors within or near SARA.

Receptor	Site ID†	Sample date(s) and size	Total PCB concentration	Condition	Data Resource
Surface water	Hudson River mile 170-180 near SARA	1997-2007	Ranged from 0.01-0.1 ppb	***PCBs detected;*** standards that protect human and wildlife consumers of fish and criterion to protect human and wildlife were exceeded.	HRNRT 2008b
Sediments/soils	Near shore Site 6*	Aug.-Sept. 2003; 1 composite	2.64 ppm (dry weight)	***PCBs detected;*** near shore sediments by SARA greater than reference Sites sampled. Sediments tested within the mid- to extreme thresholds of the sediment screening guidelines. Habitats for animals have contamination. PCB contamination has affected SARA survey plans in order to reduce staff contact with sediment and soils.	HRNRT 2007a; HRNRT 2008a; HRNRT 2010
	Near shore Site 1 (reference site)	Aug.-Sept. 2003;1 composite	0.834 ppm (dry weight)		
	Near shore-Site 9 (reference site)	Aug.-Sept. 2003;1 composite	0.508 ppm (dry weight)		
	Floodplain-Site 1*	2000; 6 samples	Averaged 9.75±13.45 ppm (±st. deviation) (dry weight)		
	amphibian breeding habitat-Site 4*	May 2004; 1 composite	2.14 ppm (wet weight)		
	amphibian breeding habitat-Site 5*	May 2004; 1 composite	1.03 ppm (wet weight)		
	amphibian breeding habitat-Site 11*	May 2004; 1 composite	3.72 ppm (wet weight)		
Earthworms	Site 1*	Sept. 2000; 1 composite	1.23 ppm	***PCBs detected;*** earthworms sampled near SARA contained a lower total PCB concentration than upstream Site 11, which is near the source of PCB contamination.	HRNRT 2010
	Site 2*	Sept. 2000;1 composite	0.49 ppm		
	Site 3*	Sept. 2000; 1 composite	0.03 ppm		
	Site 11 (upstream)	Sept. 2000;1 composite	20.30 ppm		
Emerging Adult Aquatic Insects	Site 3*	May-July 1998; composite	3481±446.9 ng/g, w.w. (±standard deviation)	***PCBs detected;*** Sites near SARA tested at concentrations greater than downstream site from SARA. Contaminated insects continue the pathway to serve as food for avian and fish species.	HRNRT 2009
	Site 4 (Chelsea Marina, downstream of SARA)	May-July 1998; composite	264.8±21.66 ng/g, w.w. (±standard deviation)		

Receptor	Site ID†	Sample date(s) and size	Total PCB concentration	Condition	Data Resource
Fish	Stillwater/Coveville section of the Hudson River	1976-2000; 2004-2010 (trend analysis for pre-and post dredging)	Levels ranged from less than 2 ppm to over 150 ppm.	***PCBs detected;*** Three species tested were above the 2ppm and 0.05 ppm criteria between 1976-2000. Trend results from 2004-2010 were dependent on species. Although levels were found to be decreasing in some fish species, levels generally remained over threshold criteria .	HRNDA 2001; Greenberg *et al.* 2011
Amphibians: bullfrog tadpoles	Site 6*	Aug.-Sept. 2003; composite	Averaged 1017±404 ppb (±st. deviation)	***PCBs detected*; Site near SARA measured orders of magnitude greater in PCB concentration than reference sites.	HRNRT 2007a
	Site 1-reference site	Aug.-Sept. 2003; composite	Averaged 80±22 ppb (±st. deviation)		
	Site 9-reference site	Aug.-Sept. 2003; composite	Averaged 40±33 ppb (±st. deviation)		
Reptiles: snapping turtle and Midland painted turtle eggs	Region 2 (includes SARA)-snapping turtle	June 2002;11 (number of nests or turtles from which eggs were collected)	Averaged 6330±7710 ppb (±st. deviation)	***PCBs detected*; Site near SARA measured orders of magnitude greater in PCB concentration than reference Sites for snapping turtles.	HRNRT 2005a,b
	Region 2 (includes SARA)-Midland painted turtle	Aug.-Sept. 2003; 3 (number of nests or turtles from which eggs were collected)	Averaged 70±31 ppb (st. deviation)		
	Reference site-upstream	Aug.-Sept. 2003; 9 (# of nests or turtles which eggs were collected)	Averaged 187±182 ppb (±st. deviation)		
	Reference site	Aug.-Sept. 2003; 8 (number of nests or turtles from which eggs were collected)	Averaged 34±16 ppb (±st. deviation)		

Receptor	Site ID†	Sample date(s) and size	Total PCB concentration	Condition	Data Resource
Birds: Tree Swallows	SARA	1994 (USFWS); egg	12.4 ppm	*PCBs detected*; Each Life stage of tree swallows contained elevated levels of total PCBs. Reference Site samples were generally a magnitude lower than samples from SARA.	US EPA 2000; Echols *et al.* 1995
	SARA	1994 by Echols *et al.*(1995); egg	5.3 ppm		
	Lock 9- reference site	1994 (USFWS); egg	6.28 ppm		
	SARA	1994 (USFWS); Nestling	Averaged 5.3±2.8 ppm (±st. deviation)		
	SARA	1997-1999 (USFWS); Nestling	6.825 ppm		
	SARA	1994 (Echols *et al.* 1995); Nestling	Averaged 2.7±0.340 ppm (±st. deviation)		
	Lock 9- reference site	1994; Nestling	0.377 ppm		
	Wisconsin site- reference site	1994; Nestling	0.049 ppm		
	SARA	1997-1999 (USFWS); Adult	3.767		
Birds: Great Blue Heron	SARA	19997-1999, 1 bird	1,000 ng/g (w.w)	***PCBs detected***; Sample from SARA tested 5 times greater than individuals collected from the lower Hudson River at Castleton Island.	US EPA 2000
Birds: avian species	Region 2 (includes SARA)	April-June 2002; eggs from 6 target species collected (N=48 eggs)	Ranged from 44 ppb to 15,1000 ppb (fresh weight basis) and averaged 3,320± 3870.	***PCBs detected;*** Concentrations varied by species and collection location within Region 2.	HRNRT 2005c
Birds: Eastern Screech Owl	Region 2 (includes SARA)	2003; 7 owl eggs	3,980±2,130 ppb (±st. deviation)	***PCBs detected;*** Eastern screech owls are opportunistic predators with diets that include a variety of Hudson River wildlife.	HRNRT 2005d
Bats	SARA (big brown bats)	2001; (N=5 females)	Averaged 271±225 ppb (±st. deviation)	***PCBs detected;*** Big brown bats and little brown bats total PCB levels tested greater than reference site samples. Little brown bats in SARA contained greater PCB concentration than big brown bats in SARA.	HRNRT 2007b
	SARA (little brown bats)	2001; (N=11 females, N=3 males)	Females averaged 889±448 ppb (±st. deviation) and males averaged 2010±335ppb		
	Reference site (little brown bats)	2001; (N=12 females)	Averaged 158±173 ppb (±st. deviation)		

Receptor	Site ID†	Sample date(s) and size	Total PCB concentration	Condition	Data Resource
Small Mammals: short tailed shrew	Site 1*	2000; (N=3)	Averaged 4.80±3.94 ppm (±st. deviation)	***PCBs detected;*** Site closest to SARA measured total PCBs concentrations greater than reference sites downstream. Small mammals have close association with floodplain soils, flora and fauna.	HRNRT 2010
	Site 1*	Sept.-Oct. 2001; (N=4)	Averaged 6.06±6.05 ppm (±st. deviation)		
	Site 23 (reference downstream site)	Sept.-Oct. 2001; (N=8)	Averaged 0.05±0.02 ppm (±st. deviation)		
Small Mammals: jumping mouse	Site 1*	Sept.-Oct. 2001; 1 composite	0.23 ppm	***PCBs detected;*** Site 1 greatest in total PCB concentration. Site 2 and 3 were comparable to the reference downstream site. Small mammals have close association with floodplain soils, flora and fauna.	HRNRT 2010
	Site 2*	Sept.-Oct. 2001;1 composite	0.05 ppm		
	Site3*	Sept.-Oct. 2001;1 composite	0.02 ppm		
	Site 23 (reference downstream site)	Sept.-Oct. 2001;1 composite	0.05 ppm		
Small Mammals: meadow vole	Site 1*	Sept.-Oct. 2001;1 composite	0.05 ppm	***PCBs detected*****;** Site 1 total PCB concentration less than reference site downstream of SARA. Small mammals have close association with floodplain soils, flora and fauna.	HRNRT 2010
	Site 20 (reference downstream site)	Sept.-Oct. 2001;1 composite	0.15 ppm		
River Otters	Section 3- encompasses SARA	1998-2000	Greatest detection of >9 µg total PCBs/ g lipid detected in river otters.	***PCBs detected;*** levels suggest health impairment for river otters near SARA based on field research .	Mayack and Loukmas 2001
Minks	Section 3- encompasses SARA	1998-2000	Levels between 21 to 50 µg total PCBs/g lipid and 50 to 139 µg total PCBs/g lipid detected.	***PCBs detected***; levels of total PCBs suggest health and reproductive impairment for minks within Section 3.	Mayack and Loukmas 2001

*Indicates sites sampled closest to SARA. †Site ID corresponds to the id given in the data resource report. Only sites sampled within or in close proximity to SARA or Region 2 sampling sites were stated in the table due to the objective of this NRCA report. For detailed information on all sites sampled along the Hudson River, refer to the corresponding Data Resource citation.

- *Sediment and soil*
  PCBs detected. Total PCB concentration in sediment and soil was measured in near shore sites, floodplain areas and amphibian breeding habitat. In near shore sediments, total PCB concentration at site 6 near SARA measured 2.640 ppm (dry weight basis) (HRNRT 2007a). Concentrations were an order of magnitude greater at this site than at the selected reference sites (0.824 and 0.508 ppm) (Table 4.8). Floodplain soils were originally assessed by SEA consultants in 2000, but were reassessed by the Trustees for one site in SARA due to methodology inconsistencies with SEA and Trustee protocols. Based on the Trustee's reassessment, total PCB concentrations ranged from 0.24-36.10 ppm and averaged 9.75 ppm (dry weight), above the extreme effect PCB concentration for sediment screening guidelines for dry weight samples (Table 4.8) (HRNRT 2010). Amphibian breeding pool sediments near sites 4, 5 and 11 located in SARA measured total PCB concentrations (wet weight basis) of 2.140 ppm, 1.030 ppm, 3.720 ppm respectively (Table 4.8) (HRNRT 2008a). Sediment and soil PCB contamination has altered park management survey plans in SARA in order to protect staff from contact with floodplain contamination (NPS 2010c).

- *Earthworms*
  PCBs detected. Earthworms (*Lumbricus terrestris*) were collected in September 2000 by SEA Consultants (2002), with 10 samples analyzed at a later date by the Hudson River Trustees (HRNRT 2010). PCBs were detected in these 10 earthworm samples collected at three sites near SARA (Table 4.8) (Appendix G). Earthworms sampled at the southern corner of SARA (site 1), measured 1.23 ppm total PCB. Battlefield Meadow (site 2) earthworms contained 0.49 ppm total PCB and at site 3 located upstream of SARA, a composite samples measured 0.03 ppm total PCB.

- *Emerging adult aquatic insects*
  PCBs detected. From May through July 1998, emerging aquatic insects were collected by the Trustees at sites along the Hudson for PCB contamination testing (HRNRT 2009). A total PCB concentration of 3481±446.9 ng/g, (wet weight [w.w] ±standard deviation) was measured at site 3, with a downstream reference site (Chelsea Marina) measuring significantly lower, at a concentration of 264.8±21.66 ng/g, (w.w.). Evidence of total PCB concentrations in emergent adult aquatic insects collected at SARA (site 3) documented a potential pathway of PCB contamination from sediments and into the food web (Table 4.8).This pathway enables contaminated insects to serve as food for avian species which rely on emerging insects as a primary food source (i.e., tree swallows).

- *Fish*
  PCBs detected. During 1976-2000, PCB concentrations in three recreational and commercially important fish species- largemouth bass (*Micropterus salmoides*), brown bullhead (*Ameiurus nebulosus*), and yellow perch (*Perca flavescens*)-were above risk-based and safety consumption levels (Figure 4.12, Table 4.8). PCB levels in the Stillwater/Coveville section of the Hudson River dropped quickly within the first three years following cessation of PCB discharges from plants in 1977 (Figure 4.12). PCB concentrations in fish decreased more slowly thereafter,

remaining relatively stable but greater than consumption levels of 2 ppm and the EPA risk-based concentration of 0.05ppm. Additional sampling and trend analyses from 2004-2010 were completed as a comparison of fish PCB concentration from pre (2004-2008) to post (2009, 2010) dredging of the Hudson River within the Stillwater section (which includes sites north and south of SARA) (NYSDEC 2010) (Appendix G). Trends of PCB concentrations from 2004-2010 was dependent on species, and either increased, decreased or did not change in bullhead, largemouth bass, yellow perch, pumpkinseed (*Lepomis gibbosus*) or forage fish (Greenberg *et al.* 2011) (Table 4.9). Although total PCB levels were found to be decreasing in fish, levels generally remained over 2 ppm and 0.05 ppm (Richter *et al.* 2010). The New York State Department of Health 2010-2011 *Chemicals in Sportfish and Game Health Advisories* continues to list a 'catch and release only' advisory for the section of the Hudson River in which SARA is located (www.nyhealth.gov/fish).

Table 4.9. Trends of total PCB concentration in fish tissue from Stillwater sites in the Hudson River, pre (2004-2008) to post (2009, 2010) dredging activity (Greenberg *et al.* 2011).

		Fish Species				
Year	**Site**	**black bass**	**bullhead**	**yellow perch**	**pumpkinseed**	**forage fish**
2004-8 vs. 2009	SW1					+
	SW2					
	SW3		-	-		
	SW4					
	SW5					
2004-8 vs. 2010	SW1				-	**not assessed**
	SW2	+	-		-	**not assessed**
	SW3		-			**not assessed**
	SW4		-		-	**not assessed**
	SW5		-		-	**not assessed**

+=increase; p<0.05

-=decrease; p<0.05

neutral; p>0.10

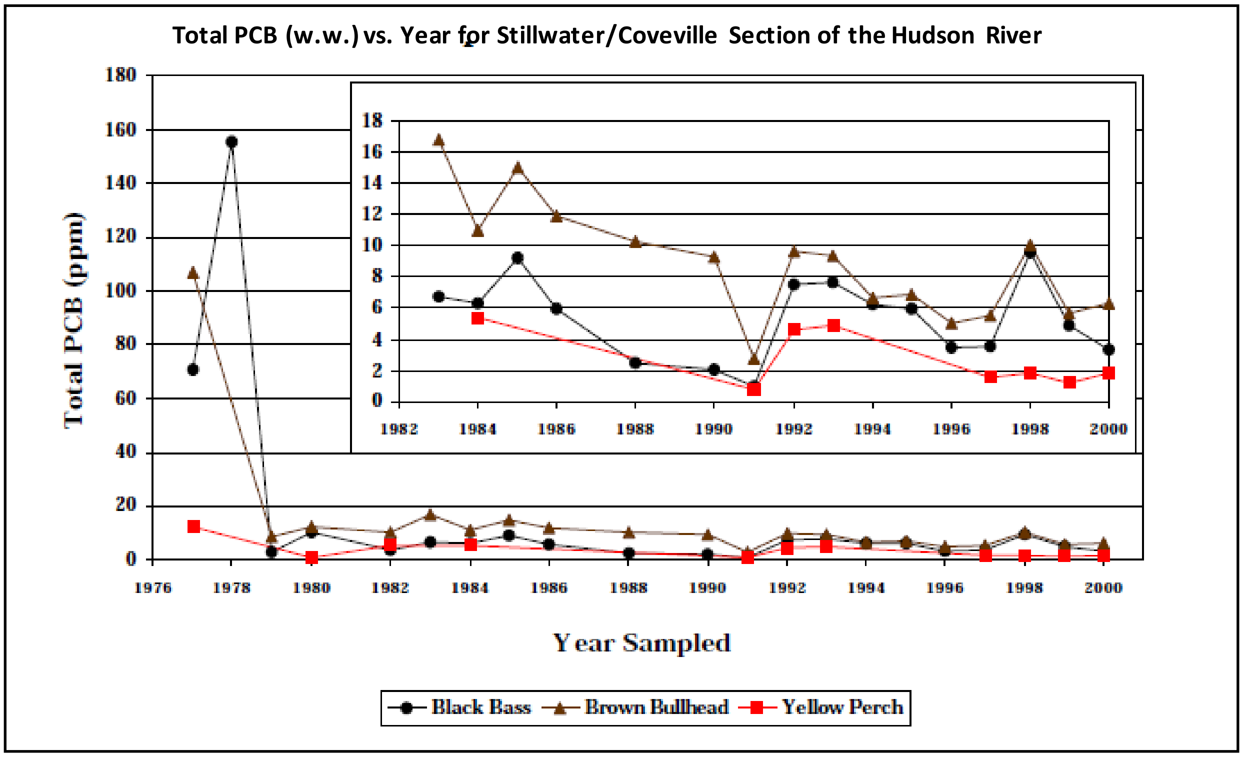


Figure 4.12. Total PCB concentration (ppm) verses year sampled for black bass, brown bullhead, and yellow perch collected from the Stillwater/Coveville section of the Hudson River. The inset graph is a data subset from 1982-2000 and is provided for visual clarity for data below 20 ppm (From HRNDA 2001).

- *Amphibians*
  PCBs detected. Total PCB concentrations in bullfrog (*Rana catesbeiana*) tadpole samples from the Hudson River sites ranged from 354-9,280 ppb (w.w.), with the closest site south of SARA (site 6) averaging 1017±404 ppb (Table 4.8). Tadpoles at site 6 measured on average, orders of magnitude greater total PCB concentrations than reference sites (Table 4.8). PCB concentrations of tadpoles collected during this time correlated well with their respective sediment concentrations (See 'Sediment and soil' section for results).

- *Reptiles*
  PCBs detected. Total PCB concentrations in snapping turtle (C*helydra serpentine serpentine)* eggs collected from Region 2 ranged from 219-27,400 ppb and averaged 6,330±7,710 ppb (Table 4.8, Appendix G). These values were magnitudes greater than reported total PCB concentrations from the reference site's snapping turtle eggs. Upstream reference regions (north of Corinth, NY) averaged 187±182 ppb, while other selected reference areas surrounding the Hudson River region averaged 34±16 (see HRNRT 2005a,b report for further reference region details). Total PCB concentrations of Midland painted turtle (*Chrysemys picta*) eggs collected from Region 2 were lower than those of snapping turtle eggs from the same region (70 ppb vs. 6,330 ppb average concentration respectively) (Table 4.8).

- *Birds*

  PCBs detected. From April 2002 through June 2002, eggs from six target species were collected from Region 2 (Appendix G): Belted Kingfisher (*Ceryle alcoyn*), American Robin (*Turdus migratorus*), Eastern Phoebe (*Sayornis phoebe*), Spotted Sandpiper (*Actitis macularis*), Red-winged Blackbird (*Agelaius phoenicius*) and American Woodcock (*Scolopax minor*) (HRNRT 2005c). Opportunity for collection of eggs other than the six target species was also available. Eastern Screech Owl (*Megascops asio*), Common Grackle (*Quiscalus quiscula*), Northern Rough-winged Swallow (*Stelgidopteryx serripennis*), Barn Swallow (*Hirundo rustica*), and Eastern Bluebird (*Sialia sialis*) were collected opportunistically. These species are common breeders in the Hudson River floodplain and have been inventoried in SARA (Andrle and Carroll 1988, Trocki and Paton 2003). Total PCB concentrations in bird eggs collected from Region 2 ranged from 44 ppb to 15,100 ppb (fresh weight basis) and average total PCB concentrations measured 3,320 ± 3,870 ppb (N=48 eggs) (Figure 4.13). These concentrations varied by species and collection location (Figure 4.13).

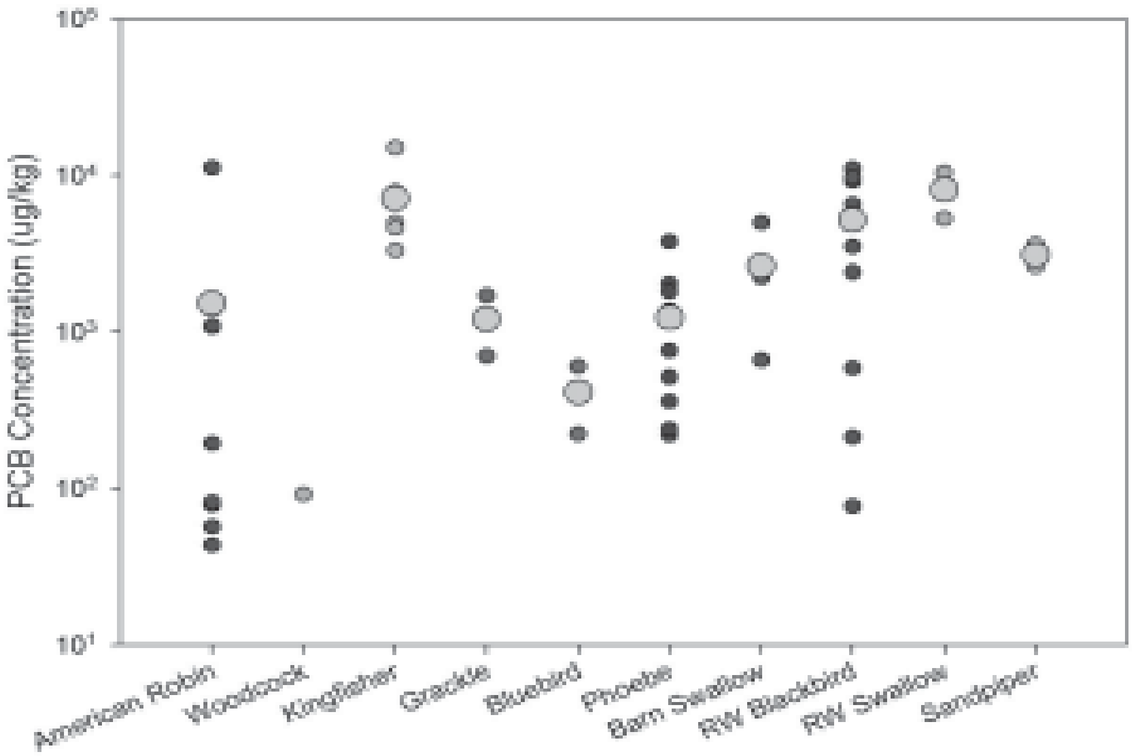


Figure 4.13. Region 2 avian egg species and total PCB concentrations. Small dots represent individual samples, larges dots represent species averages (From HRNRT 2005c).

One Great Blue Heron (*Ardea herodias*) sampled from SARA during a 1997-1999 sampling period measured 1,000 ng/g (1 ppm) total PCBs wet weight, five times greater than individuals collected from Castleton Island in the lower river (US EPA 2000). Tree Swallows (*Tachycineta bicolor*) collected from SARA in 1994 and from 1997-1999 were measured for total PCB concentrations in eggs, nestlings and adults by the U.S. Fish and Wildlife Service (Table 4.8). Average total PCB concentration in eggs measured 12.4 ppm, nestlings averaged 5.3 and 6.825 ppm (1994 and 1997-1999 respectively), and adults measured 3.767 ppm (Table 4.8). A study by Echols *et al.* (1995) measured similar total PCB concentrations in Tree Swallow eggs and nestlings collected from SARA. Eggs averaged 5.30±2.80 ppm (wet weight±st.dev.) and nestlings averaged 2.70±0.34 ppm. Reference sites sampled for Tree swallows measured up to a magnitude lower than sites sampled near SARA. Reference site samples measured 6.28 ppm in eggs and 0.377 ppm and 0.049 ppm in nestlings (Table 4.8). Eastern screech owls are opportunistic predators with diets that include every trophic level of animal life. These owls are known to feed on a variety of Hudson River wildlife which have been documented by HRNRT as containing detectable levels of PCBs. Seven Eastern Screech Owl eggs were collected in 2003 within Region 2 (Appendix G). Total PCB concentration in the eggs averaged 3,980±2,130 ppb and ranged from 1,530-7,450 ppb.

- *Bats*
  PCBs detected. Total PCB levels of bats in SARA were greater than PCB levels of bats sampled at the reference location, with the magnitude of this difference dependant on species and sex (HRNRT 2007b) (Table 4.8). Little brown bats (*Myotis lucifugus*) in SARA generally contained greater PCB concentrations than big brown bats (*Eptesicus fuscus*) in SARA, with males measuring greater total PCB concentration than female bats.

- *Small mammals*
  PCBs detected. Floodplain mammals sampled in the floodplain near SARA contained detectable levels of total PCBs (Table 4.8) (HRNRT 2010). Short-tailed shrew (*Blarina brevicauda*) total PCB concentrations were the greatest among the small mammals; averaging 4.80±3.94 ppm and 6.06±6.05 ppm total PCBs versus 0.05 ppm at the reference site. Jumping mice (*Peromyscus* spp. and *Napaeozapus* sp.) ranged from 0.02 to 0.23 ppm total PCBs, with the reference site measuring 0.05ppm. A single meadow vole (*Microtus pennsylvanicus*) tested 0.05 ppm total PCB near SARA, compared to the reference site measuring 0.15 ppm.

- *River otters*
  PCBs detected. At locations sampled near SARA (Appendix G), levels of total PCBs in river otters (*Lontra canadensis*) were greater than 9 µg total PCBs/g lipid (Mayack and Loukmas 2001). These levels suggest health impairment for river otters near SARA (Leonards *et al.*1994 and Smit *et al.* 1996) (Table 4.8).

- *Minks*
  PCBs detected. At locations sampled near SARA (Appendix X), levels of total PCBs in minks (*Mustela vison*) were calculated between 21 to 50 µg total PCBs/g lipid and 50 to 139 µg total

PCBs/g lipid (Mayack and Loukmas 2001). These levels suggest health and reproductive impairment for minks near SARA (Leonards *et al.*1994 and Smit *et al.* 1996) (Table 4.8).

Data Gaps and Confidence in Assessment
Confidence in the assessment was *medium* and confidence in the trend analysis was *low* to *not applicable* for the majority of receptors assessed in this report. It is possible that environmental receptors in SARA continue to be stressed due to PCB contamination since total PCBs have been historically detected and have measured above regulatory or guidance levels. Individual congener analysis of PCBs may provide additional insight into the relationship between PCB composition and the environmental receptor. Additionally, biological traits such as unhatched eggs and deformities should be assessed when investigating possible biological and chemical linkages in a field study.

4.4 Invasive Exotic Plants

4.4.1 Invasive Vegetation in Forests and Grasslands

Relevance and Context
Terrestrial and aquatic invasive plants are within and around SARA boundaries and threaten the structure, composition and function of SARA's natural resources. Historical plant inventories in SARA have consistently documented invasive vegetation within the park (Appendix H) and established invasive plants are near or within vegetation communities which are considered successional in nature (Figure 4.14). Of the 54 associations described in the SARA vegetation classification mapping by Edinger *et al.* (2008), 10 (18.5%) are successional types that become established after forest clearing or after the cessation of agricultural activities, creating a conducive environment for the establishment of non-native species.

Early detection strategies for invasive exotic plants in SARA's forests are being implemented through NETN Vital Signs efforts (Table 4.10). The early detection strategy detects invasive species and provides the opportunity for eradication of those populations before becoming established within the park, thus minimizing ecosystem degradation (Keefer *et al.* 2010). For example, giant hogweed (*Heracleum mantegazzianum*) is a species of concern within New York and is federally listed as a noxious weed. No sites within Saratoga County have been reported to have this plant occurring, but it is found in neighboring Washington County and is heavily established in eastern NY (www.dec.ny.gov/animals/41952.html). Due to this distribution in New York, this species is part of the early detection list for SARA. Invasive plant species are not historically documented as serving an important role in the 1777 Battle of Saratoga, thus removal of invasives would not compromise SARA's park purpose.

Table 4.10. Early detection vegetation species for SARA (Keefer *et al.* 2010).

Scientific Name	Common Name
Ampelopsis brevipedunculata	Amur peppervine
Cardamine impatiens	narrowleaf bittercress
Cynanchum louiseae/C. rossicum	Louise's & European swallow-worts
Euonymus alatus	winged burning bush
Heracleum mantegazzianum	giant hogweed
Humulus japonicus	Japanese hop
Ligustrum obtusifolium/L. vulgare	Asian and European privets
Lonicera maackii	Amur honeysuckle
Microstegium vimineum	Japanese stiltgrass
Oplismenus hirtellus ssp. undulatifolius	wavyleaf basketgrass
Polygonum perfoliatum	mile-a-minute
Pueraria montana var. lobata	kudzu
Rubus phoenicolasius	wine raspberry


A dry knapweed (Centaurea sp.) field close to tour roads and encompassing evergreen and deciduous trees in the park. Photo: R. Wagner (November 12, 2010).

Approximately 790 acres (320 ha) of grassland habitat encompass SARA (Berthiaume 2001). SARA's grasslands are designated as New York State Important Bird Areas due to the obligate grassland bird species present in these habitats. However, grassland services to bird species which rely on these habitats are threatened due to the establishment of invasive plants (Figure 4.14). Canham (2003) mapped the spatial distribution of invasive plant species and determined several species are a concern for grassland fields, particularly *Centaurea* sp. (knapweed), which was found established in over 69% of fields in SARA. *Centaurea*'s reproduction strategy makes it a difficult plant to eradicate, as a single individual plant may produce 25,000 seeds which are viable for 8 years (Mauer *et al.* 2004). Other dominant species found in SARA grasslands included *Polygonum cuspidatum* (Japanese knotweed), *Lythrum salicaria* (purple loosestrife) and *Phalaris arundinacea* (reed canary grass). Grassland habitats for invasive species were assessed using bird IBI results and are discussed in the Bird Community section of this report.

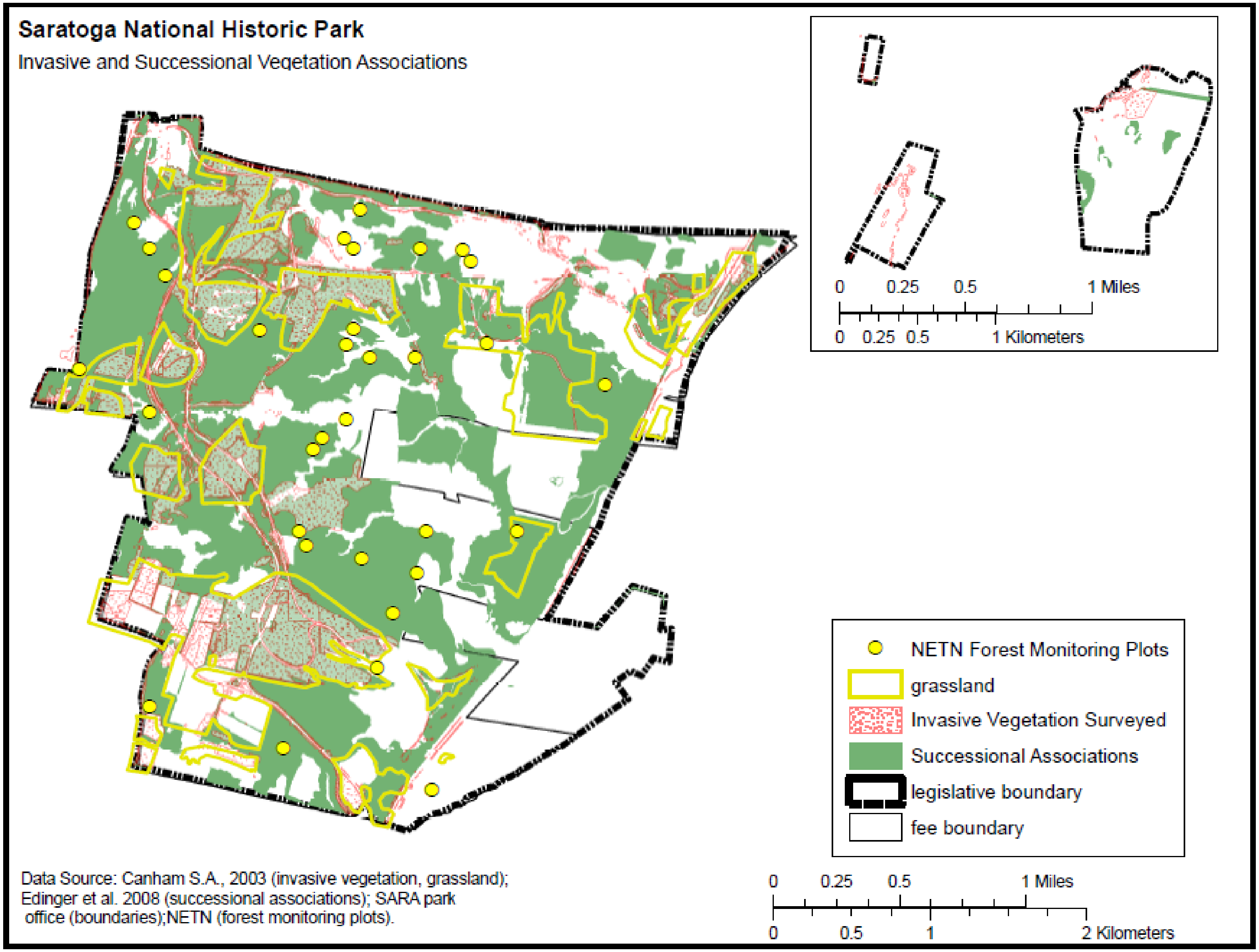


Figure 4.14. Invasive vegetation communities and successional vegetation associations in SARA based on park surveys.

Data and Methods

Key invasive exotic plant indicator species in the northeastern U.S. were identified and used for rating the condition of SARA's invasive forest vegetation composition, as this was the most quantitative and recent data for the park (Table 4.12). The average number of key indicator invasive plant species per forest plot (N=31 plots) surveyed in the most recent full cycle of plots (2008 and 2010) was calculated and compared to a rating system established for the NETN Vital Signs Program (Miller *et al.* 2011). Trend analysis was not conducted due to limited data collected because of the infancy of the NETN monitoring program.

Reference Condition/Threshold Values Utilized

Condition categories established for the NETN Vital Signs Program were used to assess the condition of invasive species within forest habitat in SARA (Miller *et al.* 2011). Less than 0.5 key indicator species/plot rated good, 0.5 to <3.5 species/plot rated caution, and 3.5 or more species/plot rated significant concern.

Table 4.11. Invasive plants identified in SARA and their respective invasiveness ratings adopted by The New York State's Office of Invasive Species Coordination or the NPS Northeast Temperate Network (NETN) (see Appendix H for complete SARA's invasive species list and historical plant surveys).

Scientific Name	Common Name	NY Invasiveness Assessment Rank [1]	NETN Key invasive indicator species [2]
Acer platanoides	Norway maple	Very High	X
Alliaria petiolata	garlic mustard	Very High	X
Berberis thunbergii	Japanese barberry	Very High	X
Celastrus orbiculatus	Oriental bittersweet	Very High	X
Cynanchum louiseas	black swallow-wort	Very High	X
Cynanchum rossicum	European swallow-wort	Very High	X
Elaeagnus umbellata	autumn olive	Very High	
Euonymus alata	winged burning bush	Very High	X
Lonicera spp.	exotic honeysuckle	Very High	X
Lonicera morrowii	Morrow's honeysuckle	Very High	
Lonicera japonica	Japanese honeysuckle	Very High	X
Lonicera tatarica	Tatarian honeysuckle	Very High	X
Lonicera x bella	Bell's honeysuckle	Very High	X
Lysimachia nummularia	creeping jenny/moneywort	Very High	
Lythrum salicaria	purple loosestrife	Very High	
Microstegium vimineum	Japanese stiltgrass	Very High	X
Phragmites australis	common reed	Very High	
Polygonum cuspidatum	Japanese knotweed	Very High	X
Rhamnus cathartica	common buckthorn	Very High	X
Robinia pseudoacacia	black locust	Very High	
Rosa multiflora	multiflora rose	Very High	X
Rubus phoenicolasius	wineberry	Very High	X
Trapa natans	water chestnut	Very High	

Scientific Name	Common Name	NY Invasiveness Assessment Rank [1]	NETN Key invasive indicator species [2]
Cardamine impatiens	narrowleaf bittercress	High	X
Centaurea stoebe ssp. *micranthos*	spotted knapweed	High	
Cirsium arvense	Canada thistle	High	
Clematis terniflora	sweet autumn virginsbower	High	
Frangula alnus	glossy buckthorn	High	X
Iris pseudacoris	paleyellow iris	High	
Ligustrum spp. *(obtusifolium, vulgare)*	privet	High	X
Phalaris arundinacea	reed canarygrass	High	
Ailanthus altissima	tree of heaven	Medium	X
Berberis vulgaris	common barberry	Medium	X
Bromus tectorum	cheatgrass	Medium	
Centaurea jacea	brownray knapweed	Medium	
Hesperis matronalis	dame's rocket	Medium	
Lotus corniculatus	birdsfoot trefoil	Medium	
Morus alba	white mulberry	Medium	
Phleum pratense	timothy	Medium	
Poa compressa	Canada bluegrass	Medium	
Pyrus communis	common pear	Medium	
Ranunculus repens	creeping buttercup	Medium	
Rhodotypos scandens	jetbead	Medium	X
Rumex acetosella	common sheep sorrel	Medium	
Solanum dulcamara	bittersweet nightshade	Medium	
Valeriana officinalis	garden heliotrope	Medium	
Viburnum sieboldii	Siebold viburnum	Medium	
Vicia cracca	cow vetch	Medium	
Vinca minor	common periwinkle	Medium	
Hemerocallis fulva	orange daylily	Low	
Hypericum perforatum	common St. Johnswort	Low	
Luzula luzuloides	forest woodrush	Not Rated	X
Polygonum caespitosum	Oriental ladysthumb	Not Rated	X

[1]NY ranking system for evaluating non-native plant species for invasiveness is described in Jordan *et al.* (2009). [2] NETN key invasive exotic plants indicator species are species that are highly invasive in forest, woodland and successional habitats in NETN parks (Miller *et al.* 2009).

Condition and Trends

Monitoring of SARA forests by NETN for invasive exotic vegetation found 3.26 key species per plot, thus categorizing SARA as *caution* for invasive exotic plants within the park (Table 4.12). Common buckthorn (*Rhamnus cathartica*) and exotic bush honeysuckle (*Lonicera* spp.) are the most relative abundant invasive species surveyed in forest plots (90.3% [n=28] and 93.5% [n=29], respectively) (Miller *et al.* 2011). Both species are NETN key indicator species and ranked as very high for invasive characteristics by the NYS Office of Invasive Species Coordination.

Table 4.12. Condition assessment for SARA's invasive exotic plants.

Measure	Condition Category	Result
Invasive exotic plants in forest habitat	Significant Concern: 3.5 or more key species per plot Caution: 0.5 to < 3.5 key species per plot Good: < 0.5 key species per plot	3.26±0.22 species (Mean number of key species per plot±S.E.)

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 SARA was limited to only forests for 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 SARA's forests. Although 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 control.

4.4.2 Invasive Aquatic Vegetation

Relevance and Context

A current and quantitative emergent and submergent invasive aquatic plant survey in SARA is not currently available. Several non-indigenous aquatic plants have been identified within the Upper Hudson watershed (02020003 HUC 8 basin) and have the potential to be dispersed into SARA's waters. In May 2010, the New York State Department of Environmental Conservation announced the presence of *Didymosphernia geminate*, commonly referred to as didymo or rock snot, in Kayaderosseras Creek in Saratoga County (NYSDEC 2010). Didymo is a non-native invasive alga (specifically a diatom species) that produces large, thick brown mats on streams bottoms. Didymo's characteristics alter stream conditions by depleting oxygen, resulting in the reduction of organisms within the stream, thereby affecting all levels of the aquatic food chain.

Once introduced to an aquatic system, didymo spreads rapidly to nearby streams, hence threatening the integrity of SARA's aquatic systems. Inventory efforts have documented both emergent exotic invasive and native invasive aquatic plant species such as *Typha* spp. (cattails), *Lythrum salicaria* (purple loosestrife), and *Phalaris arundinacea* (reed canary grass) within SARA, but the density of establishment is unknown (Stalter *et al.* 1999, Edinger *et al.* 2008).

Data and Methods

Presence/absence observations of non-indigenous invasive species identified by park staff, consultants and environmental agencies (e.g. USGS, NYDEC) occurring within and near SARA's waterbodies were collected and used to assess the condition of SARA's aquatic resources. The locations of the observations were spatially mapped by HUC8 and HUC12 boundaries and a qualitative condition assessment category was applied to each HUC 12 boundary of SARA's

Battlefield Unit. Surveys by Canham (2003) were used to map emergent invasive wetland species in the Battlefield Unit.

Reference Condition/Threshold Values Utilized

The ideal reference condition for SARA's waters was recognized as the absence of non-indigenous invasive submergent/floating species from the HUC 12 watersheds of SARA. Emergent invasive vegetation (both native invasives and non-native invasives) was also assessed for aquatic habitats in the Battlefield Unit. Due to the lack of quantitative data for several non-indigenous aquatic species, the condition categories used to assess waters in SARA were based on broad, qualitative assessments. A rating of *good* was given if plants were absent from the watershed; a *caution* rating was given if plants were absent from the watershed but present in adjacent tributaries; a *significant concern* rating was applied if species were present within the watershed.

Condition and Trends

Within SARA's HUC 12 watershed, one plant species, *Nymphoides peltata* (yellow floating-heart) was identified and mapped as non-indigenous species (Appendix X, Figure 4.15, USGS 2010). Each of SARA's three HUC 12 watersheds (McAuley Brook-Hudson River, Mill Hollow-Brook-Hudson River, Fish Creek) contained this species. Additionally, inventories by Stalter *et al.* (1999), Canham (2003) and Edinger *et al.* (2008) noted the presence of emergent aquatic invasive vegetation in the Battlefield Unit of SARA. *Typha* spp., *Lythrum salicaria*, and *Phalaris arundinacea* were found in or near waterbodies in SARA. *Lythrum salicaria* was established in the northwest corner of the Battlefield Unit, while *Phalaris arundinacea* was scattered throughout wetland habitats in SARA (Figure 4.16). The evidence of invasive species in and near wetlands and streams of the Battlefield Unit and within HUC 12 boundaries of SARA resulted in a condition assessment of *significant concern* (Table 4.13).

Table 4.13. Condition assessment for SARA's non-indigenous aquatic plants.

Measure	Condition Category	Result
Non-indigenous invasive plants in aquatic habitats	Significant Concern: plants present within the watershed Caution: plants absent from the watershed but present in adjacent tributaries Good: plants absent from the watershed and adjacent tributaries	Significant Concern. Species present in HUC 12 boundaries of SARA and emergent vegetation present within the Battlefield Unit.

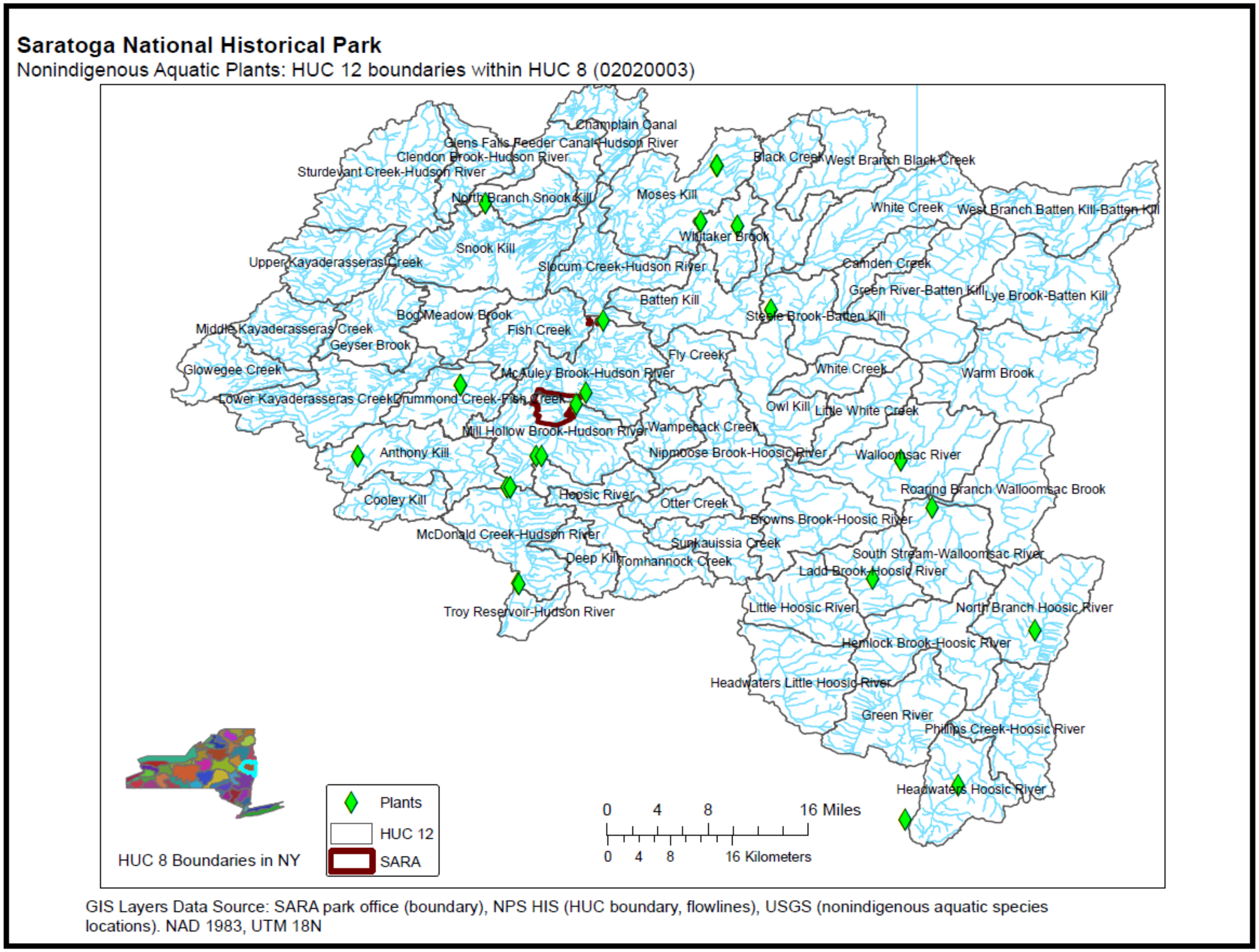


Figure 4.15. Non-indigenous aquatic plant species based on data from USGS Non-indigenous aquatic species database (NAS) for HUC 8 (02020003) and divided into HUC 12 watersheds.

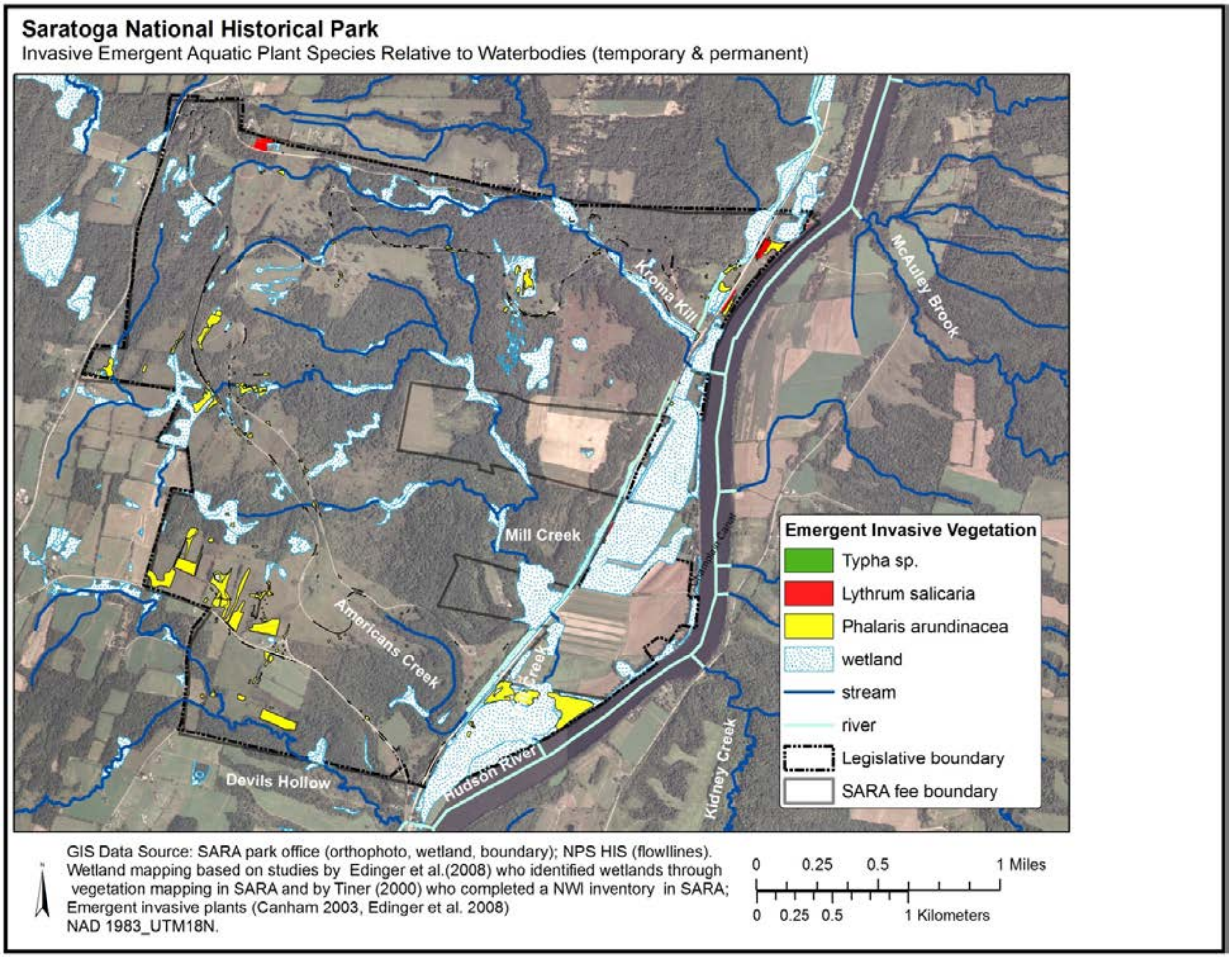


Figure 4.16. Dominant emergent invasive vegetation in SARA's Battlefield Unit in relation to aquatic habitats.

Data Gaps and Confidence in Assessment

The confidence of the assessment for aquatic systems was *low* and confidence in trend analysis was *not applicable*. Aquatic vegetation, especially emergent vegetation such as *Lythrum salicaria* and P*halaris arundinacea*, characteristically has fast growth rates and forms monocultures, thus reducing plant diversity and reducing water surface area. Data needs include continued surveys, population estimates and mapping to determine the extent and trend of non-indigenous invasive aquatic species within SARA's watersheds. The proactive surveying for species yet to colonize in SARA's waters, such as the alga, *Didymosphenia geminata* ('didymo'), will reduce harmful economic and ecological impacts to aquatic communities and maintain the biological integrity of SARA's waters (i.e., early detection promotes low impact, less costly remediation scenarios verses high impact, costly remediation scenarios). Similar to the early detection strategy lists for terrestrial species, SARA would benefit from early detection strategy lists for aquatic environments.

4.5 Invasive Exotic Animals and Disease

4.5.1 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 invasive species which pose severe threats and disruptions to SARA's environmental composition, structure and function. Table 4.14 describes the distribution and risk of several forest pests within SARA and Saratoga County, NY. SARA's forests have experienced canopy foliage problems such as chlorosis, necrosis and herbivory which are a result of both native (i.e., tent caterpillar, *Malacosoma disstria*) and invasive animal and fungal species (Miller *et al.* 2009, Wood *et al.* 2009, USDA/USFS 2010). Beech bark disease (BBD) is an example of a rampant invasion SARA's forests have encountered, threatening the vegetation which is vital to the park's historical significance (NPS 2004, Miller *et al.* 2009,). 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. From one to 19 years after colonization of the scale, the tree is colonized by a fungus (*Nectria* or *Neonectria* spp.) which invades the scale exposure, resulting in the formation of a canker. The result of this destructive duo is approximately 50% mortality of trees in five years following these colonizations (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. Such observations of forest canopy damage include a 2009 aerial survey by the USFS which noted discoloration in 7.1 acres of a maple/beech/birch forest within of the northwest corner of the SARA Battlefield Unit (Framanet 2009) (Figure 4.17). A 2011 forest health aerial survey by the NYSDEC (Adirondacks Sacandaga Flight #13) sighted no damage in the forest canopy of SARA. NETN has created an early detection species list of invasive animal species for SARA's forests as a system to provide managers with timely identification and removal of an invasion (Table 4.15) (Keefer *et al.* 2010).

A tree infected with beech scale disease in Saratoga National Historical Park. Photo: R. Wagner (November 12, 2010).

Data and Methods

As part of the Northeast Temperate Network Vital Signs monitoring program, 32 forest monitoring plots have been established in SARA to monitor invasive exotic animals and diseases in 2006, 2008 and 2010 (Figure 4.17), with the final assessment using only 2008 and 2010 data due sampling methods changing since 2006 (Miller *et al.* 2011). Details of the monitoring protocols for assessing invasive exotic animals and disease in SARA can be found in Tierney *et al.* (2009, 2011). A number of pest species pose serious threats to SARA's forests if they advance into the northeast region, including *NETN Priority 1 pests*: Asian long-horned beetle, emerald ash borer and sudden oak death and *NETN Priority 2 pests*: balsam woolly adelgid, beech bark disease, butternut canker, elongate hemlock scale, and hemlock woolly adelgid. 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.

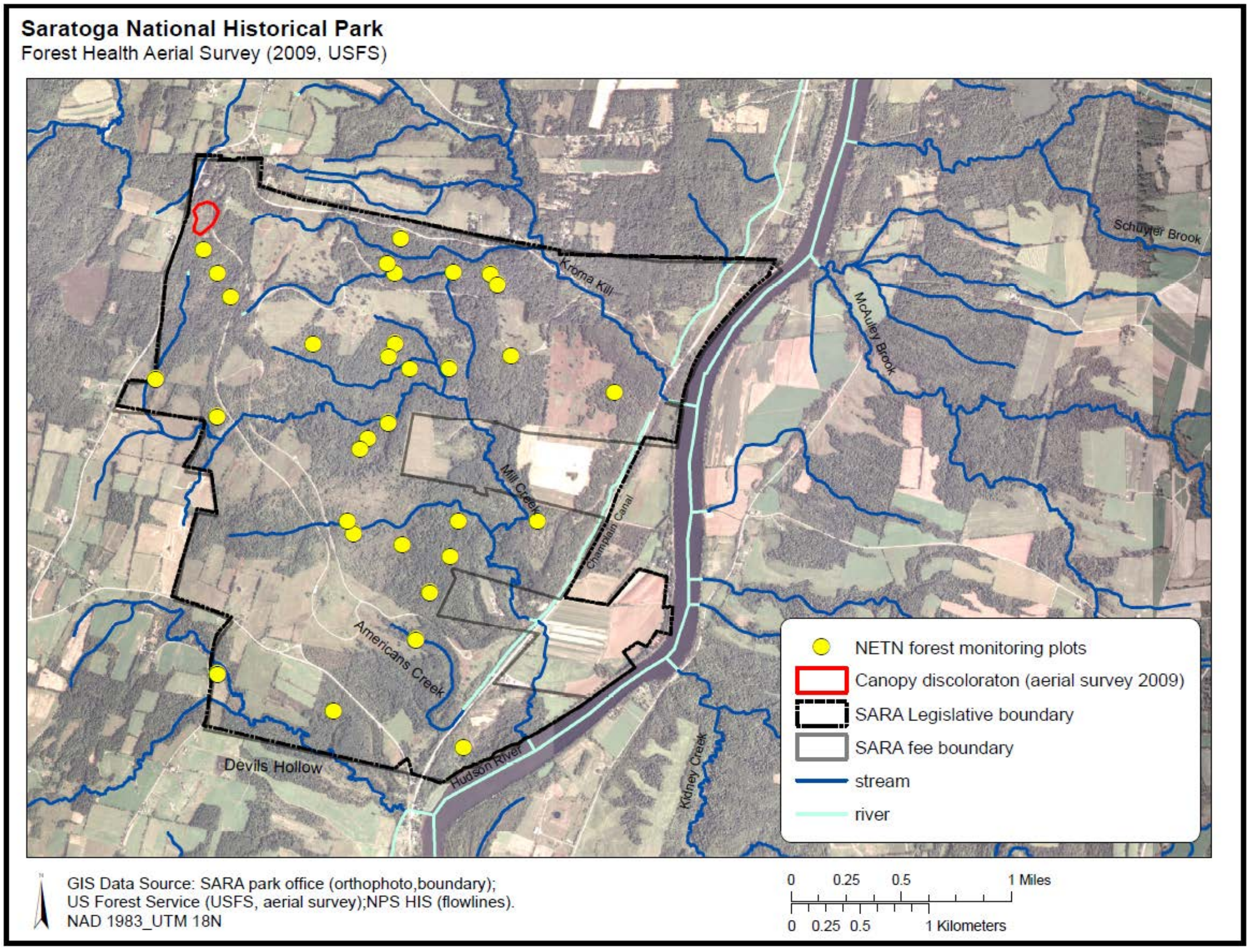


Figure 4.17. USFS 2009 aerial survey results (August 7, 2009). Red outlined area in the northwest corner locates approximately 7.1 acres of damage identified as 'discoloration' in a maple/beech/birch forest.

Table 4.14. Pests and tree diseases identified as a significant concern for NETN forests and their distribution and risk to SARA and Saratoga County, NY forests.

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

*BBD is present in SARA,

[1] Pest column does not indicate all potential species which may be detrimental to SARA's forests. Species evaluated were identified as potential species of concern under the NETN Vital Signs Program.

[2] Miller *et al.* 2010.

[3] USDA Forest Service. 2010. Alien Forest Pest Explorer (AFPE). Data displayed in table represents mapping results generated on 10/25/2010.

Reference Condition/Threshold Values Utilized

To incorporate the impact forest pests have on tree condition, forest plots with no Priority 1 or 2 pests received a condition category rating of *good*; plots with Priority 2 pests or beech bark disease (BBD) >2 were rated *caution*; plots with Priority 1 pests received a *significant concern* rating (Table 4.16).

Table 4.15. Early Detection Species for SARA (Keefer *et al.* 2010).

Scientific Name	Common Name
Hemlock woolly adelgid	*Adelges tsugae*
Emerald ash borer	*Agrilus planipennis*
Asian long-horned beetle	*Anoplophora glabripennis*
Sirex woodwasp	*Sirex noctilio*

Condition and Trend

Miller *et al.* (2011) reported that based on the 2008 and 2010 sampling period, approximately 90% of the plots were rated *good*, and the remaining were rated *caution* in SARA (Table 4.16). Although many of the forest plots in SARA were considered *good*, the impact of exotic invasive animals and disease had been observed in several plots in the park. In the 2006 and 2008 NETN forest assessments 16% were categorized as a *significant concern* for forests pests (Miller *et al.* 2009). Trees have been affected from defoliation and BBD, threatening the tree species which were vital to the historic significance of the 1777 Battle of Saratoga and the ecosystem integrity of SARA's forests.

Table 4.16. Condition assessment for invasive exotic animals in SARA.

Measure	Condition Category	Result	Assessment
Tree Condition/Forest Pests	Significant Concern:Foliage problem > 50% *or* priority 1 pest present Caution: Foliage problem 10 - 50% *or* priority 2 pest present *or* BBD > 2 Good: Foliage problem < 10% *and* no priority 1 or 2 pests *and* BBD ≤ 2	Using 2008-2010 data, it was assessed that approximately 90% of plots were GOOD, and the remaining were CAUTION.	Using results from 2008-2010. SARA was rated GOOD. High levels of defoliation were observed in 2006 possibly due to populations of forest tent caterpillar (*Malacosoma disstria*) in New York (Wood *et al.* 2009). BBD is present in SARA.

Data Gaps and Confidence in Assessment

Confidence in the assessment for invasive exotic animals and disease in forest habitats was *high* and confidence in trend analysis was *not applicable*. The proactive surveying for species yet to colonize in SARA's terrestrial and aquatic environments will reduce harmful economic and ecological impacts to aquatic communities and maintain the biological integrity of SARA. Continued monitoring of the plots in SARA will enable managers to established trend analyses for these metrics, with the number of years to monitor forest plots for trend based on study objectives and statistical power analyses. Additionally, the continued effort of establishing early detection protocols for exotic, invasive species and disease is especially significant for the detection of the destructive emerald ash borer (EAB), which is prevalent in western and southern New York and an extreme risk for Saratoga County (Table 4.14) (http://www.dec.ny.gov/animals/42674.html). In SARA, ash trees are common forest species and abundant as seedlings. Loss of ash trees would affect the structural and compositional integrity of SARA's historical forests (Miller *et al.* 2011).

4.5.2 Aquatic Habitats

Relevance and Context

A non-indigenous aquatic species is an aquatic organism that does not occur naturally in New York State 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 York 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 and can cause significant structural changes to the ecosystem. New York has over 240 species which have been introduced to aquatic environments, with more than 47 non-indigenous aquatic species having been identified in SARA's HUC 8 Upper Hudson basin (Figure 4.18, Appendix I) (USGS 2004).

Although many species are a threat to SARA's aquatic environment, non-indigenous species warnings emerge yearly in New York which alert managers and citizens to be proactive in the identification and reporting of species. The Hudson River has experienced several invaders to its system, with the most recent invasive animals being the Chinese mitten crab (*Eriocheir sinensis*) from East Asia. These crabs, which are found in fresh and salt water, move rapidly upriver where they outcompete with native species and cause destruction to habitats. Because SARA's streams are directly adjacent to the Hudson River, SARA's waters are in danger of becoming infested with invasive, exotic aquatic animals.

Data and Methods

SARA's aquatic environment was assessed using presence/absence data of invasive species in the park's aquatic systems as well as invasive species presence in connecting waterways. Data were collected from the USGS non-indigenous aquatic database (NAS) for HUC 02020003 and was supplemented by presence/absence observations by park staff and environmental agencies (e.g., NYSDEC) to assess the condition of SARA's aquatic systems. The locations of the observations were spatially mapped by HUC8 and HUC12 boundaries and a condition assessment category was applied to each HUC 12 boundary which encompasses SARA. Trend analyses were not performed for aquatic habitats due to the scarcity of quantitative data for aquatic invasive exotic animals.

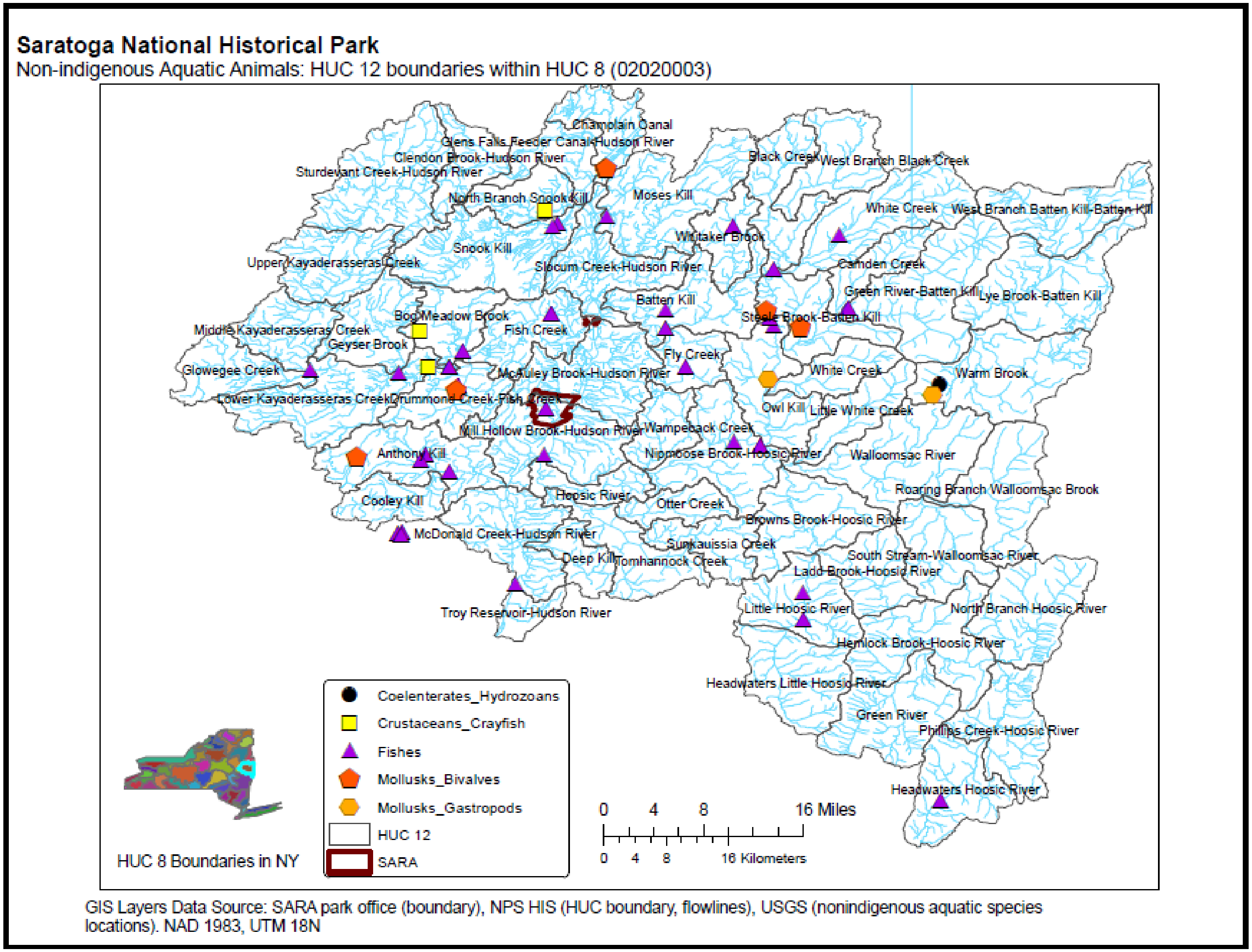


Figure 4.18. Non-indigenous aquatic animal species based on data from USGS non-indigenous aquatic species database (NAS) for HUC 8 (02020003).

Reference Condition/Threshold Values Utilized

The ideal reference condition for SARA'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 SARA were based on broad, qualitative assessments. A rating of *good* was given if species were absent from the watershed; a *caution* rating was given if species were absent from the watershed but present in adjacent tributaries; a *significant concern* rating was applied if species were present within the watershed.

Condition and Trend

Invasive fishes, mollusks and crustaceans are present in the adjoining Hudson River, endangering the tributaries flowing through SARA to the Hudson River (Table 4.17). Based on a HUC 8 spatial assessment, the Upper Hudson Basin condition was assessed as *significant concern* (USGS 2010). Within SARA's HUC12 subwatersheds, Fish Creek watershed was categorized as *significant concern* due the presence of common carp. The common carp was introduced to waters as game fish in the late 1800's but they are one of the most damaging species due to their wide distribution and severe impacts in shallow lakes and rivers. McAuley Brook subwatershed was categorized as *caution.* Mill Hollow Brook subwatershed contained blue gill and silver lamprey according to the USGS database. Although considered non-indigenous, blue gill and silver lamprey have colonized northeastern U.S. waters for over 100 years and are not thought of as a threat to aquatic biodiversity (Mather *et al.* 2003). Therefore, this subwatershed was categorized as *caution* based on the available data.

Table 4.17. Condition assessment for non-indigenous aquatic animals in SARA.

Measure	Condition Category	Result	Assessment
Aquatic Invasive Animals	Significant Concern: species present within the watershed Caution: species absent from the watershed but present in adjacent tributaries Good: species absent from the watershed and adjacent tributaries	HUC 8: Signficant Concern HUC 12 (Fish Creek): Significant Concern HUC 12 (McAuley Brook and Mill Hollow Brook): Caution	Present in HUC 8 and HUC 12 boundaries. SARA should be cautious regarding aquatic invasive animals, as the Hudson River houses by many invasive species.

Data Gaps and Confidence in Assessment

The confidence in the assessment of non-indigenous exotic aquatic animals was *low* and the confidence in 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 SARA's watersheds. Establishing routine sampling events and deploying monitoring substrates in SARA's waters may aid in the detection of invasive species. Although an early detection list for exotic species has been created for SARA's forests, an early detection list has yet to be created for SARA's aquatic systems.

Chinese Mitten Crab (Eriocheir sinensis) specimen. Photo: Smithsonian Environmental Research Center (SERC). www.serc.si.edu.

4.6 Forest Vegetation

Relevance and Context

The vegetation in SARA plays an important role in the interpretation of the park's mission. The historic configurations of fields and forests within and near SARA were vital to the overall 1777 battle strategy. Forest vegetation covers the greatest percentage of parkland (approximately 2145 acres [868 ha]), serves as vital habitat for wildlife, including rare and threatened species, enhances air and water quality, viewsheds and other ecosystem services. Comprehensive vegetation classification and mapping has been completed, with 54 vegetation associations being identified within SARA (Edinger *et al.* 2008). Most of the forest landscape within the park is hemlock northern hardwood forest, successional hardwood and successional shrubland. Although natural and human process have altered SARA's forest configuration since 1777 (i.e., thickets are now woodlands; farmland is presently wooded areas and vice-versa), the health of the forest still remains an important measure for preserving the park's overall natural resource and historical integrity. Landsat sensors have documented land conversion from forest to urban (Wang *et al.* 2009). This conversion has the potential to drastically affect biodiversity, watershed functioning and habitat condition within SARA.

Data and Methods

As part of the Northeast Temperate Network Vital Signs monitoring program, forest health had been monitored in SARA in 2006, 2008 and 2010 with a total of 32 forest monitoring plots established in the park, covering 67 acres (27 ha) of forest per plot (Miller *et al.* 2009, 2011) (Appendix J). Details of monitoring protocols for assessing forest health in NETN can be found in Tierney *et al.* (2009, 2010). Miller *et al.* (2011) noted that although 2006 was the beginning of the sampling period in SARA, several sampling methods were changed after the 2006 field season, and comparison with some of the data collected in 2010 to the original sample could not be performed. 2006 data was used only for the structural stage distribution metric (Miller *et al.* 2009, 2011). Trend analysis was not performed due to the temporal limitation of the NETN monitoring data. Measures that have been used to assess SARA forest health include the following:

• *Anthropogenic land use and forest patch size*
Northeastern U.S. forests typically are highly fragmented and impacted by anthropogenic land use and human disturbance. Several negative impacts on forests stem from fragmentation and human land use (i.e., invasive species colonization, loss of biodiversity). Forest patch size and adjacent anthropogenic land use was used to examine the extent that surrounding landscape may be influencing forest condition in SARA. These landscape parameters were examined using NETN monitoring reports which delineated forest patch size at the park level in conjunction with 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 disturbance may differ structurally from later successional stands. Disturbances have changed the structural stage distribution of forests, with distribution being further affected by factors such as anthropogenic activity, climate change, pathogens and pests. The structural stage distribution of SARA's forest is important for maintaining native vegetation species composition, which varies depending upon successional stages.

• *Snag abundance & coarse woody debris*
Standing dead trees (snags) and fallen coarse woody debris (CWD, defined as ≥ 10 cm diameter, ≥ 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*
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). Biotic homogenization was examined using Jaccard's Similarity Index to compare plant species composition between forest plots. The presence of exotic earthworms was assessed through qualitative methods by performing a visual inspection for earthworm evidence while collecting soil samples in each plot (Miller *et al*. 2011).

Reference Conditions/Threshold Values Utilized

NETN Vital Signs ecological integrity scorecard (thresholds) and condition categories were used to assess SARA's forest health. These condition categories are based on ecological studies and management goals and included ratings of *good*, *caution* or *significant concern* for each forest metric. 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-forest patch size and anthropogenic land use (ALU)*

Landscape context was analyzed using delineated forest patch size data at the 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 (Tierney *et al.* 2010). Forest patch size was defined as an area of continuous medium to high-canopy (≥8m height) forest vegetation with at least 60% overall canopy closure at least 0.5 ha (Tierney *et al.* 2010). Condition categories for forest patch size included: ≥50 ha rated *good*; patch 10 to less than 50 ha rated *caution*; patch 0.5 to less than 10 ha rated *significant concern* (Table 4.18). ALU condition categories were derived from theoretical models that examined the combined impacts of habitat loss and fragmentation (Tierney *et al.* 2010). These condition categories included: <10% anthropogenic land use rated *good*; 10-40% anthropogenic land use rated *caution*; >40% anthropogenic land use rated *significant concern* (Table 4.18).

- *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 *good* was indicated by ≥ 25% late-successional structure, *caution* was assigned for forests with < 25% late-successional structure and *significant concern* was categorized as < 25% combined mature *and* late-successional structure for SARA (Miller *et al.* 2010, Table 4.18).

- *Snag abundance & coarse woody debris*

Assessing the percentage of standing trees that are snags and calculating the ratio of CWD volume to live tree volume are metrics that can be used to rate the condition of the forest community in SARA. Forests that had ≥10% standing snags and ≥10% medium-large trees (medium-large trees are >30 DBH) as snags were rated *good*. Less than 10% standing tree snags or <10% medium-large trees as snags was categorized as *caution*. Less than 5 medium-large snags per hectare categorized the area as *significant concern* (Table 4.18). For CWD, forests >15% live tree volume was categorized as *good*, 5-15% live tree volume was *caution*, and <5% live tree volume was categorized as *significant concern* (Table 4.18).

- *Biotic homogenization*

This measure used the Jaccard Similarity Index and the percentage of earthworms found in forest plots to address biotic homogenization in SARA. A condition category was not assigned to these metrics due to a lack of repeat data. However, the data collected by NETN provided SARA 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 exotic earthworms calculated in each forest plot 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.

Condition and Trend

The following list contains forest vegetation measures and their condition assessments for SARA (Table 4.18). Trend analysis was not included due to lack of long term temporal datasets for SARA.

• *Anthropogenic land use*
caution; Anthropogenic land use based on a 200 m buffer averaged 11% per forest plot and consisted primarily of open fields (N=32 plots, 2010), (Figure 4.19) (Miller *et al.* 2011).

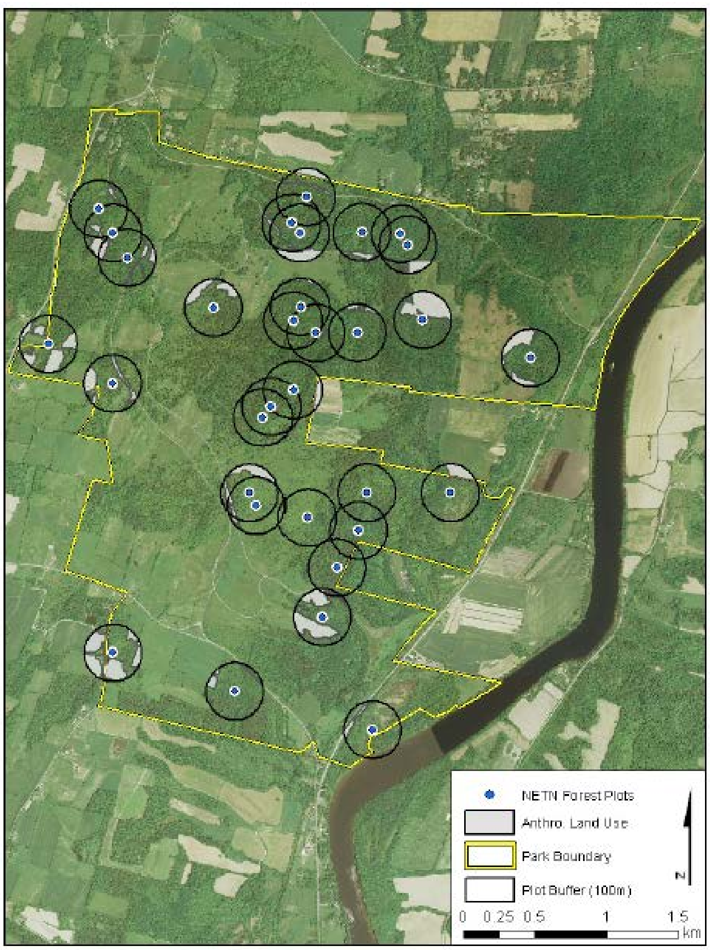


Figure 4.19. Anthropogenic land use within 200 m buffers around NETN forest plots within SARA Battlefield Unit (From Miller *et al.* 2011).

• *Forest patch size*

Forest habitat in SARA is fragmented by fields and roads inside the park boundary and agricultural lands outside of the park boundary. Fifty-six percent of forest patch area in SARA occurred in patches that were rated *good*, 32% of forest patch area was rated *caution* and 12 % was rated s*ignificant concern* (N=38 patches) (Miller *et al.* 2011) (Figure 4.20). Habitat fragmentation may have contributed to spread of invasive species in SARA, and aggressive invaders, such as exotic bush honeysuckles (*Lonicera* spp.), are maintaining habitat fragmentation by inhibiting forest succession.

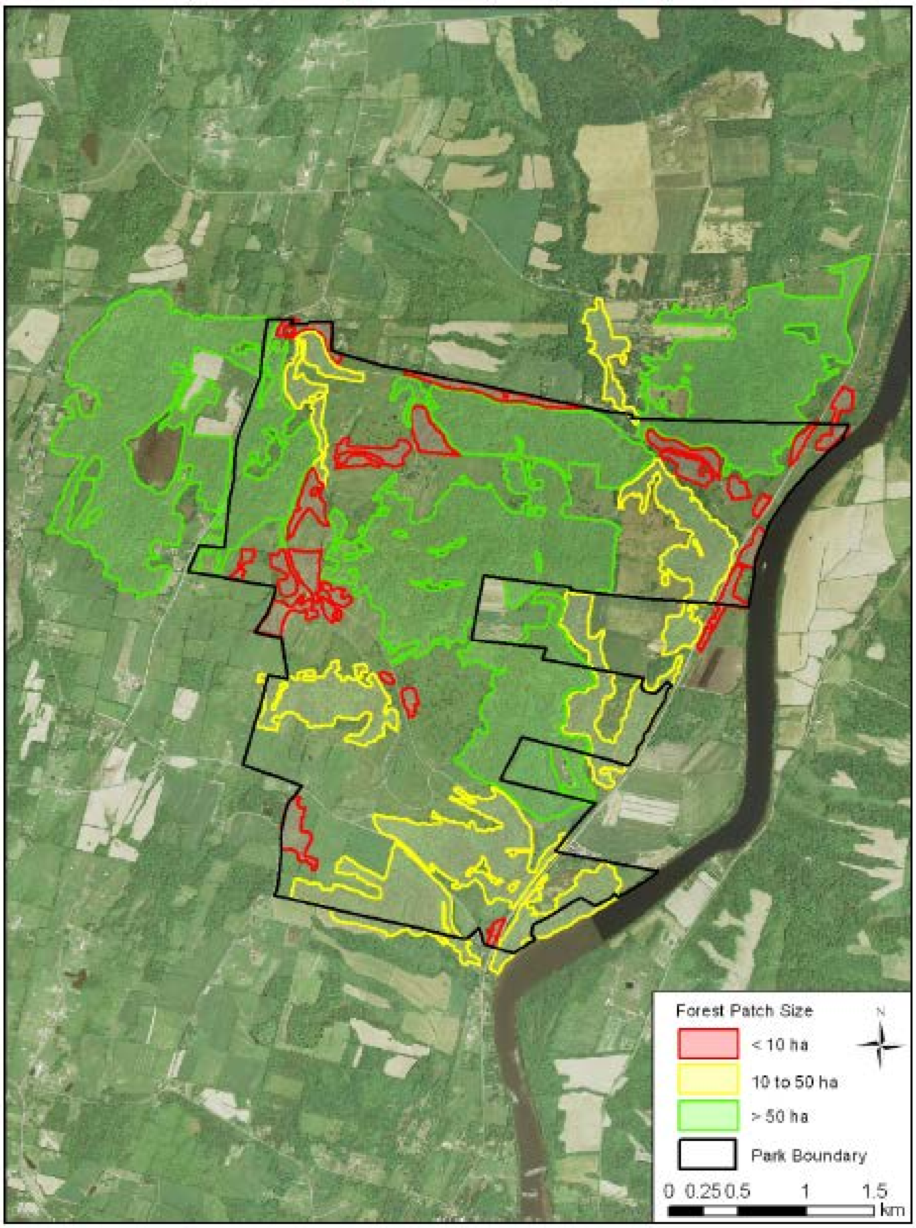


Figure 4.20. Forest patch sizes divided into three hectare category sizes within the Battlefield Unit of SARA (From Miller *et al.* 2011).

- *Structural stage distribution*

good; SARA's structural stage distribution proportions included 30.4% late successional structure and 56.5% mature and late successional structure (N=23 plots) (Miller *et al.* 2009).

- *Snag abundance*

caution; SARA contained an average of 8.1 medium to large snags/ha (N=31 plots) (Miller *et al.* 2011).

- *Coarse woody debris (CWD)*

caution; Mean percentage of coarse woody debris in SARA was 11.4% (N=25 plots) (Miller *et al.* 2011).

- *Biotic homogenization*

unrated; Jaccard Similarity Index and the percent of plots with nonnative earthworms were measurements used to assess Biotic Homogenization in SARA. Jaccard Similarity Index from data collected in SARA was 0.27, indicating that a pair of plots shared about 27% of the same species within SARA (N=19 plots). This value (0.27) will serve as a baseline for the park for the NETN forest monitoring program. SARA has a high understory diversity, and coverage of forbs, ferns, graminoids and cover of native species (Miller *et al.* 2011). The high diversity of SARA's understory and the presence of deer palatable vegetation make SARA's forests vulnerable to deer browsing pressure.

Earthworm detection was also measured in SARA plots as an indicator of biotic homogenization. In the 2008 and 2010 sampling season, 52.8% of the plots were detected with non-native earthworms. Since this metric is preliminary in the NETN forest monitoring protocol (Miller *et al.* 2011), a rating has not been established for this metric.

Data Gaps and Confidence in Assessment

Confidence in the assessment was *high* and confidence in the trend analysis was *not applicable*. Continued monitoring of forest vegetation in SARA 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 monitoring of the forest understory in SARA 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 beginning to be measured 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. Future forest monitoring plot locations in SARA should be included within the globally rare vegetation or vegetation associations of significant occurrence.

Table 4.18. Condition assessment for SARA forest vegetation based on 2006, 2008 and 2010 data collection efforts.

Measure	Condition Category	Result (±st.error)
Anthropogenic Land Use	Significant Concern:> 40% Caution: 10-40% Good:<10%	Plots averaged 11.7%
Forest Patch Area	Significant Concern:0.5<10 ha Caution: 10-50 ha Good:>50ha	56% forest patch area good 32% forest patch area caution 12% forest patch are significant concern
Structural Stage Distribution	Significant Concern: < 25% combined mature *and* late-successional structure Caution: < 25% late-successional structure Good: ≥ 25% late-successional structure	30.5% Late successional, 56.5% mature and late successional
Snag abundance	Significant Concern:< 5 med-lg snags/ha Caution: < 10% standing trees are snags or < 10% med-lg trees are snags Good: > = 10% standing trees are snags and > = 10% med-lg trees are snags1	8.06±3.15 (# of med-lg snags/ha)
Coarse Woody Debris	Significant Concern:< 5% live tree volume Caution:5 - 15% live tree volume Good:> 15% live tree volume	11.36%±2.99%
Biotic Homogenization	Signficant Concern: metric not established Caution: increased homogenization Good: no change	Unrated; Jaccard Similarity Index calculated at 0.27. Non-native earthworms present in 52.8% of plots sampled in SARA. No overall condition category established for SARA as measures are still being refined by NETN, but they serve as a baseline for the park.

4.7 White-tailed Deer Herbivory

Relevance and Context

Since the 1960's, many eastern national parks experienced expansion of the white-tailed deer (*Odocoileus virginianus*) population due to activities such as landscape alterations (e.g., suburbanization) and decline in predation (e.g., hunting efforts) (Underwood *et al.* 1997). Deer populations in SARA have been estimated at 55-60 deer/ km^2 (Underwood *et al.* 1994), growing slowly since the 1960's and exceeding densities which may degrade vegetation regeneration due to herbivory (Underwood and Porter 1997). Gilbert *et al.* (2008) surveyed terrestrial mammals in SARA and detected that white-tailed deer were commonly observed in the park, with a mean detection rate±standard error of 0.08±0.04 from March-April and increasing in November to 0.22±0.08. Seedling vegetation species and size classes of 30-75 cm tall are preferentially browsed by deer (Cornett *et al.* 2000), with significant impacts on regeneration occurring with deer densities at ≥8.5 per km^2 (Russell *et al.* 2001). NETN Vital Signs program uses the tree regeneration metric to assess the quantity and composition of advance tree regeneration in the forest understory. Indicators to assess overall tree regeneration for this metric include *seedling ratio*, *stocking index* and *deer browse index*. Additionally, tree and understory deer browse preference and avoidance species occurring in SARA have been identified from past vegetation surveys (Table 4.19, 4.20).

White-tailed deer (Odocoileus virginianus) are commonly observed at Saratoga National Historical Park, making deer herbivory a natural resources concern for park managers. Photo: R. Wagner.

Data and Methods

Two tree regeneration indicators, *seedling ratio* and *deer browse index*, were measured in SARA forest plots by NETN and used to assess deer impacts (Tierney *et al.* 2009, 2011). Seedling ratio data was collected in 2008 and 2010 while deer browsing data was only collected in 2010 (Miller *et al.* 2010, 2011). The *seedling ratio* indicator 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). The *deer browse index*, which is a qualitative assessment of deer browse impact, 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) (Table 4.21). The *stocking index* was not assessed due to the refinement needs of this metric by NETN and thus an overall tree regeneration condition category was not reported. Trend was not assessed for these indicators due to temporal limitations in the available data.

Table 4.19. Listing of major tree species observed in SARA during vegetation plot and thematic accuracy assessment sampling (Edinger *et al.* 2008) and rated by their potential to deer browsing.

Scientific name	Common name	Potential Deer Impact	Citation*
Acer saccharum	sugar maple	High	2
Cornus florida	flowering dogwood	High	1
Liriodendron tulipifera	tulip popular	High	2
Prunus pensylvanica	pin cherry	High	2
Sassafras albidum	sassafras	High	1
Thuja occidentalis	northern white cedar	High	1
Tilia americana	basswood	High	1
Tsuga canadensis	eastern hemlock	High	2
Betula alleghaniensis	yellow birch	Medium	2
Carya spp.	hickories	Medium	2
Fraxinus spp.	ashes	Medium	2
Hamamelis virginiana	witch hazel	Medium	1
Juglans nigra	black walnut	Medium	1
Nyssa sylvatica	blackgum	Medium	3
Quercus spp.	oaks	Medium	2
Ulmus spp.	elm	Medium	1
Acer pensylvanicum	striped maple	Medium/Low	2
Fagus grandifolia	American beech	Medium/Low	2
Pinus resinosa	red pine	Medium/Low	1
Pinus rigida	pitch pine	Medium/Low	1
Pinus strobus	white pine	Medium/Low	1
Pinus sylvestris	scotch pine	Medium/Low	1
Alnus spp.	alder	Low	1
Betula papyrifera	paper birch	Low	1
Betula populifolia	graybirch	Low	1
Carpinus caroliniana	musclewood	Low	1
Crataegus spp.	hawthorn	Low	1
Juniperus virginiana	red cedar	Low	1
Larix laricina	tamarack	Low	1
Ostrya virginiana	hop hornbeam	Low	1
Picea spp.	spruces	Low	1
Populus spp.	aspens	Low	1
Prunus serotina	black cherry	Low	2
Rhamnus cathartica	buckthorn	Low	1
Robina pseudoacacia	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); 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).

Table 4.20. Understory indicator species of deer browse pressure. Species listed were documented as occurring in SARA by Stalter (1993) and Edinger *et al.* (2008).

Scientific Name	Common Name	Deer Preference[1]
Ageratina altissima v. altissima	white snakeroot	Avoided
Aralia nudicaulis	wild sarsaparilla	Preferred
Aster divaricatus	white wood aster	Preferred
Carex spp.	sedge	Avoided
Dennstaedtia punctilobula	hay-scented fern	Avoided
Maianthemum spp.	Canada may flower and false solomon's seal	Browsed
Polygonatum spp.	smooth Solomon's seal	Browsed
Sanguinaria canadensis	bloodroot	Browsed
Trillium spp.	trillium	Preferred
Uvularia spp.	bellwort	Preferred

[1] 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 SARA's vegetation impact from white-tailed deer browsing. These condition categories are based on ecological studies and management goals and included ratings of *good*, *caution* or *significant concern* for the *seedling ratio* indicator, and an impact level from 1 to 5 was assigned for the *deer browse index* (Table 4.21). The reference *seedling ratio* was categorized as *good* when the seedling ration was ≥0. The *caution* rating was designated when the seedling ratio was <0 and the *significant concern* rating was assigned when the stocking index was outside the acceptable range (Miller *et al.* 2011). Deer browse indicator species metrics were not rated as *good*, *caution* or *significant concern* due to inconsistencies between 2006 and 2010 sampling methods (Miller *et al.* 2011). However, the *deer browse index* was rated from 1 to 5, with level 1 (or called 'none' for browse impact) being assigned to a forest plot located inside the deer exclosure which had no evidence of browsing; level 2 was categorized as low browsing impact; level 3 was moderate browsing impact; level 4 was high browsing impact; level 5 indicated a very high impact to vegetation from deer browsing (Miller *et al*. 2011).

Condition and Trend

The *seedling ratio* measured -0.32±0.10 and was categorized as *caution* (Miller *et al.* 2011) (Table 4.21). Seedlings less than 30 cm tall were abundant in SARA; seedlings in height classes over 1 m were less common and sapling density was low. SARA also contained the lowest seedling ratio of all NETN parks (Miller *et al.* 2011). The *deer browse index* was 3.07±0.12, which rated *moderate.* The *moderate* category indicated browse preferred regeneration was present in SARA and had little height variability, with non-preferred and browse resistant species common (Table 4.21) (Miller *et al.* 2011, Brose *et al.* 2008, Perles *et al.* 2010). These two indicators suggest that deer browse pressure may be impacting forest regeneration in SARA. Competition from invasive exotic species may also be limiting tree regeneration in conjunction with the deer population.

Table 4.21. Condition assessment for SARA forest vegetation with reference to deer herbivory.

Measure	Condition Category	Result
Seedling Ratio	Significant Concern:Stocking index outside acceptable range Caution: Seedling ratio < 0 Good:Seedling ratio ≥ 0	Seedling ratio: 0.32±0.10 (2007-2010)
Deer Browse Index	Index of deer browse impacts assessed for each plot in national historical parks and sites (adapted from Brose *et al.* 2008 and Perles *et al.* 2010). **Level** / **Browse Impact** / **Description** 1 / None / Plot located inside deer exclosure, and no browse. 2 / Low / No observed browse; browse preferred species present. 3 / Moderate / Evidence of browse; browse preferred regeneration present but with little height variability; non-preferred and browse resistant species common. 4 / High / Browse evidence common; browse preferred species rare to absent; non-preferred or browse resistant vegetation limited in height by browsing. 5 / Very High / Browse evidence omnipresent; browse preferred species absent; browse resistant plants show signs of heavy browsing and browse line evident.	Averaged 3.07±0.1 (2010)

Data Gaps and Confidence in Assessment

Confidence in the assessment was *medium* and confidence in trend was *not applicable*. The seedling ratio 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 SARA (Miller *et al.* 2011). Additionally, the deer browse impact indicator only includes 2010 data and has not been incorporated into the NETN tree regeneration metric (Miller *et al.* 2011). Seasonal frequency of vegetation browsed by deer has not been quantified for SARA to date, which may be useful information for managers with regards to herbivory and white-tailed deer population estimates. Since SARA currently contains a highly palatable and high density vegetation structure as measured by Miller *et al.* (2011), it would be useful to assess current deer densities in the park to determine if they exceed 8.5 per km^2. Quantification of deer densities may include using annually collected distance sampling data. NETN monitoring found oak (*Quercus* spp.) regeneration rare in SARA (Miller *et al.* 2011) 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, hickory (*Carya* spp.) regeneration was sparse while beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), and red maple (*Acer rubrum*) were more abundant in the seedling and sapling layers than in the canopy. Plots which rated *good* may be due to the protection of attractive seedlings from browsing. Gray dogwood has historically been found to protect attractive native tree seedlings in SARA because the dense thicket created by this species keeps palatable seedlings distant from deer (Austin 1991, Underwood *et al.* 1994).

4.8 Fish Community

Relevance and Context

SARA's aquatic environment supports a variety of freshwater fish species within several habitat types: small lakes, low gradient streams (e.g., Mill Creek, Kroma Kill, Americans Creek, Devil's Hollow Creek), moderate gradient streams (e.g., Mill Creek) and high gradient streams (e.g., South Branch - Mill Creek, Kroma Kill). Prior to 2000, a detailed fish survey had not been conducted in SARA's waters. A fish inventory by Mather *et al.* (2003) resulted in 13 freshwater fish species documented in SARA streams, canals, and ponds (Figure 4.21). Endangered, threatened or fishes of special concern listed under New York State section 182.2. (g, h, i) of 6NYCRR Part 182 have not been found in SARA's waterbodies based on the above survey. The composition of the fish community in SARA can be altered due to changes in water chemistry from surrounding development, invasive species colonization or sedimentation. Therefore, the use of fish IBI metrics can be useful short-term monitoring tools for assessing the condition of fish communities in SARA's streams.

Data and Methods

New York State agencies currently have not developed an Index of Biotic Integrity (IBI) of fish communities for the State's waterbodies. Daniels *et al.* (2002) developed the Northern Mid-Atlantic Slope Drainage IBI which encompassed waterbodies within the Hudson, Delaware and Susquehanna River basins based on fish assemblage data from the Mohawk River drainage of New York. The Northern Mid-Atlantic Slope Drainage IBI was used in conjunction with the most recent fish survey (2000) in SARA (Mather *et al.* 2003) to assess the condition of the park's fish community (Table 4.22). A final true IBI score was not calculated for SARA due to the sampling design of the most recent fish data collected (Mather *et al.* 2003) and the absence of specific measurements needed for various metrics, specifically metric number 10-12 (Table 4.22). However, knowing that the missing scores for these metrics 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 SARA. Due to these absences, nine out of the twelve metrics were assessed and each given a condition metric score of 1 (*poor*), 3 (*intermediate*) or 5 (*best condition*) for Kroma Kill and Mill Creek's stream branches in SARA. The remaining three metrics (metrics 10-12) were given a theoretic score of 1, 3 or 5. Additionally, Karr (1986) noted that it is often of value to examine individual metrics and these are reported in Table 4.22. Ponds located in SARA were not assessed using this IBI, which was developed for lotic systems. Trend analyses were not conducted due to a lack of available quantitative, temporal data for SARA's fish community.

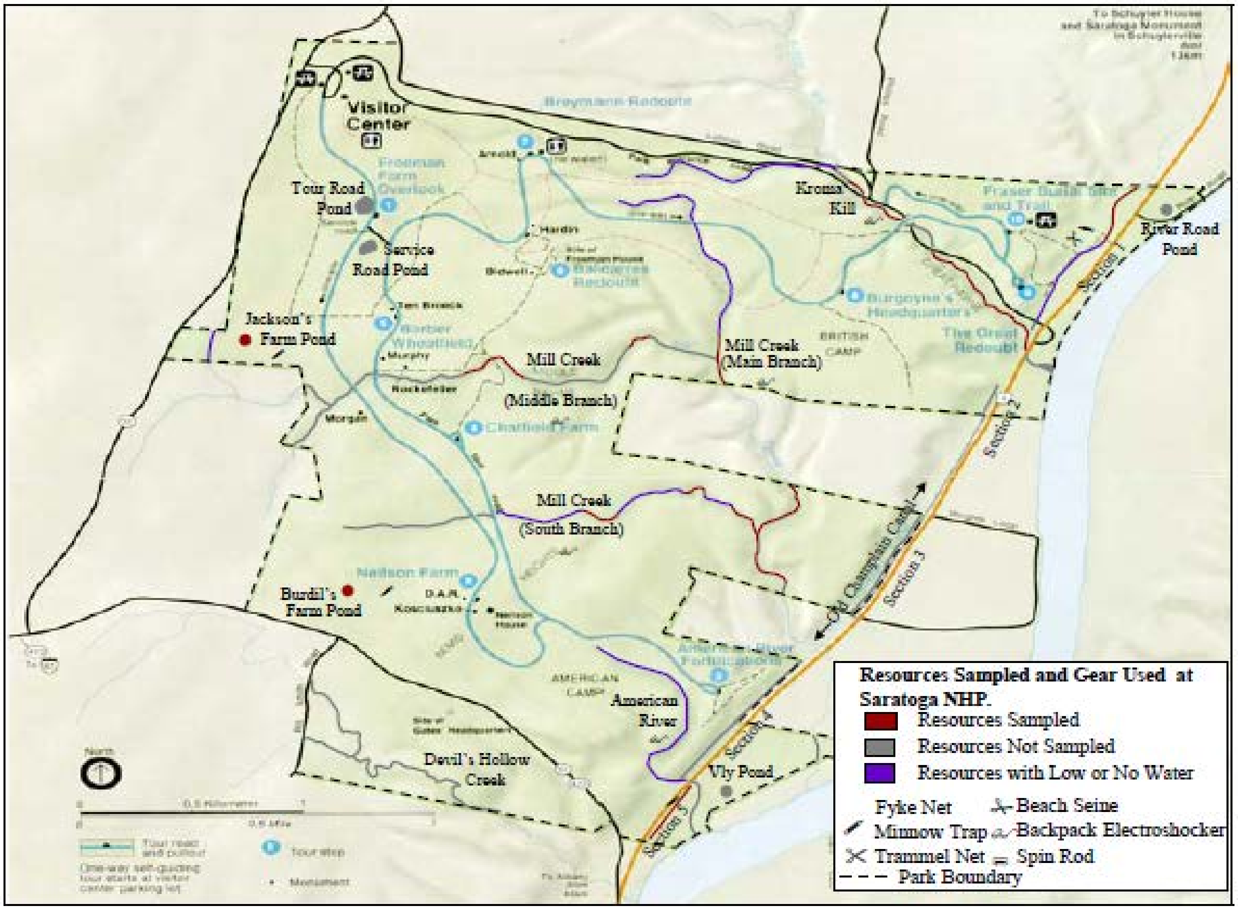


Figure 4.21. Fish sampling locations and sampling gear used for a fish inventory by Mather *et al.* (2003) in Saratoga National Historical Park during October 2000. Figure from Mather *et al.* (2003).

Reference Condition/Threshold Values Utilized

The Northern Mid-Atlantic Slope Drainage IBI used 12 metrics (Table 4.22) which have been modified from the Midwestern IBI (Karr 1986). Each condition metric scored either a 1 (*poor*), 3 (*intermediate*) or 5 (*best condition*) based on fish assemblage data from reference condition streams tested in Daniels *et al.* (2002). An overall IBI score based on the sum of the condition metric scores may be applied to a categorical scoring based on Karr *et al.* (1986) if all 12 metrics are able to be calculated based on the survey design (e.g., no fish, 12-22 *very poor*, 23-27 *very poor-poor*, 28-34 *poor*, 35-39 *poor-fair*, 40-44 *fair*, 45-47 *fair-good*, 48-52 *good*, 53-57 *good-excellent*, 58-60 *excellent*).

The lack of three metrics (metrics 10-12) (Table 4.22) prevents a calculation of a true IBI score for the streams in SARA based on Daniels *et al*. (2002) and Karr *et al*. (1986). Therefore, an estimated IBI score was calculated based giving metrics 10-12 a theoretic score of 1, 3 or 5. This method allowed for bounds to be placed on the scores to account for the three missing metrics, therefore creating a final score for each stream that include a range of scores. We then used the Karr *et al.* (1986) metric scores and created *good*, *caution* or *significant concern* categories. The resulting thresholds for the final fish IBI scores for the four streams in SARA included: no fish-34 *significant concern*, 35-47 *caution* and 48-60 *good*.

Condition and Trend

The results listed in Table 4.22 list the metric scores using Daniels *et al.* (2002) IBI metrics and data collected by Mather *et al.* (2003) in October 2000. Kroma Kill rated *caution-good* with an IBI score ranging from 38-50. Mill Creek main branch, middle branch and south branch all rated *significant concern-caution* with final scores ranging from 32-44, 32-44, and 28-40, respectively. Several of the IBI metrics for all the streams rated *5* (*best condition*) for species richness and trophic composition categories (Table 4.22). Conversely, the percent of individuals that are top carnivores rated *poor condition* (*1*) for all streams sampled in SARA. The presence of top carnivores in streams is an indicator of a diverse and ecologically balanced fish community. Additionally, Mill Creek's branches scored poorly for the number of water column species and the percent of dominant species. Water column species may serve as indicators of degradation to pool habitats, loss of riparian vegetation or stream cover. The low score for the 'percent dominant species' metric is due to the high abundance of blacknose dace (*Rhinichthys atratulus*) in SARA's streams. Black nose dace is considered a tolerant species to habitat and chemical degradation (Daniels *et al.* 2002).

Data Gaps and Confidence in Assessment

The confidence in the assessment was *medium* and trend analysis was *not applicable*. This condition assessment was based on the best available data for SARA, which was one survey conducted in SARA in 2000. An overall true IBI score for each stream could not be calculated due to a lack of fish community data needed for three metrics, but the final condition assessment was based on calculated ranges placed on each metrics score. Additionally, the calculation of individual metrics serves value in the assessment of structural composition and function of the fish community. An assessment of SARA's fish community with the inclusion of the 'fish abundance and condition' metrics (Table 4.22) will provide managers with an overall condition assessment for the park. Repeated surveys at the same stream habitats along with intense sampling effort over a period of time (i.e., years) will allow for baseline data to be established and temporal changes to be detected with greater statistical confidence.

Table 4.22. IBI metrics for the Northern Mid-Atlantic Slope drainages (Daniels *et al.* 2002) and calculated condition metric scores in parentheses for Kroma Kill and branches of Mill Creek in SARA based on Mather *et al.* (2003) sampling data.* *

	Index of Biotic Integrity metric	Kroma Kill	Mill Creek (main)	Mill Creek (middle)	Mill Creek (south)
	species richness and composition				
1	total number of fish species[a]	5	3	3	1
2	# of benthic-insectivorous species [a]	5	5	5	3
3	# of water column species [a]	3	1	1	1
4	# of terete minnow species [a]	5	3	3	3
5	% dominant species[b]	3	1	1	1
6	% of individuals that are white suckers[c]	3	5	5	5
	trophic composition*				
7	% of individuals that are generalists[d]	5	5	5	5
8	% of individuals that are insectivores[e]	5	5	5	5
9	% of individuals that are top carnivores[f]	1	1	1	1
	fish abundance and condition				
10	fish per sample[g]	1, 3 or 5			
11	% of species represented by two size classes[h]				
12	proportion of individuals with disease, tumors, fin damage, or other anomalies[i]				
	FINAL IBI SCORE†	38-50 Caution-Good	32-44 Significant concern-Caution	32-44 Significant concern-Caution	28-40 Significant concern-Caution

** Condition metric scoring includes either a 1 (poor condition), 3 (intermediate) or 5 (best condition). Metrics 10-12 could not be assessed due to lack of specific data measurements need for their calculations. Theoretic scores of 1, 3 or 5 were applied to metrics 10-12 in order to calculated a final IBI score which included a potential range score.

[a] See Daniels *et al.* (2002) for calculation using maximum species richness line (MSRL). Drainage area estimates for Kroma Kill and Mill Creek were estimated using USGS StreamStats.

[b] 5:<40%, 3:40-55%, 1:>55%

[c] 5:<3%, 3: 3-15%, 1:>15%

[d] 5:<20%, 3:20-45%, 1:>45%

[e] 5:>50%, 3:25-50%, 1:<25%

[f] 5:>5%%, 3:1-5%, 1:<1%

[g] See Daniels *et al.* (2002) for calculation using maximum density line (MDL)

[h] 5:>40%, 3:15-40%, 1:<15%

[i] 5:0%, 3:0-1%, 1:>1%

*trophic guild categorization from NJDEP and Barbour *et al.* 1999

† no fish-34 *significant concern*, 35-47 *caution* and 48-60 *good*

4.9 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.

SARA is located within Bird Conservation Region BCR13-Lower Great Lakes/St. Lawrence Plain (http://pif.rmbo.org/). In 2012, Partner's in Flight completed 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. 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.

SARA has been recognized as a New York Important Bird Area (http://iba.audubon.org/iba/stateIndex.do?state=US-NY) primarily due to the presence of many species of obligate grassland birds. Important Bird Areas are sites that provide essential habitat for birds that is not readily available in other locations. They often are selected because they provide critical habitat for species of conservation concern. SARA was recognized because of the size of its grassland habitat and the importance of that habitat to obligate grassland species. In addition, it supports many species associated with successional habitats which have shown regional declines.

For BCR-13, there are 39 species listed as species of importance. Fifteen species are listed as common species that have shown steep declines (Table 4.23). Twenty-seven species are listed as being of regional importance/concern and 9 of those are also of continental concern (showing continent-wide declines) (Table 4.24). Bird status and trend data will be updated on a regular basis so this website (http://pif.rmbo.org) will be a useful one for Park Mangers to check out on a regular basis.

Data and Methods

The following is a list of the types of data sets that are available for SARA 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 139 bird species known to occur in the park at some time during the year. This provides a checklist of birds but does not provide information on abundance and distribution, attributes that are 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 SARA. The most significant studies and datasets are described below.

Table 4.23. Common species in steep decline in Bird Conservation Region 13, the region that includes SARA (http://pif.rmbo.org/).

Species	Habitat[a]
Ruffed Grouse (*Bonasa umbellus*)	SES
Yellow-billed Cuckoo (*Coccyzus americanus*)	FOR
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	FOR
Eastern Whip-poor-will (*Antrostomus vociferus*)	FOR
Chimney Swift (*Chaetura pelagica*)	OTH
Belted Kingfisher (*Megaceryle alcyon*)	WET
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	FOR
Northern Flicker (*Colaptes auratus*)	FOR
Horned Lark (*Eremophila alpestris*)	AG-GR
Bank Swallow (*Riparia riparia*)	WET
Prairie Warbler (*Dendroica discolor*)	SES
Field Sparrow (*Spizella pusilla*)	AG-GR
Grasshopper Sparrow (*Ammodramus savannarum*)	AG-GR
Bobolink (*Dolichonyx oryzivorus*)	AG-GR
Eastern Meadowlark (*Sturnella magna*)	AG-GR

[a] 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

Table 4.24. Partners-in-Flight species of regional concern in Bird Conservation region 13. *** indicates a species that is also of continental concern (http://pif.rmbo.org/).

Species	Habitat[a]
Northern Harrier (*Circus cyaneus*)	AG-GR
American Kestrel (*Falco sparverius*)	AG-GR
Black-billed Cuckoo***	FOR
Eastern Whip-poor-will***	FOR
Belted Kingfisher	WET
Red-headed Woodpecker***	FOR
Northern Flicker	FOR
Eastern Wood-Pewee (*Contopus virens*)	FOR
Least Flycatcher (*Empidonax minimus*)	FOR
Eastern Kingbird (*Tyrannus tyrannus*)	AG-GR
Bank Swallow	WET
Barn Swallow (*Hirundo rustica*)	AG-GR
Veery (*Catharus fuscescens*)	FOR
Wood Thrush*** (*Hylocichla mustelina*)	FOR
Brown Thrasher (*Toxostoma rufum*)	SES
Golden-winged Warbler*** (*Vermivora chrysoptera*)	SES
Blue-winged Warbler (*Vermivora cyanoptera*)	SES
Cerulean Warbler*** (*Setophaga cerulea*)	FOR
Canada Warbler*** (*Cardellina canadensis*)	FOR
Eastern Towhee (*Pipilo erythrophthalmus*)	SES
Field Sparrow	AG-GR
Vesper Sparrow (*Pooecetes gramineus*)	AG-GR
Savannah Sparrow (*Passerculus sandwichensis*)	AG-GR
Henslow's Sparrow*** (*Ammodramus henslowii*)	AG-GR
Bobolink***	AG-GR
Eastern Meadowlark	AG-GR
Baltimore Oriole (*Icterus galbula*)	FOR

[a] 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.

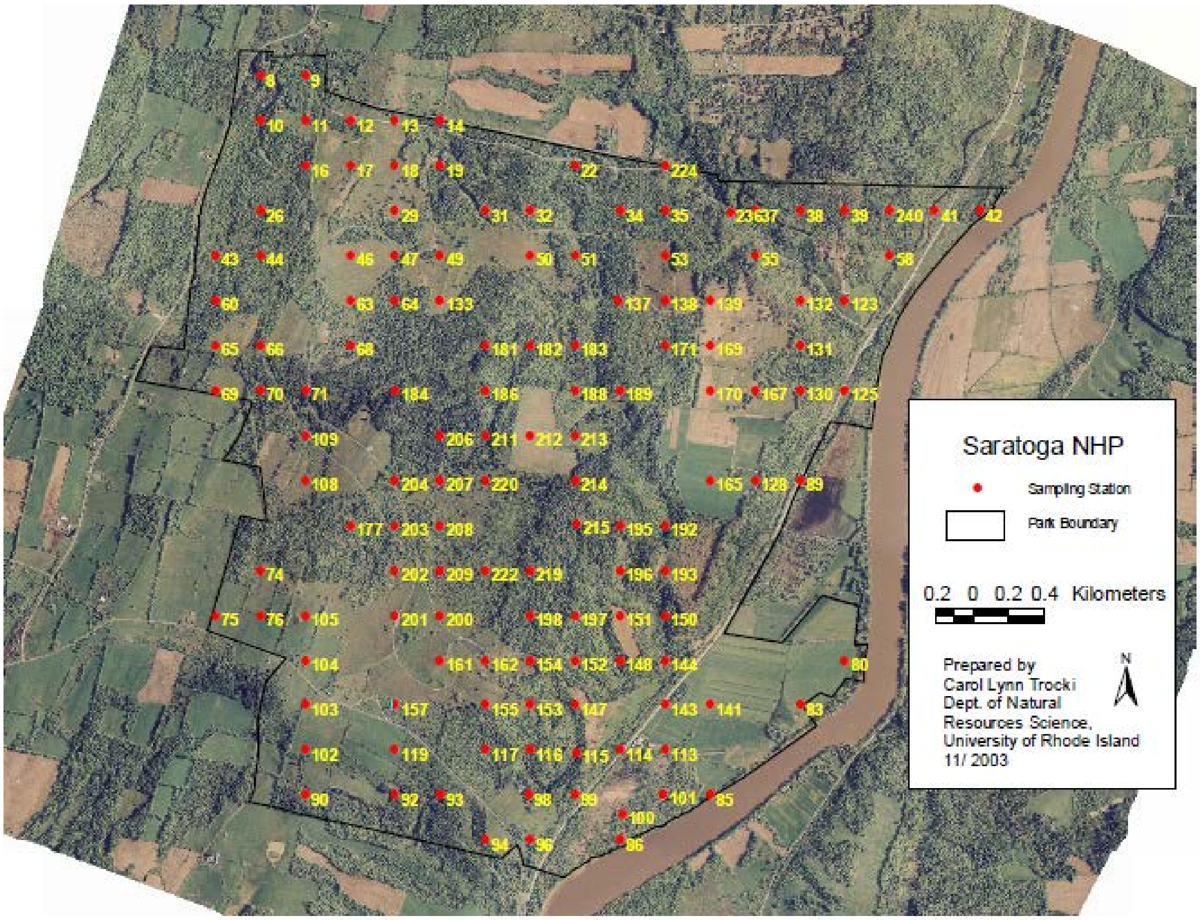


Figure 4.22. Locations of point count stations in SARA surveyed in breeding season 2002, 2003 (Trocki and Paton 2003).

A total of 73 species were detected during field surveys with 69 detected during point counts. Forty species were considered breeders at SARA. The three most common species were Song Sparrow, Common Yellow-throat and Red-winged Blackbird. All three species are associated with edge habitat.

Breeding species of regional concern included: Northern Flicker, Eastern Wood Pewee, Eastern Kingbird, Veery, Wood Thrush, Eastern Towhee, Field Sparrow, Eastern Meadowlark, and Bobolink. This group includes species breeding in forest (e.g., Veery, Wood Thrush), early successional habitats (e.g., Eastern Towhee) and in grasslands and field habitat (Field Sparrow, Eastern Meadowlark and Bobolink). Interestingly, Bobolink was actually the fifth most abundant species on site suggesting the SARA grasslands have the potential to provide important habitat for grassland species. Five breeding species were classified as common species showing steep declines: Northern Flicker, Prairie Warbler, Field Sparrow, Bobolink, and Eastern Meadowlark.

Faccio and Mitchell (2011) - Beginning in 2006/2007, volunteers associated with NETN established point count stations and surveyed birds at SARA. A total of six study sites consisting of 51 point counts were established in both forest (26 points) and grassland/ag (25 points) habitat. Ten minute point counts were conducted by volunteers between mid-May – June. Points are surveyed annually (Faccio *et al*. 2011). See Faccio and Mitchell (2011) Appendix A and B for a list of species, their relative abundances, and other summary statistics for surveys conducted from 2006-2010.

The total number of points surveyed annually varied from 20-51, and the total number of species reported ranged from 48-64. For the combined years 2006-2010, a total of 83 species have been detected. Red-winged Blackbird (Agelaius phoeniceus), Song Sparrow (Melospiza melodia) and Bobolink were among the most common species. Others in the top ten included generalists such as American Robin (Turdus migratorius) and American Crow (Corvus brachyrhynchos), the Ovenbird (Seiurus aurocapilla), an obligate forest species, and the Eastern Meadowlark, an obligate grassland species. The mix of species is a reflection of the mix of available habitat types at SARA. A number of species of regional conservation concern within BCR13 were reported at SARA including grassland obligates such as Northern Harrier, Vesper Sparrow, Savannah Sparrow, Bobolink and Eastern Meadowlark. Species of concern associated with successional habitats include Brown Thrasher, Blue-winged Warbler, Golden-winged Warbler, and Eastern Towhee.

Grassland bird conservation and knapweed control – Two studies discuss in depth both the importance of SARA as habitat for obligate grassland species which are showing continent-wide declines, and the threat which invasive knapweed represents to these grassland habitats (Trocki and Paton 2005, 2007). These two studies describe the problems with invasive knapweed, management recommendations for knapweed, and recommendations for monitoring bird response to knapweed control (Figure 4.23). Invasive knapweed outcompetes other species resulting in a change in the structure of the vegetation which then may influence the suitability of the habitat for grassland species. Trocki and Patton (2005) provide a number of excellent recommendations for improving grassland habitat. These will be referred to at the end of the bird section under management recommendations.

Breeding Bird Atlas-The New York Breeding Bird atlas was completed in 2005 http://www.dec.ny.gov/animals/7312.html. The atlas provides an overview of the breeding birds within a larger landscape around the park. SARA is included in the following blocks: Old Saratoga Unit: 6077D, 6177C; Battlefield Unit: 6075A, 6075B, 6076D, 6076C). 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 the Park. 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.

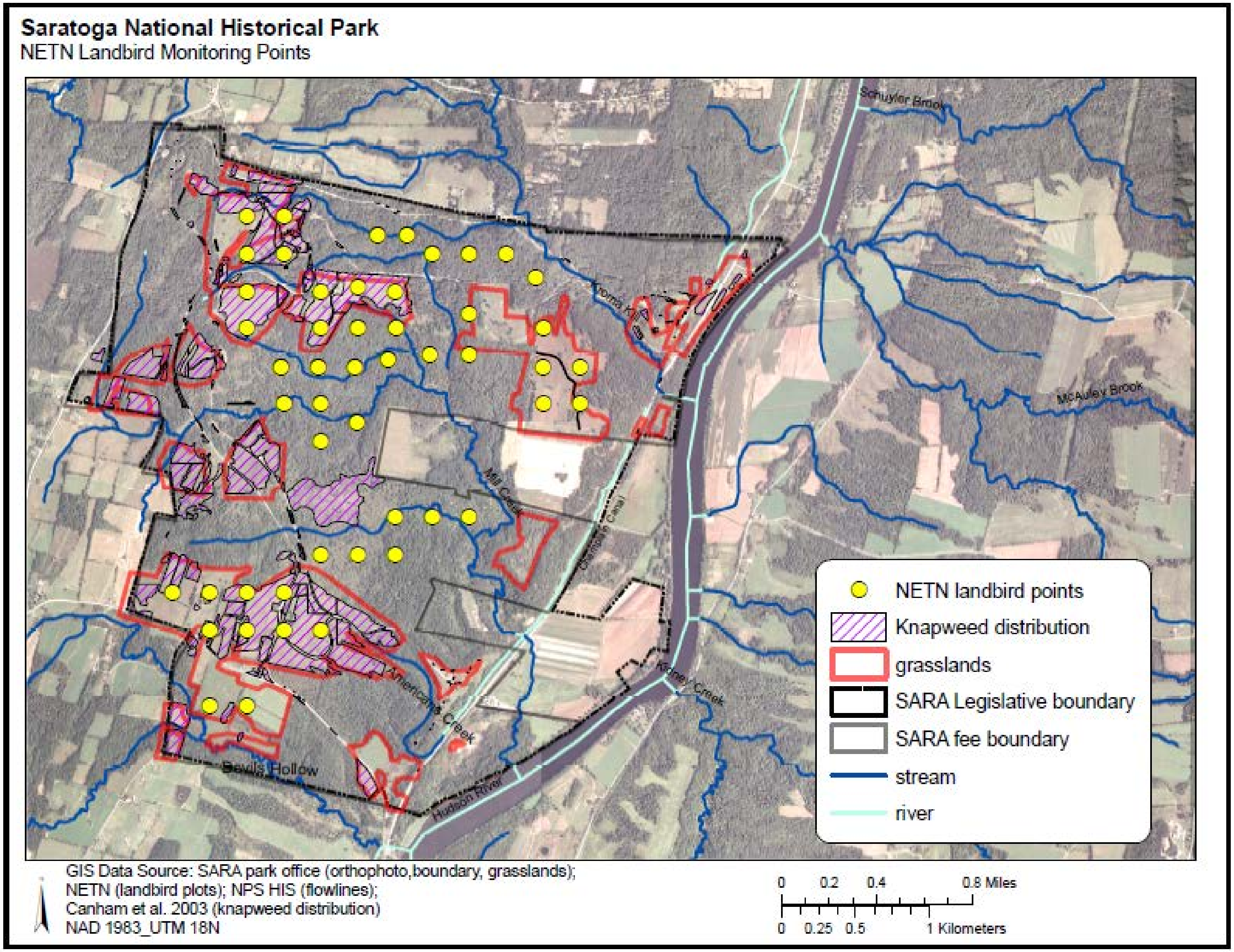


Figure 4.23. Knapweed distribution in relation to grasslands and NETN bird monitoring plots in SARA.

Reference Values/Threshold Values Utilized

Breeding birds are one of the groups that NETN is monitoring. Faccio and Mitchell (2009) developed a guild-based 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 SARA there are two guild-based biotic integrity scorecards; one for forest habitat and one for grassland habitat. The scorecard for forest habitat 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 integrity 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 *good*, *caution*, or *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 Integrity Ranks for 13 response guilds and proportional species richness thresholds (based on O'Connell *et al.* 2000, and Glennon and Porter 2005).

		Condition Categories		
Biotic Integrity Element	**Response Guild Metric (Percent Species Richness)**	**Good**	**Caution**	**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%

The ecological integrity assessment scorecard for the grassland bird community at SARA is based on the abundance and proportional richness of grassland obligate species, shrub-dependent species, edge generalist species, and exotics (Table 4.26). The threshold values for these metrics were determined from Browder *et al*. (2002) and Coppedge *et al.* (2006), and using data from the pilot season of grassland surveys at SARA. In the future, this scorecard will be expanded to include the proportion of Partners in Flight Priority (PIF) species for BCR 13 that are detected out of the total number of PIF priority species for each group (e.g., the number of PIF Priority grassland species detected divided by the total number of PIF Priority grassland species). This will provide another measure the overall value of grassland and early successional communities at SARA to rare or declining birds that are dependent on these habitats within the region. It will also prevent metrics based on numbers of species and abundance rather than just the proportion of species within a guild.

Table 4.26. Avian metrics and ratings for grassland bird surveys at SARA based on Browder *et al*. 2002, Coppedge *et al.* 2006) (Faccio, Mitchell and Pooler 2011).

		Condition Categories		
Biotic Integrity Element	**Response Guild Metric**	**Good**	**Caution**	**Significant Concern**
Abundance (birds/point):	Edge generalist species	< 6.0	6.0-10.0	> 10.0
	Shrub-dependant species	< 1.0	1.0-5.0	> 5.0
	Grassland obligate species	> 4.0	1.5-4.0	< 1.5
	Exotic species	0.0	0.1-1.0	> 1.0
Proportional Species Richness (%):	Edge generalist species	< 20%	20-50%	> 50%
	Shrub-dependant species	< 10%	10-25%	> 25%
	Grassland obligate species	> 10%	5-10%	< 5%
	Exotic species	0%	0.1-3%	> 3%
	Proportion of PIF Priority Grassland Species for BCR 13 (# detected/5)	> 80%	50-80%	< 50%
	Proportion of PIF Priority Shrubland Species for BCR 13 (# detected/4)	< 50%	50-75%	> 75%

Condition and Trend

The park-wide forest avian ecological integrity assessment for all years combined at SARA resulted in four categories ranked as *good*, six ranked as *caution*, and three ranked as *significant concern* (Table 4.27). With the exception of single brooded (which earned a *caution* rating), compositional metrics were rated *good*, while structural and functional metrics were dominated by *caution* or *significant concern.* These results indicate that the forest bird community at SARA may be affected by the generally fragmented landscape consisting of small forest blocks broken up by fields and early successional habitats, plus effects of deer on understory vegetation structure.

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 integrity assessment scores just by virtue of the fact that the forest patches are small with relatively large amounts of edge habitat. The ecological integrity assessment can still be useful in terms of monitoring direction of change. The goal should be to maintain or improve the ecological integrity assessment 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. 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.

Table 4.27. Ecolgoical integrity assessment scores based on survey data (2006-20010) for forested study areas at SARA (Faccio and Mitchell 2011).

Biotic Integrity Element	Response Guild Metric (% species richness)	Proportion Rating
Compositional:	Exotic Species	0% Good
	Nest Predators/Brood Parasite	5% Good
	Residents	25% Good
	Single Brooded	50% Caution
Functional:	Bark Prober	13% Good
	Ground Gleaner	7 % Caution
	High Canopy Forager	7 % Caution
	Low Canopy Forager	20 % Caution
	Omnivore	33 % Caution
Structural:	Canopy Nester	25 % Significant Concern
	Forest-ground Nester	12 % Caution
	Interior Forest Obligate	25 % Caution
	Shrub Nester	25 % Significant Concern

The grassland avian ecological integrity assessment consisted of four *caution* ratings (Table 4.28). The assessment did not include abundance this year. The grassland ecological integrity assessment is new and will probably be adjusted over the coming years to better reflect condition. At a regional level SARA grasslands are considered a high priority in the region because of the number of grassland obligates it supports and the high abundance of some of the grassland obligates. For example, Bobolink was the third most abundant species reported and eastern meadowlark was in the top ten. In terms of the bird community, this is the most important habitat type and should be managed to maximize the value of this habitat while still maintaining the cultural park landscape.

Table 4.28. Ecological integrity assessment scores based on survey data (2006-20010) for grassland study areas at SARA (Faccio and Mitchell 2011).

Biotic Integrity Element	Response Guild (% species richness)	Proportion Rating
Proportional Species Richness (%):	Edge Generalist	24% Caution
	Exotic	1% Caution
	Grassland Obligate	5% Caution
	Shrub-dependent	13% Caution

Management Recommendations

Trocki and Patton (2005) outlined steps that can be taken to improve grassland habitat for birds. This document provides useful information on steps that can be taken and we recommend that Park Managers consider each of their suggestions. Some of these suggestions such as monitoring grassland birds, knapweed management, and maintaining management records are already in place and should be continued. We have reiterated some of their other suggestions that we think should be considered by Park Managers:

1) Whenever possible, efforts should be made to increase total area as well as contiguity of grassland fields in the park. This recommendation may align well with the park's goals for historic and cultural landscape preservation, as greater grassland contiguity existed in the park historically. Grassland size is one of the most important factors influencing habitat quality.

2) Mowing should be avoided during the breeding season (April-late July). Bobolinks are strongly attracted to hayfields, and these fields become ecological traps if the birds are attracted to them and then lose their nest to mowing. Trocki and Patton (2005) provide suggestions for minimizing damage when mowing must be done.

3) Prescribed burning should always be conducted outside of the nesting season, and should be implemented on a rotational basis to create a habitat mosaic appropriate to the greatest number of species. Individual fields should be burned every 2-6 years and no more than 50% of any individual field should be burned in a given year.

4) Trails or roads that bisect grassland fields should be closed during the nesting season or relocated to the field perimeter, whenever feasible, to reduce disturbance to nesting birds. Future planning in the park should seek to avoid creating additional disturbance to field interiors.

5) Improved visitor education and interpretive signage should be targeted at explaining the importance of grassland nesting habitat and minimizing the impacts of disturbance during the nesting season.

Data Gaps and Confidence in Assessment

Confidence in this assessment was medium and confidence in the trend analyses was fair to high. Factors that influence the quality of the monitoring data collected by NETN depend on the skills of the volunteers who conduct the point counts, the consistency between years of the individuals who conduct the counts, and the probability that a bird that is present during the time the point count is occurring is detected. Researchers working on the monitoring program have continued to revise the monitoring protocol to address these issues (Faccio et al. 2011). They are establishing a training program for volunteers and are attempting to retain volunteers over multiple years. This will no doubt improve the quality and consistency of the data. Ten minute point counts improve the probability of detecting a species, but because points are surveyed only once per year, there is always the chance that rare or less vocal species go undetected. This can be a problem when calculating the biotic assessment index which is calculated based on the number of species within different guilds. To deal with this issue, the assessment data should be averaged over multiple years. This is what the NETN is currently doing, but it means that managers will only be able to look at trends in the ecological integrity assessment over spans of perhaps ten years instead of on an annual basis. The ability to detect changes in individual species is low, but the data can be used to detect or monitor changes in guilds such as forest interior species or shrub nesters.

Confidence in scores was higher for the forest ecological integrity assessment than for the grassland ecological integrity assessment primarily because the forest ecological integrity assessment has been around for a number of years and has been field tested. New measurements that will be included in the grassland ecological integrity assessment including the abundance of obligate grassland species and individuals, and the proportion of species of concern found on the site will probably give a better assessment of the value of these grasslands. It is evident that these grasslands are currently providing important habitat.

List Limitations

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 it 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.

4.10 Amphibians and Reptiles

Relevance and Context

Atmospherically transported pollutants, ultraviolet-B radiation, pesticides, fertilizers, road-run off, degraded water quality, disease, habitat degradation, fragmented landscape and roads are commonly identified as variables which may affect amphibian decline (Clark and Hall 1985, Sanzo and Hecnar 2006, Karraker *et al.* 2008, Cook *et al.* 2011,). Many of these stressors have been identified in SARA's environment. For example, surface waters in SARA are impacted by high nitrogen and phosphorus loads (see Water Quality section). These nutrients can cause dense masses of algae, creating an environment not conducive to egg laying. 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 (Cook *et al.* 2011). The occurrence of roads in close proximity to wetlands in SARA creates habitat fragmentation, increases road runoff into aquatic habitats and increases herpetofauna mortality due to road kill. SARA contains a number of travel corridors in the park used by amphibians during the breeding season. These travel corridors were identified by Woolbright (2001-2003) as being concentrated near Stop 1 Pond, Service Pond, Beaver Marsh, and Stop 8 Ponds (Cook *et al.* 2011).

The red-spotted newt (Notophthalmus v. viridescens) and the spring peeper (Pseudacris crucifer) are common amphibian species found in the park. Photos: R. Wagner.

Historical documentation indicates that 30 species of amphibians and reptiles have been observed throughout SARA and Saratoga County (Appendix K). The most recent inventory of amphibian and reptiles was conducted in SARA from March through September 2001, which resulted in 21 species being documented (Cook *et al.* 2011). Of the 21 species, 13 amphibian and eight reptiles were recorded, with anurans comprising 90.6% of all individuals, salamanders 8.1%, snakes 0.9%, and turtles 0.4%. The most abundant species in each taxonomic group, based on total numbers of adults recorded were spring peeper (*Pseudacris crucifer*), red-spotted newt (*Notophthalmus v. viridescens*), painted turtle (*Chrysemys picta*), and eastern gartersnake (*Thamnophis s. sirtalis*). Species richness of amphibians and reptiles varied across SARA, with the Schuyler Estate segment of the Old Champlain

Canal containing the highest species richness with 15 (71%) species found and Burdyl Marsh accounting for the greatest number of individuals (1859 individuals) (Figure 4.24) (Cook *et al.* 2011). Species of special concern under NY legislation Section 182.2(i) of 6NYCRR Part 182 are present in SARA. Species of special concern warrant attention and consideration but current information collected by the NYDEC does not justify listing these species as either endangered or threatened. Species under this listing which have been found in SARA include the spotted turtle (*Clemmys guttata),* wood turtle (*Clemmys insculpta)* and the eastern box turtle (*Terrapene carolina).* The eastern hognose snake (*Heterodon platyrhinos*) has been documented in Saratoga County, and falls under special concern listing. The Jefferson salamander (*Ambystoma jeffersonianum)* and the blue-spotted salamander (*Ambystoma laterale)* are individually listed as a species of special concern in NY, but in SARA, only the Jefferson salamander complex (*Ambystoma jeffersonianum x laterale)*, a hybrid of Jefferson and blue-spotted species, is reported. No endangered or threatened amphibian or reptiles are known to occur within SARA.

Breeding, foraging and dispersal activities require the use of different habitats in SARA for the survival of amphibians and reptiles. All of the amphibians at SARA, with the exception of the eastern red-backed salamander, depend on aquatic habitat for reproduction. Spring peeper, gray treefrog, wood frog, spotted salamander and Jefferson salamander complex all depart from wetland habitats following the breeding season, foraging, and hibernating in the uplands (Conant and Collins 1998, Petranka 1998). Therefore, it is important to consider the long-term preservation and connectivity of these areas in order to protect the sustainability of populations. Cook *et al.* (2011) calculated that by habitat, relative abundance of adults was dominant in wetlands (82.9% of individuals recorded), followed by streams (14%), uplands (3.1%), and on roads (<1%).

Data and Methods

From March through September 2001, 39 sites (stream, woodland and wetland habitats) within SARA’s Battlefield Unit, Victory Woods, and Schuyler House property were assessed for the presence of amphibians and reptiles by Cook *et al.* (2011) (Figure 4.25). Six standardized sampling methods were executed; anuran call-counts, egg-mass counts, time-constrained search, coverboards, turtle trapping, and minnow trapping. The State of New York currently does not have an amphibian index of biotic integrity. However, the Ohio Environmental Protection Agency has developed an Amphibian Index of Biotic Integrity (AmphIBI) to assess wetland quality and this was used to assess the condition of SARA’s amphibian community (Micacchion 2002, 2004).

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.

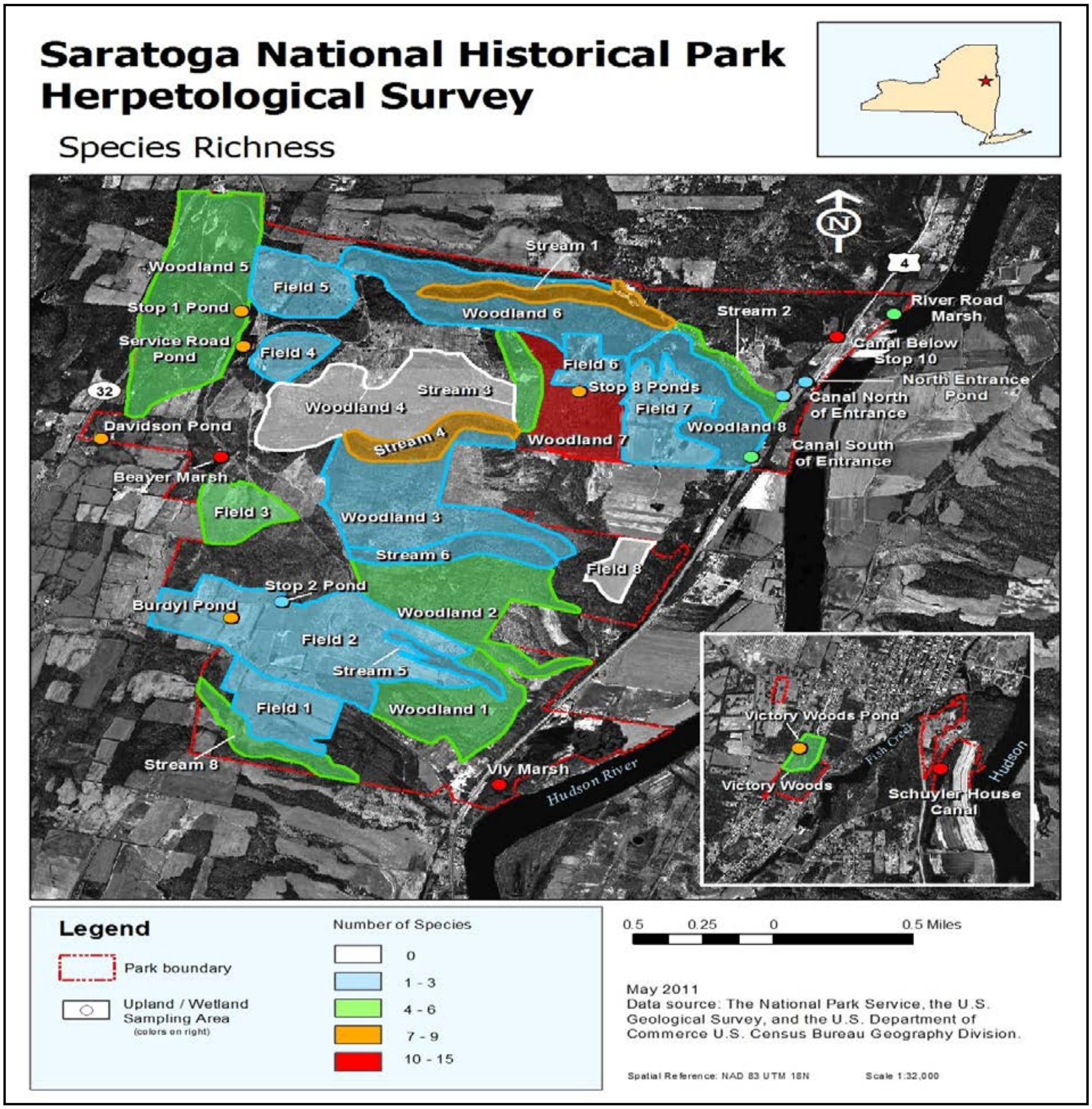


Figure 4.24. Species richness distribution of herps inventoried in SARA in 2001 by Cook *et al.* (2011). Figure from Cook *et al.* (2011).

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 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 SARA were assessed based on a qualitative analysis performed by Cook *et al.* (2011).

Reference Condition/Threshold Values Utilized

The condition categories of the amphibian community were based on the methods established by Micacchion (2004). An AmphIBI score ranging from 30-50 represented an *excellent* amphibian community; a score ranging from 20-30 represented a community in *good* condition; a score from 10-20 was a community in *fair* condition; and score less than 10 was representative of a community in *poor* condition (Micacchion 2004). For the purpose of this NRCA assessment, we altered the category language to conform to this report with *excellent* and *good* equating to *good*, *fair* equating to *caution* and *poor* equating to *significant concern*. An overall trend was not applied to the amphibian and reptile community in SARA. However, by comparing 2001 data with regional historical information, Cook *et al*. (2011) subjectively assigned species with four trend categories. Population trend categories of amphibian and reptile species in SARA included *increasing*, *decreasing*, *stable* or *unknown* per language provided by Cook *et al.* (2011).

The eastern box turtle (Terrapene carolina) is a species of concern in New York. Their occurrence within the park is rare and their population is declining. Photo: R. Wagner.

Condition and Trend

Based on the AmphIBI calculations, the average score for the amphibian communities sampled by Cook *et al.* (2011) in SARA averaged 14, which corresponded to the *caution* rating (Table 4.29). Sites in SARA that ranked low in the AmphIBI calculations *caution* to *significant concern* were the result of the absence of sensitive species and the presence of tolerant species at the sites. Sites which were categorized as *significant concern* tended to be located near the border of SARA's park boundary and include Canal below stop 10, Canal south of entrance, Davidson Pond and River Road Marsh (Figure 4.25, Table 4.29). Sites rated *good* included waterbodies on the eastern side of the park, such as Beaver Marsh, Burdyl Pond, Stop 1 pond and the site at Schuyler House Canal, which is located northeast of the Battlefield Unit (Figure 4.25). When assessing the park's herpetological species based on species richness calculations, the greatest number of species occurred in habitats scattered across SARA including Woodland 7, Vly Marsh, Beaver Marsh, and the Canal below Stop 10. Conversely, the lowest species richness of amphibian and reptile species was accounted for within the majority of the fields and woodlands of SARA and at Stop 2 Pond, North Entrance Pond and Canal North of Entrance (Figure 4.25).

Due to a lack of quantitative historical data for SARA, a statistical trend analysis of the amphibian and reptile community was not applicable for this park. However, Cook *et al.* (2011) assessed each species' status and population trend from a subjective process by using species occurrence lists from the mid-1980's and mid 1990's. Cook *et al.* (2011) determined that 18 of the 28 species that occurred historically at or in the area around SARA appeared to be stable in terms of their population status, three species have declined or have disappeared and seven species lack information for trend assessment (Table 4.30). Much of the decline seems to involve species that have been uncommon or rare in SARA and include the northern leopard frog, eastern box turtle and the Jefferson salamander. For these species identified as declining, truly "historic" data are lacking and it is impossible to know how common or rare they were at SARA, except in recent decades. Their decline in SARA however, may be due to a broader global or regional decline, along with a variety of potential stressors.

The Victory Woods wetland area was one of several areas assessed for the biotic integrity of herpetological species at Saratoga National Historical Park. Photo: R. Wagner (November 12, 2010).

Data Gaps and Confidence in Assessment

Confidence in the assessment was *medium* and the confidence in the assessment of trend was *medium*. The data for this assessment was based on monitoring efforts which occurred in 2001 and do not represent current conditions of the amphibian community in SARA. 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 SARA's wetland breeding amphibian community (Table 4.29). A caveat for the use of the AmphIBI is that it is weighted toward wetlands with moderate to long hydro-period vernal pools and semi-permanent ponds. Thus, permanent ponds may not rate as high as they should using AmphIBI.

Table 4.29. Condition assessment for SARA's amphibian community associated with the AmphIBI (Micacchion 2004) for amphibian communities sampled by Cook *et al.* (2011)*. †AmphIBI category language was changed to good, caution or significant concern to conform to NRCA language.

	AmphIBI Measures & Results						
Site	**AQAI**[1]	**Relative Abundance of Sensitive Species**[2]	**Relative Abundance of Tolerant Species**[3]	**Number of Pond Breeding Species**[4]	**Presence of Spotted Salamanders or Wood Frogs**[5]	**Condition Score & Category†**	
Beaver Marsh	3.7	15%	62%	2	1	23	Good
Burdyl Pond	3.1	11%	78%	2	1	23	Good
Canal Below Stop 10	1.9	0%	98%	3	0	0	Significant Concern
Canal South of Entrance	2.0	0%	100%	0	0	0	Significant
Davidson Pond	2.0	0%	100%	0	0	0	Significant
River Road Marsh	2.4	0%	86%	0	0	0	Significant
Schuyler House Canal	3.1	5%	69%	2	2	22	Good
Service Road Pond	2.9	2%	74%	2	2	19	Caution
Stop 1 Pond	3.3	3%	61%	2	2	22	Good
Stop 2 Pond	2.2	5%	95%	2	1	13	Caution
Stop 8 Ponds	3.6	30%	70%	2	2	26	Good
Victory Woods Pond	2.7	9%	87%	2	2	16	Caution
Vly Marsh	2.4	1%	86%	2	2	16	Caution
Average SARA Score						**14**	**Caution**

* Condition scores were estimated by summing the scores of the five metrics. Condition rating is based on the following categories, with the original AmphIBI categories in parentheses: 30-50 represents a community in *good* (*excellent)* condition; 20-30 represents communities in *good* (*good)* condition; 10-20 represents communities in *caution* (*fair)* condition; and a score <10 indicates communities in *significant concern* (*poor)* condition (after Micacchion 2004).
1. AQAI scores: 0: <3.00; 3: 3.00-4.49; 7: 4.50-5.49; 10: ≥5.5
2. Relative abundance of sensitive species scores: 0: 0%; 3: 0.01-9.99%; 7: 10-49.99%; 10: ≥50%
3. Relative abundance of tolerant species scores: 0: >80%; 3: 50.01-79.99%; 7: 25.01-50%; 10: ≤25%
4. Number of pond-breeding salamander species: 0: 0-1; 3: 2; 7: 3: 10: >3
5. Presence of spotted salamander and/or wood frogs score: 0: absent; 10: present

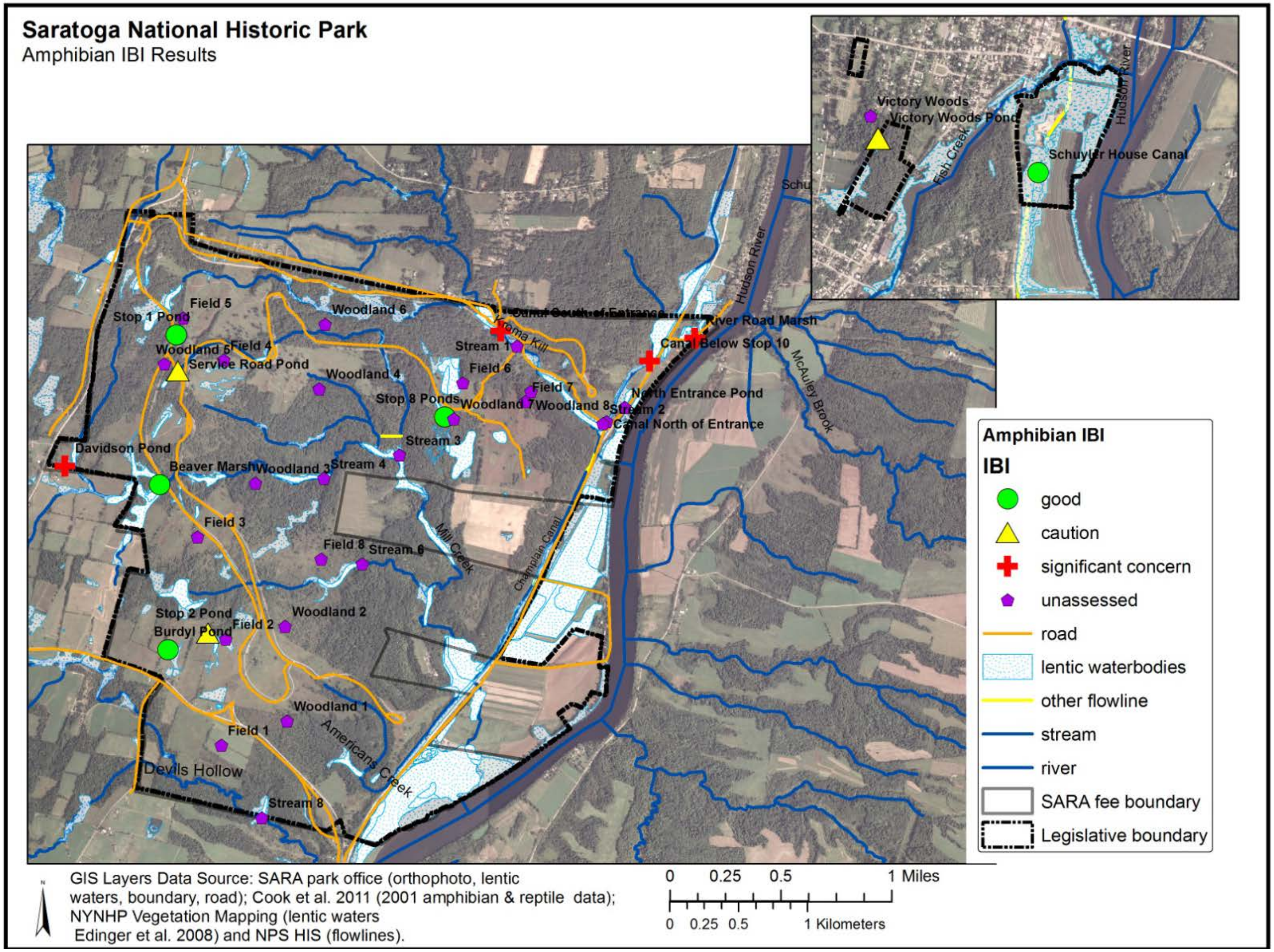


Figure 4.25. Results of the AmphIBI (Micacchion 2004) used to assess SARA's amphibian community from data collected in 2001 by Cook *et al.* (2011). The five condition categories for the amphibian assessment included: excellent, good, fair, poor, and unassessed.

Table 4.30. Abundance status and trends in amphibians and reptiles at Saratoga National Historical Park as assessed by Cook *et al*. (2011) during 2001 surveys in the park. Apparent trend symbols include: stable ↔, declining ↓, and increasing ↑.

Scientific Name	Common Name	Historic Status	Current Status	Apparent Trend
Pseudacris crucifer	Northern Spring Peeper	abundant	abundant	↔
Hyla versicolor	Gray Treefrog	abundant	abundant	↔
Rana clamitans melanota	Northern Green Frog	abundant	abundant	↔
Rana sylvatica	Wood Frog	common	common	↔
Rana catesbeiana	American Bullfrog	common	common	↔
Rana pipiens	Northern Leopard Frog	common	uncommon	↓
Rana palustris	Pickerel Frog	rare	rare	↔
Bufo americanus	Eastern American Toad	common	common	↔
Plethodon cinereus	Eastern Red-backed Salamander	common	common	↔
Ambystoma maculatus	Spotted Salamander	common	common	↔
Ambystoma jeffersonianum	Jefferson Salamander	uncommon	rare	↓
Eurycea bislineata	Northern Two-lined Salamander	common	common	↔
Notophthalmus viridescens	Red-spotted Newt	common	common	↔
Gyrinophilus porphryticus	Northern Spring Salamander*	rare	unknown	unknown
Desmognathus fuscus	Northern Dusky Salamander*	rare	unknown	unknown
Chelydra serpentina	Eastern Snapping Turtle	common	common	↔
Chrysemys picta	Painted Turtle	common	common	↔
Terrepene carolina	Eastern Box Turtle	uncommon	rare	↓
Glyptemys insculpta	Wood Turtle**	rare	unknown	unknown
Clemmys guttata	Spotted Turtle**	rare	unknown	unknown
ternotherus odoratus	Stinkpot***	unknown	rare	unknown
Lampropeltis triangulatum	Eastern Milk Snake	uncommon	uncommon	↔
Nerodia sipedon	Northern Water Snake	uncommon	uncommon	↔
Thamnophis sirtalis	Common Garter Snake	common	common	↔
Storeria dekayi	Brown Snake	uncommon	uncommon	↔
Storeria occipitomaculata	Northern Red-bellied Snake	uncommon	uncommon	↔
Orpheodrys vernalis	Smooth Green Snake*	rare	unknown	unknown
Thamnophis sauritus	Eastern Ribbon Snake*	rare	unknown	unknown

* not recorded in 2001; ** recorded in 2004; *** recorded in 2010

4.11 Visitor Usage

Relevance and Context

From 1941-2010, SARA has hosted over 7,000,000 recreational visitors (NPS Stats 2011). Visitors to SARA engage in many activities during their visits such as tour road visits, hiking, biking, horseback riding, skiing and snowshoeing. The SARA Tour Road, multiple paths and trails and the Wilkinson National Recreation Trail are commonly used by visitors to SARA. The effect visitors may have on the integrity of SARA's natural resources based on their recreational activities and visitation records were evaluated in order to provide information on possible deleterious effects (i.e., trampling, removal of resources) occurring in the park due to visitor activities and increased visitor carrying capacity.

Data and Methods

NPS Stats (2011) collects visitation data for each NPS park and these data were used to assess visitor activity. Visitation counts were analyzed from 1941-2010, traffic counts were recorded from 1991-2010, and seasonal recreation activities data were collected from 2000-2010. The *number of visitors vs. year* and *traffic count vs. year* were modeled using regression analysis to assess for trends in the data. Visitation trends were *decreasing*, *increasing*, or *no change* detected based on statistical analyses. Recreational use data was assessed to account for the most popular activities within SARA based on seasonality and to discuss potential threats or stresses to SARA natural resources from recreational use.

Reference Condition/Threshold Values Utilized

Quantitative data were absent regarding visitor use impacts on natural resources (i.e., area of soil erosion, percent trampling); therefore best professional judgment was used to assess the impacts of visitor use on SARA's natural resources and potential scenarios of visitor use conflicts in the park.

Condition and Trend

Based on the examination of the data presented below, visitor usage and its impact to SARA's natural resources was assessed as *caution*. From 1941-2010 the average number of recreational visitors to SARA was 111,782±48,428.73 (standard deviation) (median value=112,700). Visitation levels to SARA from 1941-2010 significantly increased based on yearly visitation records ($p<0.05$, N=70). Levels of yearly visitation tended to be extremely variable from 1941-2010. On average, SARA experienced approximately a 2% per year increase in visitors based on 1941-2010 visitation records. However, from 2000-2010 the number of visitors significantly decreased ($p<0.05$, N=11) (Figure 4.26).

Traffic counts were recorded from 1991-2010 at four points of entrance to SARA: Phillips Road, Route 32, Route 4, and the Tour Road (Figure 4.27). Route 4 experienced the highest traffic count from 1991-2010, with an average of 96,350 events per year, followed by Route 32 (74,768), Philips Road (72,288) and the Tour Road (29,731) (NPS Stats 2011). Based on simple linear regression analysis, all four park entrances experienced significant decreases in traffic counts from 1991-2010, which are a direct reflection of the overall decrease in recreational visitor counts for those years.

None of the four traffic entrances have significantly increased in use over the last 10 years, from 2000-2010 (Figure 4.27).

Recreational activity by season was assessed using data collected for SARA from 2000-2010. Based on these data, from late spring through early fall the most popular activities listed in order included: tour road visitors, hiking, biking and horseback riding (NPS Stats 2011). During winter months, hiking and skiing/snowshoeing were the most popular, with a few instances of horseback riding. Because trails are being used year-round in SARA, visitors may be altering the trails by inducing soil erosion, side trail formation and increasing trail width. Likewise, horses increase trail erosion and may aid in the spread of invasive exotic species.Tour roads are the most common form of recreational use during all months (excluding winter months), making their structural integrity a frequent concern for SARA. The tour roads may impact wildlife migration and habitat from tour road activity in SARA. The tour road fragments migration routes of amphibians and reptiles in SARA from neighboring wetland habitats, thereby increasing wildlife fatality. Roads and trails are also present through SARA's grasslands, which has increased fragmentation of grassland habitat.

Figure 4.26. Number of individual recreational visitors to SARA per year from 1941-2010.

Although visitation has decreased over the past 15 years in SARA, this pattern may be cyclical. Based on projected population pressures for Saratoga County and the potential for industrial growth surrounding SARA, visitor use may increase in SARA (NPScape 2011, The Chazen Companies 2005). The expected demands for recreational space will subsequently increase pressure on SARA's natural resources. Visitor use conflicts within SARA can change based on the future development surrounding SARA. For example, if an industrial operation such as drilling is established within the vicinity of SARA, the lightscape and soundscape will be altered, generating particular recreational activities less enjoyable for visitors.

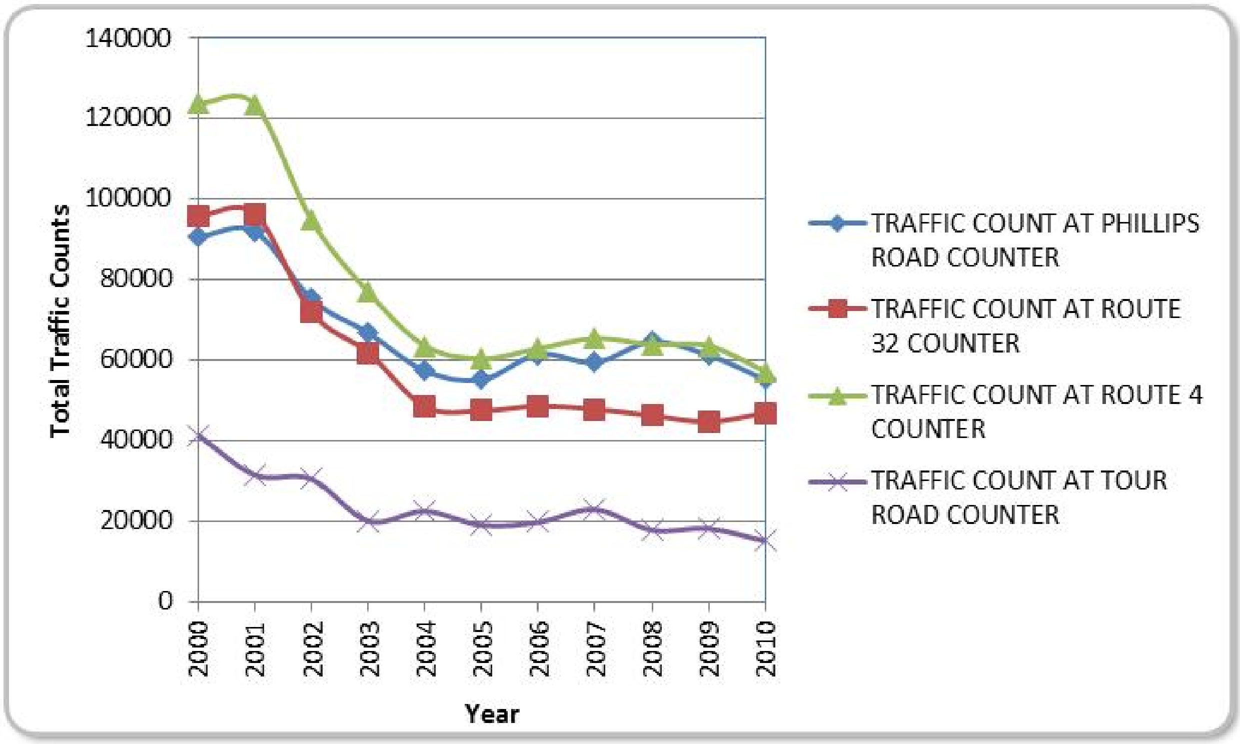


Figure 4.27. SARA total traffic counts enumerated at four entrances to the park from 2000-2010: Phillips Road, Route 32, Route 4, Tour Road.

Data Gaps and Confidence in Assessment

Confidence in the assessment was *medium* and confidence in the trend analysis was *medium*. Quantitative data are insufficient regarding impacts to natural resources due to visitor use. The NETN Forest Monitoring Protocol (Tierney *et al.* 2010) currently lists 'percent trampled' as a measurement to be sampled within SARA as part of assessing forest floor condition, which can be related to visitor use impacts. Other measurements which may supplement assessing visitor impacts to SARA's paths and trails based on SARA's management goals include, 'soil surface compaction measured from x ft. from trail center' and 'tree root exposure within x feet of trail edge'. Monitoring traffic congestion during peak visitor months and days as well as accounting for any road fatalities of amphibians and reptiles, especially during breeding season, will aid in assessing road/trail condition, air quality and wildlife impacts.

4.12 Landscape Dynamics

Relevance and Context

Landscape changes due to natural and anthropogenic impacts within and surrounding SARA 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 human population characteristics (e.g., population change, housing 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 (Wilcove 1998, Luck 2007, Heinz 2008). Thus, the rate of conversion and development of landscapes to support population growth is a concern for SARA.

Based on 2000 U.S. Census data, Saratoga County contained approximately 78,000 housing units for a population of over 200,000 people (U.S. Department of Commerce 2012). From 1990-2000, Saratoga County experienced a 15% growth in the number of household units and a 17.7% increase in population. A study by The Chazen Companies (2005) stated that the number of housing units is expected to increase to sustain a projected population in Saratoga County of 250,000 by 2040. SARA has a close spatial relationship to towns and villages experiencing housing and population growth which may increase pressure on SARA's resources. These localities to SARA include, but are not limited to: Village of Victory and Schuylerville to the north, Easton located to the east, Town and Village of Stillwater to the south, and Town of Saratoga and Saratoga Springs to the west of SARA. Along with development of housing comes the construction of impervious surfaces, such as roads and parking lots. Roads affect biotic and abiotic variables of landscapes by generating wildlife mortality, habitat fragmentation and loss of connectivity. Roads also 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 environmental properties are present surrounding SARA, unconstrained portions still exist for development in order to meet the needs of population growth in Saratoga County. Since anthropogenic land use demands will likely expand over time, monitoring the extent and pattern of the landscape (i.e., composition, configuration, connectivity) around and within SARA 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. SARA's viewshed, which is of scenic and historical value, is at risk for visually intrusive development due to the availability of land for development and conversion around the park in both

Saratoga and Washington County. Temporal and spatial measures of natural to converted land cover types, impervious surface, and connectivity can provide insight into how SARA and its surrounding environment has and will be impacted from landscape alterations.

Village of Schuylerville near the Old Saratoga Unit of the park. Photo: C. A. Cole (November 12, 2010).

Data and Methods

Feasibility studies and park reports were used in conjunction with NPScape data to provide a comprehensive assessment of SARA's landscape. NPScape products were used to evaluate a 30 km (18.6 mi) area around SARA 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 U.S. census block data, 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, 2009b). The following NPScape spatial and temporal measures were used in the assessment of landscape dynamics for SARA:

Population, Housing, Land Cover Change
Resources for population estimates and trends included NPScape MDS (Svancara *et al.* 2009a) and U.S. Census Data (U.S. Department of Commerce 2012). This analysis combined historic and current U.S. Census data with statistical projection models, was spatially processed for 30 km (18.6 mi) area around SARA at a 100 m (328 ft) spatial resolution and mapped as log density of population /km^2 for 1950, 2010, 2020, and 2030. The housing analysis combined historic and current U.S. Census data with NPScape (Svancara *et al.* 2009a) statistical projection models and was processed for 30 km (18.6 mi) area around SARA at a 100 m (328 ft) spatial resolution and mapped as #units/km^2 for 1950, 2010, 2030, and 2050.

Land cover data at local, regional and national scales for various years utilized different processing methods. Generally, analyses were processed for 30 km (18.6 mi) area around SARA at 30 m (100 ft) cells and processed for 1986-2006 land cover and land conversions. Resources included NPScape MDS (Svancara *et al.* 2009b), analyses by Wang *et al.* (2009), and National Land Cover Database (NLCD) and USGS NHD flowlines. It should be noted that the Wang *et al.* (2009) report contained land cover change analyses from 1973-2001. Due to changes in resolution in 1973 versus 1986 (changed from 100 m cell to 30m cell, respectively) we reported analyses only from 1986-2001 from this study.

Impervious Cover and Road Ecology
Impervious cover was calculated as percentage of impervious coverage using NLCD 2001 spatial data. Resources included NPScape MDS (Svancara *et al.* 2009a, b), National Land Cover Database (NLCD) and USGS NHD flowlines. Buffer distances from roads were used to assess road ecology, including measures of patch area and distance from road edges. Patch area was processed for 30 km (18.6 mi) area around SARA for 30 m (100 ft) cells and projected for major and minor roads (Svancara *et al.* 2009b). The NPScape Project mapped patch area using distances from >500 m from major roads and >500 m (1640 ft) from all roads. Resources for this analysis included NPScape MDS (Svancara *et al.* 2009b). A separate road analysis was incorporated at 100 m (328 ft) from road edges within and surrounding SARA to assess possible ecological effects resulting from roads.

Viewshed Analysis
Visually sensitive parcels surrounding SARA were analyzed and mapped for Saratoga National Historical Park (Saratoga P.L.A.N. 2007). Digital elevation models and forest layers of the USGS National Land Cover Dataset were used to assess the local land use regulations of the towns of Saratoga, Stillwater, Northumberland, Greenwich, Easton and Schaghticoke, NY in order to rank the efficacy of individual land use regulations to protect and preserve the visual landscape for SARA. Refer to The L.A. Group (2006) and Saratoga P.L.A.N. (2007) report for detailed methodology used for parcel mapping and categorization of parcels.

Reference Condition/Threshold Values Utilized

Population, Housing and Land Cover Change
Condition categories were not established for population, housing and land cover change. However, it is recognized that these factors are stressors on natural resources. Through the NPScape project,

these data offer a representation of regional scale changes for areas within and surrounding SARA. Historic and modeled future projections were used to assess population and housing trends surrounding SARA. Land cover/use for SARA was discussed by using data which explained the type of land cover and land use conversion occurring around SARA in Saratoga County and neighboring Washington 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 SARA was assessed using a threshold of 10% impervious surface. 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 *good*, imperviousness cover in a Maryland watershed could not be greater than 10%. Likewise, Schiff and Benoit (2007) found water quality and habitat quality declined as impervious surface areas increased from 0 to 10%. For the purpose of this assessment, impervious cover <10% was categorized as *good*, 11-25% *caution* and 26-100% as *significant concern*.

Patch area calculations and buffer distances from roadways within and surrounding SARA 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 SARA's grasslands, forests, wetlands, and streams within the park, we assessed this as *caution*. We did not assign a *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 *good* was assigned.

Viewshed Analysis

Viewshed analysis thresholds were based on a ranking criteria established in a viewshed analysis report for Saratoga P.L.A.N (2007) by Dodson Associates and The L.A. Group (2006). Ranking criteria were used for parcels surrounding SARA to determine visually sensitive parcels. Using a scale of 1-4, with 1 identifying the parcels of most significant concern for altering the viewshed, the ranking established included:

1-high priority; 2-high/medium priority; 3-medium priority; 4-medium/low priority; and limited agricultural development.

Condition and Trend

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

Population, Housing and Land Cover Change

Population per km^2 surrounding SARA in both Saratoga County and Washington County will continue to increase through 2030 based on projected models (Figure 4.28). Total population within the 30 km study area has increased since 1950 and is projected to continue to increase until 2030. Washington County's total population also increased for these time periods. Population density (log population/km^2) increased since 1950 and is projected to continue to increase until 2030 for both Saratoga and Washington Counties.

Housing development has increased around SARA from 1950 to 2010 (Figure 4.29). An example of this growth can be appreciated for the Town of Stillwater. Stillwater had increased by 9.7% in housing and 4% in population from 1990-2000 (U.S. Census Bureau) and within 5 years the land cover change from 2001-2006 was predominantly *medium and high intensity development* (Figure 4.30). Because the average household size is decreasing, the number of housing units will continue to grow at a faster rate than expected based on population changes alone (Saratoga P.L.A.N. 2007). Development has been projected to reach > 2,470 units/km^2 by 2050 in some areas greater than 10 km (6.2 mi) from SARA, as well as experiencing commercial/industrial development (Figure 4.29). Currently, the heaviest development closest to SARA's boundary is northeast of the park. SARA will continue to experience housing expansion to the west and south of the Battlefield Unit by 2050, although within a 1 km (0.62 mi) and 5 km (3.1 mi) buffer of SARA, housing projection models have forecasted no change in housing unit development as areas directly outside SARA will average an approximate capacity of 1-24 units/ km^2 in 2030 and 2050 (Figure 4.29). Historic and current land conservation efforts decrease the future efforts of housing expansion surrounding SARA. Additionally, natural features in the environment, such as hydric soils, slopes, bedrock and wetlands may deter development for miles around small sections SARA.

Changes in land cover within and surrounding SARA are evident from 1986 versus 2001 (Table 4.31). Specifically, deciduous forests decreased 10%, coniferous forests declined 11% and mixed forest types decreased by 26% within 5 km of SARA's boundary (Wang *et al.* 2009). Within SARA, deciduous forests and mixed forests declined 39% and 33%, respectively while coniferous forests increased. Urban land increased 26% in areas surrounding SARA (Wang *et al.* 2009). Although urban land may not significantly increase in future years within SARA's boundaries, urban land is projected to increase in areas surrounding SARA based on projected population and housing estimates. Surrounding land conservation and preservation efforts near SARA assist in keeping land cover change minimized, although some parcels of land may be subjected to land conversion.

Land cover types from natural to converted forms were analyzed from 1992-2001. From 1992 through 2001, SARA land cover remained natural or experienced very small isolated areas of conversion. Land cover conversions outside of park boundaries were agriculturally influenced (Figure 4.30). From 2001-2006, small sections of land cover change occurred within SARA, which included pasture hay to cultivated land and scrub/shrub to grassland (Figure 4.31). The largest land cover change outside of SARA from 2001-2006 is directly east of SARA across the Hudson River in

Washington County, where agricultural activities are evident due to changes in cultivated and pasture/hay land cover (Figure 4.31). Washington County has a rich agricultural history and is the only remaining region of this agricultural infrastructure in the Hudson Valley, as this area is part of the Agricultural Stewardship Association (Saratoga P.L.A.N. 2007). South and southwest of SARA, 2001-2006 land cover changes included development activities from low to high intensity development and north of the Old Saratoga Unit included conversion to medium intensity development (Figure 4.31).

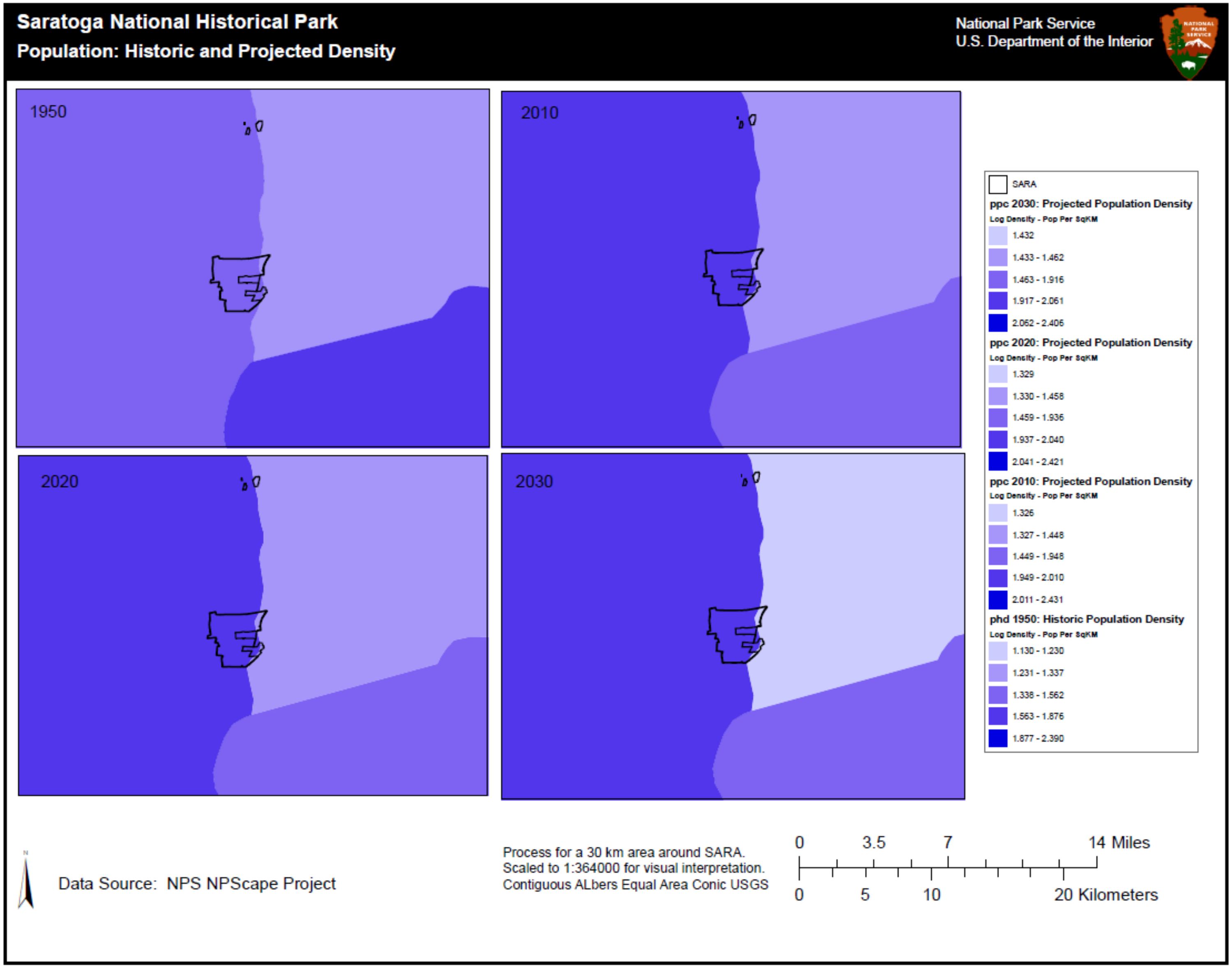


Figure 4.28. Historic and projected population density (log density, population per km^2) surrounding SARA for 1950, 2010, 2020 and 2030.

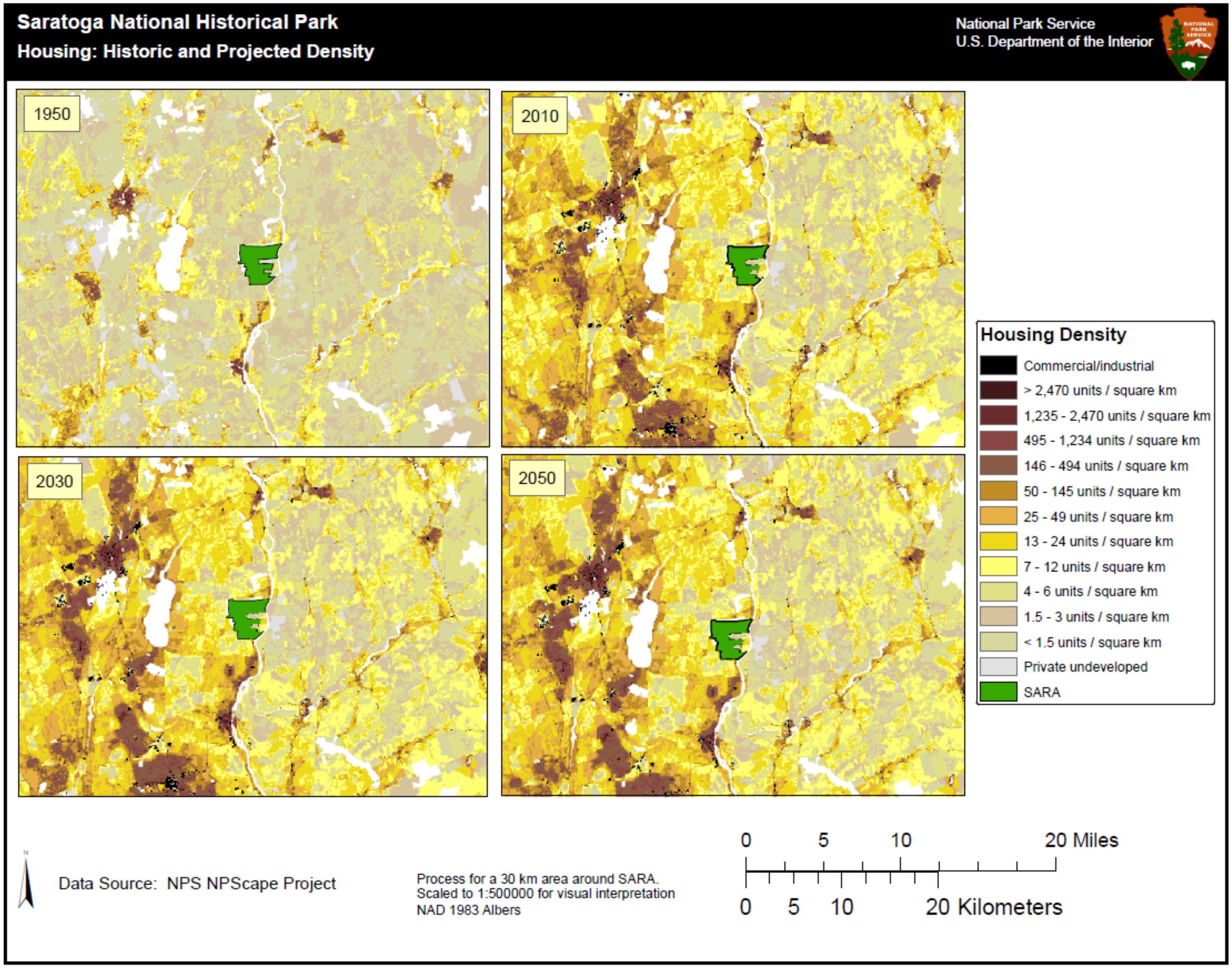


Figure 4.29. Historic and projected housing density (units/ km^2) surrounding SARA for years 1950, 2010, 2030 and 2050.

Table 4.31. Percent change in acreage of each land cover type within the SARA boundary and an adjacent 5-kilometer buffer zone from 1986 verses 2001 based on land cover analysis by Wang *et al.* (2009).

Land Cover	**Percent Acreage Changes Within SARA Boundary**	**Percent Acreage Changes Within SARA Boundary and adjacent 5 km buffer zone**
	1986-2001	**1986-2001**
Urban	-8%	26%
Deciduous Forest	-39%	-10%
Coniferous Forest	31%	-11%
Mixed Forest	-33%	-26%
Water	-83%	-9%
Wetland	7%	0%
Herbaceous Vegetation	24%	13%

Agricultural fields surround sections of Saratoga National Historical Park. Photo: R. Wagner (November 12, 2010).

Future land cover changes will likely occur in order to support population growth in Saratoga County, NY. Interstate 87 is facilitating growth within Saratoga County and this growth is converting agricultural land to residential use. Additionally, Washington County, an important component of SARA's viewshed, may experience real estate and development pressures due to its proximity to expanding communities. Urban development suitability is limited when the following environmental constraints are present: wetland areas, floodplains, depth to bedrock of 0-20 in (0-51 cm), depth to water table 0-2 ft (0-61 m) and slopes over 20%. Areas which are suitable for potential residential dwelling units due to the unconstrained environment exist adjacent to SARA (The Chazen Companies 2005) (Figure 4.32). Some of the unconstrained areas adjacent to SARA are now conserved parcels, particularly to the north and east of the Battlefield Unit, but areas to the west and south of SARA are vulnerable to residential development based on the availability of unconstrained land (Figure 4.32). Development in these unconstrained areas will increase pressure on SARA's landscape, altering the light- and soundscape and reducing the overall quality of natural resources due to anthropogenic effects (e.g., increased ozone levels from exhaust, road salt, impervious surface increase, water contamination, increased invasive plant species from landscape disturbance).

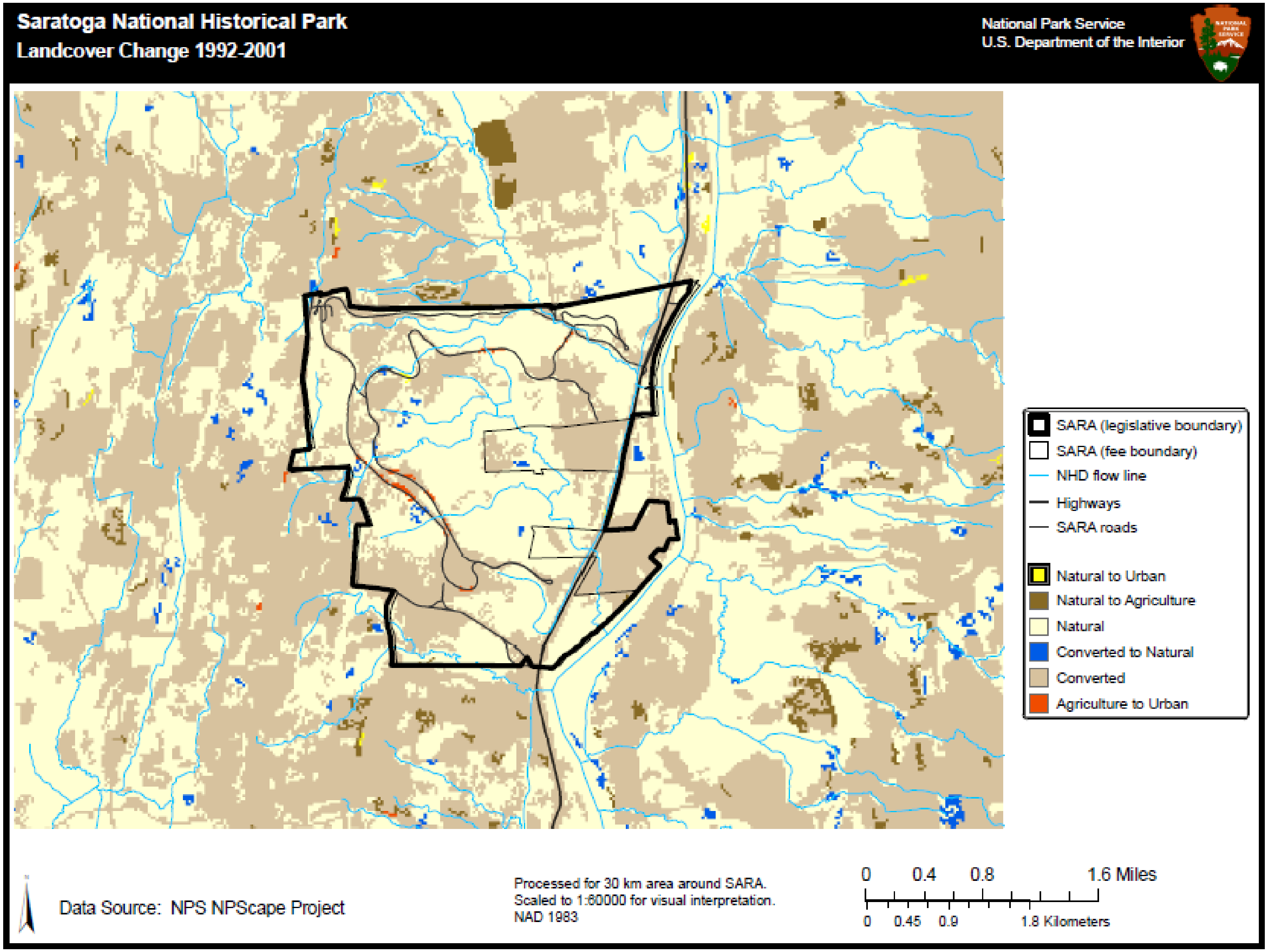


Figure 4.30. Land cover changes detected from 1992 to 2001 for land surrounding SARA's Battlefield unit.

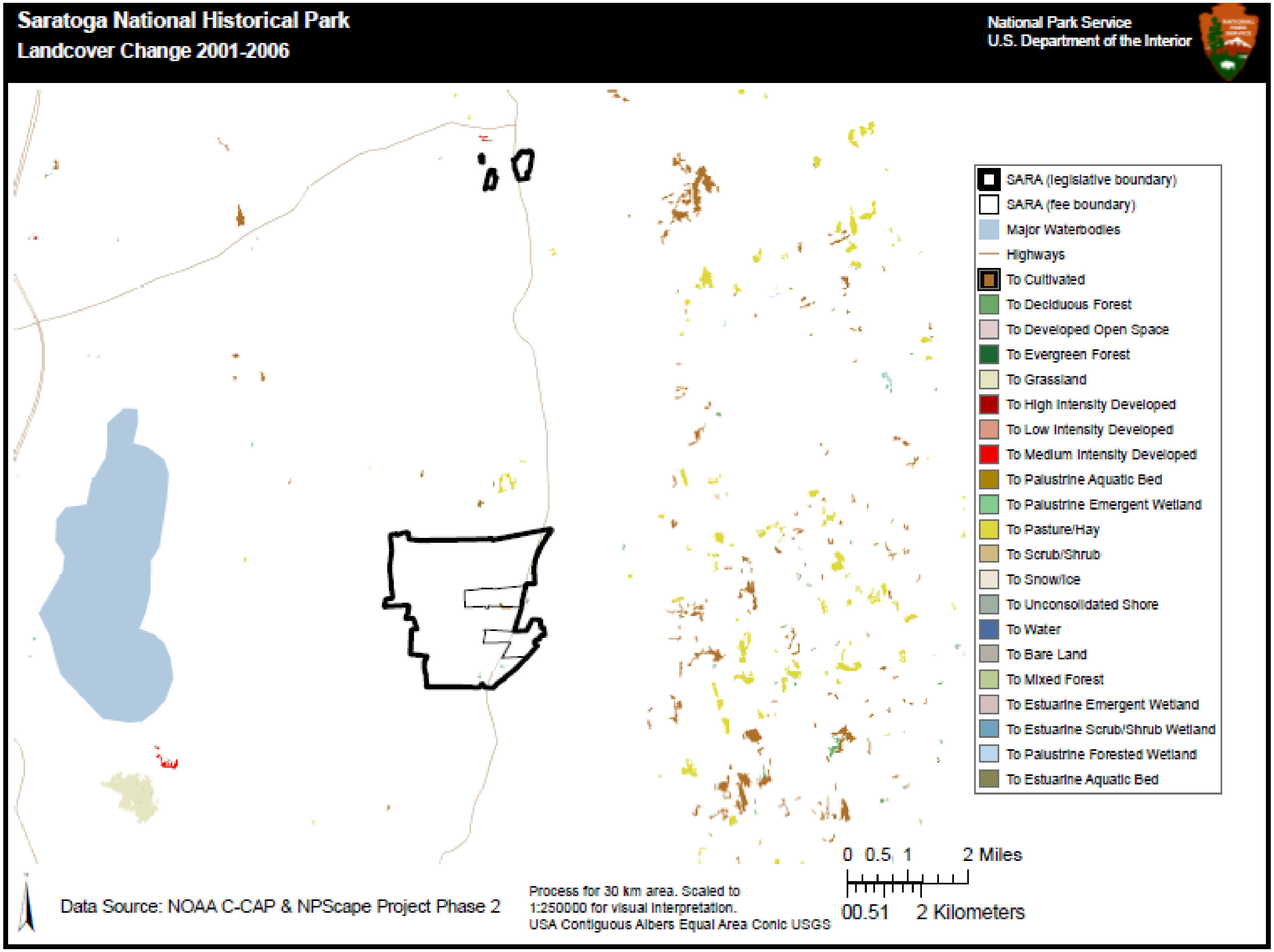


Figure 4.31. Land cover changes detected from 2001-2006 for areas surrounding SARA.

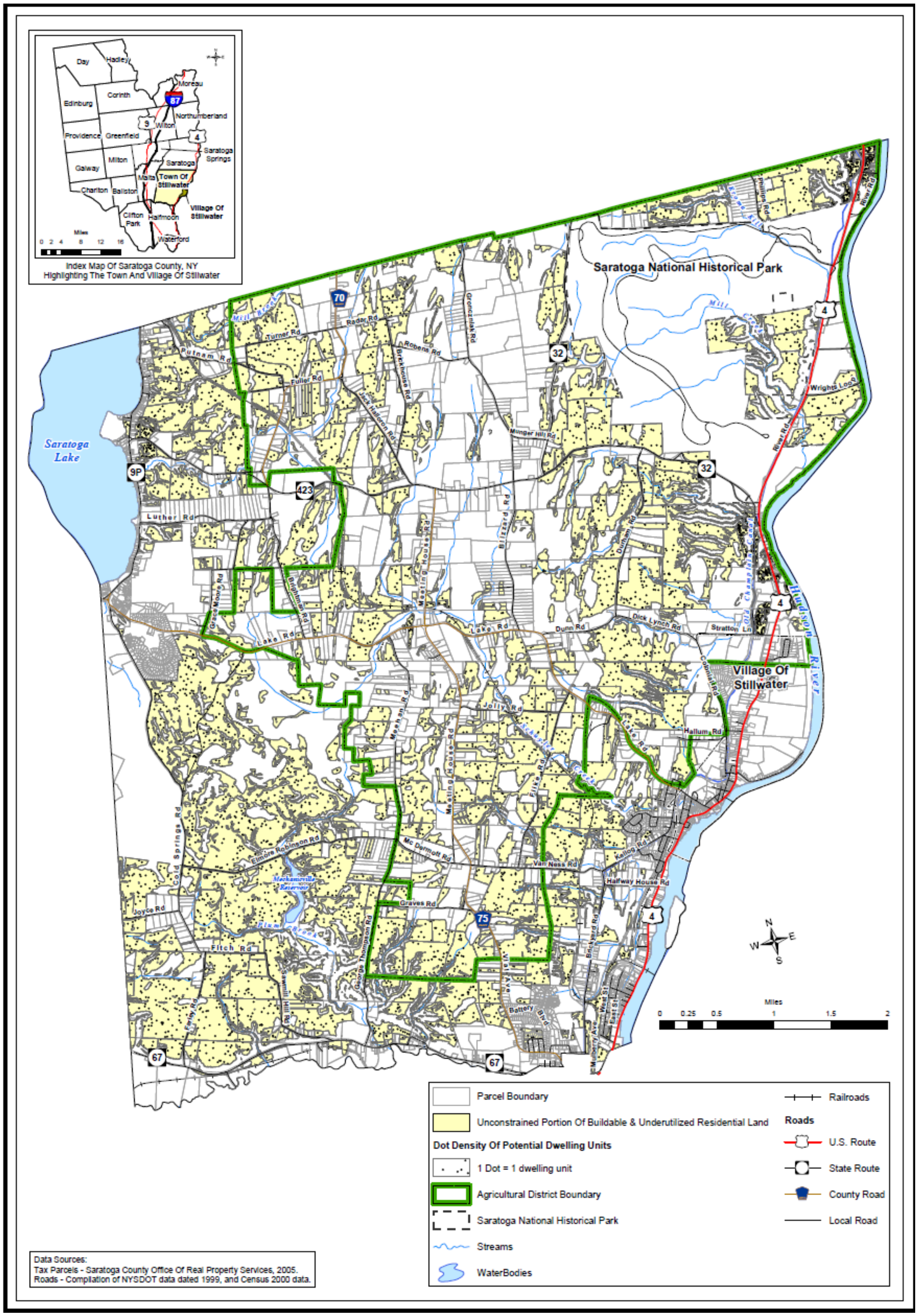


Figure 4.32. Dot density map showing potential dwelling units in the unconstrained portions of buildable residential land. From The Chazen Companies (2005).

Impervious Cover and Road Ecology

Within SARA boundaries, sources of impervious surface include small parking lots and roads traveling to the various tour stops in the park. Overall, the amount of impervious surface within the SARA Battlefield Unit is less than 10% highly developed impervious cover, rating the park g*ood* (Figure 4.33). Although this is within the threshold values for this report, small sections of impervious surfaces close to waterways can reduce water quality conditions (i.e., vehicle byproducts, thermal influences) for SARA's aquatic habitats. For example, Highway 4 in the eastern portion of SARA contributes the largest contiguous percentage of impervious surface (50-100%) to the park. These roads can affect the Champlain Canal and part of Mill Creek. Additionally, NY 32 runs through portions near SARA and Kroma Kill. The most extensive impervious surface is north of the main battlefield near the Saratoga Monument and Victory Woods (50-100%) due to the established towns of Victory Mills/ Schuylerville.

The connection of patch areas of natural habitats within and surrounding SARA was dependent on the type of road and distance from roads. Patch areas within the Battlefield Unit ranged from 0-10 km^2 (0-4 mi^2) when spatially analyzed >500 m (1640 ft) from all roads within and surrounding SARA. However, the same patch area expands in SARA to 10-50 km^2 (6-31 mi^2) when analyzed >500 m (1640 ft) from only major roads (Figure 4.34). 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 SARA. The presence of 'smaller roads', such as tour roads in SARA, have substantially decreased patch area and may affect activities of biota, such as amphibian and reptile migration to and from waterbodies. Decreasing patch area is commonly due to the result of urban development, which can decrease habitat quantity and quality due to the alteration of landscape patterns and loss of connectivity. Connectivity to key areas outside of NPS boundaries is vital to preserving habitat integrity and movement activities of animals and should be considered when evaluating conservation efforts of natural resources. Expansive habitats in SARA, such as wetland complexes outside the east and southeast fee boundary section of the park, have been disconnected by roadways, particularly Highway 4 (Figure 4.34). These wetlands near the Champlain Canal serve as breeding habitats for a variety of species important to the biological composition of SARA (e.g., water birds, amphibians, reptiles, emergent vegetation) and should be managed as habitats which serve as a resource for providing biological richness to SARA.

Based on a 100 m spatial analysis of roads in the park, SARA was categorized as *caution*. A buffer of 100 m extends into SARA's grasslands, forests, wetlands, and streams within the park, potentially affecting species distribution or ecosystem function (Figure 4.35). The impact of roads on ecological communities has been extensively studied for a variety of species. Ecological effects due to roads include but are not limited to: affecting grassland bird populations due to noise traffic, invasive plant spread, increased wildlife mortality, reduction in amphibian and reptile movement, and chemical pollution to aquatic and terrestrial environments (Forman and Alexander 1998, Forman *et al.* 2002, Van Bohemen *et al.* 2003, Flory and Clay 2006, Eigenbrod *et al.* 2009).

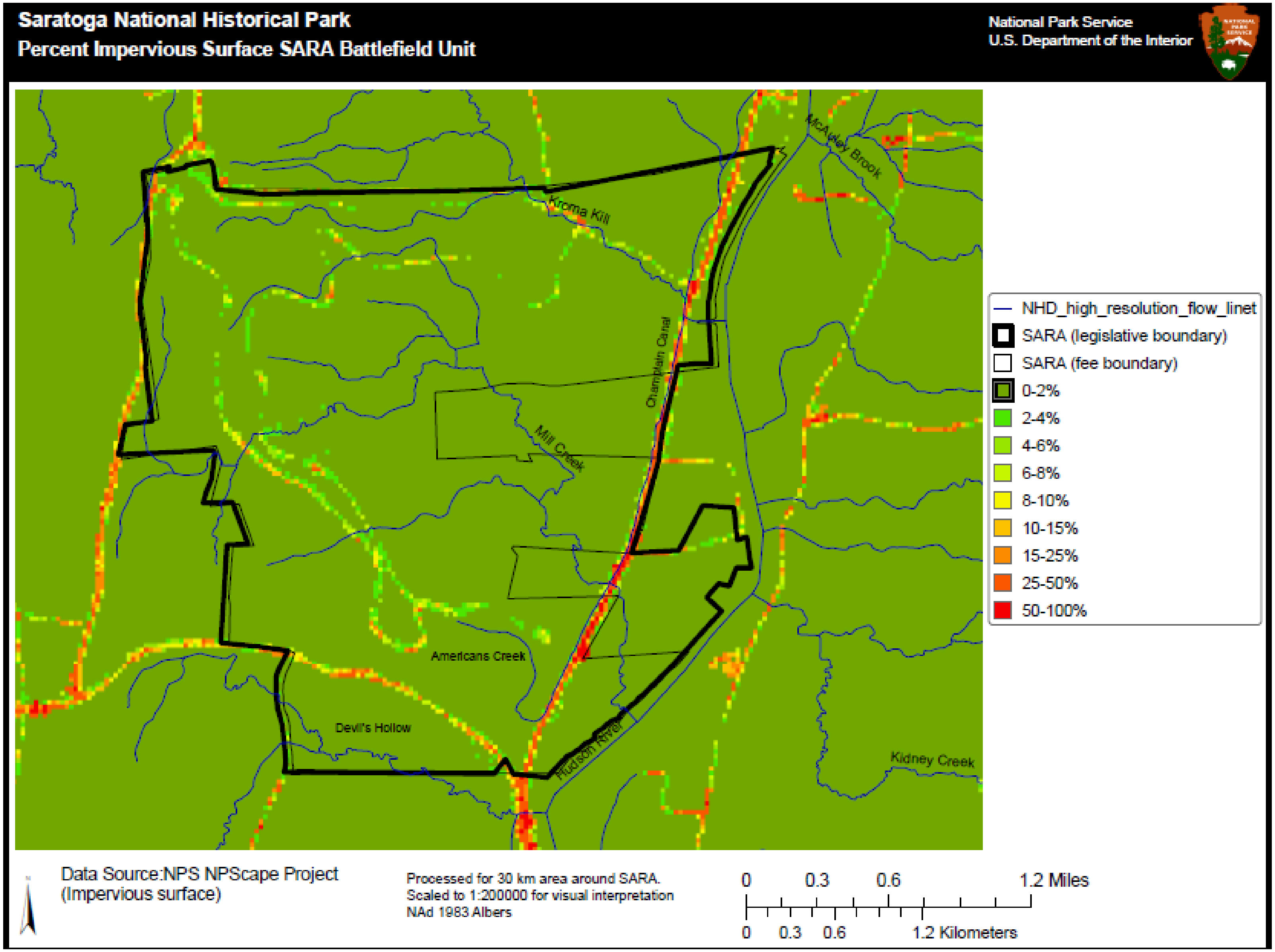


Figure 4.33. Percent impervious surface (0-100%) within HUC 12 watersheds surrounding SARA Units.

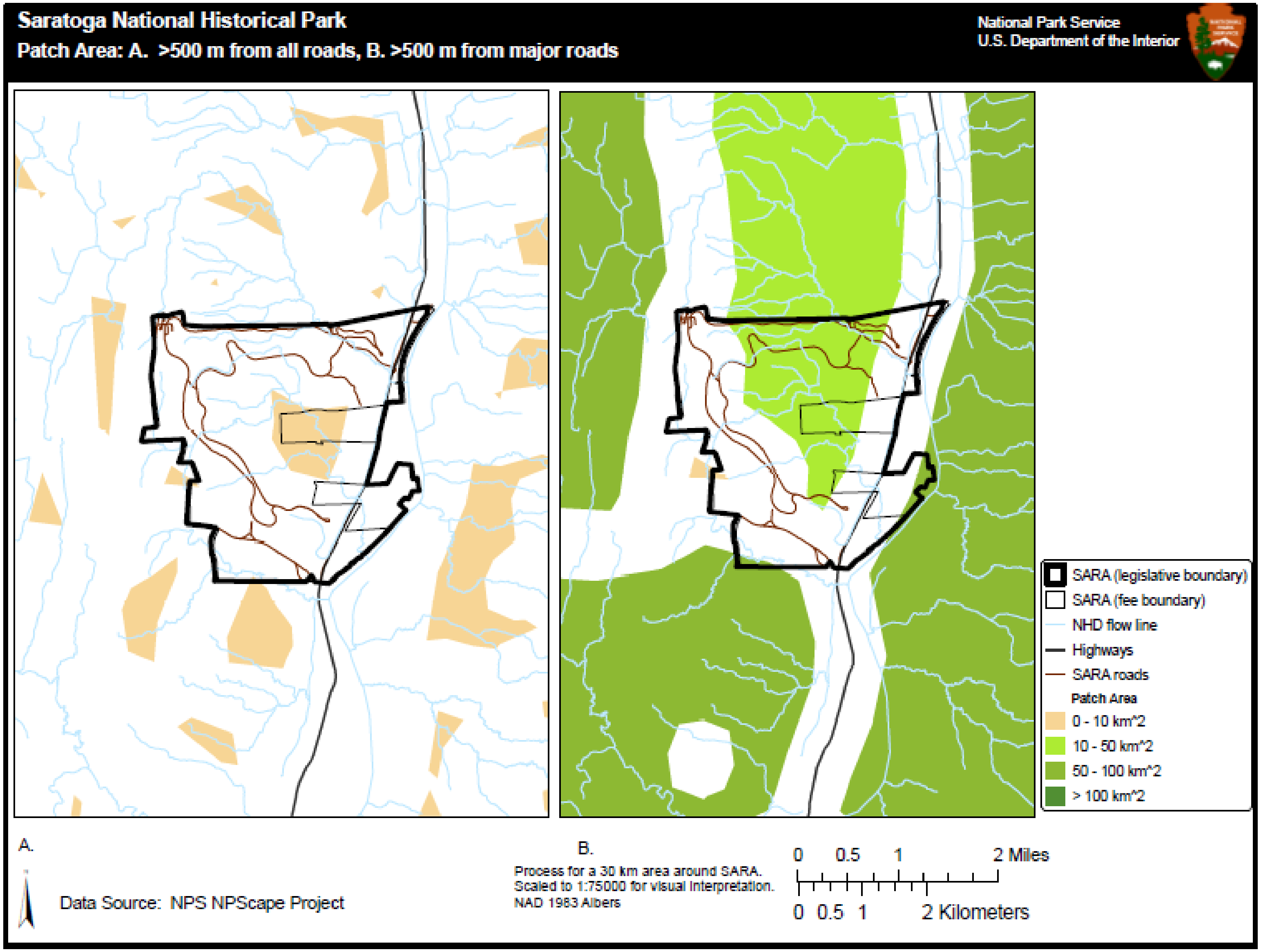


Figure 4.34. Patch area calculated from (A) >500m from all roads and (B) >500 m from major roads within and surrounding SARA's Battlefield Unit.

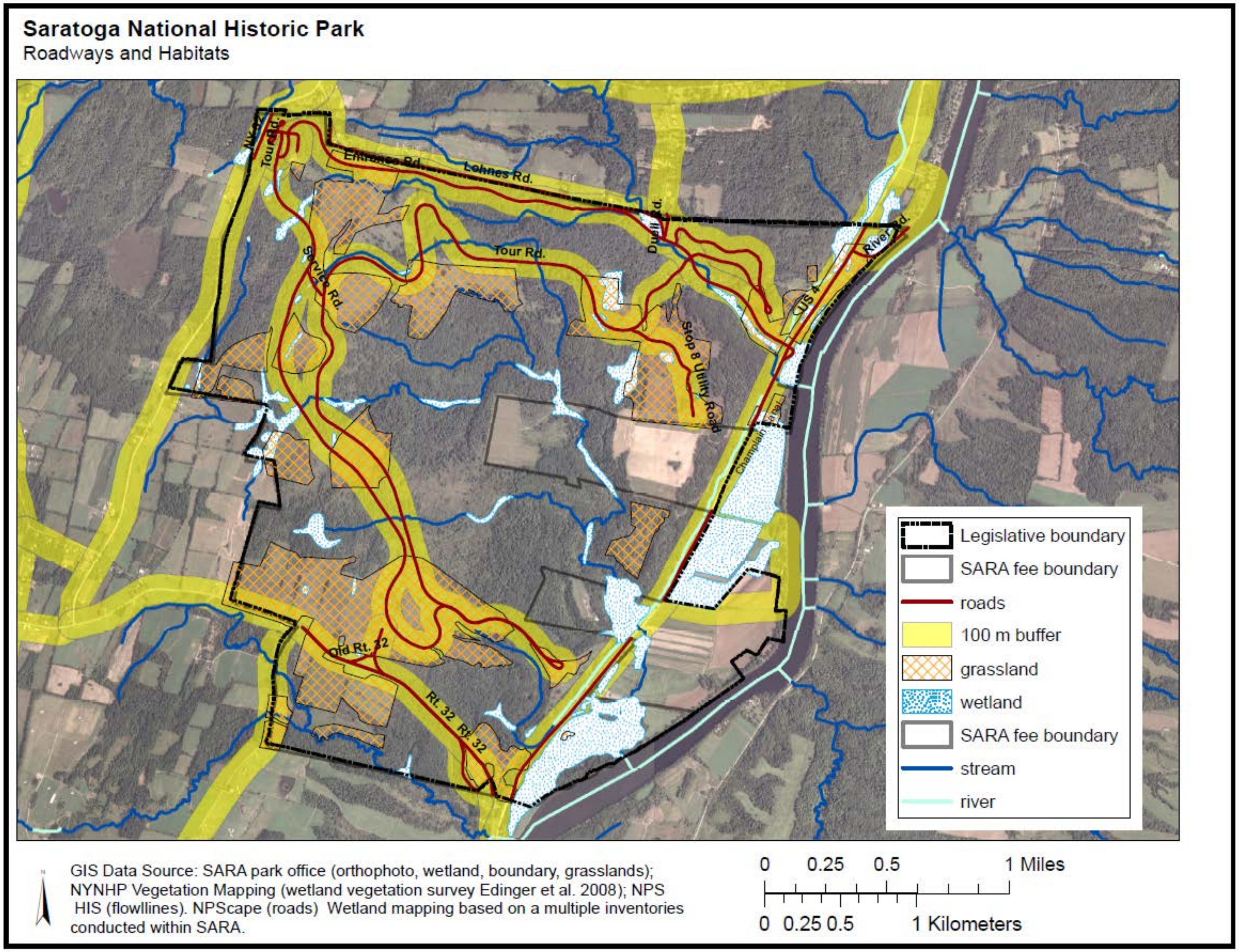


Figure 4.35. 100 meter buffer around roads within and surrounding SARA in relation to terrestrial and aquatic habitats.

Viewshed Analysis

Viewshed from Saratoga National Historical Park facing the Hudson River toward Washington County, NY. Photo: R. Wagner (November 12, 2010).

Land parcels were identified around SARA that were considered visually sensitive based on current land use controls and were prioritized according to historic, viewshed and scenic values (Figure 4.36, 4.37). The majority of parcels assesses in all three counties surrounding the park's viewshed were categorized as *medium/low* priority (Table 4.32). Eighty parcels (5.5%) were rated as *high* priority and 225 (15.4%) parcels were rated *high/medium* priority in terms of risk of viewshed alteration around SARA (The LA Group 2006) (Table 4.32). The 80 parcels around SARA are large, farming (agriculturally leased) or vacant parcels, which, if developed, will affect the historical viewshed of SARA. Several parcels close to SARA are categorized as Limited Agricultural District, which are preserved strictly for agricultural use under various protection methods (e.g., Saratoga County Purchase Development Rights Program). In Washington County, 65 (11%) parcels were rated the highest priority as they are in the foreground of SARA's viewshed (The LA Group 2006). Any development to the land located above the ridgeline of the Hudson River in Washington County (i.e., cell phone towers, buildings) can degrade SARA's viewshed. Because of conservation efforts, some of these lands have been preserved due to agricultural easements. Rensselaer County contained no parcels at *high* priority risk for development. Due to authority limitations of NPS, land use planning by NPS beyond SARA boundaries is limited, but viewshed preservation remains important to preserving the natural and historic integrity of SARA.

Data Gaps and Confidence in Assessment

Average confidence for the variables assessed in this section was *medium* and confidence in trend was *medium*. Using projected modeling estimates is an advantageous method to forecast changes within areas around SARA. 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. Since SARA is situated in a county experiencing rapid growth and land alterations, further studies and monitoring efforts of landscape connectivity within SARA and the park's adjacent environment will provide insight on conservation and preservation needs for SARA's natural resources, particularly during park and township planning and development processes.

Table 4.32. Descriptive statistics and rankings calculated for visually sensitive parcels surrounding SARA for Saratoga, Washington and Rensselaer counties. Ranking categories and results reported initially in the Saratoga P.L.A.N (2007) and The LA Group (2006) reports.

County	Ranking	Towns/Villages	Number of Parcels	% of Total # of Parcels	Amount of Land Area (acres)	Developable Land Area (acres)
Saratoga	1-high priority	Saratoga, Stillwater, Schuylerville, Victory Mills & Stillwater	80	5.5%	3358.8	2227.2
Saratoga	2-high/medium priority	Saratoga, Stillwater, Schuylerville, Victory Mills & Stillwater	225	15.4%	4095.3	2874.8
Saratoga	3-medium priority	Saratoga, Stillwater, Schuylerville, Victory Mills & Stillwater	549	37.6%	6122.0	4445.2
Saratoga	4-medium/low priority	Saratoga, Stillwater, Schuylerville, Victory Mills & Stillwater	595	40.9%	2183.1	1381.4
Saratoga	Limited Agricultural Development	Saratoga, Stillwater, Schuylerville, Victory Mills & Stillwater	10	0.68%	857.8	313.9
Washington	1-high priority	Easton & Greenwich	65	10.8%	3702.6	2280.6
Washington	2-high/medium priority	Easton & Greenwich	91	15.1%	5677.3	3738.4
Washington	3-medium priority	Easton & Greenwich	156	26.4%	3287.7	1933.3
Washington	4-medium/low priority	Easton & Greenwich	278	47.1%	1267.2	780.7
Washington	Limited Agricultural Development	Easton & Greenwich	9	1.6%	1258.5	170.9
Rensselaer	2-high/medium priority	Schaghticoke	1	10.3%	2.8	0.0
Rensselaer	4-medium/low priority	Schaghticoke	10	89.6%	23.8	15.3

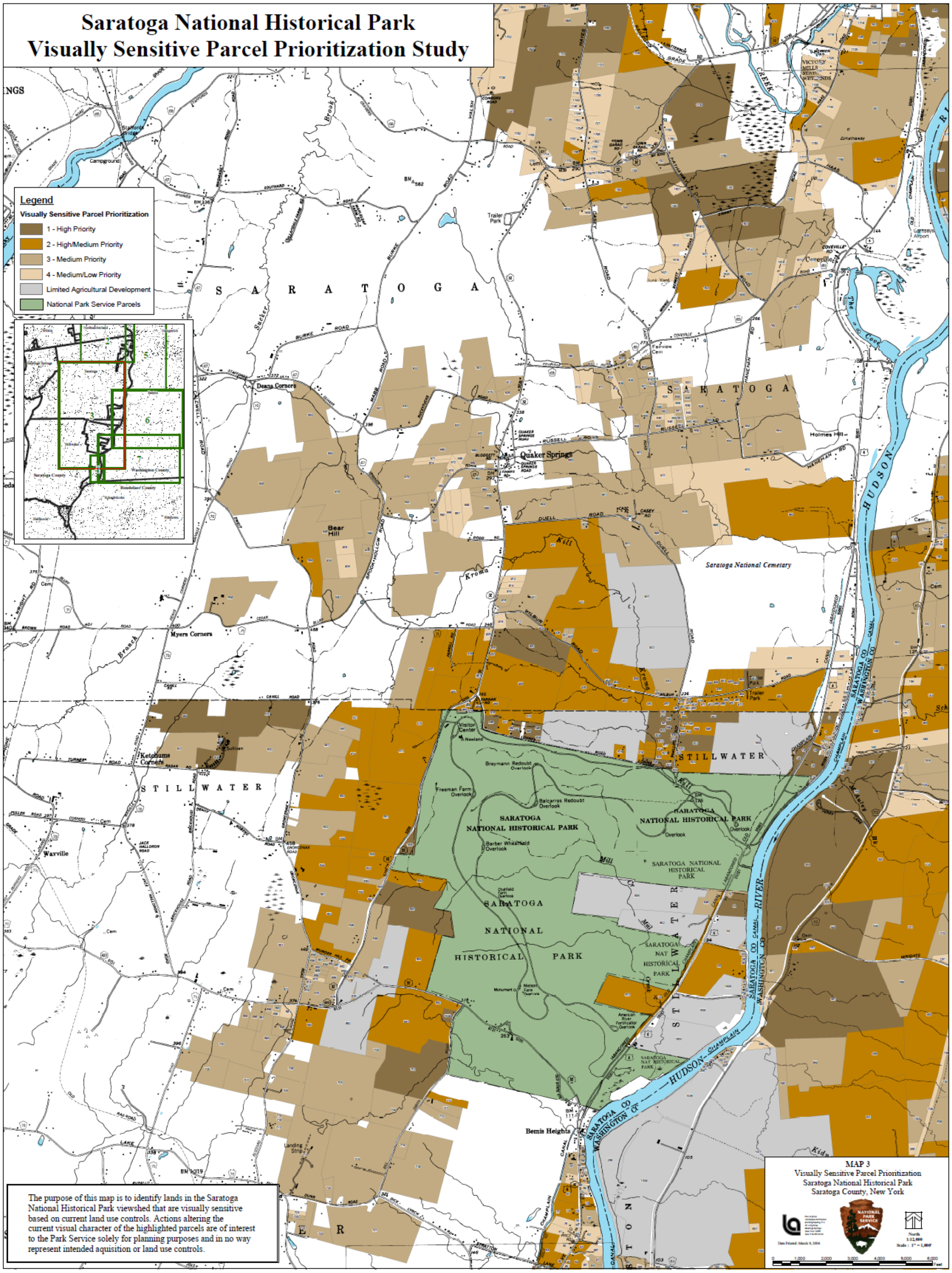


Figure 4.36. Areas surrounding SARA Battlefield Unit which have been identified as “visually sensitive parcel prioritization”. Analysis by The L.A. Group (2006) and prepared for by Saratoga Plan (2007) by Dodson Associates.

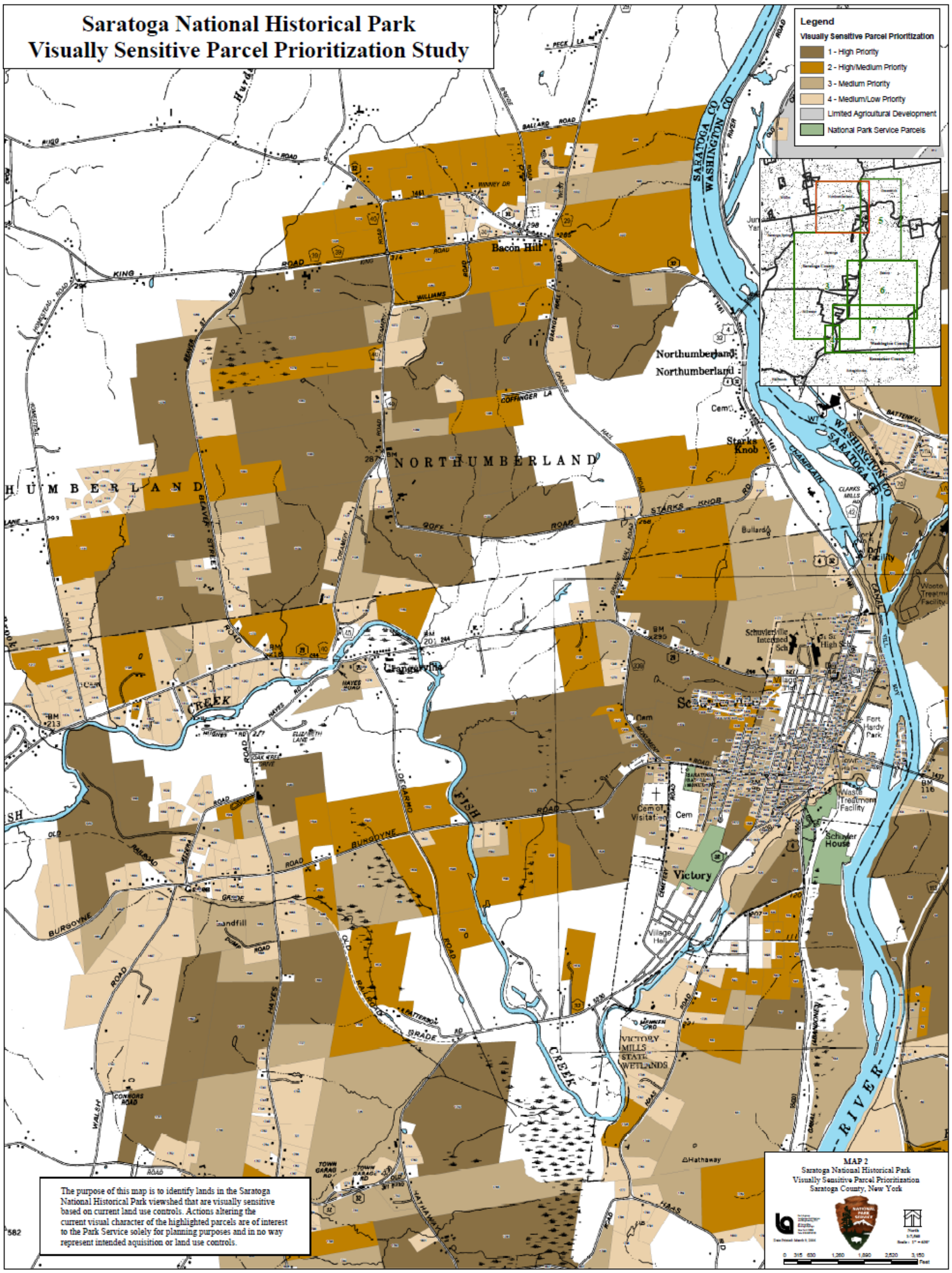


Figure 4.37. Areas surrounding Old Saratoga Units which have been identified as “visually sensitive parcel prioritization”. Analysis by The L.A. Group (2006) and prepared for by Saratoga Plan (2007) by Dodson Associates.

Chapter 5 Discussion

SARA is located near the southern extent of the Adirondack Mountain region in New York's upper Hudson River Valley. Regionally, SARA is within an area which is growing rapidly in population, facilitated by Interstate 87 (The Northway). Many development pressures are shielded by Saratoga Lake located to the west of the SARA's main battlefield unit. To the east, SARA is bordered by the Hudson River, long known for its water quality problems, especially with PCB's (polychlorinated biphenyls). Although SARA is a small cultural park, it operates as a biological refuge near an expanding suburban/urban environment for many resident and migratory species. Lands surrounding the park are rural/agricultural in character, but may change in land use due to development. 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. SARA's mosaic landscape of fields, grasslands, mature forested areas and streams, wetlands, rivers and floodplains are not exempt from these impacts.

Table 4.33 provides a summary of SARA'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. It is imperative that SARA park personnel continue their interaction with local and regional entities to make sure that the park's interests are known and included in local and regional planning efforts. The adjacent threats and stressors to SARA becomes 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 fully assess management actions and thus, park personnel are hindered in their management of 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 SARA not only for their ecological value but for their historical significance (e.g., SARA's vegetation is part of the park's historic battle structure).

Air quality is very difficult for the park to manage 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, such as what is already established for ozone monitoring. Specifically, the park should work towards developing visibility monitoring stations within its boundaries since viewshed is an important cultural objective for the park. Secondarily, a monitoring program for wet deposition of sulfur and nitrogen, as well as mercury would also be beneficial for investigating these contaminates 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 slightly impacted within SARA, likely from increased levels of acid precipitation. The impacts to SARA 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 SARA.

Impacts to water resources are more of a local issue compared to air resources, and thus it is more likely that SARA personnel can respond to changes in water quality in the park (although some impacts occur within the watershed outside of park boundaries). SARA has a diverse hydrological system of streams, wetlands and springs. The determination of stream quantity needs or identifying a stream quantity threshold for SARA should consider the management objectives for SARA's surface waters (e.g., to maintain fish and macroinvertebrate communities, conserve a threatened species, recreational value, cultural restoration). There is no stream gaging station within the park making baseline reference hydrology unknown. 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. SARA should work with the USGS, NETN and local conservation entities and universities to instate a gaging monitoring program at either Kroma Kill and/or Mill Creek. In addition to a gaging station, SARA 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. Depending on the water sampling 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 SARA. 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. This is currently being demonstrated in SARA with the monitoring of mercury methylation in several vernal pools within the park. Any wetland complexes adjacent to park boundaries should be proactively conserved as these environments benefit the park's wildlife community and enhance landscape connectivity. Lastly, SARA's environment has been exposed to a legacy of PCB contamination and it is possible that environmental receptors in SARA are stressed due to this historical contamination.

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 SARA vulnerable to invasion, yet sampling frequency is too low to make an adequate 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 SARA's watersheds. SARA 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 SARA's terrestrial ecosystems will provide valuable temporal data useful for management actions. Knapweed management should rigorously continue in the park. At the present, areas such as wetlands within SARA are unassessed while forest systems within SARA are systematically sampled for invasive species.

Forest health issues in SARA are present, as pests and abundances of snags and coarse wood debris remain some of the forest health issues in the park. SARA personnel need to inspect for the emerging population dispersion of the emerald ash borer as well as the spreading of beech bark disease which currently afflicts the park's historical trees. 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.

SARA contains a diverse wildlife community due to a landscape matrix of streams, wetlands, grasslands and forests. SARA's fish community data was sparse and analysis was thereby limited. Fish communities need to be sampled on a 5-year basis in order to develop some understanding of trends. The forest bird community in SARA was overall good in composition but remains unstable in terms of its structure and function. Bird species status varied with their need for intact interior forest. Results indicate that the forest bird community at SARA may be affected by the generally fragmented landscape consisting of small forest blocks broken up by fields and early successional habitats, plus experiencing the effects of deer on understory vegetation structure. At a regional level, SARA grasslands are considered a high priority in the region because of the high abundance of grassland obligates it supports. The grassland IBI used to assess SARA's bird community is new and will probably be adjusted over the coming years to better reflect condition. Since SARA currently contains a high palatable and high density vegetation structure, current quantification of deer densities within the park and adjacent areas would assist in assessing the effects of white-tailed deer on herbivory. Further investigation of white-tailed deer herbivory may also identify if oak regeneration in SARA is due to deer browsing, as NETN monitoring found oak regeneration rare in SARA. It is difficult to assess amphibian and reptile populations within SARA of due to a lack of quantitative historical data for SARA. The park contains species which are considered to be of special concern and it is likely that increasing the ecological integrity of wetlands and streams and preserving adjacent riparian areas would benefit these populations.

Finally, SARA is located in a setting where development will continue to expand towards the park and within the park's viewshed. 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. Keeping external impacts secluded from SARA 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.

5.1 Potential Natural Resource Indicators to Assess in SARA

Natural resource vital signs monitoring is a long-term survey and analysis of data 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 rational for management actions within the park. NETN vital sign indicators have been used in this NRCA to characterize the status and determine trends of

SARA'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 SARA. 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 SARA'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 recognize 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 SARA's natural resources but are not listed below since they have been recognized by NETN staff. These indicators include: Wetland Communities, Visitor Use, Landscape Dynamics, Phenology and Weather and Climate (http://science.nature.nps.gov/im/units/netn/monitor/monitoringprotocols_vital.cfm).

5.1.1 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.

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 SARA. 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.

5.1.2 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. SARA 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. These 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. Because SARA has smaller tributaries 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 versus multiple years for fish and thus macroinvertebrates can integrate the physical, chemical and biological environment in a shorter time period than fish. 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 (Barbour *et al.* 1999, Rosenberg and Resh 1992). 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 macroinvertebates 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 requires laboratory processing.

5.1.3 Biological Integrity

Focal Species

Grassland Plant Communities

Grasslands are declining in regions throughout the northeastern U.S. due to land use alterations such as farming and suppression of fire. The grassland communities in SARA are maintained primarily for their cultural value in interpreting the historic landscape. However, these habitats in SARA are an important resource for a variety of species. The native grasses provide valuable habitat for ground-nesting birds and a variety of mammals, and their structure, composition, and management affect what fauna use this habitat type. The grasslands in SARA are of particular importance to bird species (Trocki and Paton 2005). Grassland bird populations are declining throughout North America at a dramatic rate (Vickery *et al.* 1999). The importance of SARA to obligate grassland species was formally recognized when SARA was designated as a New York State Important Bird Area, primarily due to presence of many obligate grassland bird species (Wells 1998). Field vegetation at SARA is dominated by brome grass (*Bromus* spp.), goldenrod (*Solidago* spp.), bluestem (*Andropogon* spp.), sedges (*Carex* spp.), bedstraw (*Galium* spp.), and dogwood seedlings (*Cornus* spp.) but invasive vegetation has been established in these fields as well. Seventeen invasive species were detected in the park in 2003, several of which pose concerns for grassland field management. In particular, park natural resource staff have identified *Centaurea* sp. (knapweed) as the greatest threat to field management (Canham 2004). Invasive species encroachment into grassland habitats (particularly by knapweed) is a serious concern for park managers because the changes in vegetation structure and composition caused by the knapweed invasion may influence grassland bird species declines. Grasslands are most directly influenced by land management and each grassland field within SARA has a unique management history. Most grasslands have been subject to haying, burning, mowing and occasional manual shrub removal. They represent a transitional community, which if left unmanaged, will eventually revert to forest. Standard techniques are widely used for monitoring the structure, composition and dynamics of grassland plant communities and include the use of quadrats, transects, point intercepts, and others. Since grasslands are susceptible to exotic invasive plant species, their presence and spread should be monitored and controlled. In SARA, it will be important to assess changes in grassland plant communities and determine the need for management changes in order to enhance habitat value while still maintaining the cultural significance of these habitats.

Herpetofauna

Herpetofauna refers to the amphibian and reptile populations of a specific region, such as frogs, toads, turtles, salamanders, snakes, terrapins and lizards. Herptofauna 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 herptofaunal communities before they would in other sectors of the terrestrial ecosystem. Therefore, the health and diversity of herptofauna in SARA 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 (Blaustein and Wake 1990), changing climate (Rohr and Madison 2003), disease (Blaustein *et al.* 1994) and contaminants (Beattie and Tyler-Jones 1992). 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 (richness) are the commonly-used measures to describe herptofauna in forested ecosystems and Index of Biotic Integrity for amphibians have 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 herptofauna 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 herptofauna 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 SARA 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, SARA 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 (relative area coverage, e.g. m^2/ha) 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 SARA 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 SARA 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 SARA'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, grasslands and wetlands in SARA 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 SARA 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 SARA's ecosystem.

Mammals

Mammal assessments focus on target species including mesocarnivores (e.g., raccoon, stripped 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 SARA (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 SARA 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.

5.1.4 Landscape

Soundscape

The total ambient acoustic environment associated with a given environment in an area is referred to as the *soundscape*. Additionally, *s*oundscape can be defined as the human perception of those physical sound resources. The natural ambient sound level of a park is the natural soundscape of that park absent of any human-produced sound. In SARA, the soundscape is usually composed of both natural ambient sounds and an assortment of sounds made by humans. Natural soundscapes are considered to be an important part of the NPS mission: “sounds are intrinsic elements of the environment that are often associated with the parks and their purposes. They are inherent components of ‘the scenery and the natural and historic objects and the wildlife therein’ protected by the NPS Organic Act.” (Directors Order #47). 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 progressivly rarer (Jensen and Thompson 2004). Furthermore, natural soundscapes are important to the natural functioning of many parks and may be a valuable indicator for assessing ecosystem health (NPS 2013). Work by Lynch *et al.* (2011) found that soundscapes in National Parks are under many threats either through activities within parks or from sound production outside parks. Noises which impair the soundscape can originate from a number of sources, including motorized equipment such as boats and snowmobiles, aircrafts, adjacent land uses, general park operations (e.g., mowing), increased visitor use and highway traffic. The idea that soundscapes acoustically represent specific landscapes has led to the notion that soundscapes can offer insights into ecological quality or integrity of an area (Krause 2002, Pijanowski *et al.* 2011). Behavior and reproductive success of all vertebrates may be influenced by increased noise.

Soundscape can affect wildlife in a number of ways, such as by influencing animal communications, affect territory establishment, courtship and mating, nurturing young, predation and predator avoidance. Increased noise can adversely affect not only individual species but populations of species. Natural soundscape alterations may be especially significant for amphibian bird and bat populations in SARA.

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 SARA. In 2000, Director's Order 47 specified how parks should monitor and plan to protect park acoustical environments. NPS Management Policies (NPS 2006, 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. Pijanowski *et al.* (2011) demonstrated that acoustic diversity and temporal acoustic patterns of soundscapes can be compared across multiple land use types. Sound level meters, digital media storage devices and noise modeling software can be used to record and predict sound levels when measuring the frequency and magnitude of human-caused sounds and the cultural and natural soundscape features. Understanding the status and trends in SARA's soundscape will assess the need, if any, for management and restoration efforts.

Lightscape

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). 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, and 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).

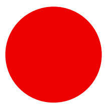
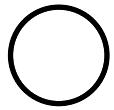
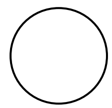
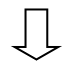
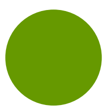
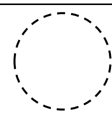
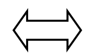
Natural lightscapes are critical for nighttime scenery, such as viewing a starry sky, but are also critical for maintaining nocturnal habitat. Adding artificial light to such habitat may result in substantial impact to certain species (Rich and Longcore 2006). Research into the ecological consequences 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 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 (i.e., Rich and Longcore 2006; Bruce-White and Shardlow 2011). Impacts from light pollution include: influences on organismal movements (Lorne and Salmon 2007; Stone *et al.* 2009), foraging (Santos *et al*. 2010), interspecific interactions (Svensson and Rydell 1998), communication (Miller 2006), reproduction (Boldogh *et al.* 2007) and mortality (Black 2005). Furthermore, air pollution exacerbates the scattering of light and dims the stars. Dark night skies are considered an air quality related value under the 1977 Clean Air Act Amendments.

Lightscapes 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 SARA. 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.

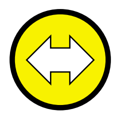
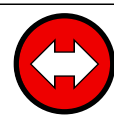
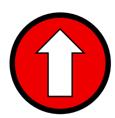
Measuring of the intensity, spectra and periodicity of artificial light is important to understanding the status and trends of the lightscape in SARA. Additional studies on the ecological effects of light pollution on specific species are needed to identify critical wavelengths and thresholds in terms 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).

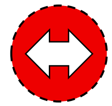
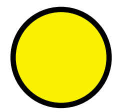
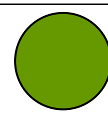
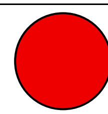
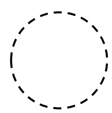
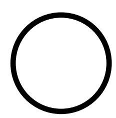
Table 4.33. Summary of SARA natural resource condition status for selected measurements.

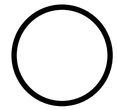
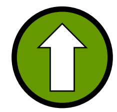
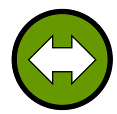
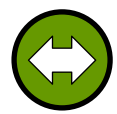
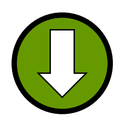
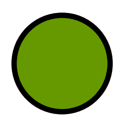
Key to Symbol Definitions

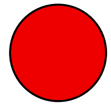
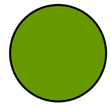
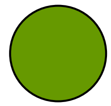
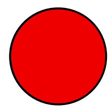
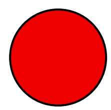
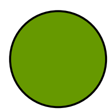
Condition Status		Confidence in Data		Trend	
	Significant concern*		High		Improving
	Caution/Moderate		Medium		Deteriorating
	Good		Low		Unchanging

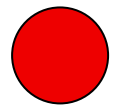
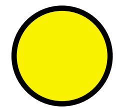
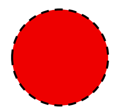
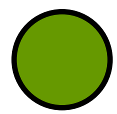
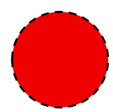
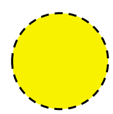
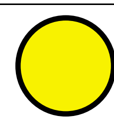
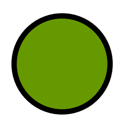
*This symbol was also used to indicate *Present* for the Hudson PCB contamination assessment.

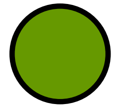
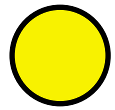
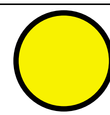
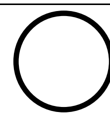
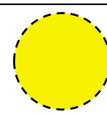
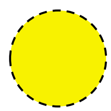
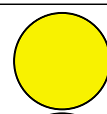
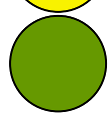
Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Air & Climate	Air Quality	Ozone		NPS ARD calculations from 2006-2010 indicated park ozone level was70.7 ppb. (1)	Exceeds regulatory threshold of 75 ppb and the NPS ARD *good* rating of 60 ppb.(1)	No statistical trend detected.(2)
Air & Climate	Air Quality	Wet Nitrogen Deposition		NPS ARD calculations from 2006-2010 indicated park level was.5 kg/ha/yr. (1)	Exceeds NPS ARD *good* rating of <1 kg/ha/yr. (1)	No statistical trend detected.(3)
Air & Climate	Air Quality	Wet Sulfur Depostion		NPS ARD calculations from 2006-2010 indicated park level was 3.6 kg/ha/yr. (1)	Exceeds NPS ARD *good* rating of <1 kg/ha/yr.(1)	Levels have been statistically decreasing for park.(3)

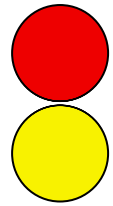
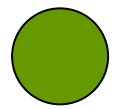
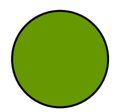
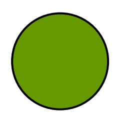
Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Air & Climate	Air Quality	Mercury (Hg)		Hg levels were 7.5 and 7.4 ng/L from neighboring Hg monitoring stations. (4)	Equated 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 6.0 dv. (1)	Exceeds NPS ARD *good* rating of ≤2 dv. (1)	Trend not assessed for park although eastern U.S. parks showing no significant trend. (1)
Geology & Soils	Forest Soil Dynamics	Ca:Al		NPS NETN sampling Ca:Al median 31.52. (7)	NPS NETN *good* 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 13.22. (7)	NPS NETN *good* categorical rating of median C:N>25. (7)	Statistical trend not assessed.
Water	Stream Water Quantity	Quantity/Flow		No in park long term water quantity data available. NRCA discusses short term stream discharge in SARA 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-(Kroma Kill, Americans Creek, Upper Mill Creek)	Temperature		NPS NETN sampled streams and average temperatures were calculated. (8,9,10)	NY State has no numerical standards for stream temperature. (8,11)	Decreasing trend. (8,9,10)

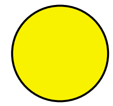
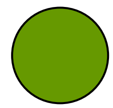
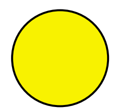
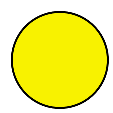
Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Water	Stream Water Chemistry-(Mill Creek Confluence)	Temperature		NPS NETN sampled streams and average temperatures were calculated. (8,9,10)	NY State has no numerical standards for stream temperature. (8,11)	No statistical trend detected. (8,9,10)
Water	Stream Water Chemistry-(Kroma Kill, Mill Creek Confluence)	Dissolved Oxygen		NPS NETN sampled streams 2006-2010. Average values for streams ranged from 10.0-10.2 mg/L, with 100% of individual samples within NY standards. (8,9,10)	NY State water standards: 5.0 mg/L- non-trout waters ; 6.0 mg/L-trout waters ; 7.0 mg/L- cold water trout spawning. (8,11)	Increasing trend.
Water	Stream Water Chemistry-(American's Creek, Upper Mill Creek)	Dissolved Oxygen		NPS NETN sampled stream 2006-2010. Average value for streams ranged from 7.7-9.0 mg/L, with 82-97% of individual samples within NY standards.(8,9,10)	NY State water standards: 5.0 mg/L- non-trout waters ; 6.0 mg/L-trout waters ; 7.0 mg/L- cold water trout spawning.(8,11)	No statistical trend detected.
Water	Stream Water Chemistry-(Kroma Kill, Mill Creek Confluence, Upper Mill Creek, American's Creek)	pH		NPS NETN sampled streams 2006-2010. Average values for streams ranged from 7.90-8.50, with 81-97% of individual samples within NY standards. (8,9,10)	NY State water standards: 6.5≤pH≤8.5. (8,11)	No statistical trend detected.
Water	Stream Water Chemistry- (Kroma Kill, Mill Creek Confluence, Upper Mill Creek, American's Creek)	Specific conductance		NPS NETN sampled streams 2006-2010. Average values for streams ranged from 361-500 (µS/cm), with 46-100% of individual samples within criteria.(8,9,10)	Range for good fisheries mix. (8,11,12)	Increasing trend.
Water	Stream Water Chemistry-(Kroma Kill, Mill Creek Confluence, Upper Mill Creek, American's Creek)	Acid Neutralizing Capacity		NPS NETN sampled streams 2006-2010. Average values for streams ranged from 2788-4060 (mg/L), with 100% of individual samples within criteria.(8,9,10)	Criteria includes ANC> 5 (mg/L) (100 µeq/L). (8,13)	Statistical trend not assessed.

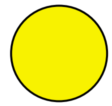
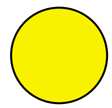
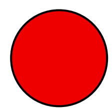
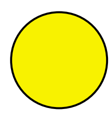
Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Water	Stream Water Chemistry-(Kroma Kill, Mill Creek Confluence, Upper Mill Creek)	Total Nitrogen		NPS NETN sampled streams 2006-2010. Average values for streams ranged from 0.63-4.33 (mg/L), with 0-40% of individual samples within criteria.(8,9,10)	0.54 mg/L (streams). (8,14)	Statistical trend not assessed.
Water	Stream Water Chemistry-(American's Creek)	Total Nitrogen		NPS NETN sampled streams 2006-2010. Average value for stream was 0.34 (mg/L), with 80% of individual samples within criteria.(8,9,10)	0.54 mg/L (streams). (8,14)	Statistical trend not assessed.
Water	Stream Water Chemistry-(Upper Mill Creek)	Total Phosphorus		NPS NETN sampled streams 2006-2010. Average value for stream was 31.6 (µg/L), with 60% of individual samples within criteria.(8,9,10)	33 µg/L (streams). (8,14)	Statistical trend not assessed.
Water	Stream Water Chemistry-(Kroma Kill, Mill Creek Confluence, Upper Mill Creek, American's Creek)	Total Phosphorus		NPS NETN sampled streams 2006-2010. Average values for streams ranged from 37.6-54.6 (µg/L), with 30-60% of individual samples within criteria.(8,9,10)	33 µg/L (streams). (8,14)	Statistical trend not assessed.
Water	Stream Water Chemistry-(Kroma Kill, Mill Creek Confluence)	NO_2+NO_3		NPS NETN sampled streams 2006-2010. Average values for streams ranged from 3.19-3.78 (mg/L), with 0-10% of individual samples within criteria.(8,9,10)	0.30 mg/L (streams). (8,14)	Statistical trend not assessed.
Water	Stream Water Chemistry-(American's Creek, Upper Mill Creek)	NO_2+NO_3		NPS NETN sampled streams 2006-2010. Average values for streams ranged from 0.06-0.14 (mg/L), with 90-100% of individual samples within criteria.(8,9,10)	0.30 mg/L (streams). (8,14)	Statistical trend not assessed.

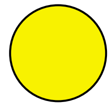
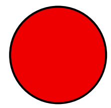
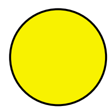
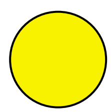
Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Water	PCB Contamination	Total PCBs detected		Each habitat and trophic level was assessed for presence of contamination based on previous studies conducted. (15)	Reference conditions were generally comparing concentrations in upstream vs. downstream sites. (15)	Trends for fish discussed.
Biological Integrity	Invasive Exotic Plants-Forest Grassland	Key Species Per Plot		From 2007-2010, 3.26 key indicator species per plot were detected. (16)	<0.5 key indicator species per plot rates NETN parks in *good* condition (16).	Statistical trend not assessed.
Biological Integrity	Invasive Exotic Plants-Aquatic	Present or Absent in HUC 8 and HUC 12 Watersheds		Invasive exotic plants are present in watersheds surrounding SARA. (17,18,19 20)	Absence of invasive species in habitats ideal reference condition.	Statistical trend not assessed.
Biological Integrity	Invasive Exotic Animals/Disease-Tree Species	Priority Pests Present		Using 2008-2010 data, it was assessed that approximately 90% of plots were *good.* (7)	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 12 Fish Creek Watershed		Invasive exotics are present in watersheds surrounding SARA. (20)	Absence of invasive species in habitats ideal reference condition.	Statistical trend not assessed.
Biological Integrity	Invasive Exotic Animals/Disease-Aquatic	Present or Absent in HUC 12 McAuley Brook and Mill Hollow Brook		Invasive exotics are present in watersheds surrounding SARA. (20)	Absence of invasive species in habitats ideal reference condition.	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Anthropogenic Land Use		Averaged 11% based on 2010 data analyses.(7,21)	<10% Anthropogenic land use around park considered *good* by NETN criteria. (7,21)	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Forest Patch		56% plots *good*, with the remaining falling into the *caution* or *significant concern* categories. (7,21)	>50 ha around park considered *good* by NETN criteria. (7,21)	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	Structural Stage Distribution		30.5% late successional . 56.5% mature and late successional (based on 2006, 2008 and 2010 data collection). (7,21)	≥ 25% late-successional structure in park considered *good* by NETN criteria. (7,21)	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Snag Abundance		8.06 (# of medium-large snags/ha) based on 2006, 2008 and 2010 data collection. (7,21)	≥10% standing trees as snags and ≥ 10% medium-large trees as snags in park considered *good* by NETN criteria. (7,21)	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Coarse Woody Debris		11.36% live tree volume based on 2006, 2008 and 2010 data collection. (7,21)	> 15% live tree volume in park considered *good* by NETN criteria. (7,21)	Statistical trend not assessed.
Biological Integrity	Forest Vegetation	Biotic Homogenization		Unrated. NETN refining metric. (7,21)	Metric being refined by NETN. (7,21)	Statistical trend not assessed.
Biological Integrity	White-Tailed Deer Herbivory	Seedling Ratio		Based on data collected during 2007-2010, seedling ratio was 0.32 for the park. (7,16)	Seedling ratio ≥ 0 defined as *good* by NPS NETN. (7,22)	Statistical trend not assessed.
Biological Integrity	White-Tailed Deer Herbivory	Deer Browse Index		Deer browse index calculated at 3.07, indicating evidence of browse; browse preferred regeneration present but with little height variability; non-preferred and browse resistant species common. (7)	Plot located inside deer exclosure and no browse present based on impacts assessed for each plot in national historical parks and sites. (22,23).	Statistical trend not assessed.
Biological Integrity	Fish Community	Northern Mid-Atlantic Slope Drainage Fish IBI-Kroma Kill	 	Data were incomplete from survey to calculate true overall IBI score for metrics 10-12 and therefore bounds were placed on the scores and categories (24). Scores within '35-60' rated the stream caution-good.	IBI used reference streams in Mid-Atlantic region to create Fish IBI ratings.(25)	Statistical trend not assessed.

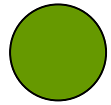
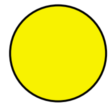
Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
Biological Integrity	Fish Community	Northern Mid-Atlantic Slope Drainage Fish IBI-Mill Creek main, mid and south branches		Data were incomplete from survey to calculate true overall IBI score for metrics 10-12 and therefore bounds were placed on the scores and categories (24). Scores within ‘no fish-47’ rated the stream significant concern-caution.	IBI used reference streams in Mid-Atlantic region to create Fish IBI ratings.(25)	Statistical trend not assessed.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-exotic species (%)		0% based on data from 2006-2011. (26)	0% rates this IBI metric as good. (27)(28)(29)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-nest predator/brood parasites (%)		5% based on data from 2006-2011.(26)	<10% rates this IBI metric as good.(27)(28)(29)	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 (%)		25% based on data from 2006-2011.(26)	<28% rates this IBI metric as good.(27)(28)(29)	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)-single brood (%)		50% based on data from 2006-2011.(26)	>68% rates this IBI metric as good.(27)(28)(29)	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 (%)		13% based on data from 2006-2011.(26)	>11% rates this IBI metric as good.(27)(28)(29)	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 (%)		7% based on data from 2006-2011.(26)	>9% rates this IBI metric as good.(27)(28)(29)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Forested	Guild-based Avian Index of Biotic Integrity (IBI)-high canopy forager (%)		7% based on data from 2006-2011.(26)	>12% rates this IBI metric as good.(27)(28)(29)	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)-low canopy forager (%)		20% based on data from 2006-2011.(26)	>22% rates this IBI metric as good.(27)(28)(29)	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 (%)		33% based on data from 2006-2011.(26)	<30% rates this IBI metric as good.(27)(28)(29)	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 (%)		25% based on data from 2006-2011.(26)	>35% rates this IBI metric as good.(27)(28)(29)	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 (%)		12% based on data from 2006-2011.(26)	>18% rates this IBI metric as good. (27)(28)(29)	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 (%)		25% based on data from 2006-2011.(26)	>35% rates this IBI metric as good.(27)(28)(29)	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 2006-2011.(26)	<18% rates this IBI metric as good.(27)(28)(29)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Birds-Grassland	Guild-based Avian Index of Biotic Integrity (IBI)		% edge generalist, exotic, grassland obligate and shrub dependent birds rated caution based on data from 2006-2011.(26)	IBI based on 4 response guild measures.(30)(31)(32)	Statistical trend not assessed. Confidence in data ranged from fair to high.
Biological Integrity	Amphibians & Reptiles	Amphibian IBI & Population Trend		Average IBI score for SARA was 14 (fair) based on data collected in 2001 (33.) and calculated using the AmphIBI. (34)	AmphIBI contains 5 metrics used to calculate IBI. Overall score of 30-50 rates waterbodies as *excellent* condition. (34)	Statistical trend not assessed. Subjective trend analysis indicated more species stable, although some declining or unknown.

Priority Resource or Value	Indicator of Condition	Specific Measure	Condition Status	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Notes
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.(35)	Increasing trend since park has been established indicate a 2% increase in visitation, with growth in population in the region.(35)	Visitation increasing from 1941-2010 and decreasing from 2000-2010. Population growth in county increasing.
Landscapes	Landscape Dynamics	Population		Modeled significant increase in total population and population density from 1950 to 2030 for 30 km^2 area around park.(36)(37)(38)	Modeled historic and future population projections from1950-2030 using a 30 km^2 buffer around park. (36)(37)(38)	Projected increasing trend.
Landscapes	Landscape Dynamics	Housing		Projected increase in number of housing units/km^2 within a 30 km^2 area around park.(36)(37)(38)	Modeled historic and future population projections from1950-2010 using a 30 km^2 buffer around park.(36)(37)(38)	Projected increasing trend.
Landscapes	Landscape Dynamics	Land Cover Change (acreage)-Urban, Mixed, Deciduous, Coniferous forest types		26% increase in urban and 10%-26% decrease for forest types within 5km surrounding buffer.(39)	Compared historical land cover from 1986-2001 within a 5 km buffer. (39)	Statistical trend not assessed.
Landscapes	Landscape Dynamics	Road Ecology and 100 m buffer from road edge		Roads within 100 m of habitats are present in SARA. Patch area decreases with the presence of smaller roads in park. (36)(40)	Roads not within 100 m of aquatic habitats or grasslands. (41)(42)	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
Landscapes	Landscape Dynamics	% Impervious Coverage		SARA averaged < 10% impervious coverage in park boundaries, with some areas near major roads containing >26% impervious coverage.(36)(37)(40)(43)(44)	Studies have found water and habitat quality is 'good' when not >10% impervious coverage. (36)(37)(40)(43)(44)	Statistical trend not assessed.
Landscapes	Landscape Dynamics	Viewshed as % Land Parcels being Visually Sensitive		Greatest percentage of surrounding land parcels for SARA are of medium to low priority in terms of visual sensitivity.(45)(46)	Viewshed analysis thresholds were based on a ranking criteria established in a viewshed analysis report. (45)(46)	Statistical trend not assessed.

References and Data Sources

(1) National Parks Service (NPS). 2010. Rating Air Quality Conditions. Air Resources Division. National Park Service. Fort Collins, CO. http://www.nature.nps.gov/air/planning/docs/20100112_Rating-AQ Conditions.pdf .

(2) National Park Service (NPS). 2010b. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report/NRPC/ARD/NRR-2010/266. 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. Vermeylen, 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., 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.

(8) 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.

(9) NPS Northeast Temperate Network (NETN) raw stream data collected by NETN biologists.

(10) United States Environmental Protection Agency (EPA). 2011. STORET/WQX Data Warehouse. http://www.epa.gov/storet/dw_home.html. Accessed: February 1, 2011.

(11) New York Department of Environmental Conservation. NYCRR Part 703: Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations. http://www.dec.ny.gov/regs/4590.html. Accessed September 27, 2011.

(12) United States Environmental Protection Agency (EPA). 1997. Volunteer Stream Monitoring: A Methods Manual, EPA 841-B-97-003. Office of Water.

(13) 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.

(14) United States Environmental Protection Agency (EPA). 2000. Ambient water quality criteria recommendations. Information supporting the development of state and tribal nutrient criteria for rivers and streams in nutrient ecoregion VII. EPA 822-B-00-018. December 2000.

(15) Various reports were used to assess PCB levels in the Hudson River and investigate PCB effects/dose concentrations for a variety of trophic levels. Consult the SARA NRCA report regarding PCB contamination in the Hudson River for specific data references and thresholds used for this assessment.

(16) 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.

(17) Canham, S. A. 2003. Saratoga National Historical Park Invasive Plant Assessment,Summer 2003. Saratoga National Historical Park, Stillwater, NY, USA.

(18) Edinger, Gregory J., Aissa L. Feldmann, Timothy G. Howard, John J. Schmid, Frederick C. Sechler, Elizabeth Eastman, Ery Largay, and Lesley A. Sneddon. April 2008. Vegetation Classification and Mapping at Saratoga National Historical Park. Technical Report NPS/NER/NRTR—2008/117. National Park Service. Northeast Region, Philadelphia, PA. D-64.

(19) Stalter, R., Lynch, P., Schaberl, J. 1993 Vascular flora of Saratoga National Historical Park, New York. Bulletin of the Torrey Botanical Club, 120, 166-176.

(20) United States Geological Survey (USGS). 2004. Nonindigenous Aquatic Species Database, Gainesville, FL. Retrieved from http://nas.er.usgs.gov, March 3, 2010.

(21) Miller, K. M., G. L. Tierney, and B. R. Mitchell. 2009. Northeast Temperate Network 2006-2008 forest health monitoring report. Natural Resource Report NPS/NETN/NRR— 2009/104. National Park Service, Fort Collins, Colorado.

(22) 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.

(23) 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.

(24) 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.

(25) Daniels, R.A., K. Riva-Murray, D.B. Halliwell, D.L. Vana-Miller, and M.D. Bilger. 2002. An index of biological integrity for Northern Mid-Atlantic Slope Drainages. *Transactions of the American Fisheries Society* 131:1044-1060.

(26) Faccio, S., and B. R. Mitchell. 2011. Northeast Temperate Network breeding landbird monitoring : 2010 annual report. Natural Resource Data Series NPS/NETN/NRDS—2011/161. National Park Service, Fort Collins, Colorado

(27) 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.

(28) 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.

(29) 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.

(30) Faccio, S., B. R. Mitchell, and P. S. Pooler. 2011. Northeast Temperate Network breeding landbird monitoring protocol: 2011 revision. Natural Resource Report NPS/NETN/NRR—2011/400. National Park Service, Fort Collins, Colorado.

(31) Browder , S.F., D. H. Johnson, and I.J. Ball. 2002. Assemblages of breeding birds as indicators of grassland condition. Ecological Indicators 2: 257-270.

(32) Coppedge, B.R., D.M. Engle, R.E. Masters, and M.S. Gregory. 2006. Development of a grassland integrity index based on breeding bird assemblages. E*nvironmental Monitoring and Assessment* 118: 125-145.

(33) Cook, R. P., D.K. Brotherton, B.C. Timm, and J.L. Behler. 2011. Saratoga National Historical Park Amphibian and Reptile Inventory: March-September 2001. Draft Technical Report NPS/NETN/NRTR 2011/XXX.National Park Service, Fort Collins, Colorado.

(34) 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.

(35) National Park Service NPS Stats-Public Use Statistics Office. 2011. Web Access: http://www.nature.nps.gov/stats/.

(36) National Park Service NPScape data. 2011. Web Access: http:*science.nature.nps.gov/im/monitor/npscape/.*

(37) 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.

(38) United States Department of Commerce. United State Census Bureau. Accessed: http://www.census.gov/#.

(39) 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.

(40) 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.

(41) Haskell D.G. 2000. Effects of forest roads on macroinvertebrate soil fauna of the Southern Appalachian mountains. *Conservation Biology* 14: 57 –63.

(42) Forman, R.T.T., B. Reineking, A. Hersperger. 2002. Road traffic and nearby grassland bird patterns in a suburbanizing landscape. *Environmental Management* 29: 782–800.

(43) 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.

(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) Saratoga P.L.A.N. with Dodson Associates, Ltd. 2007. Battles of Saratoga Preservation and Viewshed Protection Plan: Old Saratoga on the Hudson Region, New York. Completed Dec. 2007.

(46) The LA Group. 2006. Viewshed analysis for Saratoga National Historical Park. Unpublished report prepared for the U.S. Department of the Interior, National Park Service, Stillwater, N.Y.

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. Smith, A. H. Magill, M. E. Martin, R. A. Hallett, and J. L. Stoddard. 2003. Is nitrogen deposition altering the nitrogen status of northeastern forests? *Bioscience* 53:375-389.

Austin, K. A. 1991. Ecology of gray dogwood (*Cornus racemosa*) on: Saratoga National Historical Park. PhD dissertation. State University of New York College of Environmental Science and Forestry: Syracuse, N.Y.

Bank, M. S., C. S. Loftin, and R. E. Jung. 2005. Mercury bioaccumulation in northern two-lined salamanders from streams in the northeastern United States. *Ecotoxicology* 14: 181-191.

Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid bioassessment protocols for use in streams and Wadeable Rivers: Periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. http://water.epa.gov/scitech/monitoring/rsl/bioassessment/index.cfm.

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 breedingsuccess in the frog *Rana temoraria*. *Journal of Herpetology* 26:353-360.

Berthiaume, J. 2001. Forest Field Configuration at Saratoga National Historical Park 2000 field forest. National Park Service, Boston, MA.

Black, A. 2005. Light induced seabird mortality on vessels operating in the Southern Ocean: incidents and mitigation measures. *Antarctic Science* 17:67-68.

Blackwell, M. S. A. and E. S. Pilgrim. 2011. Ecosystem services delivered by small-scale wetlands. *Hydrological Sciences Journal* 56:1467-1484.

Blaustein, A. R., and D. B. Wake. 1990: Declining amphibian populations: A global phenomenon? *Trends in Ecology & 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.

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 Soil Pollution* 1:395-408.

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 Soci*ety 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. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

Browder , S. F., D. H. Johnson, and I. J. Ball. 2002. Assemblages of breeding birds as indicators of grassland condition. *Ecological Indicators* 2:257-270.

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 Bailey, S. W. 2005. Identifying calcium sources at an acid deposition-impacted spruce forest: a strontium isotope, alkaline earth element multi-tracer approach: *Biogeochemistry* 74:63-99.

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. Vermeylen, 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.

Cadwell, D. H. and R. J. Dineen. 1987. Surficial Geologic Map of New York: Hudson - Mohawk Sheet. Scale 1:250,000. Map and Chart Series No. 40. New York State Museum - Geologic Survey. The University of the State of New York, The State Education Department, Albany, NY.

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 Resources. Res., 47, W02512, doi:10.1029/2010WR009438.

Canham, S. A. 2003. Saratoga National Historical Park Invasive Plant Assessment, Summer 2003. Saratoga National Historical Park, Stillwater, NY, USA.

Carlisle, D. M., D. M. Wolock, and M. R. Meador. 2011. Alteration of streamflow magnitudes and potential ecological consequences: a multiregional assessment. *Frontiers Ecol Environ* 9: 264-270.

Clark, D. R., Jr., and R. F. Shore. 2001. Chiroptera. In: R.F. Shore and B.A.Rattner, editors, *Ecotoxicology of Wild Mammals*; pp. 159-214. John Wiley & Sons Ltd., West Sussex, England.

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.

Conant, R. and J. T. Collins. 1998. A field guide to reptile and amphibians: Eastern and central North America. 3rd Edition Expanded. Boston: Houghton Mifflin Co.

Cook, R. P., D. K. Brotherton, B. C. Timm, and J. L. Behler. 2011. Saratoga National Historical Park Amphibian and Reptile Inventory: March-September 2001. Draft Technical Report NPS/NETN/NRTR—2011/XXX. National Park Service, Fort Collins, Colorado.

Coppedge, B. R., D. M. Engle, R. E. Masters, and M. S. Gregory. 2006. Development of a grassland integrity index based on breeding bird assemblages. Environmental Monitoring and Assessment 118:125-145.

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.

Daniels, R. A., K. Riva-Murray, D. B. Halliwell, D. L. Vana-Miller, and M. D. Bilger. 2002. An index of biological integrity for Northern Mid-Atlantic Slope Drain-ages. *Transactions of the American Fisheries Society* 131:1044-1060.

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, Colorado.

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., G. B. Lawrence, A. J. Bulger, T. J. Butler, C. S. Cronan, C. Eagar, 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., 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.

Dunning, J. B., B. J. Danielson, and H. R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. *Oikos* 65:169-175.

Dumyahn, S. L. and B. C. Pinjanowski. 2011. Soundscape conservation. *Landscape Ecology* 26:1327-1344.

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.

Echols, K. B., D. E. Tillitt, J. W. Nichols, A. L. Secord, and J. P. McCarty. 2004. Accumulation of PCB congeners in nestling tree swallows (*Tachycineta bicolor*) on the Hudson River, New York. *Environmental Science & Technology* 38:6240-6246.

Edinger, G. J., A. L. Feldmann, T. G. Howard, J. J. Schmid, F. C. Sechler, E. Eastman, E. Largay, and L. A. Sneddon. 2008. Vegetation classification and mapping at Saratoga National Historical Park. Technical Report NPS/NER/NRTR—2008/117. National Park Service. Northeast Region, Philadelphia, PA. D-64.

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* 14:24.

Ellsworth, A. 2011. Emerging contaminants in the waters of the Northeast Region. In: Science and Management, Winter 2010-2011. National Park Service Northeast Region.

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* 37:1613-1622.

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., and B. R. Mitchell. 2011. Northeast Temperate Network breeding landbird monitoring: 2010 annual report. Natural Resource Data Series NPS/NETN/NRDS—2011/161. National Park Service, Fort Collins, Colorado

Faccio, S., B. R. Mitchell, and P. S. Pooler. 2011. Northeast Temperate Network breeding landbird monitoring protocol: 2011 revision. Natural Resource Report NPS/NETN/NRR—2011/400. National Park Service, Fort Collins, Colorado.

Fairchild, W. L., D. C. G. Muir, R. S. Currie, and Y. L. Yarechewski. 1992. Emerging insects as a biotic pathway for movement of 2.3.7.8.-tetrachlorodibenzofuran from lake sediments. *Environmental Toxicology and Chemistry* 11:867-872.

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.

Fisher, D. W., Y. W. Isachsen, and L. V. Rickard. 1970. Geologic Map of New York: Hudson - Mohawk Sheet. Scale 1:250,000. New York State Museum and Science Services, Map and Chart Series No. 15. The University of the State of New York, The State Education Department, Albany, NY.

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* 29:782-800.

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.

Framanet, B. and R. Lilja. USFS 2009. Aerial Detection Survey Results: Durham Field Office. www.na.fs.fed.us/. Accessed January 4, 2011.

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. Natuural Resource Technical Report. NPS/NER/NRTR—2012/599. National Park Service. Fort Collins, Colorado.

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.

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. M. 1987. The Saratgoa Battlefield: A vegetative history. Unpublished paper prepared for the Saratoga National Historical Park.

Gordon, N. D., T. A. McMahon and B. L. Finlayson. 2004. Stream hydrology: An introduction for ecologists. Vol. 1. 2nd ed. Wiley, 429 pp. P. R. Kaughman and E. G. Robinson, 1997: Physical habitat assessment. EPA. EPA/620/R-94/004.

Great Lakes Sport Fish Advisory Task Force. 1993. Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory.

Greenberg, M. S., B. Conetta, L. J. Field, and J. W. Kern. 2011. PCBs in fish tissues at the Hudson River PCBs Superfund Site: Remedial Action Monitoring Results in Perspective. Presentation. Sixth International Conference on Remediation of Contaminated Sediments. New Orleans, LA, Feb. 7-9, 2011.

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.

Hamilton W. J. Jr. 1941. The food of small forest mammals in eastern United States. *Journal of Mammalogy* 22:250-263.

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.

Harvey, M. J. *Bats of the Eastern United States*. 1992. Cookeville, TN, Center for the Management, Utilization and Protection of Water Resources, Tennessee Technological University.

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. Pp. 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.

Heath, R., F. Mack, and J. Tannenbaum. 1963. Ground water studies in Saratoga County, New York. Bulletin GW-49, New York Department of Conservation, Water Resources Commission, Albany, NY.

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.

Hetling, L. J., E. G. Horn, and R. J. Tofflemire. 1978. Summary of Hudson River PCB study results. NYSDEC, Albany, NY.

Horsley, S. B., R .P. Long, S. W. Bailey, R. A. Hallet, 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.

Hudson River Natural Resource Trustees (HRNRT). 2001. Injuries to Hudson River fishery resources: Fishery closures and consumption restrictions. Hudson River Natural Resource Damage Assessment. Final Report, June 2001.

Hudson River Natural Resource Trustees (HRNRT). 2005a. Data report for screening for organochlorine and metal contaminant levels in Hudson River, New York bullfrogs (*Rana catesbeinana*) and snapping turtles (*Chelydra serpentina serpentina*). Hudson River Natural Resource Damage Assessment. Public Release Version, February 28, 2005.

Hudson River Natural Resource Trustees (HRNRT). 2005b. Data report for the collection of eggs from the common snapping turtle (*Chelydra serpentina serpentina*) from the Hudson River, New York. Hudson River Natural Resource Damage Assessment. Public Release Version, February 28, 2005.

Hudson River Natural Resource Trustees (HRNRT). 2005c. Data report for the collection of eggs from spotted sandpipers, American woodcock, belted kingfisher, American robin, red-winged blackbird, and Eastern phoebe associated with Hudson River from Hudson Falls to Schodack Island, New York. Hudson River Natural Resource Damage Assessment. Final revised version June 15, 2005.

Hudson River Natural Resource Trustees (HRNRT). 2005d. Data report for the collection of eggs from eastern screech owl associated with the Hudson River from Hudson Falls to Schodack Island, New York. Hudson River Natural Resource Damage Assessment, final report April 28, 2005.

Hudson River Natural Resource Trustees (HRNRT). 2007a. Data report for the collection of bullfrog (*Rana catesbeiana*) tadpoles and near-shore sediment samples from the Hudson River, New York. Hudson River Natural Resource Damage Assessment. Public Release Version, May 2007.

Hudson River Natural Resource Trustees (HRNRT). 2007b. Work Summary and Data Report, Collection of Bats from the Hudson River, New York 2001 and 2002 Samples. Hudson River Natural Resource Damage Assessment. Public Release Version, September 20, 2007.

Hudson River Natural Resource Trustees (HRNRT). 2008a. Data report for the preliminary investigation of amphibian breeding habitat and screening of breeding pool sediments for polychlorinated biphenyl contamination, Hudson River, New York. Final report, January 4, 2008.

Hudson River Natural Resource Trustees (HRNRT). 2008b. Injury determination report Hudson River surface water resources. Hudson River Natural Resource Damage Assessment. Public Release Version, December 2008.

Hudson River Natural Resource Trustees (HRNRT). 2009. Data report Organochlorine and metal contaminant levels in Hudson River aquatic insects. Natural Resource Damage Assessment. Public Release Version New York. September 2009.

Hudson River Natural Resource Trustees (HRNRT). 2010. Data report for the collection of small mammals and American woodcock from the floodplain of the Hudson River, New York in year 2001, analysis of floodplain earthworms from the year 2000, and re-analysis of select floodplain soils and small mammals from the year 2000. Hudson River Natural Resource Damage Assessment. Public Release Version, January 2010.

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.

Jordan, M., Moore, G., and R. Weldy. 2009. New York State Plant Ranking System for Evaluating Non-Native Plant Species for Invasiveness. Draft April 15, 2009. Accessed January 10, 2011. Available at http://www.nyis.info/ (accessed 13 December 2012).

Karr, J. R., K. D. Fausch, P. L. Angermeirer, 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* 18:724-34.

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.

Keranen, K. M., H. M. Savage, G. A. Abers, and E. S. Cochran. 2013. Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 Mw 5.7 earthquake. Geology. doi: 10.1130/G34045.1.

Kiviat, E. 1980. A Hudson River tidemarsh snapping turtle population. *Transactions of the Northeast Section Wildlife Society* 37:158-168.

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.

Krause, B and S. Gage. 2003. Testing biophony as an indicator of habitat fitness and dynamics SEKI natural soundscape vital signs pilot program. Sequoia National Park, p 18.

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.

Leonards, P. E. G., M. D. Smit, A. W. J. J. de Jongh, and B. van Hattum. 1994. Evaluation of Dose-Response Relationships for the Effects of PCBs on the Reproduction of Mink (*Mustela vison*). Institute for Environmental Studies. Vrije Universiteit, Amsterdam.

Levin, S. A. 1981. The problem of pattern and scale in ecology. *Ecology* 73:1942-1968.

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 Annals of the New York Academy of Science* 1162:99-135.

Luck, G. W. 2007. A review of the relationships between human population density and biodiversity. *Biological Review* 82:607-645.

Lussier, C. M., H. S. Ginsberg, and R. A. LeBrun. 2006. Distribution of mosquitoes in National Park Units of the Northeastern United States. Technical Report NPS/NER/NRTR—2006/046. National Park Service. Boston, MA.

Lynch, P. 1987. Saratoga National Historical Park water resource management program, Baseline inventory, annual review and summary. Unpublished Report, Saratoga National Historic Park, Stillwater, NY.

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. 2003. Freshwater fish inventory: Northeast emperate Network, 1999-2001. Technical Report NPS/NER/NRTR—2005/16. National Park Service. Woodstock, VT.

Mauer, T., M. J. Russo, and M. Evans. 2004. Element stewardship abstract for *Centaurea maculosa*, Spotted Knapweed. The Nature Conservancy, Arlington, VA.

Mayack, D. T. and J. Loukmas. 2001. Progress report on Hudson River mammals: Polychlorinated biphenyl (PCB) levels in mink, otter, and muskrat and trapping results for mink, the Upper Hudson River drainage, 1998-2000. Progress Report to the New York State Department of Environmental Conservation.

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.

Mercury Deposition Network (MDN). Available at http://nadp.sws.uiuc.edu/mdn/ (accessed 13 December 2013).

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

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.

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. 2009. Northeast Temperate Network 2006-2008 forest health monitoring report. Natural Resource Report NPS/NETN/NRR—2009/104. National Park Service, Fort Collins, CO.

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.

Mills, J. N., J. M. Johnson, T. G. Ksiazek, B. A. Ellis, P. E. Rollin, T. L. Yates, M. O. Mann, M. R. Johnson, M. L. Campbell, J. Miyashiro, M. Patrick, M. Zyzak, D. Lavender, M. G. Novak, K. Schmidt, C. J. Peters, and J. E. Childs. 1998. A survey of hantavirus antibody in small-mammal populations in selected United States national parks: *American Journal of Tropical Medicine and Hygiene* 58:525-532.

Mitchell, B. R., W. G. Shriver, F. Dieffenbach, T. Moore, D. Faber-Langendoen, G. Tierney, P. Lombard, and J. Gibbs. 2006. Northeast Temperate Network Vital Signs Monitoring Plan. Technical Report NPS/NER/NRTR—2006/059. National Park Service, Northeast Temperate Network, Woodstock, VT.

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* 56:93-133.

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* 192:349-359.

National Atmospheric Depostion Program (NADP). Available at http://nadp.sws.uiuc.edu/ (accessed 13 December 2013).

National Park Service (NPS). 1986. List of mammals and amphibians captured in 1986. Unpublished, in Saratoga National Historical Park files.

National Park Service (NPS). 1997. Baseline water quality data, inventory and analysis, Saratoga National Historical Park. Technical Report NPS/NRWRD/NRTR-97-96. Water Resources Division, Fort Collins, CO.

National Park Service (NPS). 2004. Saratoga National Historical Park General Management Plan (GMP), Environmental Impact Statement. U.S. Dept. of the Interior, National Park Service, Northeast Region, Boston, MA.

National Park Service (NPS). 2006. 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 13 December 2013).

National Parks Service (NPS). 2010a. Rating Air Quality Conditions. Air Resources Division. National Park Service. Fort Collins, CO. http://www.nature.nps.gov/air/planning/docs/20100112_Rating-AQ-Conditions.pdf .

National Park Service (NPS). 2010b. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report/NRPC/ARD/NRR-2010/266. National Park Service, Denver, CO.

National Park Service (NPS). 2010c. "Toxic Spill and Cleanup Threaten Resources at Saratoga". In: Science and Management, Winter 2009-2010 publication. Northeast Region, Natural Resources and Science.

National Park Service (NPS). 2013. Lightscape/ Night Sky. Available at http://www.nps.gov/grba/naturescience/lightscape.htm (accessed 13 December 2013).

National Park Service (NPS). 2013. Natural Sounds. Available at http://www.nature.nps.gov/sound/ (accessed 13 December 2013).

National Park Service Hydrographic & Impairment Statistics (NPS HIS). 2011. Available at http://www.nature.nps.gov/water/HIS/index.cfm (accessed 13 December 2013).

New York Coop News. 2010. *Environmental Flows: Conserving the natural flow regime of rivers.* Volume I, Issue 3. December 2010.

New York Department of Environmental Conservation. NYCRR Part 703: Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations. Available at http://www.dec.ny.gov/regs/4590.html (accessed 13 December 2013).

New York State Department of Health.2010. Chemicals in sportfish and game: 2010-2011. Health Advisories. Available at http://www.health.state.ny.us/environmental/outdoors/fish/fish.htm.

Newell, A. J., D. W. Johnson, and L. K. Allen. 1987. Niagara River Biota Contamination Project: Fish Flesh Criteria for Piscivorous Wildlife. DEC Technical Report 87-3, Bureau of Environmental Protection, Div. of Fish and Wildlife. New York.

Noss, R. F. 1999. Assessing and monitoring forest biodiversity: A suggested framework and indicators. *Forest Ecology and Management* 115:135-146.

NPS Stats-Public Use Statistics Office. 2011. Available at http://www.nature.nps.gov/stats/.

NPSpecies - The National Park Service Biodiversity Database. https://science1.nature.nps.gov/npspecies/web/main/start

NYSDEC. 2010. New York State Department of Environmental Conservation Didymo Alert. Available at http://www.dec.ny.gov/animals/54244.html (accessed 13 December 2013).

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.

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. W. S. Davis 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:S27-S38.

Patrick, D. A., H. L. Hunter Jr., and A. J. K. Calhoum. 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.

Petranka, J. W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, DC.

Pijanowski, B. C., L. J. Villanueva-Rivera, S. Dumyahn, A. Farina, B. Krause, B. M. Napoletano, S. H. Gage, and N. Pieretti. 2011. Soundscape ecology: The science of sound in the landscape. *Bioscience* 61(3):203–216.

Pollard, E. 1988. Temperature, rainfall, and butterfly numbers. *Journal of Applied Ecology* 25:819-828.

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.

Richter, W., M. W. Kane,and L. C. Skinner. 2010. Analysis of fall fish data collected under the baseline and remedial action monitoring programs of the Hudson River PCBs Superfund Site from 2004 through 2009. April 2010. Division of Fish, Wildlife and Marine Resources. New York State Department of Environmental Conservation.

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. P., S. M. Wiegmann, D. A. Rogers, and D. M. Waller. 2004. Biotic impoverishment and homogenization in unfragmented forest understory communities. *Conservation Biology* 18:787-798.

Rosenberg, D. M. and V. H. Resh. 1992. *Freshwater biomonitoring and benthic macroinvertebrates.* Vol. 1. 1st ed. Chapman & Hall.

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. Lourenco, 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. 2006. Effects of road de-icing salt (NaCl) on larval wood frogs (*Rana sylvatica*). *Environmental Pollution* 140:247-256.

Saratoga P.L.A.N. with Dodson Associates, Ltd. 2007. Battles of Saratoga Preservation and Viewshed Protection Plan: Old Saratoga on the Hudson Region, New York. Completed Dec. 2007.

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* 43:712-730.

Schindler, D. W. 1988. Effects of acid rain on fresh water ecosystems. *Science* 239:149-157.

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.

Semlitsch R. D. and J. R. Bodie. 1998. Are small, isolated wetlands expendable? *Conservation Biology* 5:1129-1133.

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 , 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. Available at http://www.defra.gov.uk/science/project_data/DocumentLibrary/WC02008/WC02008_2866_FRP.pdf

Smit, M. D., P. E. G. Leonards, A. J. Murk, A. W. J. J. de Jongh, and B. van Hattum 1996 Development of Otter-Based Quality Objectives for PCBs. Institute for Environmental Studies. Vrije Universiteit, Amsterdam. p. 129.

Snyder, C. D., J. A. Young, R. Villella and D. P. Lemarie. 2003. Influences of upland and riparian land use patterns on stream biotic integrity. *Landscape Ecololgy* 18:647-664.

Stalter, R., P. Lynch, and J. Schaberl. 1993 Vascular flora of Saratoga National Historical Park, New York. *Bulletin of the Torrey Botanical Club* 120:166-176.

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., 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, 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.

The Chazen Companies. 2005. Stillwater Comprehensive Plan Saratoga County, New York. Adopted by Town Board July 6, 2006. Available at http://www.stillwaterny.org/ (accessed 13 December 2013).

The LA Group. 2006. Viewshed analysis for Saratoga National Historical Park. Unpublished report prepared for the U.S. Department of the Interior, National Park Service, Stillwater, NY.

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. 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.

Tiner, R., I. Huber, G. Smith, and M. Starr. 2000. Wetlands inventory of Saratoga National Historical Park. Produced for the National Park Service under Agreement FWS-14-16-0009-01-1807, Saratoga National Historical Park, Stillwater, NY.

Trocki, C., and P. Paton. 2003. Avian surveys in Northeast Temperate Network. Technical Report NPS/NER/NRTR—2005/004. National Park Service. Woodstock, VT.

Trocki, C. L and P. Paton. October 2005. Developing a conservation strategy for grassland birds at Saratoga National Historical Park. Natural Resources Report NPS/NER/NRR—2005/004. National Park Service. Boston, MA.

Trocki, C., and P. Paton. August 2007. Study Design for Assessing the Effects of Knapweed Control on Grassland Birds at Saratoga National Historical Park. Natural Resources Report NPS/NER/NRR—2007/015. National Park Service. Boston, MA.

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, B.H., and W.F. Porter. 1997. Reconsidering paradigms of overpopulation in ungulates: white-tailed deer at Saratoga national Park. In: W. J. McShea, H. B. Underwood and J. H. Rappole, Editors, *The Science of Overabundance*. Smithsonian Press, Washington, DC.

Underwood, B. H., K. A. Austin, W. F. Porter, R. L. Burgess and R. W. Sage, Jr. 1994. Interactions of white-tailed deer and vegetation at Saratoga National Historical Park. College of Environmental Science and Forestry. State Univ. New York, Syracuse, NY.

United States Department of Agriculture, National Resources Conservation Service (USDA NRCS). 2004. Soil Survey of Saratoga County, New York. United States Department of Agriculture, National Resources Conservation Service, Syracuse, NY.

United States Department of Commerce. 2012. United State Census Bureau. Available at http://www.census.gov/# (accessed 13 December 2013).

United States Environmental Protection Agency (EPA).1980. *Ambient Water Quality Criteria Document for Polychlorinated Biphenyls.* Office of Health and Environmental Assessment, Cincinnati, OH. EPA 440/5-80-068.

United States Environmental Protection Agency (EPA). 1997. Volunteer Stream Monitoring: A Methods Manual, EPA 841-B-97-003. Office of Water.

United States Environmental Protection Agency (EPA). 2000. Ambient water quality criteria recommendations. Information supporting the development of state and tribal nutrient criteria for rivers and streams in nutrient ecoregion VII. EPA 822-B-00-018. December 2000.

United States Environmental Protection Agency (EPA). 2000. Phase 2 Report: Further site characterization and analysis. Volume 2-Revised baseline ecological risk assessment Hudson River PCBs reassessment. Region 2, New York

United States Environmental Protection Agency (EPA). 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 (EPA) . 2006. Air Quality Criteria for Ozone and Related Photochemical Oxidants. Volume I of III. U.S. Environmental Protection Agency, Washington, DC.

United States Environmental Protection Agency (EPA). 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 (EPA). 2011. STORET/WQX Data Warehouse. Available at http://www.epa.gov/storet/dw_home.html (accessed 13 December 2013).

United States Environmental Protection Agency (EPA). Western Ecology Division. 2011. Level III and IV Ecoregions of the Continental United States. Available at http://www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm (accessed 13 December 2013).

United States Forest Service (USFS). 2010. Forest Health Protection-Beech Bark Disease. Available at http://www.na.fs.fed.us/fhp/bbd/ (accessed 13 December 2013).

United States Geological Survey (USGS). 2004. Nonindigenous Aquatic Species Database, Gainesville, FL. Available at http://nas.er.usgs.gov/ (accessed 13 December 2013).

United States Geological Survey (USGS). Stream Stats. Accessed: Jan. 10, 2011. Available at http://water.usgs.gov/osw/streamstats/ (accessed 13 December 2013).

United States Department of Agriculture (USDA) Forest Service. 2010. Alien Forest Pest Explorer (AFPE). http://www.nrs.fs.fed.us/tools/afpe/3.

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 Manen2001a.

Vana-Miller, D., C. Martin, and L. White. 2001. Water Resources Management Plan – Saratoga National Historical Park, NY.

Vickery, P. D., P. L. Tubaro, J. M. C. daSilva, B. G. Peterjohn, J. R. Herkert, and R. B. Cavalcanti. 1999. Conservation of grassland birds in the Western Hemisphere. *In* Ecology and Conservation of Grassland Birds in the Western Hemisphere (P. Vickery and J. Herkert, eds.). *Studies in Avian Biology* 19:2-26.

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.ecologyandsociety.org/vol7/iss2/art7/ (accessed 13 December 2013).

Wallace, Z. P., G. M. Lovett, J. E. Hart, and B. Machona. 2007. Effects of nitrogen saturation on tree growth and death in a mixed-oak forest. *Forest Ecology and Management* 243:210–218.

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.

Wells, J. V. 1998. Important bird areas in New York State. National Audubon Society, New York, NY.

Whitaker, J. Jr., and M. G. Ferraro. 1963. Summer food of 220 short-tailed shrews from Ithaca, New York. *Journal of Mammalogy* 44:419.

Whitaker, J. Jr., and R. E. Mumford. 1972. Food and ectoparasites of Indiana shrews. *Journal of Mammalogy* 53:329-335.

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.

Wood, D. R. Yanai, D. Allen, S. Wilmont. 2009 Sugar maple decline after defoliation by forest tent caterpillar. *Journal of Forestry* 107:29-37.

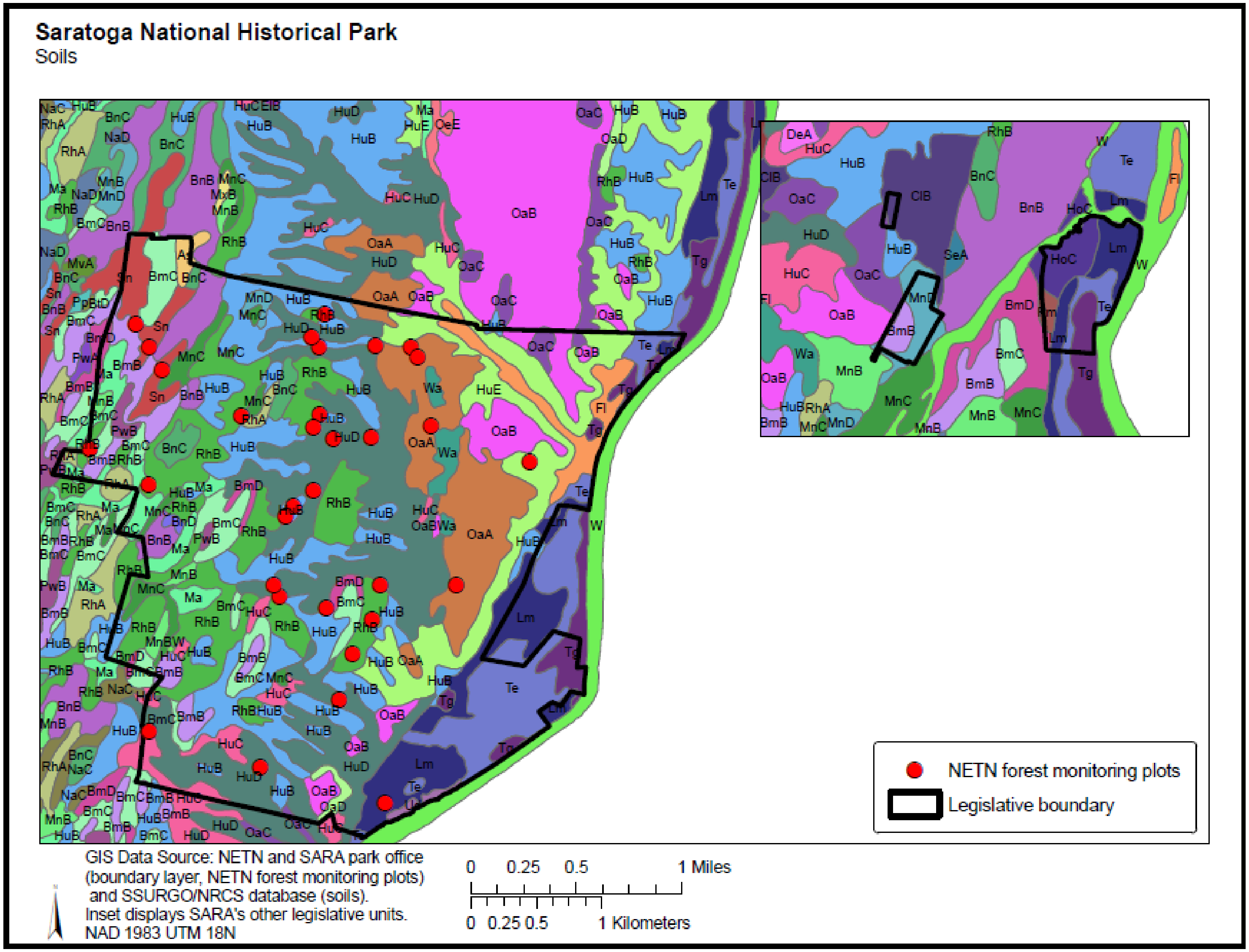
Woolbright, L. 2001-2003. The amphibian community of the Saratoga National Historical Park. Study # SARA-00002. Unpublished annual reports in park service files.

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 aluminium 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, and 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: Soil associations for SARA in relation to NETN forest monitoring plots.



Soil Map Abbreviation and Description Listing

ALA-Allagash fine sandy loam- nearly level

ALE-Allagash fine sandy loam- steep

ALC-Allagash fine sandy loam- strongly sloping

As-Allis silt loam

BCE-Becket sandy loam- steep- very bouldery

BCC-Becket sandy loam- strongly sloping- very bouldery

BEE-Becket-Tunbridge complex- steep- very bouldery

BEC-Becket-Tunbridge complex- strongly sloping- very bouldery

BHE-Berkshire loam- steep- very bouldery

BHC-Berkshire loam- strongly sloping- very bouldery

BLE-Berkshire-Tunbridge complex- steep- very bouldery

BLC-Berkshire-Tunbridge complex- strongly sloping- very bouldery

BmD-Bernardston silt loam- 15 to 25 percent slopes

BmB-Bernardston silt loam- 3 to 8 percent slopes

BmC-Bernardston silt loam- 8 to 15 percent slopes

BnD-Bernardston-Manlius-Nassau complex- hilly

BnC-Bernardston-Manlius-Nassau complex- rolling

BnB-Bernardston-Manlius-Nassau complex- undulating

BOE-Bice loam- steep- stony

BOC-Bice loam- strongly sloping- stony

BPE-Bice-Woodstock complex- steep- stony

BPC-Bice-Woodstock complex- strongly sloping- stony

BtD-Broadalbin silt loam- 15 to 25 percent slopes

BtB-Broadalbin silt loam- 3 to 8 percent slopes

BtC-Broadalbin silt loam- 8 to 15 percent slopes

BvD-Broadalbin-Manlius-Nassau- complex- hilly

BvC-Broadalbin-Manlius-Nassau- complex- rolling

BvB-Broadalbin-Manlius-Nassau- complex- undulating

BxB-Burdett silt loam- 3 to 8 percent slopes

CcD-Charlton loam- 15 to 25 percent slopes

CcB-Charlton loam- 3 to 8 percent slopes

CcC-Charlton loam- 8 to 15 percent slopes

CfD-Chatfield-Hollis complex- hilly- very rocky

CeC-Chatfield-Hollis complex- rolling- rocky

CeB-Chatfield-Hollis complex- undulating- rocky

Cg-Cheektowaga mucky very fine sandy loam

ChC-Chenango silt loam- loamy substratum- rolling

ChB-Chenango silt loam- loamy substratum- udulating

ClA-Claverack loamy fine sand- 0 to 3 percent slopes

ClB-Claverack loamy fine sand- 3 to 8 percent slopes

COE-Colton gravelly sandy loam- steep

COC-Colton gravelly sandy loam- strongly sloping

Cs-Cosad fine sandy loam

DeA-Deerfield loamy fine sand- nearly level

DeB-Deerfield loamy fine sand- undulating

ElB-Elmridge very fine sandy loam- 3 to 8 percent slopes

FcC-Farmington silt loam- 3 to 15 percent slopes- very rocky

FaB-Farmington silt loam- 3 to 8 percent slopes- rocky

FU-Fluvaquents-Udipsamments complex- flooded

Fl-Fluvaqvents frequently flooded

GaB-Galway loam- 3 to 8 percent slopes

GaC-Galway loam- 8 to 15 percent slopes

HcD-Hinckley gravelly loamy sand- hilly

HcA-Hinckley gravelly loamy sand- nearly level

HcC-Hinckley gravelly loamy sand- rolling

HcB-Hinckley gravelly loamy sand- undulating

HoA-Hoosic gravelly sandy loam- nearly level

HoC-Hoosic gravelly sandy loam- rolling

HoB-Hoosic gravelly sandy loam- undulating

HuE-Hudson silt loam- 25 to 35 percent slopes

HuB-Hudson silt loam- 3 to 8 percent slopes

HuC-Hudson silt loam- 8 to 15 percent slopes

HuD-Hudson silt loam- hilly

In-Ilion silt loam

Lm-Limerick-Saco complex

LY-Lyme fine sandy loam- very stony

Ma-Madalin mucky silty clay loam

MnD-Manlius-Nassau complex- hilly- rocky

MnC-Manlius-Nassau complex- rolling- rocky

MnB-Manlius-Nassau complex- undulating- rocky

Ms-Massena silt loam

MvA-Mosherville silt loam- 0 to 3 percent slopes

MvB-Mosherville silt loam- 3 to 8 percent slopes

MxB-Mosherville-Hornell complex- undulating

NaD-Nassau-Rock outcrop complex- hilly

NaC-Nassau-Rock outcrop complex- rolling

Ne-Newstead loam

NuB-Nunda silt loam- 3 to 8 percent slopes

NuC-Nunda silt loam- 8 to 15 percent slopes

OeE-Oakville and Windsor soils- 25 to 35 percent slopes

OaD-Oakville loamy fine sand- hilly

OaA-Oakville loamy fine sand- nearly level

OaC-Oakville loamy fine sand- rolling

OaB-Oakville loamy fine sand- undulating

Pm-Palms muck

Pp-Palms muck- ponded

PtB-Paxton gravelly sandy loam- 3 to 8 percent slopes

PtC-Paxton gravelly sandy loam- 8 to 15 percent slopes

Pu-Pits- quarry

Pv-Pits- sand and gravel

PwA-Pittstown silt loam- 0 to 3 percent slopes

PwB-Pittstown silt loam- 3 to 8 percent slopes

Ra-Raynham silt loam

RhA-Rhinebeck silt loam- 0 to 3 percent slopes

RhB-Rhinebeck silt loam- 3 to 8 percent slopes

Sa-Scarboro mucky loamy sand

SCB-Schroon sandy loam- gently sloping- stony

SeA-Scio silt loam- 0 to 3 percent slopes

SeB-Scio silt loam- 3 to 8 percent slopes

Sh-Shaker very fine sandy loam

SKB-Skerry fine sandy loam- gently sloping- very stony

Sn-Sun silt loam

StA-Sutton loam- 0 to 3 percent slopes

StB-Sutton loam- 3 to 8 percent slopes

Te-Teel silt loam

Tg-Tioga fine sandy loam

TNE-Tunbridge-Lyman complex- steep- very rocky

TNC-Tunbridge-Lyman complex- strongly sloping- very rocky

TNF-Tunbridge-Lyman complex- very steep- very rocky

Ud-Udipsamments- dredged

Ue-Udorthents- smoothed

UnB-Unadilla very fine sandy loam- 3 to 8 percent slopes

UnC-Unadilla very fine sandy loam- 8 to 15 percent slopes

Wa-Wareham loamy sand

W-Water

WnD-Windsor loamy sand- hilly

WnA-Windsor loamy sand- nearly level

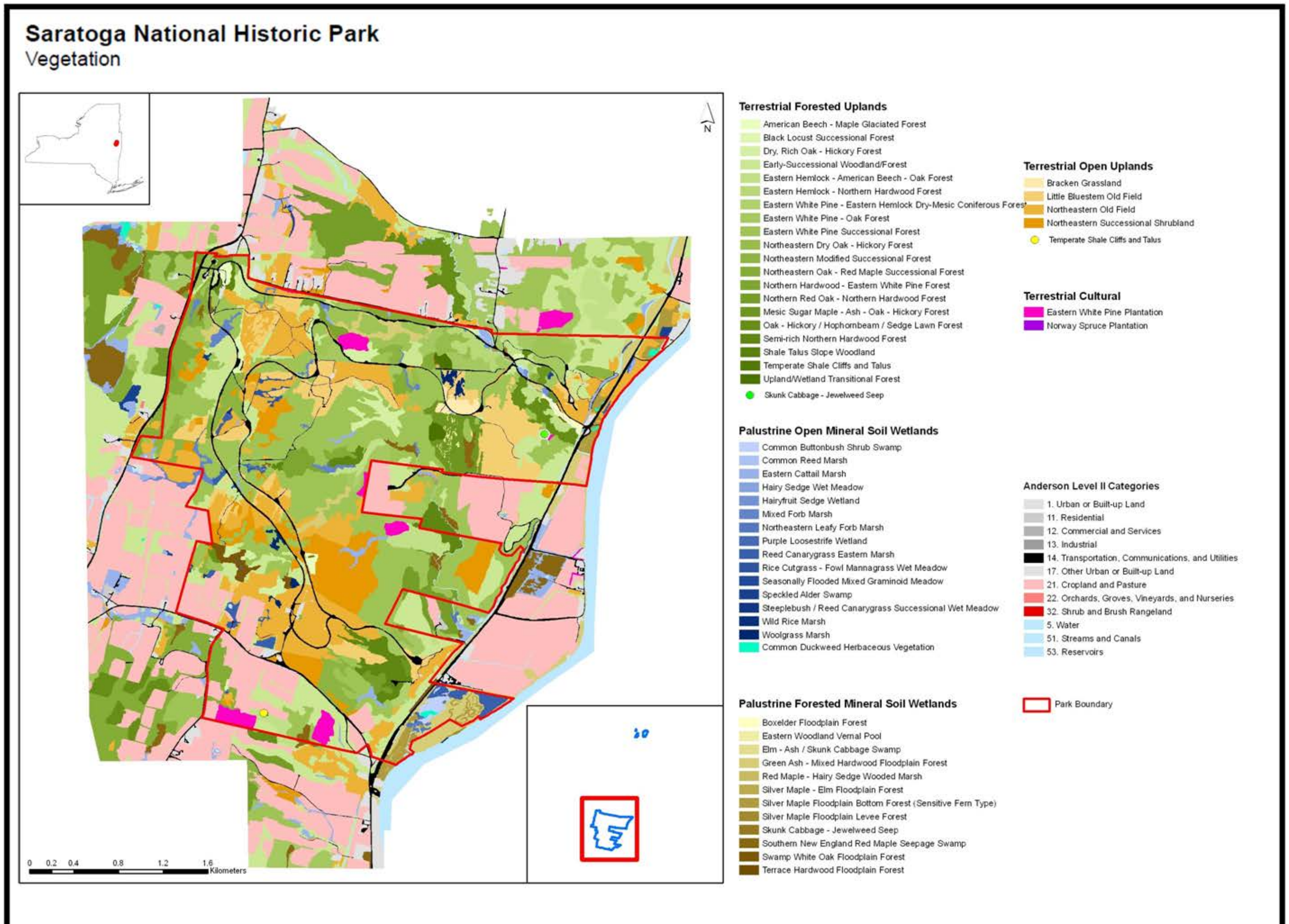
WnC-Windsor loamy sand- rolling

WnB-Windsor loamy sand- undulating

WO-Wonsqueak muck- ponded

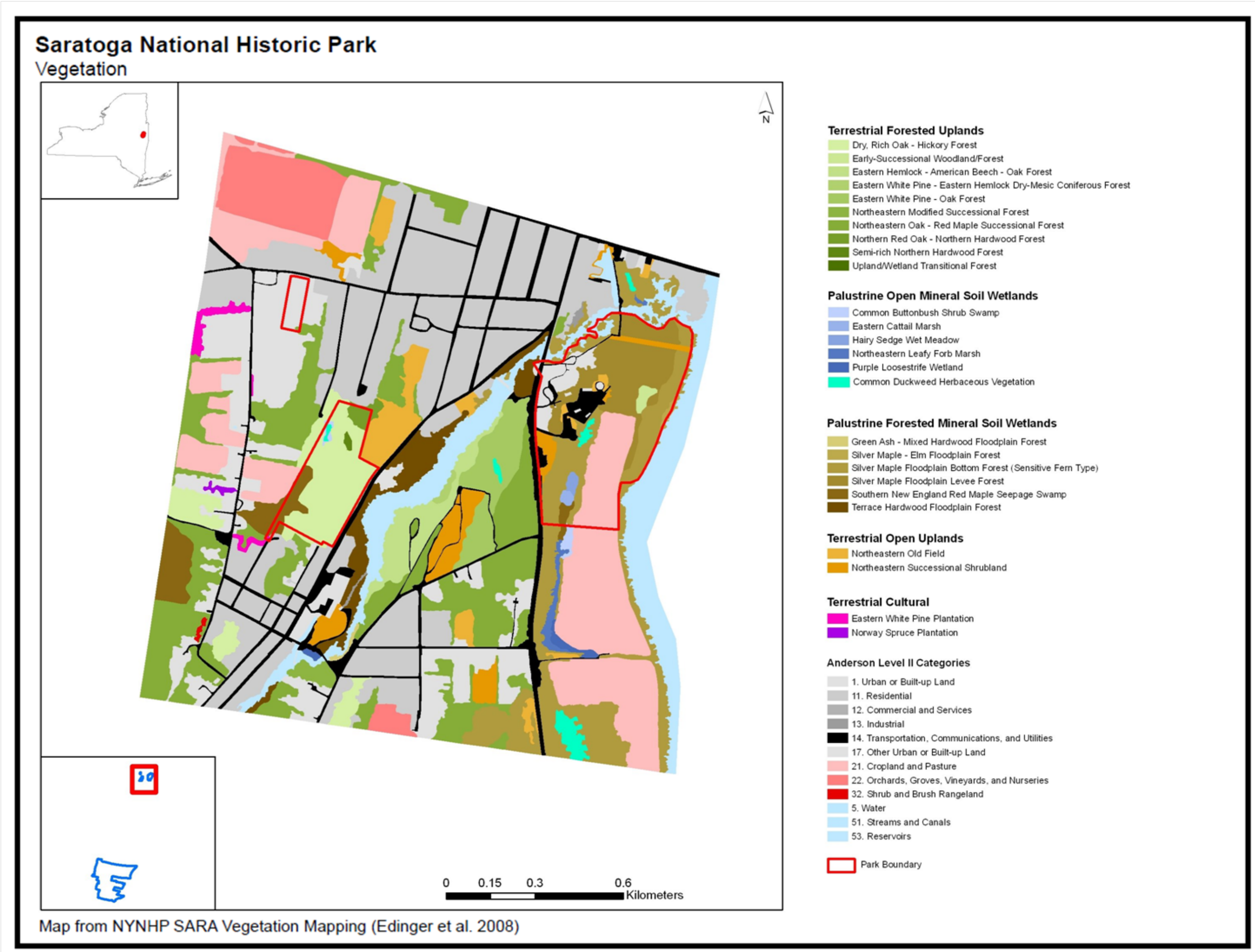
WrB-Woodbridge loam- 3 to 8 percent slop

Appendix B: Vegetation associations for SARA's Battlefiled Unit (Edinger et al. 2008).



Map from NYNHP SARA Vegetation Mapping (Edinger et al. 2008)

Appendix C. Vegetation associations for SARA's Old Saratoga Unit (Edinger *et al.* 2008).



Appendix D: Plant species identified in SARA as sensitive for ozone foliar injury and their categorization as a bioindicator for ozone foliar damage.

Order	Family	Scientific Name[1]	Common Names	Bioindicator of ozone damage[2]
Asterales	Asteraceae	*Eupatorium rugosum*	richweed snakeroot white snakeroot	X
Asterales	Asteraceae	*Rudbeckia laciniata*	cutleaf coneflower green-head coneflower	X
Asterales	Asteraceae	*Solidago altissima*	Canada goldenrod	
Dipsacales	Caprifoliaceae	*Sambucus canadensis*	American elder	X
Ericales	Ericaceae	*Gaylussacia baccata*	black huckleberry	X
Ericales	Ericaceae	*Lyonia ligustrina*	he-huckleberry maleberry	X
Fabales	Fabaceae	*Apios americana*	apios americana groundnut potatobean	X
Fabales	Fabaceae	*Robinia pseudoacacia*	black locust false acacia yellow locust	
Fagales	Betulaceae	*Alnus rugosa*	Speckled alder	X
Fagales	Betulaceae	*Corylus americana*	American hazelnut hazel hazelnut	X
Gentianales	Apocynaceae	*Apocynum androsaemifolium*	bitterroot flytrap dogbane spreading dogbane	X
Gentianales	Apocynaceae	*Apocynum cannabinum*	Indian hemp common dogbane dogbane hemp dogbane prairie dogbane	
Gentianales	Asclepiadaceae	*Asclepias incarnata*	rose milkweed swamp milkweed	
Gentianales	Asclepiadaceae	*Asclepias syriaca*	broadleaf milkweed common milkweed	X
Hamamelidales	Platanaceae	*Platanus occidentalis*	American sycamore sycamore	X
Laurales	Lauraceae	*Sassafras albidum*	sassafras	
Pinales	Pinaceae	*Pinus rigida*	pitch pine	
Ranunculales	Ranunculaceae	*Clematis virginiana*	Virginia bower devil's darning needles virgin's bower	

Appendix D: Continued.

Order	Family	Scientific Name[1]	Common Names	Bioindicator of ozone damage[2]
Rhamnales	Vitaceae	*Parthenocissus quinquefolia*	American ivy Virginia creeper fiveleaved ivy woodbine	
Rosales	Hydrangeaceae	*Philadelphus coronarius*	sweet mock orange	
Rosales	Rosaceae	*Prunus serotina*	black cherry black chokecherry	X
Rosales	Rosaceae	*Prunus virginiana*	Virginia chokecherry chokecherry common chokecherry	
Rosales	Rosaceae	*Rubus allegheniensis*	Allegheny blackberry	X
Salicales	Salicaceae	*Populus tremuloides*	quaking aspen	X
Scrophulariales	Oleaceae	*Fraxinus americana*	white ash	X
Scrophulariales	Oleaceae	*Fraxinus pennsylvanica*	green ash	

1. National Park Service. 2006. Ozone Sensitive Plant Species, by Park, November 2006. www.nature.nps.gov/air/permits/aris/docs/Ozone_Sensitive_ByPark_3600.pdf
2. National Park Service. 2003. NPS Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Service Lands: Results of a June 24-25, 2003 Workshop Baltimore, Maryland. www.nature.nps.gov/air/Pubs/pdf/BalkFinalReport1.pdf

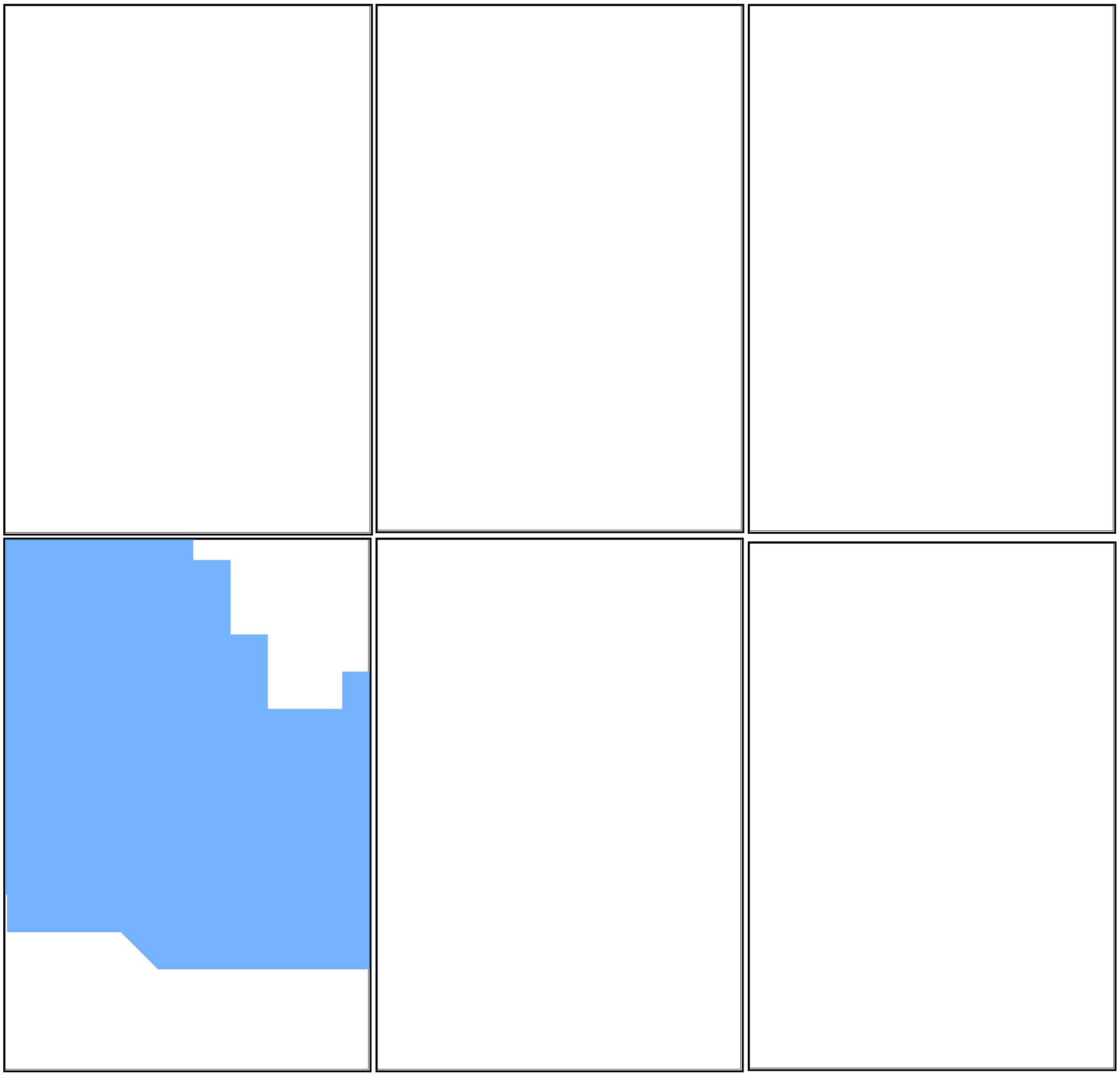
Appendix E: Variables, calculation methods and results used to determine park rankings and risk from acidification due to acidic deposition (Sullivan et al. 2011a).

Variable	Method of Calculation	Result
Nitrogen Pollutant Exposure Variables		
Average N deposition	Average total annual N deposition for all lands within the park (kg/ha/yr)	10.30
Average S deposition	Average total annual S deposition for all lands within the park (kg/ha/yr)	10
N emissions by county	Total county-level annual N emissions, as areally weighted average of all counties bordering on the park and within 100 miles of the park boundary, per unit area	3.34
S emissions by county	Total county-level annual S emissions, as areally weighted average of all counties bordering on the park and within 100 miles of the park boundary, per unit area	1.84
Ecosystem Sensitivity Variables		
Percent sensitive vegetation types	Amount of land within parks that occur within the network occupied by vegetation types expected to contain red spruce and/or sugar maple	16.66
Number of high-elevation lakes	Number of high-elevation lakes within the park	0
Length of low-order streams	Total length of streams within park that are 1st, 2nd, 3rd order (km)	2.72
Length of high-elevation streams	Total length of streams within park that occur at high elevation (km)	0
Average slope	Average slope of lands within park (degrees)	5.26
Sensitive area	Occurrence of more than 5% of park land within one or more of three regional studies that mapped acid sensitive areas in the United States	1
Park Protection Variables		
Amount of lands in the park receiving special protection	Area of park designated as wilderness and/or Class I	0
Percent of lands in the park receiving special protection	Percent of park designated as wilderness and/or Class I	0

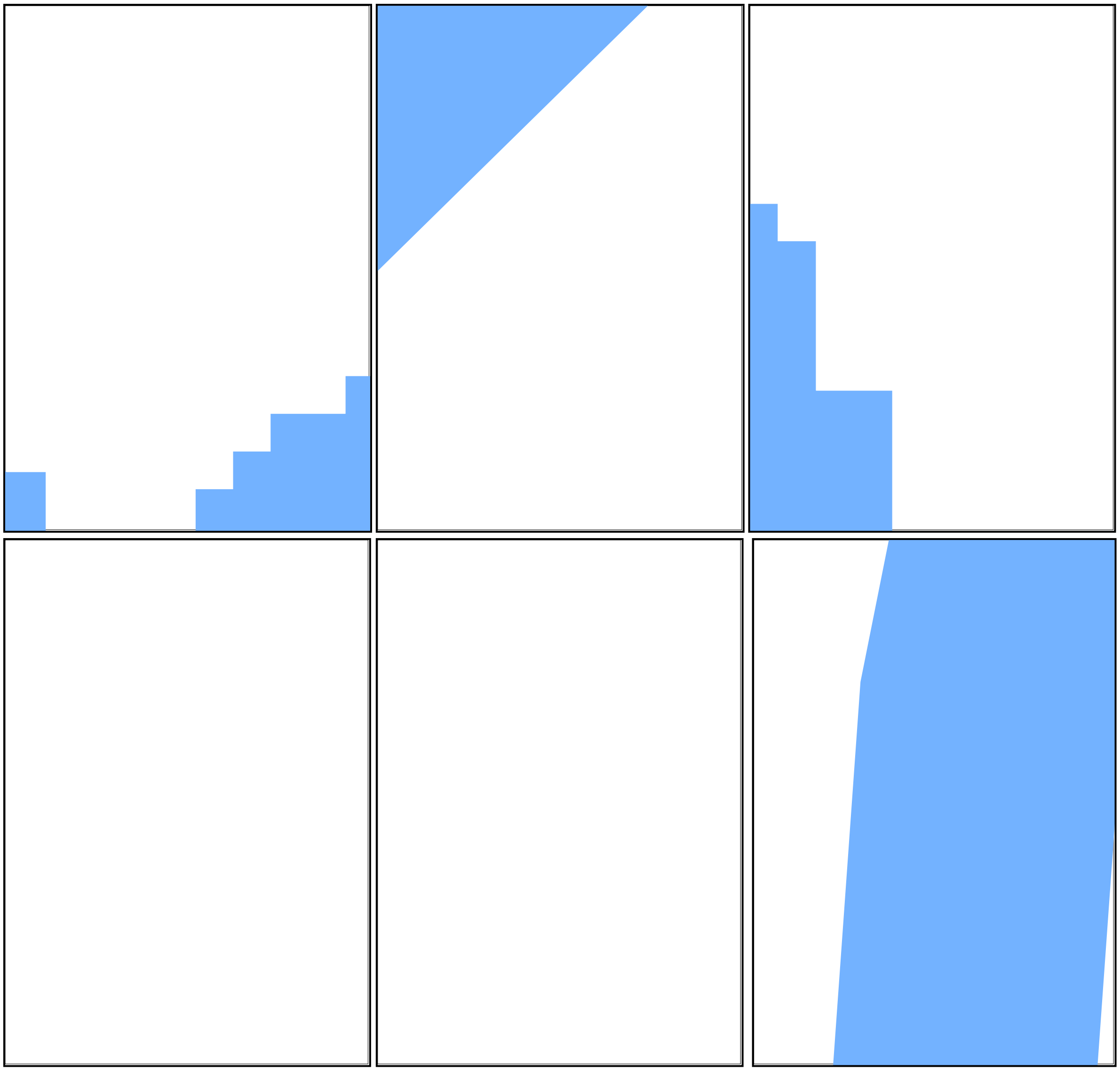
Appendix F: Variables, calculation methods and results used to determine park rankings and risk from nutrient enrichment from atmospheric nitrogen deposition (Sullivan et al. 2011b).

Variable	Method of Calculation	Result
Nitrogen Pollutant Exposure Variables		
Average N deposition	Average total annual N deposition for all lands within the park (kg/ha/yr)	10.30
N emissions by county	Total county-level annual N emissions, as areally weighted average of all counties bordering on the park and within 100 miles of the park boundary, per unit area	2.95
Ecosystem Sensitivity Variables		
Percent sensitive vegetation types	Percent of land within the park occupied by arctic, alpine, meadow, wetland and arid and semi-arid vegetation	6.28
Number of high-elevation lakes	Number of high-elevation lakes within the park	0
Park Protection Variables		
Amount of lands in the park receiving special protection	Area of park designated as wilderness and/or Class I	0
Percent of lands in the park receiving special protection	Percent of park designated as wilderness and/or Class I	0

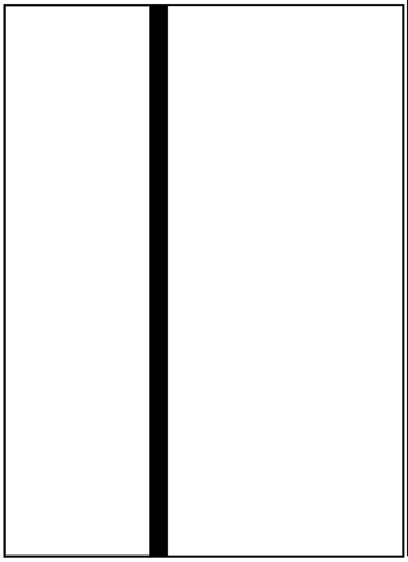
Appendix G: Total PCB sample locations closest to SARA and used for the SARA NRCA condition assessment.

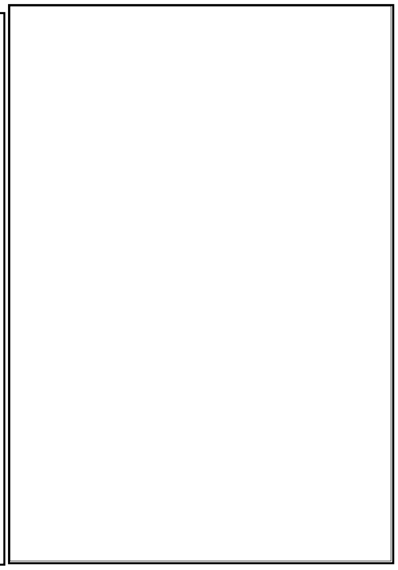


Appendix G: Continued

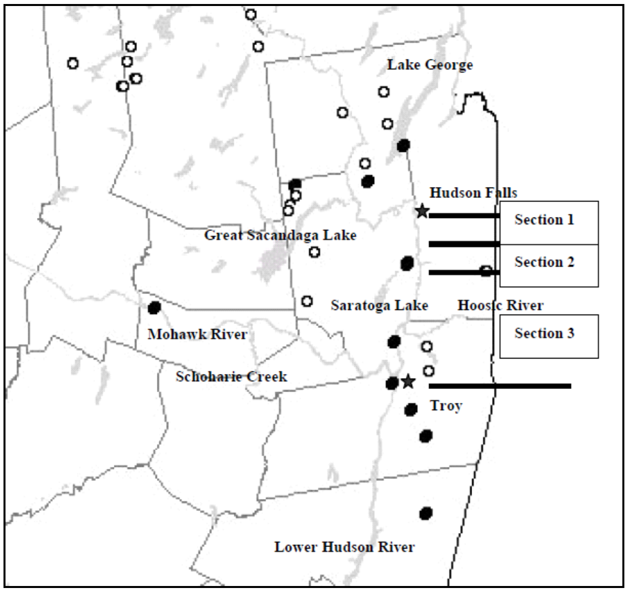


Appendix G: Continued

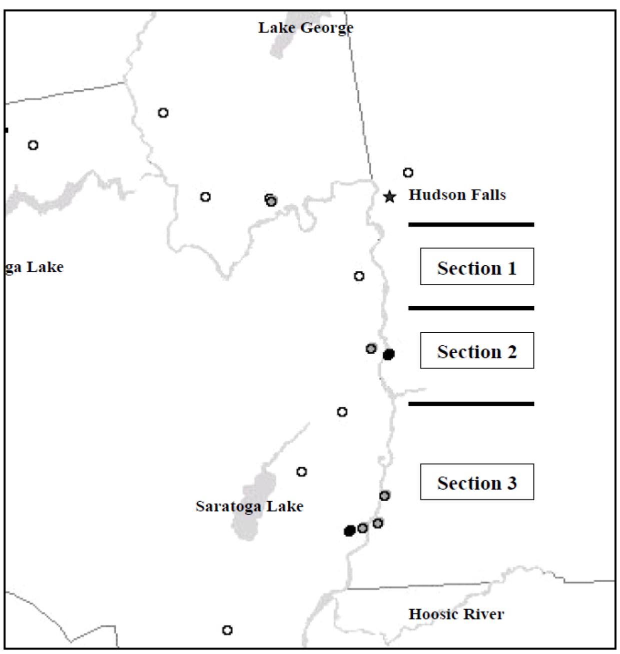




Appendix G: Continued



Region 2 Otter sampling. (Figure from Mayack and Loukmas 2001). Location of otters (40) collected from trappers during 1998-99 and 1999-2000 seasons. Open circles indicate otters with levels less than 9 µg total PCBs/g lipid; closed circles indicate levels equal to or greater than 9 µg total PCBs/g lipid. Location for a number of sites is obscured due to overlapping symbols. PCB contaminated reaches of the upper Hudson River are identified by EPA as Sections 1, 2, and 3; sediments are contaminated with PCBs at mean levels of 42, 26, and 9 mg/kg, respectively (TAMS Consultants 2000).



Region 2 Mink sampling. (Figure from Mayack and Loukmas 2001). Location of mink with PCB levels equal to or greater than 9 µg total PCBs/g lipid trapped by research staff during 1999-2000 or collected from trappers during 1998-1999 and 1999-2000 seasons. Open circles indicate mink with levels ranging from 9 to less than 21 µg total PCBs/g lipid. Gray circles indicate levels ranging from 21 to less than 50 µg total PCBs/g lipid. Closed circles indicate levels ranging from 50 to 139 µg total PCBs/g lipid. Location for a number of sites is obscured due to overlapping symbols. Sites are not indicated for mink with elevated levels from the Mohawk River (Montgomery County, 15.0 µg total PCBs/g lipid) and lower Hudson River (41.3 µg total PCBs/g lipid). PCB contaminated reaches of the upper Hudson River are identified by EPA as Sections 1, 2, and 3; sediments are contaminated with PCBs at mean levels of 42, 26, and 9 mg/kg, respectively (TAMS Consultants 2000).

Appendix H. SARA invasive plants assessment ratings and species occurrence documented in SARA surveys.

		Assessment Type		Historical Presence/Absence Inventories				
Scientific Name	**Common Name**	**NY Invasiveness Assessment Rank** [1]	**NETN Key invasive indicator species**[2]	**Stalter**[3] **(field survey 1987-1990)**	**Canham (2003) (field survey in 2003)**	**NETN sampling (Miller *et al.* 2009) (field survey in 2006, 2008)**	**Edinger *et al.* (2008) (field survey in 2003-2005)**	**Keefer *et al.* (2010)**[4] **(no field survey)**
Acer platanoides	Norway maple	Very High	x	x	x	x	X	x
Ailanthus altissima	tree of heaven	Medium	x				X	x
Aira caryophyllea	silver hairgrass	Not Rated		x				x
Alliaria petiolata	garlic mustard	Very High	x	x	x	x	X	x
Allium vineale	wild garlic	Not Rated				x	X	x
Anthoxanthum odoratum	sweet vernalgrass	Not Rated		x		x	x	x
Arenaria serpyllifolia	thymeleaf sandwort	Not Rated		x				
Barbarea vulgaris	garden yellowrocket	Not Rated		x				x
Berberis thunbergii	Japanese barberry	Very High	x		x	x	x	x
Berberis vulgaris	common barberry	Medium	x	x				x
Bromus inermis	smooth brome	Not Rated		x				
Bromus tectorum	cheatgrass	Medium						x
Campanual rapunculoides	creeping bellflower	Not Rated		x				
Cannabis sativa	marijuana	Not Rated		x				
Cardamine impatiens	Narrowleaf bittercress	High	x			x		
Celastrus orbiculatus	Oriental bittersweet	Very High	x	x	x	x	x	x
Centaurea jacea	brownray knapweed	Medium		x	x		x	x

		Assessment Type		Historical Presence/Absence Inventories				
Scientific Name	**Common Name**	**NY Invasiveness Assessment Rank** [1]	**NETN Key invasive indicator species**[2]	**Stalter**[3] **(field survey 1987-1990)**	**Canham (2003) (field survey in 2003)**	**NETN sampling (Miller *et al.* 2009) (field survey in 2006, 2008)**	**Edinger *et al.* (2008) (field survey in 2003-2005)**	**Keefer *et al.* (2010)**[4] **(no field survey)**
Centaurea stoebe ssp. *Micranthos*	spotted knapweed	High			x		x	x
Chenopodium album	lambsquarter	Not Rated		x				
Cirsium arvense	Canada thistle	High						x
Cirsium vulgare	bull thistle	Not Rated					x	x
Clematis terniflora	sweet autumn virginsbower	High		x				
Commelina communis	Asiatic dayflower	Not Rated		x				
Convallaria majalis	European lily of the valley	Not Rated		x				x
Cynanchum louiseas	black swallow-wort	Very High	x					
Cynanchum rossicum	European swallow-wort	Very High	x					
Dactylis glomerata	orchid grass	Not Rated		x				
Daucus carota	Queen Anne's lace	Not Rated		x			x	x
Dianthus armeria	Deptford pink	Not Rated		x				
Digitaria sanguinalis	large crabgrass	Not Rated		x				
Echinochloa crusgalli v. muricata	barnyard grass	Not Rated		x				
Echium vulgare	blueweed	Not Rated		x				
Elaeagnus umbellata	autumn olive	Very High		x	x			x
Epipactis helleborine	helleborne	Not Rated		x		x		
Euonymus alata	winged burning bush	Very High	x			x		
Festuca rubra	red fescue	Not Rated		x				

		Assessment Type		Historical Presence/Absence Inventories				
Scientific Name	**Common Name**	**NY Invasiveness Assessment Rank** [1]	**NETN Key invasive indicator species**[2]	**Stalter**[3] **(field survey 1987-1990)**	**Canham (2003) (field survey in 2003)**	**NETN sampling (Miller *et al.* 2009) (field survey in 2006, 2008)**	**Edinger *et al.* (2008) (field survey in 2003-2005)**	**Keefer *et al.* (2010)**[4] **(no field survey)**
Frangula alnus	glossy buckthorn	High	x			x		
Galinsoga quadriradiata	hairy galinsoga	Not Rated		x				
Glechoma hederacea	ground ivy	Not Rated		x			x	x
Hemerocallis fulva	orange daylily	Low		x				x
Hesperis matronalis	dame's rocket	Medium					x	x
Hieracium auranticum	orange hawkweed	Not Rated		x				
Hieracium pilosella	mouse ear hawkweed	Not Rated		x				
Holcus lanatus	common velvetgrass	Not Rated		x				
Hypericum perforatum	common St. Johnswort	Low		x				
Hypochaeris radicata	hairy cat's ear	Not Rated		x				
Inula helenium	elecampane	Not Rated		x				
Iris pseudacoris	paleyellow iris	High					x	x
Lactuca serriola	prickly lettuce	Not Rated		x				
Lamium amplexicaule	henbit	Not Rated		x				
Lathyrus latifolia	everlasting peavine	Not Rated		x				
Leonurus cardiaca	motherwort	Not Rated		x				
Linaria vulgaris	yellow toadflax	Not Rated		x				
Lingustrum spp. *(obtusifolium, vulgare)*	privet	High	x			x		
Lonicera japonica	Japanese honeysuckle	Very High	x					
Lonicera morrowii	Morrow's honeysuckle	Very High			x			x
Lonicera spp.	exotic honeysuckle	Very High	x			x		

		Assessment Type		Historical Presence/Absence Inventories				
Scientific Name	**Common Name**	**NY Invasiveness Assessment Rank** [1]	**NETN Key invasive indicator species**[2]	**Stalter**[3] **(field survey 1987-1990)**	**Canham (2003) (field survey in 2003)**	**NETN sampling (Miller *et al.* 2009) (field survey in 2006, 2008)**	**Edinger *et al.* (2008) (field survey in 2003-2005)**	**Keefer *et al.* (2010)**[4] **(no field survey)**
Lonicera tatarica	Tatarian honeysuckle	Very High	x	x	x		x	x
Lonicera x bella	Bell's honeysuckle	Very High	x		x			
Lotus corniculatus	birdsfoot trefoil	Medium		x				
Luzula luzuloides	forest woodrush	Not Rated	x					
Lysimachia nummularia	creeping jenny/moneywort	Very High					x	x
Lythrum salicaria	purple loosestrife	Very High		x	x		x	x
Medicago lupulina	black medic	Not Rated		x				
Medicago sativa	alfalfa	Not Rated		x				
Melilotus officinalis	yellow sweetclover	Not Rated		x				
Mentha x piperita	peppermint	Not Rated		x				
Microstegium vimineum	Japanese stiltgrass	Very High	x			x		
Morus alba	white mulberry	Medium		x			x	x
Myosotis scorpioides	forget-me-not	Not Rated						x
Pastinaca sativa	wild parsnip	Not Rated		x				
Phalaris arundinacea	reed canarygrass	High			x		x	x
Phleum pratense	timothy	Medium		x				
Phragmites australis	common reed	Very High			x		x	x
Picea abies	Norway spruce	Not Rated		x				
Pinus sylvestris	Scots pine	Not Rated		x				
Plantago lanceolata	narrowleaf plantain	Not Rated		x				x
Plantago major	common plantain	Not Rated		x			x	x

		Assessment Type		Historical Presence/Absence Inventories				
Scientific Name	**Common Name**	**NY Invasiveness Assessment Rank [1]**	**NETN Key invasive indicator species[2]**	**Stalter[3] (field survey 1987-1990)**	**Canham (2003) (field survey in 2003)**	**NETN sampling (Miller *et al.* 2009) (field survey in 2006, 2008)**	**Edinger *et al.* (2008) (field survey in 2003-2005)**	**Keefer *et al.* (2010)[4] (no field survey)**
Poa compressa	Canada bluegrass	Medium		x				x
Poa trivialis	roughtstalk bluegrass	Not Rated		x				
Polygonum caespitosum	Oriental ladysthumb	Not Rated	x			x		
Polygonum cuspidatum	Japanese knotweed	Very High	x	x	x		x	x
Polygonum persicaria	spotted ladysthumb	Not Rated					x	x
Portulacca oleracea	common purslane	Not Rated		x				
Potentilla recta	sulphur cinquefoil	Not Rated		x				x
Prunella vulgaris	healall	Not Rated		x				
Pyrus communis	common pear	Medium		x				
Ranunculus acris	tall buttercup	Not Rated		x				
Ranunculus repens	creeping buttercup	Medium					x	x
Raphanus raphanistrum	wild radish	Not Rated		x				
Rhamnus cathartica	common buckthorn	Very High	x	x	x	x	x	x
Rhodotypos scandens	jetbead	Medium	x			x		
Robinia pseudoacacia	black locust	Very High		x	x	x	x	x
Rosa multiflora	multiflora rose	Very High	x			x	x	x
Rubus idaeus	European red raspberry	Not Rated		x				
Rubus phoenicolasius	wineberry	Very High	x			x		
Rumex acetosella	common sheep sorrel	Medium		x				x
Rumex cripus	curly dock	Not Rated		x				
Salix fraglis	crack willow	Not Rated		x				
Securigera varia	crownvetch	Not Rated						x

		Assessment Type		Historical Presence/Absence Inventories				
Scientific Name	**Common Name**	**NY Invasiveness Assessment Rank** [1]	**NETN Key invasive indicator species**[2]	**Stalter**[3] **(field survey 1987-1990)**	**Canham (2003) (field survey in 2003)**	**NETN sampling (Miller *et al.* 2009) (field survey in 2006, 2008)**	**Edinger *et al.* (2008) (field survey in 2003-2005)**	**Keefer *et al.* (2010)**[4] **(no field survey)**
Setaria faberi	giant foxtail	Not Rated		x				
Setaria viridis	green foxtail	Not Rated		x				
Silene vulgaris	bladder campion	Not Rated		x				
Solanum dulcamara	bittersweet nightshade	Medium		x			x	x
Sonchus asper	spiny sowthistle	Not Rated		x				
Syringa vulgaris	common lilac	Not Rated		x				
Taraxacum officinale	dandelion	Not Rated		x				
Thlaspi arvense	field pennycress	Not Rated		x				
Tragopogon dubius	western salsify	Not Rated		x				
Trapa natans	water chestnut	Very High			x		x	
Trifolium arvense	rabbitfoot clover	Not Rated		x				
Trifolium aureum	hop clover	Not Rated		x				
Trifolium campestre	large hop clover	Not Rated		x				
Trifolium hybridum	alsike clover	Not Rated		x				
Trifolium pratense	red clover	Not Rated		x				
Trifolium repens	white clover	Not Rated		x				
Tussilago farfara	coltsfoot	Not Rated		x				x
Valeriana officinalis	garden heliotrope	Medium						x
Verbascum thapsus	common mullein	Not Rated		x			x	x
Veronica serpyllifolia	thymeleaf speedwell	Not Rated		x				
Viburnum sieboldii	Siebold viburnum	Medium		x				
Vicia cracca	cow vetch	Medium		x				

		Assessment Type		Historical Presence/Absence Inventories				
Scientific Name	**Common Name**	**NY Invasiveness Assessment Rank** [1]	**NETN Key invasive indicator species**[2]	**Stalter**[3] **(field survey 1987-1990)**	**Canham (2003) (field survey in 2003)**	**NETN sampling (Miller *et al.* 2009) (field survey in 2006, 2008)**	**Edinger *et al.* (2008) (field survey in 2003-2005)**	**Keefer *et al.* (2010)**[4] **(no field survey)**
Vinca minor	common periwinkle	Medium		x				

[1]NY ranking system for evaluating non-native plant species for invasiveness is described in Marilyn *et al.* (2009). [2] NETN key invasive exotic plants indicator species are species that are highly invasive in forest, woodland and succesional habitats in NETN parks (Miller *et al.* 2009). [3]Stalter identified many alien species, some of which are not considered to possess invasive characteristics. Invasiveness of species in Stalter's listing was referenced with the Invasive Plant Atlas of the United States. [4]Keefer *et al.* provided a listing of all invasive species known or thought to occur in SARA.

Appendix I. Non-indigenous aquatic species listed in the USGS database as occurring in HUC 8 02020003 watershed*.

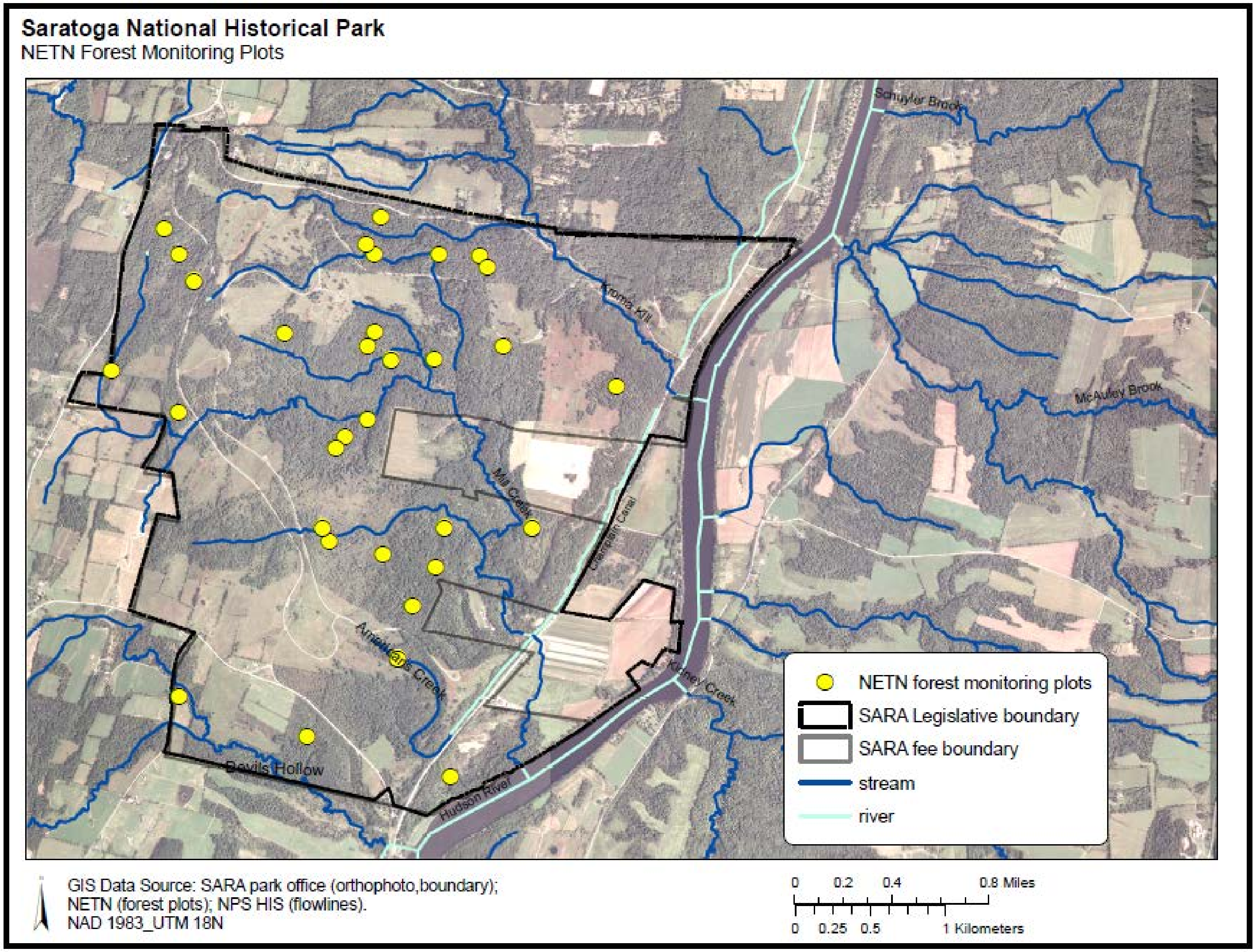
Category	Family	Scientific Name	Common Name
Coelenterates-Hydrozoans	Olindiidae	*Craspedacusta sowerbyi*	freshwater jellyfish
Crustaceans-Crayfish	Cambaridae	*Orconectes virilis*	virile crayfish
Fishes	Centrarchidae	*Lepomis macrochirus*	bluegill
Fishes	Centrarchidae	*Micropterus dolomieu*	smallmouth bass
Fishes	Centrarchidae	*Pomoxis nigromaculatus*	black crappie
Fishes	Clupeidae	*Alosa pseudoharengus*	alewife
Fishes	Cyprinidae	*Carassius auratus*	goldfish
Fishes	Cyprinidae	*Ctenopharyngodon idella*	grass carp
Fishes	Cyprinidae	*Cyprinus carpio*	common carp
Fishes	Esocidae	*Esox lucius*	northern pike
Fishes	Esocidae	*Esox lucius x E. masquinongy*	tiger muskellunge
Fishes	Ictaluridae	*Noturus miurus*	brindled madtom
Fishes	Petromyzontidae	*Ichthyomyzon unicuspis*	silver lamprey
Fishes	Salmonidae	*Oncorhynchus mykiss*	rainbow trout
Fishes	Salmonidae	*Salmo trutta*	brown trout
Mollusks-Bivalves	Corbiculidae	*Corbicula fluminea*	Asian clam
Mollusks-Bivalves	Dreissenidae	*Dreissena polymorpha*	zebra mussel
Mollusks-Gastropods	Lymnaeidae	*Radix auricularia*	European ear snail
Plants	Lamiaceae	*Mentha gracilis*	creeping whorled mint
Plants	Apiaceae	*Conium maculatum*	poison hemlock
Plants	Asteraceae	*Sonchus arvensis*	field sow thistle

Category	Family	Scientific Name	Common Name
Plants	Boraginaceae	*Myosotis scorpioides*	true forget-me-not
Plants	Cabombaceae	*Cabomba caroliniana*	Carolina fanwort
Plants	Caryophyllaceae	*Myosoton aquaticum*	giant chickweed
Plants	Chenopodiaceae	*Chenopodium glaucum*	oak-leaved goosefoot
Plants	Haloragaceae	*Myriophyllum spicatum*	Eurasian water-milfoil
Plants	Iridaceae	*Iris pseudacorus*	yellow iris
Plants	Juncaceae	*Juncus gerardii*	black-grass rush
Plants	Lamiaceae	*Mentha aquatica*	watermint
Plants	Lamiaceae	*Mentha spicata*	spearmint
Plants	Lythraceae	*Lythrum salicaria*	purple loosestrife
Plants	Menyanthaceae	*Nymphoides peltata*	yellow floating-heart
Plants	Najadaceae	*Najas minor*	brittle naiad
Plants	Onagraceae	*Epilobium hirsutum*	great hairy willow herb
Plants	Poaceae	*Agrostis gigantea*	redtop
Plants	Poaceae	*Echinochloa crusgalli*	barnyard grass
Plants	Poaceae	*Poa trivialis*	rough-stalked meadow grass
Plants	Polygonaceae	*Polygonum persicaria*	lady's thumb
Plants	Polygonaceae	*Rumex longifolius*	yard dock
Plants	Polygonaceae	*Rumex obtusifolius*	bitter dock
Plants	Potamogetonaceae	*Potamogeton crispus*	curly pondweed
Plants	Primulaceae	*Lysimachia nummularia*	moneywort
Plants	Salicaceae	*Salix alba*	white willow
Plants	Salicaceae	*Salix fragilis*	crack willow
Plants	Solanaceae	*Solanum dulcamara*	bittersweet nightshade

Category	Family	Scientific Name	Common Name
Plants	Trapaceae	*Trapa natans*	water-chestnut
Plants	Typhaceae	*Typha angustifolia*	narrow-leaved cattail

This appendix does not list all non-indigenous species present in the 02020003 watershed, only those species reported to the USGS database.

Appendix J. NETN forest monitoring plots established for SARA from 2007 through 2010.



Appendix K. Summary of literature describing accounts of amphibians and reptiles from Saratoga National Historical Park.

Species (Common Name)	NPS (1986)	Lynch (NPS 1987-1988)	Troha (NPS 1995)	Vana-Miller (2001)	Woolbright (2001-2003)	NPS Incidental Observations (1995-2010)	Cook *et al.* (2011)
Northern Spring Peeper	X	X	X	X	X		X
Gray Treefrog		X	X	X	X		X
Northern Green Frog		X	X	X	X		X
Wood Frog	X	X	X	X	X		X
American Bullfrog			X	X	X		X
Northern Leopard Frog		X	X	X	X		X
Eastern American Toad	X	X	X	X	X		X
Pickerel Frog				X			X
Eastern Red-backed Salamander	X	X	X	X			X
Spotted Salamander		X		X	X		X
Jefferson Salamander	X			X			X
Northern Two-lined Salamander	X	X	X	X	X		X
Red-spotted Newt	X	X	X	X	X		X
Spring Salamander	X			X			
Northern Dusky Salamander				X			
Eastern Snapping Turtle				X			X
Painted Turtle		X	X	X			X
Eastern Box Turtle		X		X			X
Wood Turtle		X		X		X (2004)	
Stinkpot				X*		X (2010)	
Northern Map Turtle				X*			
Spotted Turtle				X		X (1995-1998)	
Common Garter Snake		X	X	X			X
Eastern Milk Snake		X		X			X
Northern Water Snake		X		X			X

Species (Common Name)	NPS (1986)	Lynch (NPS 1987-1988)	Troha (NPS 1995)	Vana-Miller (2001)	Woolbright (2001-2003)	NPS Incidental Observations (1995-2010)	Cook *et al.* (2011)
Brown Snake		X		X	X		X
Northern Red-bellied Snake		X		X			X
Smooth Green Snake			X	X			
Eastern Hognose Snake				X*			
Eastern Ribbon Snake				X			

* known from Saratoga County but have not been found at SARA.

NPS 374/123442, January 2014

National Park Service
U.S. Department of the Interior

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