National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Natural Resource Condition Assessment

Weir Farm National Historic Site

Natural Resource Report NPS/NETN/NRR—2016/1256

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Weir Farm National Historic Site
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Natural Resource Condition Assessment

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Natural Resource Report NPS/NETN/NRR—2016/1256

Geri Tierney and James Gibbs

Environmental Science and Forestry College
State University of New York
Syracuse, NY 13210

August 2016

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Tierney, G., and J. Gibbs. 2016. Natural resource condition assessment: Weir Farm National Historic Site. Natural Resource Report NPS/NETN/NRR—2016/1256. National Park Service, Fort Collins, Colorado.

NPS 413/133675, August 2016

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Executive Summary

This Natural Resource Condition Assessment (NRCA) evaluates current conditions and trends for a subset of natural resource indicators and identifies critical data gaps for Weir Farm National Historic Site (WEFA). The resources and indicators included herein reflect the park's resource setting, status of resource stewardship planning and science, and availability of data and expertise to assess current conditions for a variety of potential indicators. The goal of this report is to provide clear, credible, integrative reporting to assist and inform park managers, stake-holders and the public.

Established in 1990, the park preserves a significant site of American Impressionism and maintains a setting of artistic expression, while offering opportunities for inspiration and education. The 28-ha (68-ac) park, located in southwestern Connecticut, preserves about a quarter of the historic farm and woodlot that was the summer home and workplace of J. Alden Weir (1852-1919), a pioneer of the Impressionist tradition in American art. These rolling hills, fields and forest, stone walls, rock outcrops, streams and pond have provided inspiration to artists for more than a century, and continue to do so in the present day.

Lying within a network of protected areas extending west and east of the park, WEFA provides valuable forest, wetland and pond habitat within a suburban residential landscape. Species of conservation interest documented in the park include five bat species, one turtle, and several bird species.

Using the NPS Vital Signs Indicator Framework, 23 Vital Signs of natural resource condition were selected for assessment and reporting herein. Assessment points were established to distinguish between acceptable or desired conditions (i.e., *good condition*) and those that warrant *moderate concern* or *significant concern*. These assessment points were derived from knowledge of ecological integrity, regulatory or program standards, park management goals, historical data or other sources.

Key findings and recommendations for WEFA are summarized below by resource category.

Air and Climate

Key findings	Recommendations
Ozone pollution warrants *significant concern* for human health, and *moderate concern* for park vegetation.	Continue to monitor and work collaboratively with federal, state and local partners to reduce air pollution.
Acidic deposition rates for both nitrogen and sulfur have declined, but remain at levels which warrant *significant concern* to park ecosystems.	
Mercury deposition and transformation rates exceed levels which may harm park ecosystems, warranting *moderate concern*.	
Impaired visibility of park views due to anthropogenic haze warrants *moderate concern*. Natural light quality is an important data gap at WEFA.	Consider monitoring key landscape scenes using time-lapse photography.
Current condition of temperature and precipitation variables show extreme warm and wet conditions compared to the historical record.	Expand efforts to identify and monitor status and trends of key indicators of climate change, and to identify and monitor valued park resources at high risk to climate change impacts.
Modeled data indicate anthropogenic noise may warrant *significant concern*. Modeled data indicate anthropogenic light pollution may warrant *moderate concern*.	Consider on-site monitoring.

Geology and Soils

Key findings	Recommendations
Forest soils are well buffered, but warrant concern for nitrogen saturation and aluminum toxicity.	Continue to monitor and work collaboratively with federal, state and local partners to reduce air pollution, a major stressor affecting forest soil chemistry.

Water Quantity and Quality

Key findings	Recommendations
Assessment points for understanding condition of water quantity have not been established.	Consider establishing assessment points based on monitored levels and ecological function.
Water chemistry in Weir Pond showed *good condition*, but warranted some concern for increasing trends in specific conductance and chloride.	Continue to monitor, and investigate sources of chloride loading to Weir Pond. Work collaboratively with state agencies and park neighbors to reduce water pollution from roads, adjacent residences and other sources.

Biological Integrity

Key findings	Recommendations
Weir Pond remains uninvaded by exotic aquatic plants.	Continue invasive plant detection and management programs.
Invasion of park forests by exotic plants warrants *significant concern*.	
Detections of emerald ash borer and viburnum leaf beetle in Fairfield County warrant *significant concern*. The Asian longhorned beetle also poses enormous threats to park forest resources.	Early detection of key forest pests and rapid response must continue to be a high priority.
Wetland vegetation is not monitored. Preliminary assessment of wetland buffers indicates *moderate concern* for buffer width.	Consider monitoring park wetlands using rapid assessment methods.
Most forest stands display mature or late-successional structure, rating *good condition*. Low levels of standing dead trees (snags) and coarse woody debris (CWD) warrant *moderate concern*. Low levels of tree regeneration warrant *significant concern*. Moderate levels of tree foliage damage warrant *moderate concern*. Tree growth rates in the park are lower than regional means, while tree mortality rates are within expected levels.	Continue to monitor. Allow snags and CWD to remain in place. Consider management options, including deer exclosures.
High deer density in Fairfield County warrants *significant concern* for impacts to vegetation. Assessment of deer-browse indicator species in forest plots indicated *moderate concern*. Road kill data show an improving trend in deer density (ie, a declining trend in density).	Continue to monitor. Consider using deer exclosures to protect key sites or vegetation from browsing.
Eight of thirteen forest bird condition metrics warranted *significant concern* for ecological integrity. Seven of thirteen metrics showed deteriorating trends.	Continue to monitor.
Sensitive species, pond-breeding salamanders and vernal pool-breeding amphibians were well represented in the amphibian community at the time of the park inventory in 2000.	Consider annual monitoring to determine status and trends of key species.
Population trends for bat species are an important data gap.	Consider establishing a bat monitoring program.
Population trends for mammal species are a data gap.	Consider monitoring key mammal species.
Population trends for terrestrial invertebrate species are a data gap.	Consider monitoring selected invertebrate taxa.

Landscapes

Key findings	Recommendations
Forest patch size is sufficient to support invertebrates, small mammals and many bird species, but patch configuration and perforation has reduced the amount of interior or intact forest habitat.	Continue to monitor, and work with local partners to advocate for appropriate land uses in the park neighborhood.
Levels of anthropogenic land use surrounding the forest plots at WEFA may be a *moderate concern*.	
Coverage by impervious surfaces in the park is minimal, representative of *good condition*.	

Acknowledgments

For useful input during the scoping and analysis phases of this assessment, and for reviewing and providing useful input on drafts of this report, we thank L. Cook, G. Waters, C. Roman, B. Gawley, C. Arnott, C. Chapin, S. Colwell, M. Norris, P. Sharpe, H. Salazer, B. Mitchell, F. Dieffenbach, A. Kozlowski, B. Oko, J. Kace, P. Halsey and P. Sesto. We thank J. Wheeler, H. Kilpatrick, M. Gregonis, and H. Salazar for sharing data useful to this assessment. We also thank E. Brown and J. White of the NPS Natural Sounds & Night Skies Division (NSNSD) for providing guidance and data for assessing soundscape and lightscape, respectively. This report was prepared under Task Agreement P14AC00983 between the National Park Service, Northeast Region and the Research Foundation of SUNY on behalf of the SUNY College of Environmental Science and Forestry, through the North Atlantic Coast Cooperative Ecosystem Studies Unit (CESU).

NRCA Background Information

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

NRCAs Strive to Provide…

- *Credible condition reporting for a subset of important park natural resources and indicators*
- *Useful condition summaries by broader resource categories or topics, and by park areas*

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

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

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

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

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

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

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

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

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

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

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

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

Important NRCA Success Factors

- *Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline*
- *Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures ⇨ indicators ⇨ broader resource topics and park areas)*
- *Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings*

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

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

NRCA Reporting Products…

Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations*
  (near-term operational planning and management)
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values*
  (longer-term strategic planning)
- *Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public*
  ("resource condition status" reporting)

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

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

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

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

Introduction and Resource Setting

Introduction

Weir Farm National Historic Site (WEFA) was established in 1990 to preserve and interpret historically significant properties and landscapes associated with the life and work of J. Alden Weir (1852-1919), a pioneer of the Impressionist tradition in American art (Public Law 101-485). Located in the Connecticut towns of Wilton and Ridgefield, the 28-ha (68-ac) park preserves about a quarter of the historic farm and woodlot that was Weir's summer home and workplace in the late 19th and early 20th centuries (NPS 1995).

These rolling hills, fields and forest, stone walls, rock outcrops, streams and a pond were inspirational to J. Alden Weir, as well as to visiting artists such as Childe Hassam, John Twachtman, Emil Carlsen and Albert Pinkham Ryder, seeking to paint outdoors *en plein air*[1] (Gardner and McKay 1990). After Weir's death in 1919, the site continued to be occupied by artists, including Weir's daughter Dorothy Weir Young and son-in-law, sculptor Mahonri Young, and later by painters Doris and Sperry Andrews (NPS 1995). The park is an outstanding example of a landscape which inspired American artists (NPS 1995). WEFA is one of only two national park units focused primarily on fine art. Together with protected areas lying to the southwest (the Weir Preserve) and to the northeast (the Town of Ridgefield's Nod Hill Refuge), WEFA provides an important natural and cultural resource within a fragmented, suburban landscape.

Enabling Legislation

WEFA was established in 1990 by Public Law 101-485 "(1) to preserve a significant site of the tradition of American Impressionism; (2) to maintain the integrity of a setting that inspired artistic expression and encourages public enjoyment; and (3) to offer opportunities for the inspirational benefit and education of the American people." In 1998, Public Law 105-363 authorized and provided funding for the acquisition of additional land to permit the development of visitor and administrative facilities at WEFA. In 2009, Public Law 111-11 clarified acceptable location and maintenance of such additional land.

Geographic Setting

WEFA is located in a low-density residential suburb in the Connecticut towns of Wilton and Ridgefield (Figure 2-1), and lies within a network of protected areas extending west and east of the park (see Appendix A). WEFA is bordered to the southwest by the 45- ha (110-ac) Weir Preserve, to the northeast by the 10.9- ha (26.9- ac) Town of Ridgefield's Nod Hill Refuge, and by private homes on 0.8-ha (2-acre) lots and a small cemetery. Another 35 ha (86 acres) of undeveloped land lying southeast of WEFA is owned by the CT Department of Transportation (CT DOT) for possible future transportation use.[2] This CT DOT property has been proposed for inclusion in the Norwalk River

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[1] Painting *en plein air* ("in full air") is done outdoors, with the painter reproducing actual visual conditions at the time of painting.

[2] This land was acquired for a proposed upgrade to Route 7 referred to as the "Super Seven Expressway."

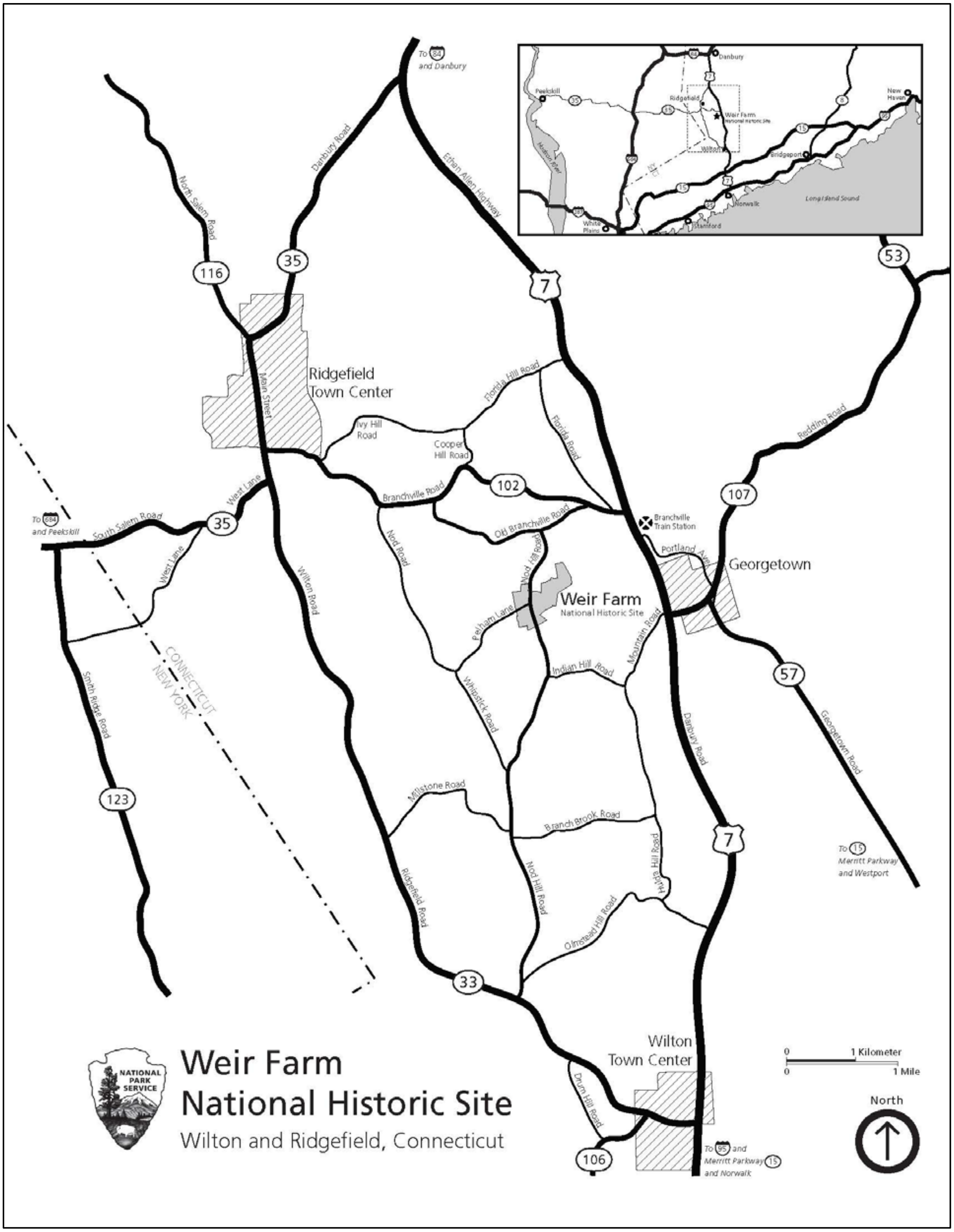

Figure 2-1. Location of Weir Farm National Historic Site in Fairfield County, Connecticut, USA.

Valley Trail, a 61-km (38-mi) multi-use trail proposed to run along the Norwalk River from Long Island Sound north to Danbury CT. The proposed trail could potentially connect to WEFA.

Pelham Lane bisects the 24- ha (59.4-ac) main WEFA site from the west, and intersects with Nod Hill Road, which runs north-south, separating this site into three areas: 1) the Weir complex, including the Weir House, studios, barn, outbuildings, garden, orchard and agricultural fields; 2) the Burlingham complex, including the park Visitor center, the Burlingham barn, gardens, orchard and agricultural fields; and 3) the Pond and Woodland complex, including the Caretaker's House, forest, old fields and wetland areas, and Weir Pond (Figure 2-2). A secondary site (3.6 ha [8.9 ac] in size), lying north of the main park site, was obtained for the development of park visitor and administrative facilities; this site contains one residential lot and a small forested area.

The park lies on a north-south ridge (Nod Hill), approximately 180 m (600') above sea level, within the Hudson Highlands subsection of the Eastern Broadleaf Forest Province Ecoregion (NPS 1995, Keys et al. 1995). WEFA is underlain by gneiss that is covered by glacial till from the Wisconsinan glaciation (Thornberry-Ehrlich 2012). Slopes in the park range from 3 to 50% (NPS 1995). Soil depth and drainage vary across the site, ranging from scattered areas of excessively drained sandy loams and bedrock outcrops to small, poorly drained depressions of peats and mucks (USDA NRCS 1995). Poorly drained Ridgebury, Leicester, and Whitman soils cover about 4 ha (10 ac) at WEFA (USDA NRCS 2014). Abandoned pegmatite mines (dating from the 19th century) are located adjacent to park boundaries (Thornberry-Ehrlich 2012).

The topographic and soil variability drive the vegetation composition with oaks (*Quercus spp*.) and sweet birch (*Betula lenta)* dominating the upland soils, and red maple (*Acer rubrum)* dominating the wetlands (Metzler et al. 2009). The area has a mean annual temperature of 10°C (50°F) with an average frost-free season of 160 days. An annual average of 114 cm (45 in) of precipitation is evenly distributed throughout the year, and annual average snowfall is about 102 cm (40 in; NPS 1995).

Visitation Statistics

WEFA has hosted more than 300,000 recreational visitors since opening in 1990. The number of annual visitors has increased over time, averaging about 24,000 from 2010 – 2014. Visitation in 2014 was the highest yet recorded, exceeding 34,000 visitors. Visitation rates are highest June through October and lowest during winter (NPS 2015).

Figure 2-2. Map of the main property of Weir Farm National Historic Site. The secondary park site, containing no visitor attractions, lies north of this site and is shown in Figure 2-3.

Natural Resources

Ecological Units and Watershed

The park lies in the headwaters of the Norwalk River Watershed, with parts of the site draining north to Candees Pond, parts draining north to Cooper Pond Brook, and parts draining south to Barrett's Brook, which flows to Streets Pond and on to Comstock Brook (NPS 1995, USDA NRCS 1995).

The park vegetation mapping project identified six upland vegetation associations (covering 15.3 ha), five wetland associations (covering 3.9 ha), and an additional two anthropogenic old-field types occurring in annually mowed areas (covering 4.3 ha), for a total of 13 vegetation associations occurring at WEFA (Metzler et al. 2009; Table 2-1 and 2-2). An additional 3 ha of anthropogenic land cover comprised of agricultural grounds, lawn and gardens, buildings, road, and parking areas were not evaluated in this assessment (Figure 2-3).

Table 2-1. Upland vegetation classes and area mapped at WEFA by Metzler et al. (2009).

Upland Associations	**Area in park (ha)**	**Description at WEFA**
Northeastern Dry Oak - Hickory Forest	12.4	Dominated by northern red oak (*Quercus rubra*), sweet birch (*Betula lenta*), maples (*Acer* spp.), and hickories (*Carya* spp.) with mapleleaf viburnum (*Viburnum acerifolium*) in the understory. This matrix forest at WEFA occurs in a midslope position on moderately deep, acidic loamy soils.
Lower New England Slope Chestnut Oak Forest		Dominated by black oak (*Quercus velutina*) and chestnut oak (*Quercus prinus*), with black huckleberry (*Gaylussacia baccata*) and Blue Ridge blueberry (*Vaccinium pallidum*) in the shrub layer. In some locations, the shrub layer is dominated by mountain laurel (*Kalmia latifolia*). At WEFA, occurs on or near bedrock outcrops with shallow soils.
Mesic Sugar Maple - Ash - Oak - Hickory Forest	1.47	Dominated by sugar maple (*Acer saccharum*) with other hardwoods, and with *Carex laxiflora* (broad looseflower sedge) and other sedges in the herb layer. Occurs on dry, rich slopes in two WEFA locations: east of the parking area, and a small area east of Nod Hill Road of the secondary park site.
Semi-rich Northern Hardwood Forest	0.97	Dominated by sugar maple (*Acer saccharum*) and white ash (*Fraxinus americana*), with sparse shrub cover including northern spicebush (*Lindera benzoin)* and a ground cover of ferns. At WEFA, occurs along streambanks and the border of wetlands receiving groundwater seepage.
Northeastern Modified Successional Forest	0.46	Dominated by sweet birch (*Betula lenta)*, with eastern poison ivy (*Toxicodendron radicans*) and dewberry (*Rubus* sp.) in the understory. Occurring in two border areas west of Weir Pond.
Montane Cliff (Common Rocktripe Type)	0.04	Common rocktripe (*Umbilicaria mammulata*) is conspicuous on exposed and shaded outcrops of acidic, granitic gneiss. Other bryophytes and lichens co-occur, and sedges are scattered in small pockets where humus accumulates. Noted on a single cliff face at WEFA.

Table 2-2. Wetland vegetation classes and area mapped at WEFA by Metzler et al. (2009).

Wetland Associations	Area in park (ha)	Description at WEFA
Southern New England / Northern Piedmont Red Maple Seepage Swamp	2.24	Relatively closed canopy dominated by red maple (*Acer rubrum*), with American elm (*Ulmus americana*), birches (*Betula* spp.), and green ash (*Fraxinus pennsylvanica*), and a diverse herb layer. One variant of this type has abundant interrupted fern (*Osmunda claytoniana*), and is associated with seeps receiving groundwater discharge during heavy rains. A more-disturbed jewelweed (*Impatiens capensis*) variant occurs just west of the Weir Farm domestic grounds, and receives storm water runoff from Pelham Lane.
Lower New England Red Maple - Blackgum Swamp	0.94	Relatively open canopy with red maple (*Acer rubrum*) dominant, often with green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), and/or blackgum (*Nyssa sylvatica*). Common winterberry (*Ilex verticillata*) and highbush blueberry (*Vaccinium corymbosum*) are characteristic shrubs, and coastal sweetpepperbush (*Clethra alnifolia*) can be dominant. Occurs in very poorly drained soils in depressions, often with standing water after heavy rains.
Northeastern Buttonbush Shrub Swamp	0.44	Dominated by common buttonbush (*Cephalanthus occidentalis*), with very sparse herb layer including smallspike false nettle (*Boehmeria cylindrica*). Occurs on the edge of Weir pond and in semipermanently flooded depressions within the wetland complex at WEFA.
Blueberry Wetland Thicket	0.25	Shrub thickets dominated by highbush blueberry (*Vaccinium corymbosum*) and common winterberry (*Ilex verticillata*), with scattered red maple (*Acer rubrum*) and other shrubs. This community occurs in undrained depressions with organic soils influenced by fluctuating water levels.
Old Field Seep	0.14	Low-lying managed fields receiving groundwater discharge, composed primarily of grasses and sedges, with some shrubs and vines.

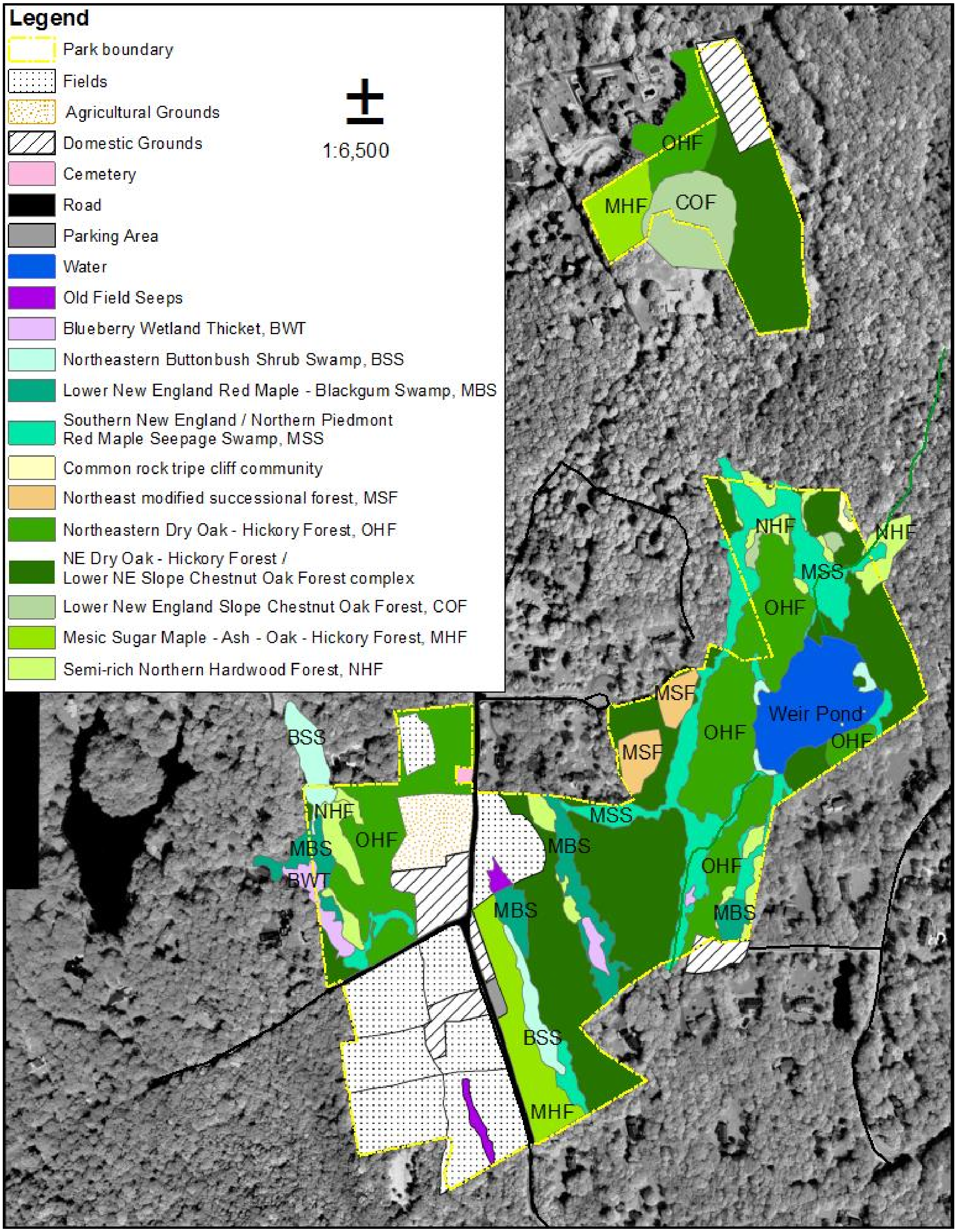

Figure 2-3. Map of Weir Farm National Historic Site, showing mapped vegetation classes (Metzler et al. 2009). A small unnamed pond occurs in the NW corner of the main site (mapped here as BSS).

The matrix forest at WEFA is a Northeastern Dry Oak - Hickory Forest dominated by northern red oak (*Quercus rubra*), sweet birch (*Betula lenta*), maples (*Acer* spp.), and hickories (*Carya* spp.) with mapleleaf viburnum (*Viburnum acerifolium*) notable in the understory. Embedded within this forest type are patches of Lower New England Slope Chestnut Oak Forest, occurring in small areas where bedrock occurs near the surface, creating drier soil conditions. Together these two associations account for 80% of WEFA's forest cover. Wetlands and intermittent streams dissect the main site (see Section 4.4.3). The most common wetland type at WEFA is Southern New England / Northern Piedmont Red Maple Seepage Swamps, occurring in low-lying contours across the site and accounting for just over half of the wetland area at WEFA. No rare vegetation associations or critical habitats have been documented at WEFA (Metzler et al. 2009).

Resource Descriptions

Two ponds occur in the park. Weir Pond was created in 1896 when J. Alden Weir blocked a seasonal stream, some springs, and a wetland with an earthen and stone dam (NPS 1990, NPS 1995). The dam, though reinforced at the toe with a concrete retaining wall, has been determined to be leaking (USDA NRCS 1995). Weir Pond drains an estimated 22.1 ha (54.7-ac) watershed and contains a tiny island (Figure 2-4; HDR, Inc. 2015, Metzler et al. 2009). The second, unnamed pond occurs in the NW corner of the main park site, and extends onto adjacent land to the north[3] (USDA NRCS 1995, Brotherton et al. 2005). Wetlands dissect the main site at WEFA, providing valuable wildlife habitat (see Section 4.4.3). Three seasonal streams drain into Weir Pond, and additional streams run through park wetlands much of the year (USDA NRCS 1995, Farris and Chapman 1999). The outlet from Weir Pond is a perennial stream that briefly traverses the park and continues beyond the park boundary (Gawley et al. 2014; Greg Waters, personal communication, 20 October 2015).

As part of a regional network of protected areas, WEFA provides important open space and wildlife habitat. Documented species present in the park include 21 mammal species (including 5 bats), at least 70 bird species, 3 fish species, 12 amphibian species, 7 reptile species and 21 butterfly species (Gates and Johnson 2012, Gilbert et al. 2008, NPS 2015; Greg Waters, personal communication, 26 May 2015). More than 40 of these wildlife species are designated by the Connecticut Department of Energy and Environmental Protection (CT DEEP) as Species of Greatest Conservation Need (CT SGCN; CT DEEP 2015). These are species which were identified by CT DEEP staff and other experts as those species in the state in greatest need of conservation, and are identified in Appendix B. CT SGCN species differ from state Special Concern (SC) species, which are native species "documented by scientific research and inventory to have a naturally restricted range or habitat in the state, to be at a low population level, to be in such high demand by man that its unregulated taking would be detrimental to the conservation of its population or has been extirpated from the state" as defined by the Connecticut Endangered Species Act of 1989 (CGS 26-303).

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[3] The unnamed pond in the NW corner of the main park site was mapped as Northeastern Buttonbush Shrub Swamp (BSS) on the park vegetation map (Metzler et al. 2009). However, it was identified as an open water pond by the park Natural Resource Evaluation (USDA NRCS 1995) and it was confirmed to be a pond by park staff (G. Waters, personal communication, 13 January 2015).

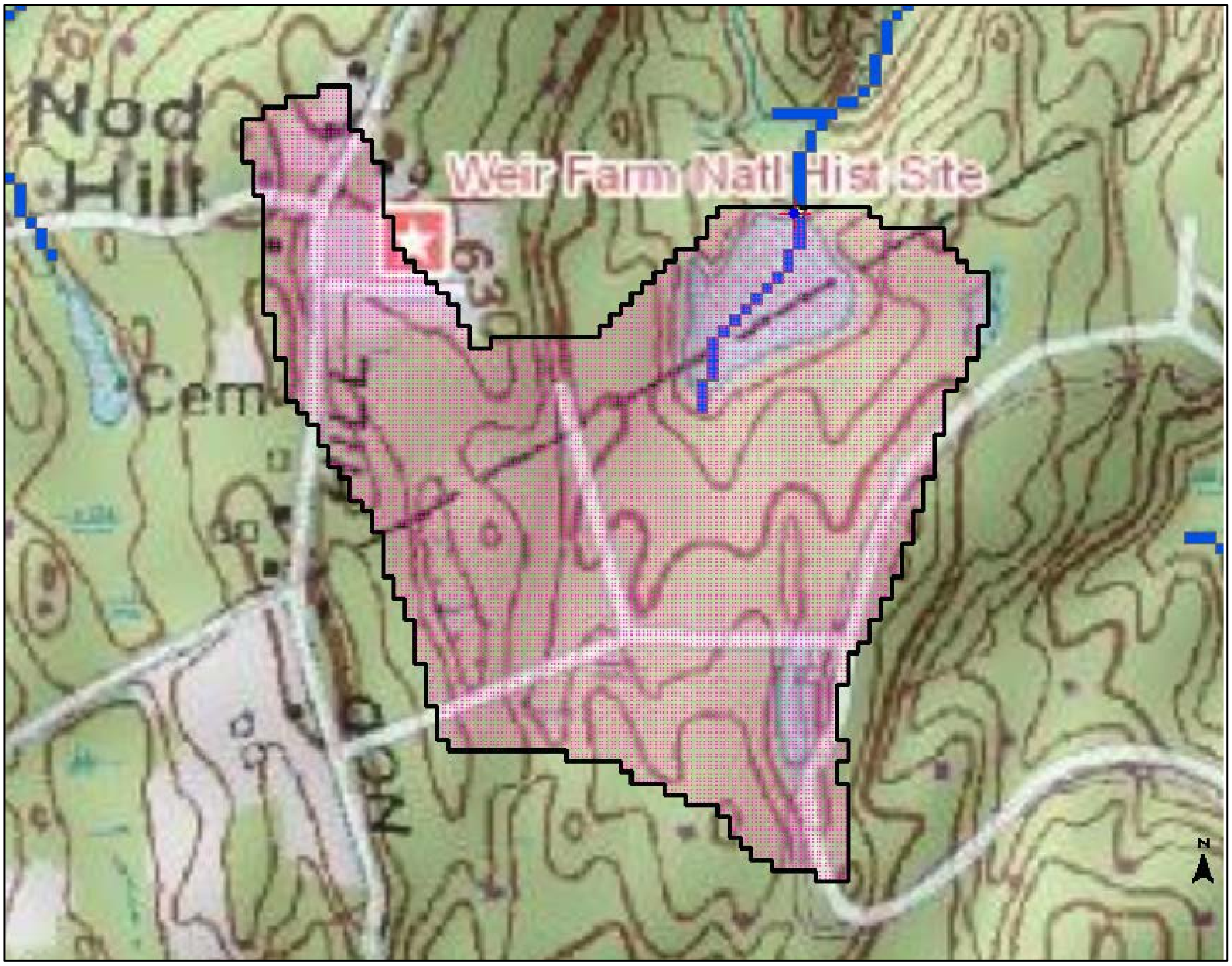

Figure 2-4. Map of Weir Pond basin (reproduced from HDR, Inc. 2015).

In addition to CT SGCN status, several wildlife species documented in WEFA have additional state or regional conservation status, and one species was recently listed on the federal threatened species list. The northern long-eared bat (*Myotis septentrionalis*) has been seriously impacted by the white-nose syndrome health crisis, and was listed as federally Threatened throughout its range in April 2015. This species, which was captured in mist nets at WEFA during a bat inventory in 2010, also has State of Connecticut Endangered status (Gates and Johnson 2010). Three additional bat species documented during the park bat inventory have conservation status in the state of Connecticut: the eastern red bat (*Lasiurus borealis*) and the hoary bat (*Lasiurus cinereus*) have state SC status, and the little brown bat (*Myotis lucifugus*) is listed as state Endangered. One reptile, the eastern box turtle (*Terrapene carolina carolina*), documented at the park also has state SC status (Brotherton et al. 2005). Four bird species with state conservation status occur on the official park species list, and another five bird species observed in the park during monitoring have regional conservation status (see Section 4.4.6 Breeding Birds).

Two plants listed as state SC have been documented at WEFA: blackhaw (*Viburnum prunifolium*) and twoflower dwarfdandelion (*Krigia biflora*; Glenn 1998, Metzler et al. 2009). A small population of the former occurs on the eastern edge of the site (Metzler et al. 2009).

Resource Issues Overview

Natural resource issues affecting WEFA include global and regional threats such as air pollution, climate change, habitat fragmentation and invasive species. These threats originate from sources outside the park's borders. Climate change is already having measurable impacts on many species across the globe, and is expected to have dramatic impacts over the coming century (IPCC 2007). Atmospheric deposition is a key concern affecting forest health and soil quality across the region (Likens et al. 1996, Driscoll et al. 2001), and the advance of invasive exotic forest pests is a substantial threat to forest resources (Gandhi and Herms 2010). Invasive plant species such as Japanese barberry (*Berberis thunbergii*), Oriental bittersweet (*Celastrus orbiculata*), and burningbush (*Euonymus alatus*) have colonized areas in the park, and park staff have taken action to control these populations (Wheeler and Miller 2014).Overbrowsing by white-tailed deer (*Odocoileus virginianus*) is a regional concern affecting the vegetation composition at WEFA (NPS 1995, Metzler et al. 2009).

On a local scale, key natural resource issues include maintaining open fields and field edges to preserve the historic cultural landscape, screening views of neighboring homes, repairing the Weir Pond dam, and protecting water quality in Weir Pond from adjacent residential septic systems and landscape maintenance (NPS 1995, Farris and Chapman 1999, Thornberry-Ehrlich 2012, G. Waters personal communication, 23 November 2014). The park is bisected by Nod Hill Road and Pelham Lane, small residential roads that subject the park to road impacts. In addition, a proposal to build a new exit ramp to nearby Route 7 as part of a major road upgrade referred to as the "Super Seven Expressway" is within the watershed of wetlands in the NE corner of the park (Farris and Chapman 1999); this project has been opposed by residents of the towns of Wilton and Ridgefield for many years, and is dormant at this time (Greg Waters, personal communication, 5/26/15). There is a lack of groundwater data available for this region; future groundwater data collection would inform understanding of water quality in Weir Pond.

Resource Stewardship

Management Directives and Planning Guidance

The NPS's preferred alternative in the park General Management Plan/Environmental Impact Statement (GMP/EIS) focuses on reuniting the historic property, presented as it appeared historically, with the art it inspired (NPS 1995). The farm's buildings and landscape are maintained to appear to visitors as nearly as possible as they appeared to their historic occupants circa 1940, to reflect use by both the Weirs and Youngs. The pond and woodland areas are maintained to appear as they did in 1940, and subsequent growth of shrubs, vines and saplings at field edges are removed to expose stone walls and keep fields open. The park network of foot paths has been expanded to link key sites. NPS works with adjacent neighbors to promote vegetative screening between the site and nearby residential properties (NPS 1995).

The GMP/EIS divided WEFA into four management zones: cultural, natural, development, and transportation. The cultural zone is comprised of two subzones: 1) a protected subzone and 2) a protected/adaptive use subzone. The former subzone contains the majority of WEFA land including the Weir complex, Weir Pond and forest area. Resources in this subzone are to be preserved or restored and interpreted for the public. The latter subzone includes the Burlingham complex (acquired by Weir in 1907); resources in this subzone may be modified for special or administrative uses provided that the historic character of the site is retained. The natural management zone includes WEFA's wetlands. Due to the fragility and ecological significance of these areas, human intrusion in the natural zone is minimized to protect these natural resources. A development zone was designated along Weir Farm Lane, as well as in a small location along Nod Hill Road, to guide future placement of an administration and maintenance facility on park property, if off-site locations for such facilities are not possible. Finally, the transportation zone includes Nod Hill Road and Pelham Lane, non-federally-owned transportation corridors which traverse the park (NPS 1995).

Motorized vehicles (except Segways and automated wheelchairs), bicycles, and horses are not permitted in the park; nor are hunting, camping, swimming, or wading. Catch and release fishing is permitted in Weir Pond, and cross-country skiing is permitted. Dogs are allowed in the park, but must be leashed.

NPS collaborates with the private, non-profit Weir Farm Art Center to operate the artist-in-residence programs at WEFA. The Weir Farm Art Center is dedicated to promoting the legacy of J. Alden Weir and also owns and manages the adjacent Weir Preserve. In addition, a Friends of Weir Farm National Historic Site group was started in 2015 to support WEFA programming and operations.

Status of Supporting Science

WEFA is part of the Northeast Temperate Network (NETN) of the NPS Inventory and Monitoring Program (I&M). As part of this program, twelve baseline inventories have been completed (Water quality, Base cartography, Air quality data, Air quality related values, Climate, Geologic resources, Soil resources, Water body location and classification, Vegetation map, Species lists, Species occurrence and distribution, and Natural resource bibliography); four Vital Sign Inventories have been completed (Amphibians and reptiles, Terrestrial mammals, Fish, and Land cover); and monitoring is underway for seven monitoring protocols (Air quality, Breeding landbirds, Climate, Invasive species – Early detection, Forest health, Phenology, and Water quality). These and many other data sources are summarized in Table 2-3.

Table 2-3. Datasets available for assessing natural resource condition at Weir Farm National Historic Site. GIS indicates spatial data are available.

Natural Resource or Issue	Data type	Year(s) collected	Source
Air quality	Air quality assessment	1999-present	NPS ARD
	Deposition sensitivity assessment		Sullivan et al. 2011a, 2011b
	Ozone sensitivity assessment		NPS 2004
Contaminants	Air quality assessment	2011-present	NPS ARD
	Hg wet deposition monitoring	2004-present	Mercury Deposition Network
Climate & phenology	Climate inventory	2006	Davey et al. 2006
	Climate trends	1901-2012	Monahan and Fisichelli 2014a, 2014b
	Phenology monitoring (GIS)	2010-present	NETN
Geology	Inventory	2007	Thornberry-Ehrlich 2012
Soil	SSURGO soil map		USDA NRCS
	Soil chemistry monitoring (GIS)	2007-present	NETN (Miller et al. 2014)
Water quantity and quality	Baseline report	1998-1999	Farris and Chapman 1999
	Monitoring (GIS)	2006-present	NETN (Gawley and Roy 2014)
	Bathymetry	2014	NETN
Streams-macroinvertebrates	None	N/A	N/A
Invasive species	Invasive aquatic plant detection and monitoring	2006-present	NETN (Gawley and Roy 2014)
	Invasive species early detection (ISED)	2010-present	NETN (Wheeler and Miller 2014)
	Forest invasive plant monitoring (GIS)	2006-present	NETN (Miller et al. 2014)
Wetlands	Natural resource evaluation	1995	USDA NRCS 1995
	National Wetlands Inventory	2010	U.S. FWS 2010
Forest vegetation	Monitoring (GIS)	2006-present	NETN (Miller et al. 2014)
White-tailed deer herbivory	Fairfield County population estimates	2009-present	CT DEEP
	Herbivory impacts monitoring (GIS)	2006-present	NETN (Miller et al. 2014)
	Ridgefield CT population estimate	2015	Town of Ridgefield

Table 2-3 (continued). Datasets available for assessing natural resource condition at Weir Farm National Historic Site. GIS indicates spatial data are available.

Natural Resource or Issue	Data type	Year(s) collected	Source
Birds	Park bird inventory	2002-2003	Trocki and Paton 2003
	Forest bird monitoring	2006–present	NETN (Faccio and Mitchell 2015)
	Detection	2010-present	eBird 2015
Amphibians and reptiles	Observation	1980-1982	Klemens 1980, 1982
	Inventory	2000	Brotherton et al. 2005
	Egg mass survey	2010	Klemens et al. 2012
Fish	Inventory	1999-2001	Mather et al. 2003
Bats	Inventory	2010	Gates and Johnson 2012
Terrestrial mammals	Inventory	2004	Gilbert et al. 2008
Terrestrial invertebrates	Observation in park	2009-2012	Park files, Greg Waters
	CT Butterfly Atlas	1955-1959	http://www.butterfliesandmoths.org/project/CBAP
	Route 7 Inventory		DeMasi 1991
	Town of Ridgefield species list	2010	Klemens et al. 2012
Visitor usage	Automated counters and visitor book	1993-present	NPS 2015
Flora	Inventory	1998	Glenn 1998
Vegetation classification and mapping	Classification and mapping (GIS)	2003-2005	Metzler et al. 2009
Landcover / ecosystem cover	Landcover change	1973-2002	Wang and Nugranad-Marzilli 2009
	Landcover and land use		NPS 2015
Cultural landscape	Cultural landscape report	1994-1996	Zaitzevsky 1996
	Cultural landscape inventory	2010-2012	NPS 2013
Soundscape	Model predictions		NPS Natural Sounds & Night Skies Division (NSNSD)
	Model predictions of aircraft noise	2006, 2011	U.S. DOT FAA 2007a, 2007b
Lightscape	Model predictions		NPS NSNSD

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Study Scoping and Design

Preliminary Scoping

A scoping meeting, held at the park on 23 October 2014, was attended by Linda Cook and Greg Waters (NPS WEFA), Charles Roman, Bill Gawley, Carmen Chapin and Sheila Colwell (NPS Northeast Region), Brian Mitchell and Adam Kozlowski (NPS Inventory & Monitoring Program, NETN), Paul Halsey (Weir Preserve), Jack Kace and Ben Oko (Ridgefield Conservation Commission), Patricia Sesto (Town of Wilton), and Geri Tierney (SUNY ESF). After a description of the NRCA program, WEFA natural resource manager Greg Waters presented an overview of the park and key natural resource and management issues. These issues are summarized in Section 2.2.3 (Resource Issue Overview). Geri Tierney presented the NPS Vital Signs Framework (Table 3-1) as a proposed framework for assessing and reporting at WEFA. Sheila Colwell presented protected species documented at WEFA. Attendees suggested existing local and regional datasets and reports available for inclusion in this natural resource assessment; these datasets are summarized in Section 2.3.2 (Status of Supporting Science). The group considered whether to include management recommendations within this NRCA, but a decision was not reached. The scoping meeting continued with a tour of the site led by Greg Waters.

During subsequent discussion, WEFA Park Superintendent Linda Cook indicated the importance of natural light quality, visibility, “crispness” of view, and phenology to landscape artists. Superintendent Cook would like to use a “light meter” or some other method to rate daily visual quality to provide potential visitors (particularly artists) with useful information about visual condition on a given day. NETN Coordinator Brian Mitchell suggested automated, time-lapse photographic monitoring at key locations, to help document and understand light quality. As a result of this discussion, an additional Vital Sign (Visibility and particulate matter) was added to the indicator framework.

Study Design

Indicator Framework, Focal Study Resources and Indicators

This NRCA uses the NPS NETN Vital Signs framework to guide selection and reporting of indicators. Starting from the list of 19 vital signs recommended for WEFA (Mitchell et al. 2006), we removed from consideration two Vital Signs of low importance (Fishes and Streams-macroinvertebrates), combined two related Vital Signs (Climate & Phenology), and added seven additional indicators of interest at WEFA (Visibility and particulate matter, Soundscape, Lightscape, Wetland vegetation, Bats, Mammals, and Terrestrial invertebrates) to reach a total of 23 Vital Signs or other indicators to be reported herein (Table 3-1). One or more metrics were used to describe the condition of each Vital Sign or other indicator selected for inclusion.

Reporting Areas

At the scoping meeting, the reporting area for this assessment was determined to be land lying within the WEFA boundary excluding agricultural areas, lawn and gardens, buildings, roads, and parking areas. Relevant data from areas surrounding the park is included in the assessment of some Vital Signs, but the surrounding land itself is not assessed herein.

Table 3-1. NPS Vital Signs and metrics selected for assessment as indicators of natural resource condition at Weir Farm National Historic Site.

Category	Vital Sign	Metrics for Assessment
Air and Climate	Ozone	Ozone concentration, injury to sensitive species
	Acidic deposition & stress	Total nitrogen and sulfur wet deposition rates, dry deposition rates
	Visibility and particulate matter	Haze index, qualitative assessment of light quality
	Contaminants	Mercury concentration in wet deposition
	Climate & phenology	Monthly temperature and precipitation, phenophase dates, snow cover duration and depth
	Soundscape	Anthropogenic sound pressure level
	Lightscape	Anthropogenic light ratio
Geology and Soils	Forest soil	Nutrient ratios, base saturation
Water	Water quantity (Pond)	Pond water level
	Water chemistry (Pond)	Temperature, pH, dissolved oxygen, specific conductance, nitrogen, phosphorus, ANC, chloride, chlorophyll
Biological Integrity	Invasive exotic plants	Presence and relative abundance of key species
	Invasive exotic animals	Detections of key pests
	Wetland vegetation	Extent, width and condition of buffer, % cover of invasive plants, qualitative assessment of disturbance and alteration
	Forest vegetation	Forest structural stage, snag abundance, coarse woody debris, tree regeneration, tree condition and presence of forest pests, tree growth and mortality rates
	White-tailed deer herbivory	Deer population density, browse vegetation impacts
	Breeding birds	Guild species richness
	Amphibians and reptiles	Amphibian index of biotic integrity
	Bats	Species richness, population trends of select species
	Mammals	Population trends of select species
	Terrestrial invertebrates	Species richness, population trends of select species
Human use	Visitor usage	Number of visitors, visual assessment of trampling
Landscapes	Landcover / ecosystem cover / connectivity	Forest patch size, forest density
	Land use	Anthropogenic land use, impervious cover

General Approach and Methods

Assessment points (also known as reference values) are used to distinguish expected or acceptable condition (i.e., *good condition*) from undesired conditions that warrant concern, further evaluation or management action (Bennetts et al. 2007). Herein, assessment points were drawn from knowledge of ecological integrity, as well as from regulatory or program standards, park management goals, historical data, data from relatively undisturbed sites, predictive models, or expert opinion. When warranted by available information from one or more of these categories, a second assessment point was set to attempt to distinguish conditions that warrant *moderate concern* from *significant concern*. For example, the scientific literature on white-tailed deer browsing impacts on native vegetation in the eastern U.S. suggests that negative impacts on vegetation may be measurable at deer density levels as low as 8 deer/km^2, but that severe impacts are documented at deer densities at or above 20 deer/km^2 (Section 4.4.5). In this case, two assessment points were used.

In a National Historical Site such as WEFA, expected or acceptable condition for ecological integrity may conflict with desired condition for preservation or interpretation of a historical landscape; this potential conflict is evident in Vital Signs such as Landcover and Forest vegetation. In these cases, assessment of ecological integrity benchmarks is valuable because it provides a deeper understanding of park condition, as well as a consistent baseline to assess management goals. However, in cases such as these, ratings of moderate concern or significant concern may not warrant management action. Additional condition reporting based on park management goals may become possible as NETN and park staff progress in development of scorecards that track progress towards park resource management goals.

Trends in condition were determined by a statistical test of significance if sufficient data were available. Unless otherwise specified, an alpha value of 0.10 was used to determine statistical significance.

Confidence in condition status was assigned by considering the quality and depth of the available data, as well as the justification for the assessment points used to determine condition. High confidence was assigned to assessments based on abundant, quantitative data from multiple sites reflecting the range of variation in the park resource, and which relied on well-justified assessment points. Medium confidence was assigned to assessments based on sufficient, quantitative or qualitative data from at least one representative site in or near the park, and which relied on well-justified assessment points. Low confidence was assigned to assessments based on preliminary or incomplete data, or preliminary or incomplete assessment points. Confidence in trends was based on the length and quality of the dataset and the level of significance of the trend. High confidence in a trend was reserved for datasets containing at least 10 years of quantitative data, while medium confidence in a trend required a dataset that contains at least 8 years of quantitative or qualitative data.

NPS stoplight reporting categories and symbology (Figure 3-1) were used to report condition status, trends in condition, and confidence in assessment (Appendix C). For cases in which confidence in condition status differed from confidence in a trend, confidence in condition status was symbolically presented.

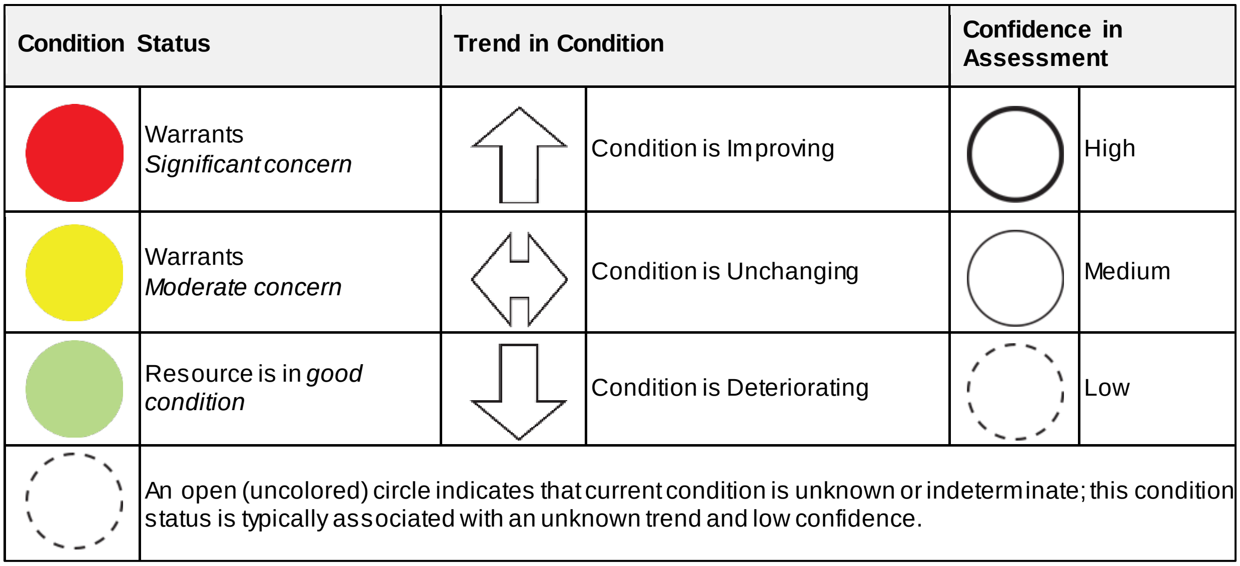

Figure 3-1. NPS symbology for reporting condition status, trends in condition, and confidence in assessment.

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Natural Resource Conditions

Air and Climate

To better understand status and trends in air quality affecting national parks, the National Park Service Air Resources Division (NPS ARD) compiles air quality data from monitoring stations across the nation, and uses these data to estimate air quality metrics and associated condition ratings for all parks within the contiguous U.S. (NPS ARD 2015a). Many small parks, such as WEFA, do not contain on-site air monitoring stations; status metrics for these parks are interpolated using data from nearby monitoring stations. Air quality status assessments for ozone, visibility, and atmospheric deposition are based on five-year average concentrations, and trends are assessed for a subset of parks from 10-year datasets (NPS ARD 2013).

Ozone

<u>Description and Relevance</u>

Ground level ozone is a hazard to human health and to vegetation, particularly to ozone-sensitive species. Ozone is produced by a chemical reaction of nitrogen oxides and volatile organic compounds, from industrial and automobile emissions, in the presence of sunlight during hot summer months. WEFA is located in an ozone non-attainment region, indicating that ozone levels exceed the U.S. Environmental Protection Agency (U.S. EPA)'s National Ambient Air Quality Standards (NAAQS) for protecting public health (CT DEEP 2015, NPS ARD 2015b). A vegetation risk assessment of ozone injury at WEFA determined there was high risk to ozone-sensitive plant species due to high regional ozone exposure levels, but noted that low soil moisture conditions during times of high ozone exposure may reduce the likelihood of ozone injury (NPS 2004). Ozone-sensitive plant species present at WEFA are shown in Table 4-1.

<u>Data and Methods</u>

Several ozone monitoring station are located in Fairfield County, CT within 25 km (15 miles) of WEFA. This status assessment was based on interpolated NPS ARD estimates of average ozone concentrations at WEFA for the five-year period 2009-2013 (NPS ARD 2015b).

<u>Assessment Points</u>

NPS ARD assesses ozone condition in national park units separately for protection of human health and for protection of vegetation (Table 4-2; NPS ARD 2015a and 2015b). For the former, they assessment points shown in Table 4-2 are tied to the primary National Ambient Air Quality Standard (NAAQS) for ground-level ozone set by the EPA, and are based on human health effects. A status adjustment is made for parks, such as WEFA, falling within ozone nonattainment regions; ozone condition in these parks is elevated to *significant concern*. To better assess ozone condition relevant to ozone-sensitive vegetation, NPS ARD uses the W126 metric. This metric sums weighted ozone concentrations during daylight hours during the growing season. NPS ARD assessment points for the W126 metric are derived from recorded impacts to sensitive vegetation (U.S. EPA 2014). An ozone risk assessment for NETN suggested a W126 assessment point of 5.9 ppm-hrs to protect highly sensitive species in the network (NPS 2004), which is slightly lower than the current NPS ARD assessment point.

Table 4-1. Ozone-sensitive plant species at WEFA (NPS 2006).

Latin name	Common name
Ailanthus altissima	Tree-of-heaven
Alnus incanca ssp. rugosa	Speckled alder
Apios americana	Groundnut
Apocynum androsaemifolium	Spreading dogbane
Apocynum cannabinum	Hemp dogbane
Asclepias syriaca	Common milkweed
Aster acuminatus	Whorled aster
Clematis virginiana	Devil's darning needles
Fraxinus americana	White ash
Fraxinus pennsylvanica	Green ash
Gaylussacia baccata	Black huckleberry
Liriodendron tulipifera	Yellow-poplar
Lyonia ligustrina	Maleberry
Parthenocissus quinquefolia	Virginia creeper
Populus tremuloides	Quaking aspen
Prunus serotina	Black cherry
Robinia pseudoacacia	Black locust
Rubus allegheniensis	Allegheny blackberry
Sambucus canadensis	American elder
Sassafras albidum	Sassafras
Vitis labrusca	Northern fox grape

Table 4-2. Ozone condition assessment points rating developed by NPS ARD (2015a).

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Human health: Ozone concentration[1] (ppb)	<= 60	61 - 75	>= 76
Vegetation: W126[2] (ppm hrs)	< 7	7 - 13	> 13

[1] Estimated five-year average of annual 4th-highest daily maximum 8-hour concentration.

[2] Estimated five-year average of the maximum 3-month 12-hour W126.

Condition and Trend

Ozone condition at WEFA warrants *significant concern* for human health, based both on the park lying within an ozone non-attainment region (NPS ARD 2015a), and based on interpolated average five-year (2009-2013) ozone concentration at WEFA (Table 4-3, NPS ARD 2015b). Ozone condition at WEFA warrants *moderate concern* for vegetation health (Table 4-3, NPS ARD 2015b).

NPS ARD did not determine trends for WEFA; ten-year trends in the W126 metric at nearby national park units range from unchanging to significantly improving (Figure 4-1; NPS ARD 2013).

Table 4-3. Five-year (2009-2013) average values and ratings for ozone condition metrics at WEFA (NPS ARD 2015b).

Metric	5-yr average	Rating
Human health: O_3 concentration (ppb)	78.8	*significant concern (≥ 76)*
Vegetation: W126 metric (ppm-hrs)	10.6	*moderate concern* (7 – 13)

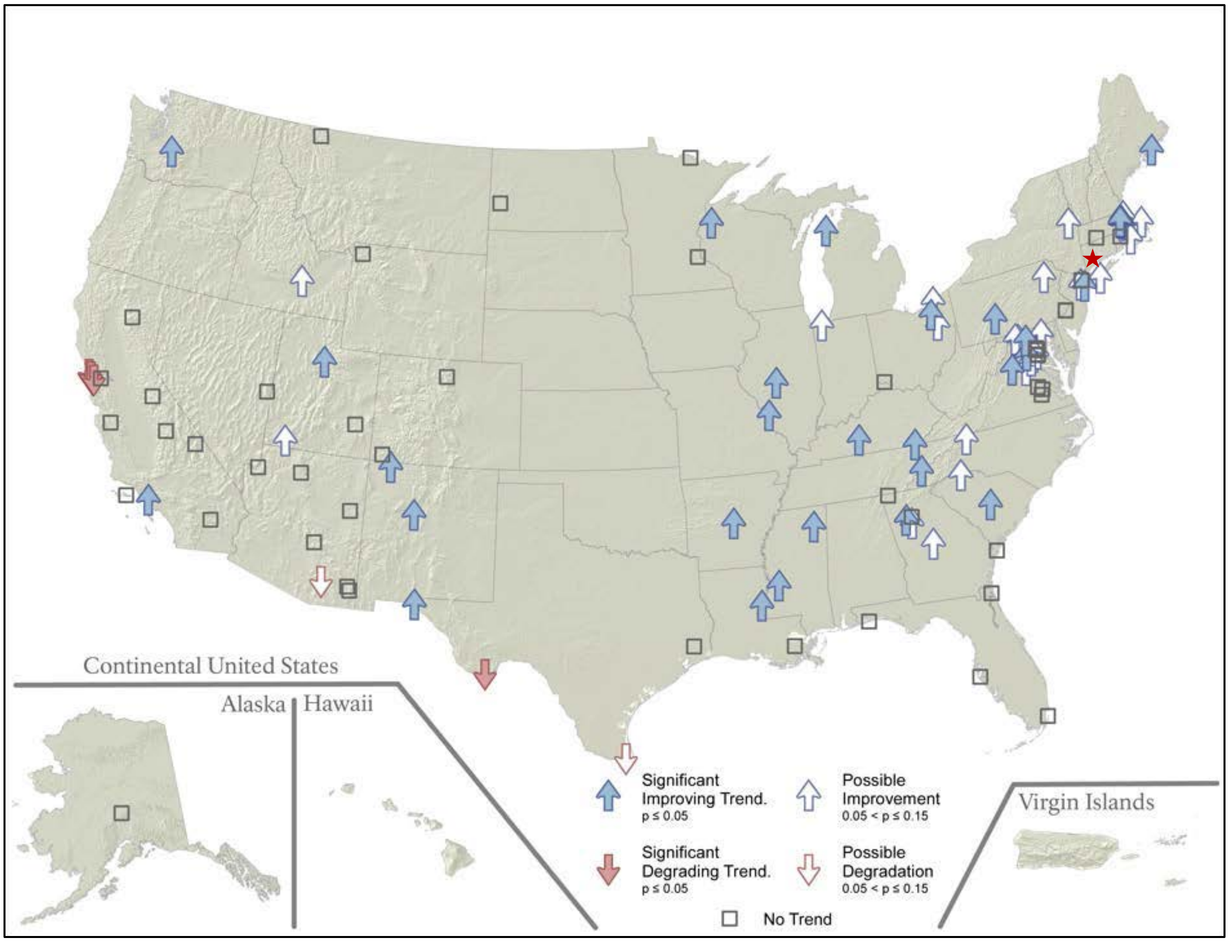

Figure 4-1. National trends in W126 metric (ppm-hrs/yr), 2000–2009 (excerpted from NPS ARD 2013). Red star shows approximate location of WEFA.

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

Confidence in status assessment is medium because estimates are based on interpolated data from off-site ozone monitors. Trends were not determined.

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Acidic Deposition & Stress

Description and Relevance

Emissions of sulfur (S) and nitrogen (N) from power plants, factories, automobiles and other sources have dramatically altered precipitation chemistry in many regions, particularly the northeastern U.S. (Driscoll et al. 2001). Atmospheric deposition of S and N has contributed to acidification of soils and surface waters, export of nutrient cations (Ca, Mg, etc.), and mobilization of aluminum (Al; a toxin) in soils (Likens et al. 1996, Reuss and Johnson 1985). In addition, S deposition can stimulate microbes to transform mercury (Hg) into a toxic, bioavailable compound (methyl mercury, MeHg; U.S. EPA 2008). N is a limiting nutrient necessary for plant growth that has historically been retained within northeastern forested ecosystems. As atmospheric deposition has increased N inputs by five- or 10-fold in the northeastern U.S., concern has arisen that excess N may "saturate" forested ecosystems, causing excess nitrification and N leaching which in turn would exacerbate the effects of acidification (Aber et al. 1998).

Broad-scale patterns of wet deposition across the northeast are well characterized and are most substantial at high elevations and in the southern and western parts of the northeast region (U.S. EPA

2008). Substantial additional acidity can result from dry and occult deposition,[4] and these patterns of deposition are not well characterized (NPS ARD 2013). Since passage of the 1990 Clean Air Act Amendments, wet deposition of S has decreased 35% or more across the eastern US, while wet deposition of N changed little in the 1990s, but generally has decreased since 2000 (U.S. EPA 2008).

Sullivan et al. (2011a) assessed ecosystem sensitivity to acidification for I&M park units based on vegetation, lakes and streams within the park. WEFA was found to have high ecosystem sensitivity, very high pollutant exposure and moderate park protection yielding an overall high risk from acidic deposition. Sullivan et al. (2011b) also assessed sensitivity to nutrient N enrichment for I&M park units based on sensitive vegetation and lakes. WEFA was found to have moderate ecosystem sensitivity and very high pollutant exposure, yielding an overall very high risk from N enrichment.

Data and Methods

NPS ARD assesses conditions of sulfur and nitrogen wet deposition from National Atmospheric Deposition Program (NADP) data as an indicator of acidic deposition and stress on natural ecosystems in national park units across the nation, including WEFA (NPS ARD 2014). Condition is calculated using normalized 30-year precipitation values in order to reduce the influence of yearly variations in precipitation on results. For parks without onsite monitoring stations, park values are interpolated from nearby stations. The closest NADP site for monitoring wet deposition is located 48 km (30 miles) west of WEFA in West Point, NY (NY99). NPS ARD has determined trends in sulfur and nitrogen wet deposition for a subset of park units which did not include WEFA (NPS ARD 2013).

NPS ARD has not assessed dry deposition since data availability is more limited (NPS ARD 2013). The closest Clean Air Status and Trends Network (CASTNET) monitoring site for monitoring dry deposition is located 128 km (80 miles) northeast of WEFA in Abington, CT (ABT146).

Assessment Points

NPS ARD has set condition assessment points for N and S wet deposition as shown in Table 4-4. However, if park ecosystems are ranked “very high” in sensitivity to acidification or nutrient enrichment, wet deposition condition ratings are adjusted up to the next worse category (NPS ARD 2015a). WEFA was found to have high ecosystem sensitivity to acidification and moderate ecosystem sensitivity to nutrient enrichment, so condition ratings were not adjusted from those assigned based on concentration (Sullivan et al. 2011a and 2011b).

Condition and Trend

NPS ARD has interpolated average five-year (2009-2013) wet deposition rates for WEFA to be 4.2 kg/ha/yr total nitrogen and 3.2 kg/ha/yr total sulfur (NPS ARD 2015b). Both total N and total S rates exceed benchmarks which warrant *significant concern* (> 3 kg/ha/yr). NPS ARD did not determine trends in wet deposition for WEFA. Ten-year trends in sulfate and nitrogen (combined nitrate and

[4] Occult deposition is the deposition of air-borne pollutants directly on surfaces (such as vegetation or buildings) by direct contact with mist or clouds.

ammonium) wet deposition for other park units of the northeastern US show significantly improving trends (Figures 4-2 and 4-3; NPS ARD 2013) and regional trends are likely to be representative of WEFA.

Table 4-4. Wet deposition condition assessment points and rating developed by NPS ARD (2015a).

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Total N wet deposition (kg/ha/yr)	< 1	1 - 3	> 3
Total S wet deposition (kg/ha/yr)	< 1	1 - 3	> 3

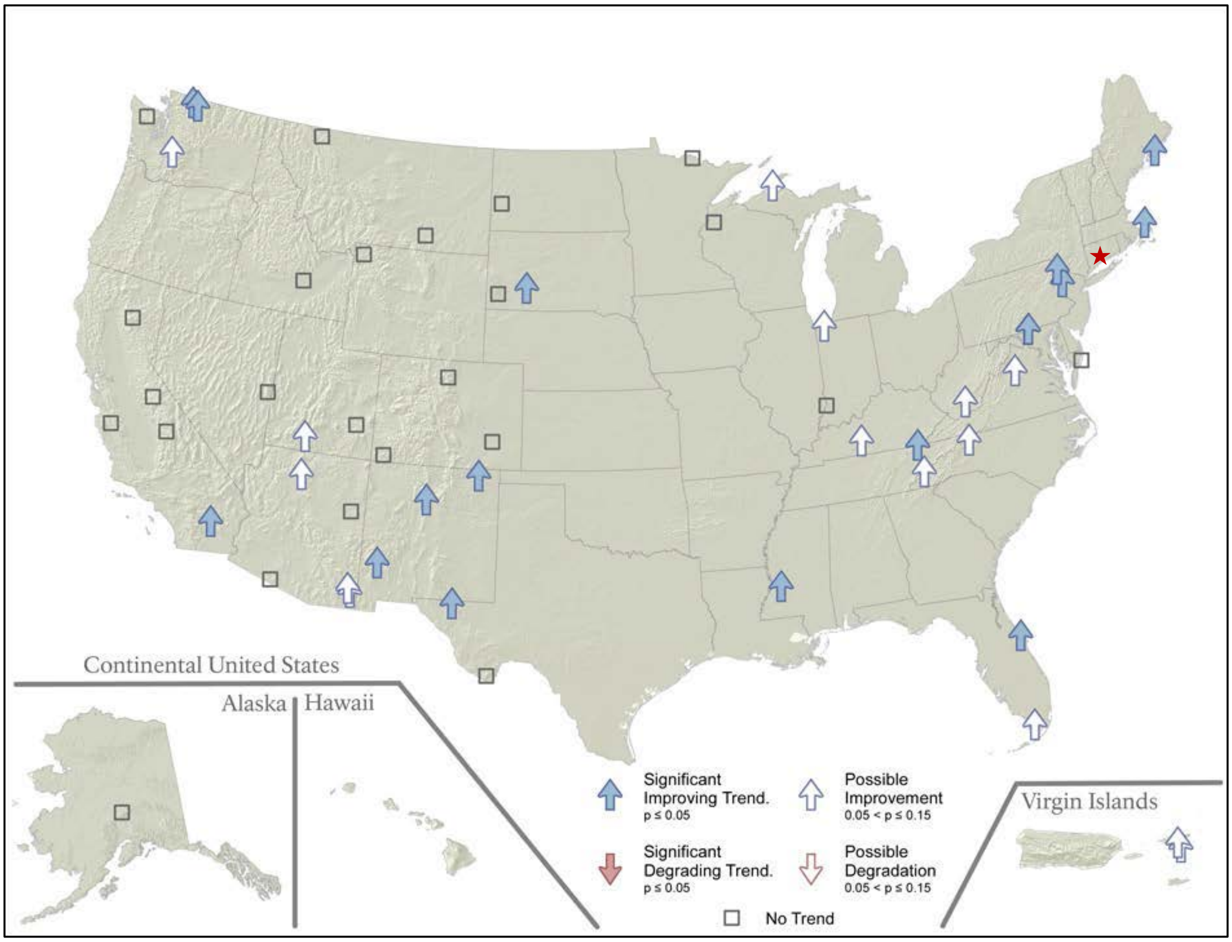

Figure 4-2. National trends in sulfate concentrations in precipitation (µeq/L/yr), 2000–2009 (excerpted from NPS ARD 2013). Red star shows approximate location of WEFA.

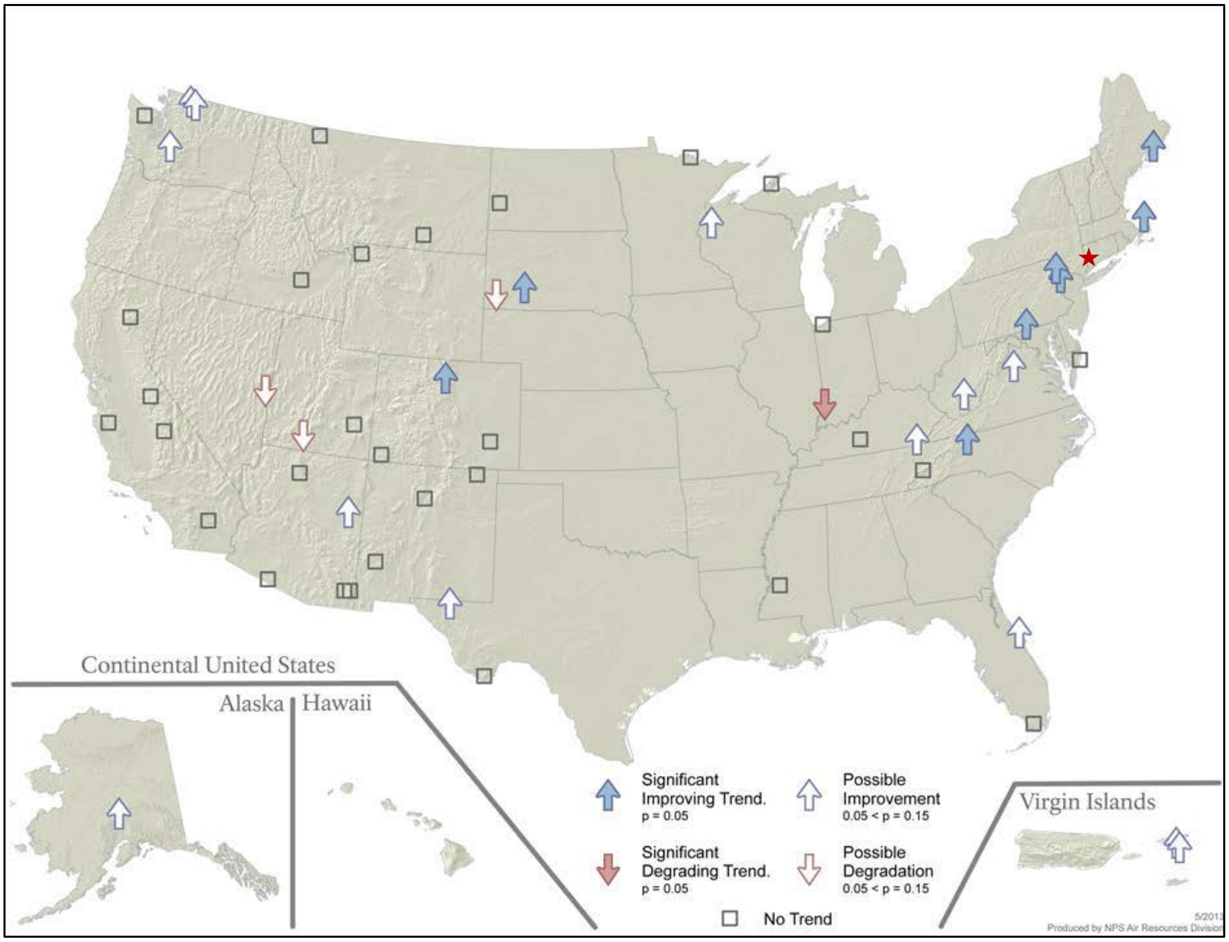

Figure 4-3. National trends in nitrogen concentrations in precipitation (μeq/L/yr), 2000–2009 (excerpted from NPS ARD 2013). Red star shows approximate location of WEFA.

Data Gaps and Level of Confidence

Confidence in status assessment is medium. Data was interpolated from sites at least 48 km (30 miles) away, and complements onsite forest soil and pond sampling to increase understanding of acidic deposition stress at WEFA. Confidence in regional trends is high.

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Visibility and Particulate Matter

Description and Relevance

The ability to clearly see landscape features is important to national park visitors. NPS actively seeks to "protect clean, clear air and spectacular scenery now and for future generations" (Action 37 in NPS 2012). At WEFA, many visitors seek to paint the park landscape, and appreciate crisp, clear days for landscape viewing. Visibility is a complex concept and is "closely associated with conditions that allow appreciation of the inherent beauty of landscape features" (Malm 1999). Perception of visibility is affected by many factors which can be grouped into four main categories: 1) the optical characteristics of illumination (including sun angle and cloud cover); 2) the physical interaction of light with particles in the atmosphere (via scattering and absorption); 3) characteristics of the viewed scene or target (color, texture, form and brightness); and 4) psychological processes and value judgments of the observer (Malm 1999).

Regional haze can impair the view by obscuring the color, texture and lines of the viewed landscape. Haze is caused by small (< 10 micron) particles (sulfates, nitrates, organic material, elemental carbon or soot, and soil) suspended in the atmosphere. Fine particulate matter (< 2.5 microns; PM-2.5) have a bigger impact on visibility and human health than coarser particles (2.5 - 10 microns). Particles may originate from natural sources (such as windblown dust or soot from wildfires) or from anthropogenic sources (including farming, traffic, and industry). Some particles are emitted directly into the atmosphere, while others form from chemical reactions in the atmosphere. In recent times, sulfates have been found to contribute 60 to 90% of the visibility degradation in the eastern U.S.; atmospheric concentrations of sulfates are highest during the summer months due to chemical reactions of atmospheric sulfate in the presence of sunlight (Malm 1999).

Data and Methods

Visibility is monitored at a network of sites across the nation by the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring network, including 50 national parks. NPS ARD interpolates visibility estimates for additional national park units, such as WEFA, that do not contain an IMPROVE site. The closest IMPROVE monitoring site is located 64 km (40 miles) north of WEFA at Mohawk Mountain, CT.

Three types of measurements are made at IMPROVE sites: view, optical and particle. The visual appearance of a view is qualitatively documented with automatic photographic or video imagery. At some IMPROVE sites, optical monitors measure the ability of the atmosphere to scatter or absorb light. A particle monitor measures the mass and chemical composition of fine (PM-2.5) and coarse (PM-10) atmospheric particles.

NPS ARD has assessed 10-year trends (2000-2009) in visibility at a subset of national park units as the trend in Haze Index on the 20% clearest days and 20% haziest days (NPS ARD 2013). This Haze Index is expressed as deciviews (dv), which represent a linear scale of human-perceived changes in air quality, analogous to the decibel scale for sound. The Haze Index is near 0 dv for a pristine environment, and an increase of 1 dv represents a small but perceptible change in condition regardless of baseline visibility (Pitchford and Malm 1994).

Assessment Points

NPS ARD assesses conditions for visibility at national park units using the Haze Index, as the deviation of current estimates of five-year average visibility from estimated average natural visibility in the absence of anthropogenic visibility impairment (Table 4-5; NPS ARD 2015a). Interpolated estimates are used to assess conditions within the contiguous U.S., and are less accurate in the eastern U.S. due to the scarcity of IMPROVE sites. In the eastern U.S., estimated natural background particulate concentrations yield visual ranges of 100 – 130 km (60 – 80 miles); this range varies across the landscape with topography, vegetation and other landscape features (Malm 1999).

Table 4-5. Visibility assessment points and rating developed by NPS ARD (2015a).

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Haze Index (deciviews)	< 2	2 - 8	> 8

Condition and Trend

At WEFA, NPS ARD estimated the average five-year (2009-2013) Haze Index to be 5.1 deciviews (dv), warranting *moderate concern* (2-8 deciviews; NPS ARD 2015b).

NPS ARD did not determine a trend in visibility for WEFA; ten-year trends in visibility at national park units in New England show significant improving trends (Figure 4-4; NPS ARD 2013). Reductions in sulfur dioxide and nitrogen oxide emissions from electric utilities and industrial boilers, required by the Clean Air Act, have contributed to these improving trends (NPS ARD 2013).

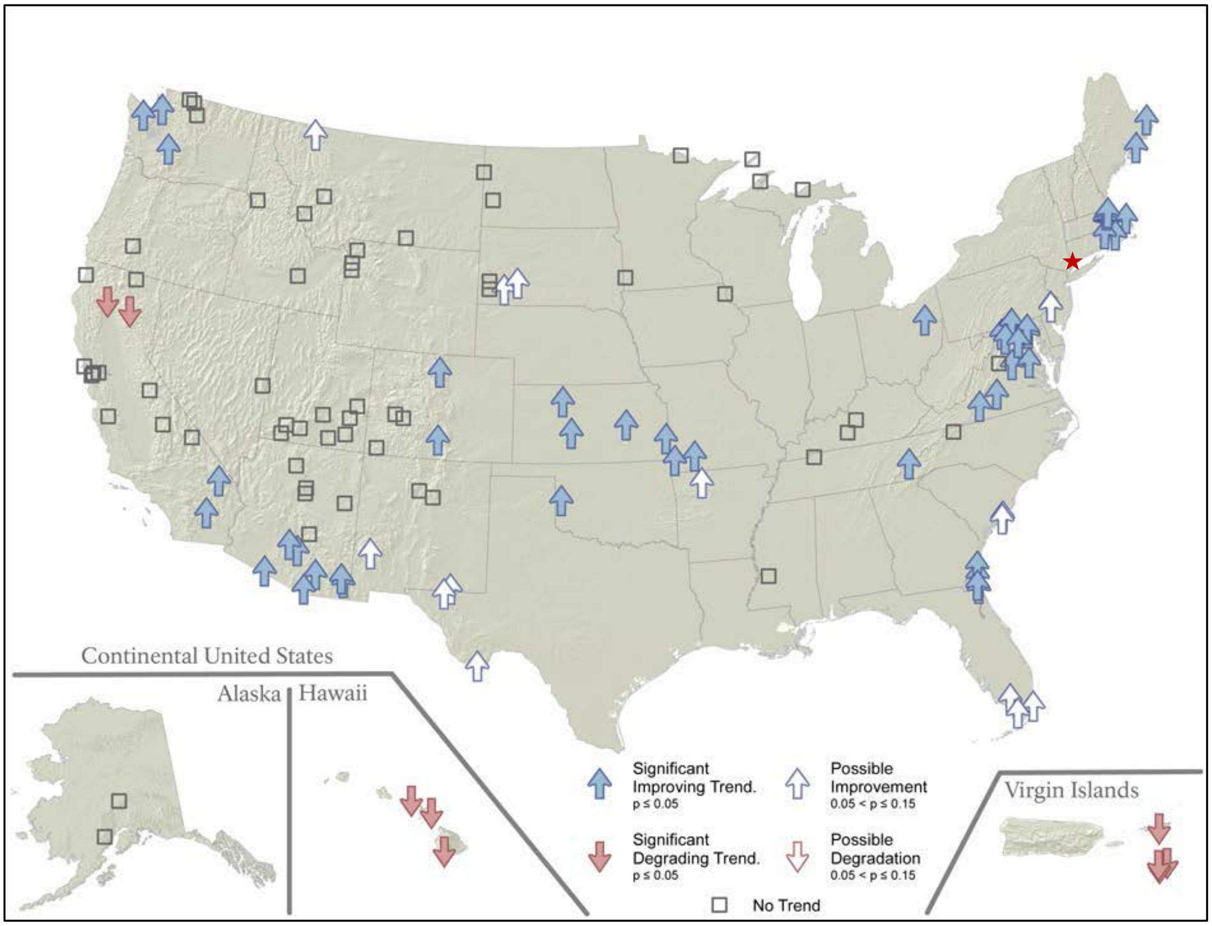

Figure 4-4. National trends in haze index (deciview) on haziest days, 2000–2009 (excerpted from NPS ARD 2013). Red star shows approximate location of WEFA.

Data Gaps and Level of Confidence

Confidence in visibility conditions at WEFA, interpolated from data collected at least 64 km (40 miles) away, is low. Confidence in regional ten-year trends is high.

Natural light quality is an important data gap at WEFA. The quality of daylight at any given time creates the conditions sought by artists working outdoors at this site, which is fundamental to WEFA's mission. Park staff could use automated, time-lapse photographic monitoring to monitor key landscape scenes at WEFA. The resulting dataset could be evaluated by a professional landscape artist to assign ratings for light quality, and further investigation could determine if the professional landscape artist's light quality ratings were correlated with monitored visibility metrics or other extractable metrics from the photo dataset.

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Contaminants

Description and Relevance

Deposition of heavy metal contaminants was identified as a Vital Sign for NETN parks (Mitchell et al. 2006). Of particular interest is mercury (Hg), an environmental contaminant of concern in aquatic and, more recently, terrestrial ecosystems (Evers et al. 2005, Rimmer et al. 2009). Hg is emitted by coal-burning power plants, solid waste incineration, and other sources; once in the atmosphere, Hg is widely disseminated. Typically deposited in an inorganic form in rainwater (wet deposition), on dust (dry deposition), or due to gravity (air deposition), Hg is transformed by microorganisms in wetland sediments or forest soil into an organic form (methyl mercury, MeHg), a process which can be stimulated by S deposition (U.S. EPA 2008). MeHg is a neurotoxin which bioaccumulates up the food chain, affecting the reproduction, growth, development, and behavior of a variety of organisms including mammals, fish, salamanders, birds, plants, invertebrates and soil microflora.

<u>Data and Methods</u>
Two national networks monitor Hg deposition, both operating under the framework of the NADP: the Mercury Deposition Network (MDN) monitors wet deposition of Hg, and the Atmospheric Mercury Network (AMNet) measures dry and total deposition of Hg. The nearest MDN/AMNet site to WEFA is located approximately 56 km (35 mi) SW in Bronx NY (NY06), where Hg wet deposition has been monitored since January 2008, and dry and total deposition of Hg has been monitored since August 2008. Using available data sources outside the park, NPS ARD has estimated Hg contamination at several NPS units using landscape factors that influence the uptake of Hg, estimated wet Hg deposition, and predicted levels of MeHg in surface waters (Holly Salazer, personal communication, 9/29/15, unpublished NPS data). NPS has also determined 10-year trends in Hg deposition at a subset of national park units which did not include WEFA (NPS ARD 2013).

<u>Assessment Points</u>
NPS ARD (2015) has developed draft condition ratings for Hg deposition. The draft Hg status condition assessment is based on two factors: 1) estimated 3-year average Hg wet deposition ($\mu g/m^2/yr$) and 2) predicted surface water MeHg concentrations (ng/L) in park surface waters. The combination of these two factors leads to condition ratings of *good condition*, *moderate concern* or *significant concern* as shown in Table 4-6.

Table 4-6. Mercury status assessment matrix developed by NPS ARD (2015).

	Mercury wet deposition rating ($\mu g/m^2/yr$)				
Predicted methylmercury concentration rating (ng/L)	**Very Low** < 3	**Low** ≥ 3 and < 6	**Moderate** ≥ 6 and < 9	**High** ≥ 6 and < 9	**Very High** > 12
Very Low < 0.038	🟢	🟢	🟢	🟡	🟡
Low ≥ 0.038 and < 0.053	🟢	🟢	🟡	🟡	🟡
Moderate ≥ 0.053 and < 0.075	🟢	🟡	🟡	🟡	🔴
High ≥ 0.075 and < 0.12	🟡	🟡	🟡	🔴	🔴
Very High >0.012	🟡	🟡	🔴	🔴	🔴

Condition and Trend

NPS ARD has estimated three-year (2011–2013) wet Hg deposition at WEFA to be moderate at 8.37 μg/m^2/yr, and has predicted MeHg concentration in park surface waters is high at 0.093 ng/L (Holly Salazer, 9/29/15, unpublished NPS data, USGS 2015). This combination of values corresponds to a condition rating of *moderate concern* (Table 4-6; NPS ARD 2015). Ten-year trends in Hg concentration in precipitation are possibly improving at assessed national park units in the northeastern US (Figure 4-5, NPS ARD 2013).

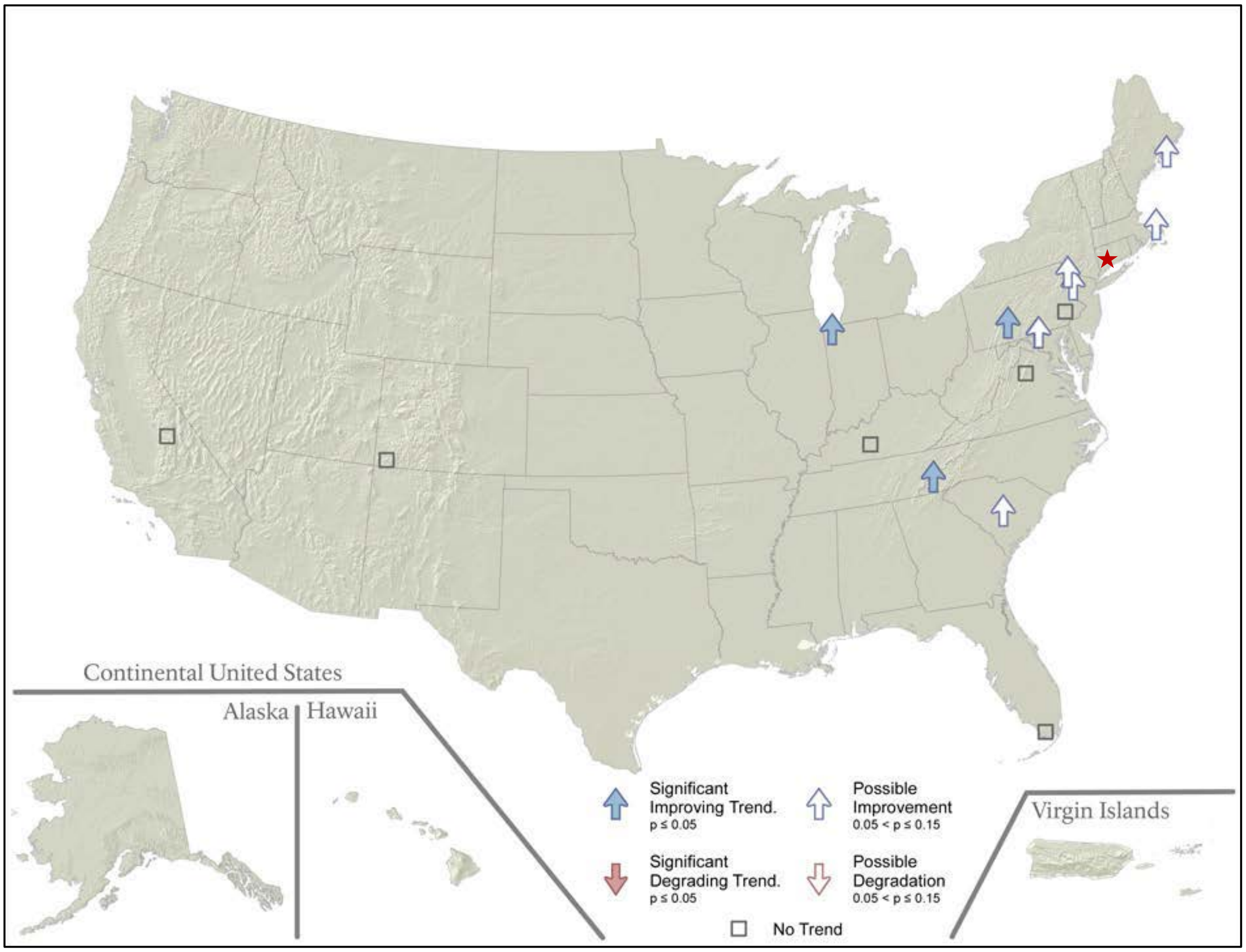

Figure 4-5. National trends in mercury concentrations in precipitation (ng/liter/yr), 2000–2009 (excerpted from NPS ARD 2013).

Data Gaps and Level of Confidence

Confidence in Hg condition is low because there are no park-specific studies examining Hg and toxics levels in park ecosystems. The degree of confidence in the regional trend is low due to the scarcity of available data and weakness of trend.

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Climate & Phenology

Description and Relevance

Climate is a dominant driver of ecological structure, composition and functional relationships. Anthropogenic climate change is expected to cause “major changes in ecosystem structure and function, species’ ecological interactions, and species’ geographical ranges, with predominantly negative consequences for biodiversity” (IPCC 2007). NPS Director Jonathan B. Jarvis has stated that “climate change continues to be the most far-reaching and consequential challenge ever faced by our national parks” (NPS 2014).

It is clear that global warming is occurring (IPCC 2013). Many observed physical and biological changes have already been linked to human-induced warming, including the rise in global average temperature and changes in phenology of many species (Parmesan and Yohe 2003, IPCC 2007).[5] Modeled future climate scenarios suggest that temperatures across much of the globe, including much of the U.S., will shift outside the range of historical variability by mid-century (Mora et al. 2013).

Data and Methods

Monahan and Fisichelli (2014a) used gridded climate data from the Climatic Research Unit's (CRU) high-resolution time series to examine 25 climate-related variables over 112 years (1901-2012) at 289 parks across the nation, including WEFA. For each park, the study area included a 30-km (18.6-mi) buffer surrounding the park. They used a moving window analysis at 3 scales (10-, 20-, and 30-year windows) to characterize each park's historical range of variability (HRV; Figure 4-6), and to compare recent averages to historical conditions, noting extreme current condition (i.e., <5% or >95% percentile compared to HRV).

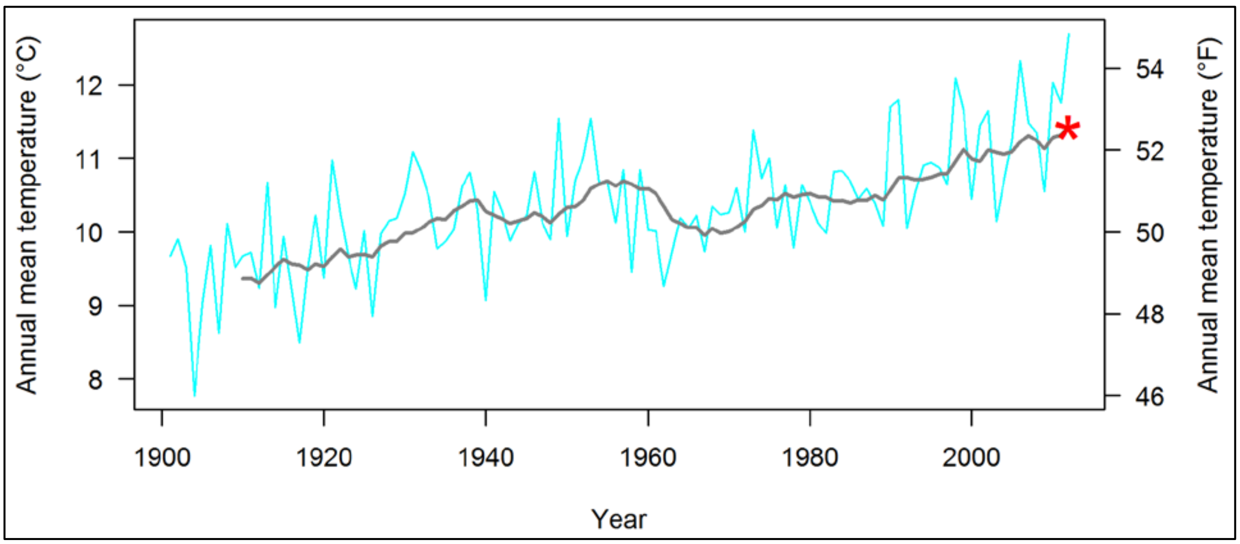

Figure 4-6. Time series used to characterize the historical range of variability and most recent percentile for annual mean temperature at Weir Farm National Historic Site. The blue line shows temperature for each year, the gray line shows temperature averaged over progressive 10-year intervals, and the red asterisk shows the average temperature of the most recent 10-year window (2003–2012).Excerpted from Monahan and Fisichelli (2014b).

Current conditions at WEFA were "extreme warm" for 4 of 7 temperature variables, and "extreme wet" for 4 of 7 precipitation variables (Figure 4-7). No variables showed current condition of "extreme cold" or "extreme dry." Eleven additional variables were examined. Of these, current conditions of three variables (mean annual percent cloud cover, annual number of wet days, wet days of the warmest quarter) were "extreme high;" current conditions of two variables (annual frost days

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[5] Phenology is the study of the timing of recurrent biological events, such as flowering, leaf-out, migration, and hibernation, and provides a simple and straightforward process in which to track changes in the ecology of species in response to climate change (Denny et al. 2014).

and cloud seasonality) were “extreme low” (1.1%); and current conditions of six variables (mean diurnal range, isothermality, temperature seasonality, temperature annual range, precipitation seasonality, vapor pressure of the warmest quarter) were not extreme (Monahan and Fisichelli 2014a).

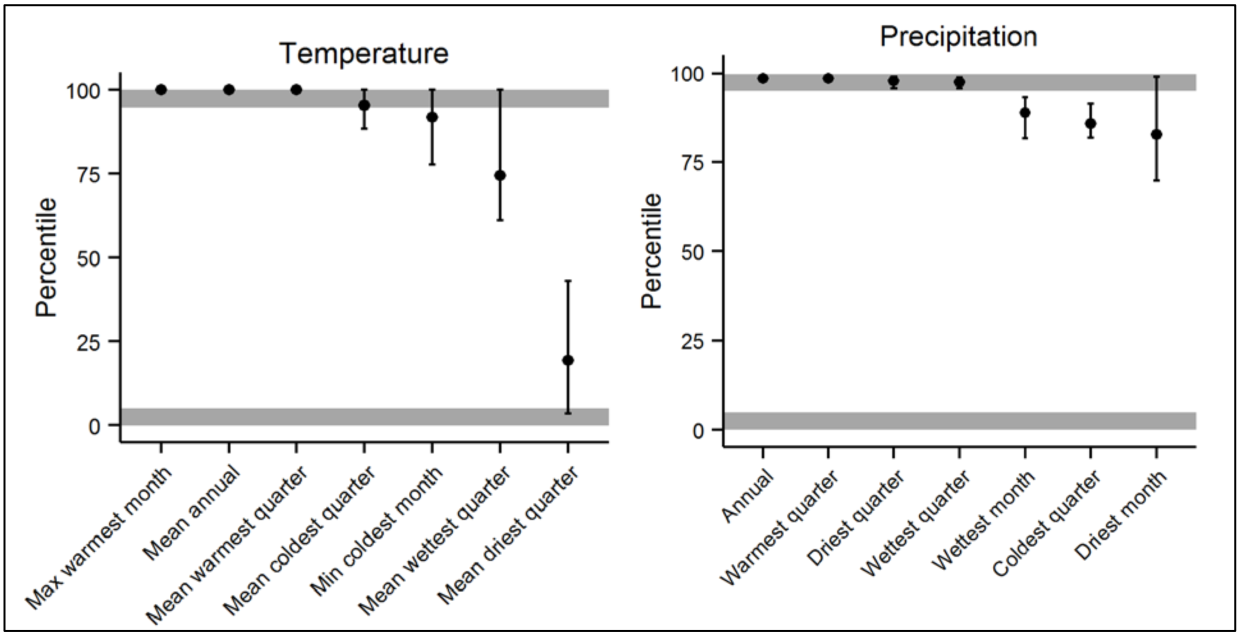

Figure 4-7. Recent temperature and precipitation percentiles at Weir Farm National Historic Site. Black dots indicate average recent percentiles across the 10, 20, and 30-year intervals (moving windows). Variables were considered “extreme” if the mean percentiles were <5th percentile or >95th percentile (i.e., the gray zones). Black bars indicate the range of recent percentiles across 10, 20, and 30-year moving windows. Excerpted from Monahan and Fisichelli 2014b.

Fisichelli et al. (2014) investigated potential forest change over the 21st century in response to climate change at 121 national parks, including WEFA. They examined potential changes in tree habitat suitability and uncertainty in potential change under two possible future climate scenarios (“least change” and “major change”). The two scenarios represented an increase in mean annual temperature of 3–6° C (5.4–10.8° F) in the eastern U.S. and varied change in precipitation (-27 to + 75%) over baseline conditions (1961 – 1990). They further examined present levels of nonnative biotic stressors (exotic plants and forest insect pests and diseases). For WEFA, this analysis predicted high levels of forest change, with an average 75% of modeled tree species undergoing large change[6] in habitat suitability, and moderate uncertainty (a 40% difference in the number of tree species undergoing high change between the two climate scenarios). Levels of predicted forest change and uncertainty were similar for other parks in the region. Quantification of current biotic stress from nonnative species at WEFA indicated that 14% of plant species currently found at the park were nonnative, and a high number (54) of exotic forest insects and diseases were present in the park or

[6]Large change is defined as >50% decrease or >100% increase in habitat suitability.

nearby region. Many forest trees are foundation species, which have strong role in creating or maintaining habitat for other species, so impacts to these trees will ramify through the park.

Phenology data has been collected at WEFA since 2011 using the NETN Phenology protocol (Tierney et al. 2013). Observations of five plant species and one animal species have been collected from sites within the park since 2012, and observations of two additional animal species were collected from 2011-2013 (Table 4-7).

Table 4-7. Species monitored for phenology at WEFA.

Species	Common name	Years collected	Total observations
Acer rubrum	red maple	2012-present	1607
Acer saccharum	sugar maple	2012-present	1506
Alliaria petiolata	garlic mustard	2012-present	850
Asclepias syriaca	common milkweed	2012-present	1060
Chrysemys picta	painted turtle	2012-present	162
Lepomis macrochirus	bluegill	2011-2013	135
Lithobates sylvaticus	wood frog	2011-2013	166
Syringa vulgaris	common lilac	2012-present	384

Assessment Points

Assessment points for climate condition have not been determined.

Condition and Trend

Although assessment points for climate condition have not yet been determined, the extent and magnitude of ecosystem impacts expected over the next century under current warming projections would warrant *significant concern*.

Data Gaps and Level of Confidence

Confidence in status assessment is low because understanding of ecosystem changes in response to climate change is poor and because assessment points have not been established. Continued monitoring of species phenology in the park will be informative.

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Soundscape

Description and Relevance

The natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wildlife" protected by the NPS Organic Act of 1916 (16 USC 1). NPS Management Policies require the NPS to "restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise)," "protect natural soundscapes from unacceptable impacts," and preserve the cultural soundscape "for appropriate transmission of cultural and historic sounds that are fundamental components of the purposes and values for which the parks were established" (§ 4.9 and 5.3.1.7 in NPS 2006). Director's Order 47 (NPS 2000) directs park managers to monitor the park soundscape and manage noise. Parks may be affected by noise sources originating both within the park (due to park equipment and management) as well as outside the park (such as airplane and automobile traffic, and nearby land uses and development).

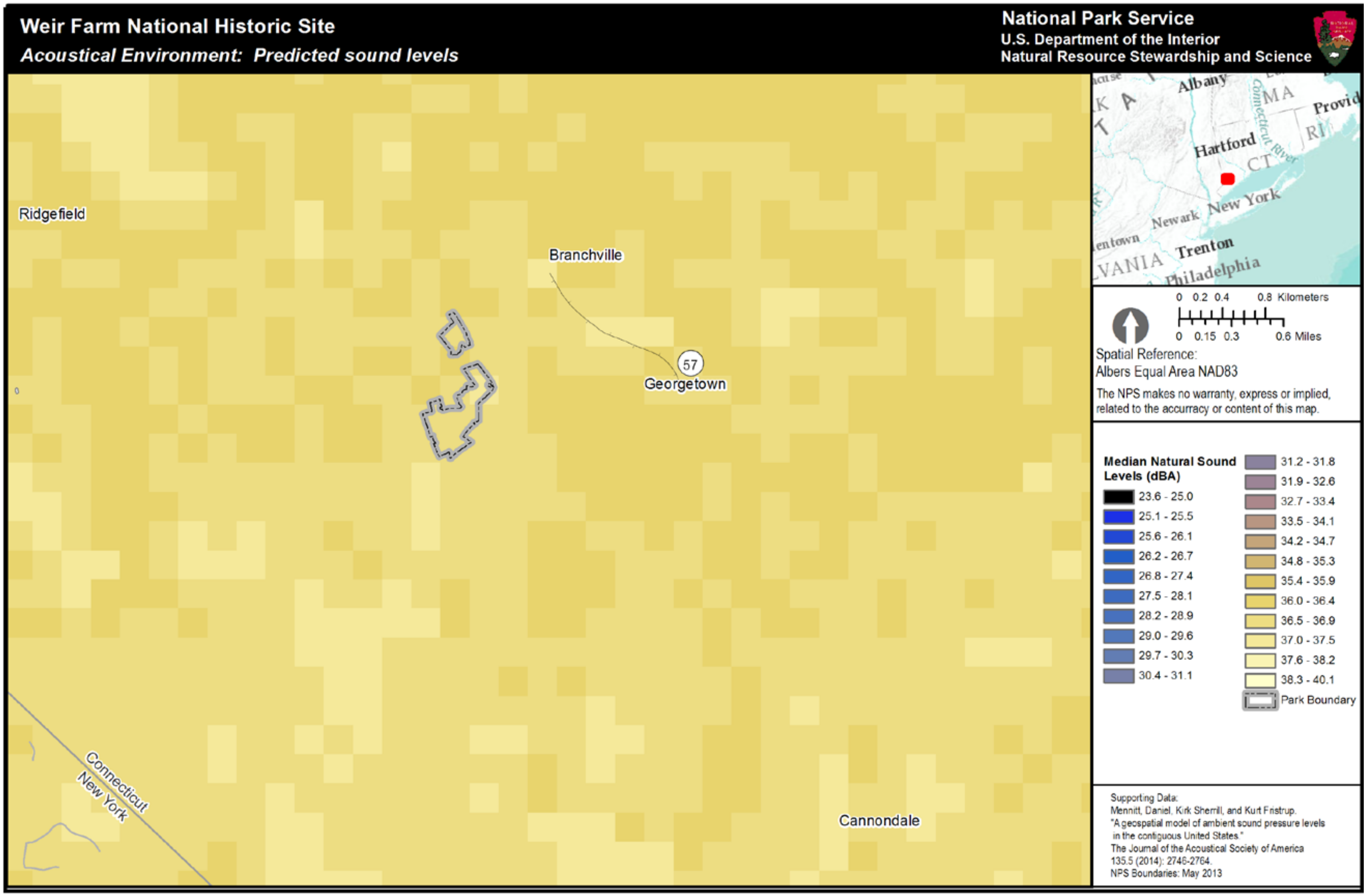
To understand soundscape condition, it is useful to distinguish between acoustic resources (physical sound sources such as wildlife, waterfalls, wind, rain, and cultural or historical sounds), the soundscape (the human perception of physical sound sources), and the acoustic environment (all acoustic resources, including anthropogenic noise). Clarifying this distinction allows managers to create objectives for safeguarding both the acoustic environment and the visitor experience (NPS NSNSD 2014).

The New York/New Jersey/Philadelphia Metropolitan Area Airspace Redesign Project, approved in 2007 and partially implemented as of 2012, was predicted to impact aircraft traffic and resulting noise levels at WEFA (U.S. DOT FAA 2007a, U. S. DOT FAA 2007b).

Data and Methods

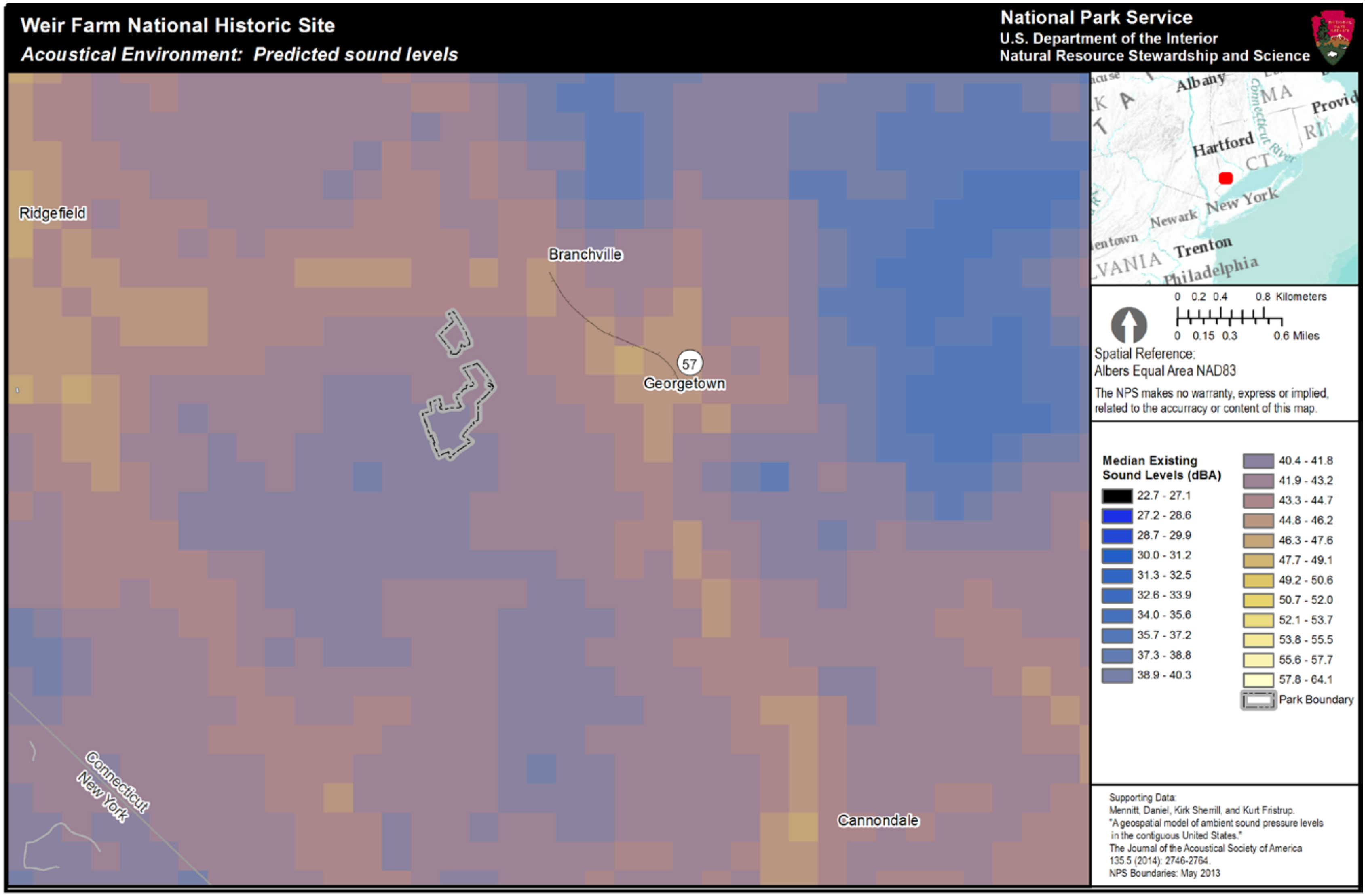
Soundscape data have not been collected at WEFA. However, two analyses using modeled data provide limited information relevant to soundscape at WEFA. First, the New York/New Jersey/Philadelphia Metropolitan Area Airspace Redesign EIS included an aircraft noise analysis for nine locations within WEFA, using the Federal Aviation Administration (FAA)'s Noise Integrated Routing System (NIRS) computer model (U.S. DOT FAA 2007a). This analysis predicted that the selected Airspace Redesign project would result in an average of 10.2 daily jet operations over WEFA in 2011, causing 36.5 dB yearly average day/night sound level (DNL) of aircraft noise (U.S. DOT FAA 2007a, U.S. DOT FAA 2007b). The DNL metric averages the total amount of noise energy (dB) produced in a 24-hour period, weighting nighttime (10:00 p.m. and 7:00 a.m.) noise 10 dB higher than daytime noise. The FAA has established a DNL level of 65 dB as the threshold above which aircraft noise is considered to be incompatible with residential areas (U.S. DOT FAA 2007a). However, appropriate DNL levels for aircraft noise in national park units have not been defined.

Second, using acoustic data collected at 244 sites, the NPS Natural Sounds & Night Skies Division (NSNSD) has developed a geospatial model which predicts both natural and existing ambient sound levels with 270 meter resolution using 109 spatial explanatory layers from seven categories (location, climatic, landcover, hydrological, anthropogenic, temporal, and equipment; Mennitt et al. 2014). Anthropogenic explanatory variables included road density, distance to all roads and major roads, flight frequency observation data, and a naturalness index based upon land use, housing density and traffic. Natural ambient sound level refers to the acoustical conditions that exist in the absence of human-caused noise and represents the level from which the NPS measures impacts to the acoustic environment (Figure 4-8). Existing ambient sound level refers to the current sound level in an area, including both natural and human-caused sounds (Figure 4-9). In addition, the model calculates the difference between these two metrics, providing a measure of impact to the natural acoustic environment from anthropogenic sources. The resulting impact metric indicates how much anthropogenic noise has raised the existing sound pressure levels in a given location (Figure 4-10). Sound pressure levels are shown as L_{50} dBA, where L_{50} represents the level that is exceeded 50 percent of the time during a summer day, and dBA is the sound pressure level (amplitude) in decibels (dB) adjusted (weighted) to reflect human hearing sensitivity to frequencies from 1,000 to 6,000 Hz (Turina et al. 2013).



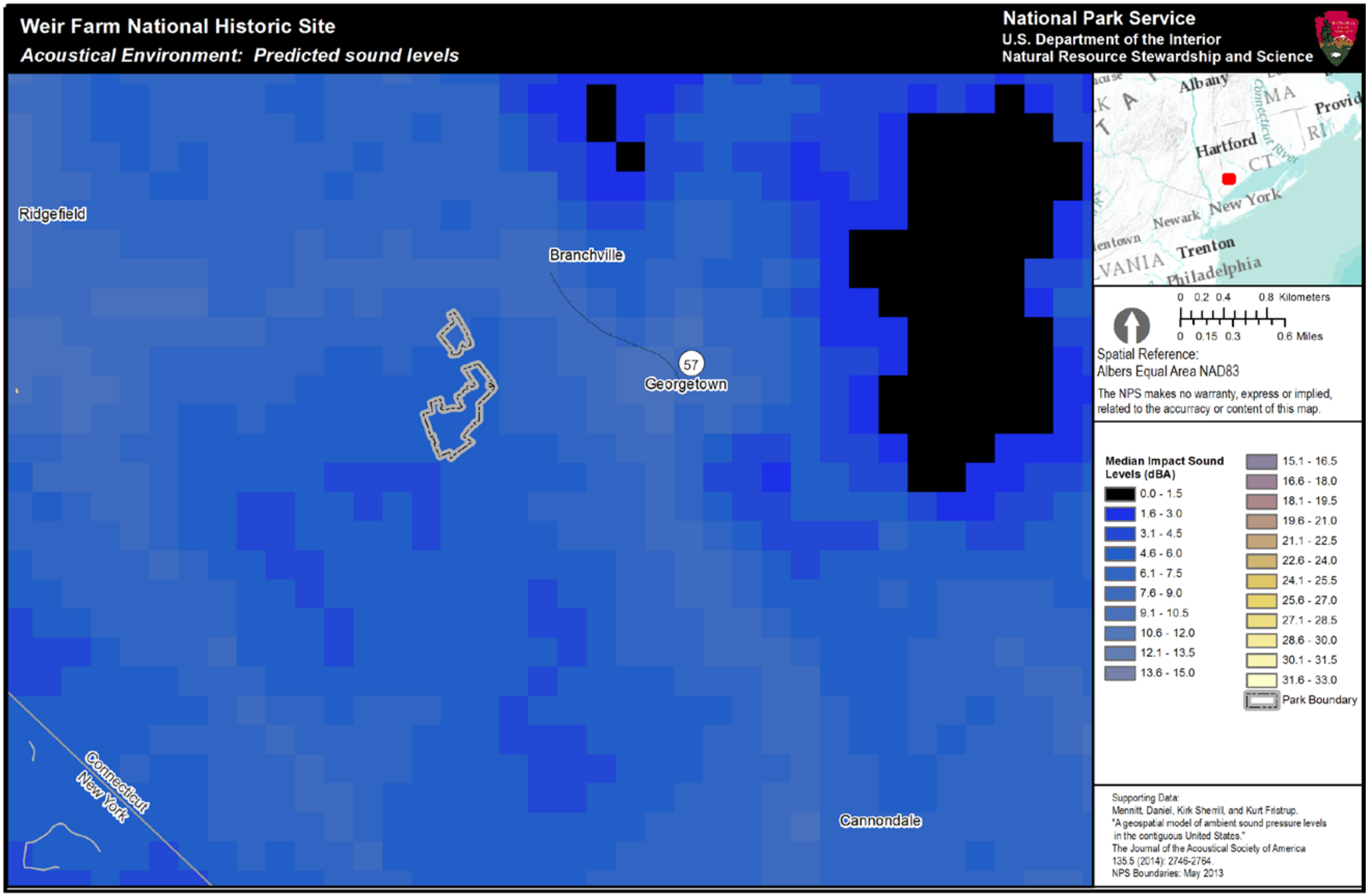
NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20150114

Figure 4-8. Modeled natural ambient sound levels (L_{50} dBA) within Weir Farm NHS range from 36.3 to 36.9 (unpublished data provided by NPS NSNSD).



NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20150114

Figure 4-9. Modeled existing ambient sound levels (L50 dBA) within Weir Farm NHS range from 41.4 to 42.4 (unpublished data provided by NPS NSNSD). Note that the color scale and maximum sound level shown here differs from the previous figure.



NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group 20150114

Figure 4-10. Modeled impact sound levels (L50 dBA) within Weir Farm NHS range from 4.6 to 5.8 (unpublished data provided by NPS NSNSD). Impact sound levels represent alteration to the natural acoustic environment from anthropogenic sources (i.e., noise).

Assessment Points

Soundscape assessment points should address the effects of noise on human health and physiology, wildlife, the quality of the visitor experience, and finally, the inherent value of the acoustic environment (NPS NSNSD 2014). Various characteristics of sound can contribute to how noise affects the acoustic environment. These characteristics include rate of occurrence, duration, amplitude (loudness), pitch, and whether the sound occurs consistently or sporadically. In order to capture these aspects, the quality of the acoustic environment should be assessed using a number of different metrics including existing ambient sound level (measured in decibels), percent time human-caused noise is audible, and noise free interval. Functional effects produced by increases in sound level should also be considered. For example, the *listening area* (the area in which a sound can be perceived by an organism) is reduced when background sound levels increase due to sound masking (Barber et al. 2010).

NPS NSNSD has developed interim guidance to assist Park units in assessing soundscape condition (Turina et al. 2013). The suggested assessment points for non-urban parks (Table 4-8) are applicable to WEFA, but may be adjusted to accommodate management objectives and functional effects specific to WEFA. Since each 3 dB increase in background sound level will reduce a given listening area by half, the assessment point between *moderate concern* and *significant concern* corresponds to a 50% reduction in listening area (Turina et al. 2013). This means that a rating of *significant concern* is applied to a park in which anthropogenic noise has increased background sound levels enough to reduce by half the area over which a park visitor can perceive sounds.

Table 4-8. Suggested assessment points for Soundscape condition in non-urban parks (Turina et al. 2013).

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Mean Impact Sound Pressure Level (L_{50} dBA)	≤ 1.5	1.5 -3.0	≥ 3.0
Corresponding Reduction in Listening Area	≤ 30%	30 – 50 %	≥ 50%

Condition and Trend

Soundscape condition was assessed for WEFA by NPS NSNSD using a modeled dataset (Mennitt et al. 2014). Impact SPL across the park fell within the range 4.6-5.8 L_{50} dBA (Figure 4-10), corresponding to a reduction in listening area of ≥ 50 % and warranting *significant concern*. The trend in soundscape condition was not assessed. Nationwide trends indicate that prominent sources of noise in parks (namely vehicular traffic and aircraft) are increasing (U.S. DOT FHWA 2013, U.S. DOT FAA 2010). However, conditions in specific parks may differ from national trends.

Data Gaps and Level of Confidence

Confidence in status assessment is low, because this assessment did not incorporate onsite monitoring. The trend was not assessed.

Confidence in soundscape assessment could be increased by onsite monitoring. NPS has developed an Acoustical Monitoring Training Manual (NPS NSNSD 2013) which provides guidance to park managers seeking to define park acoustical zones, select sounds and sites of interest for monitoring, deploy and maintain automated recorders and meteorological instruments, collect data, conduct on-site listening sessions, and analyze acoustical data. A useful first step is to develop an inventory of audible sounds to better understand what sounds presently contribute to the acoustic environment, which are the most common, and which could possibly threaten the quality of the acoustic environment. Inventory data can be collected simply by a single, focused listener in calm weather conditions during a series of listening sessions in several different locations and across different times of day to capture spatial and temporal variation in acoustic conditions (Lynch et al. 2011).

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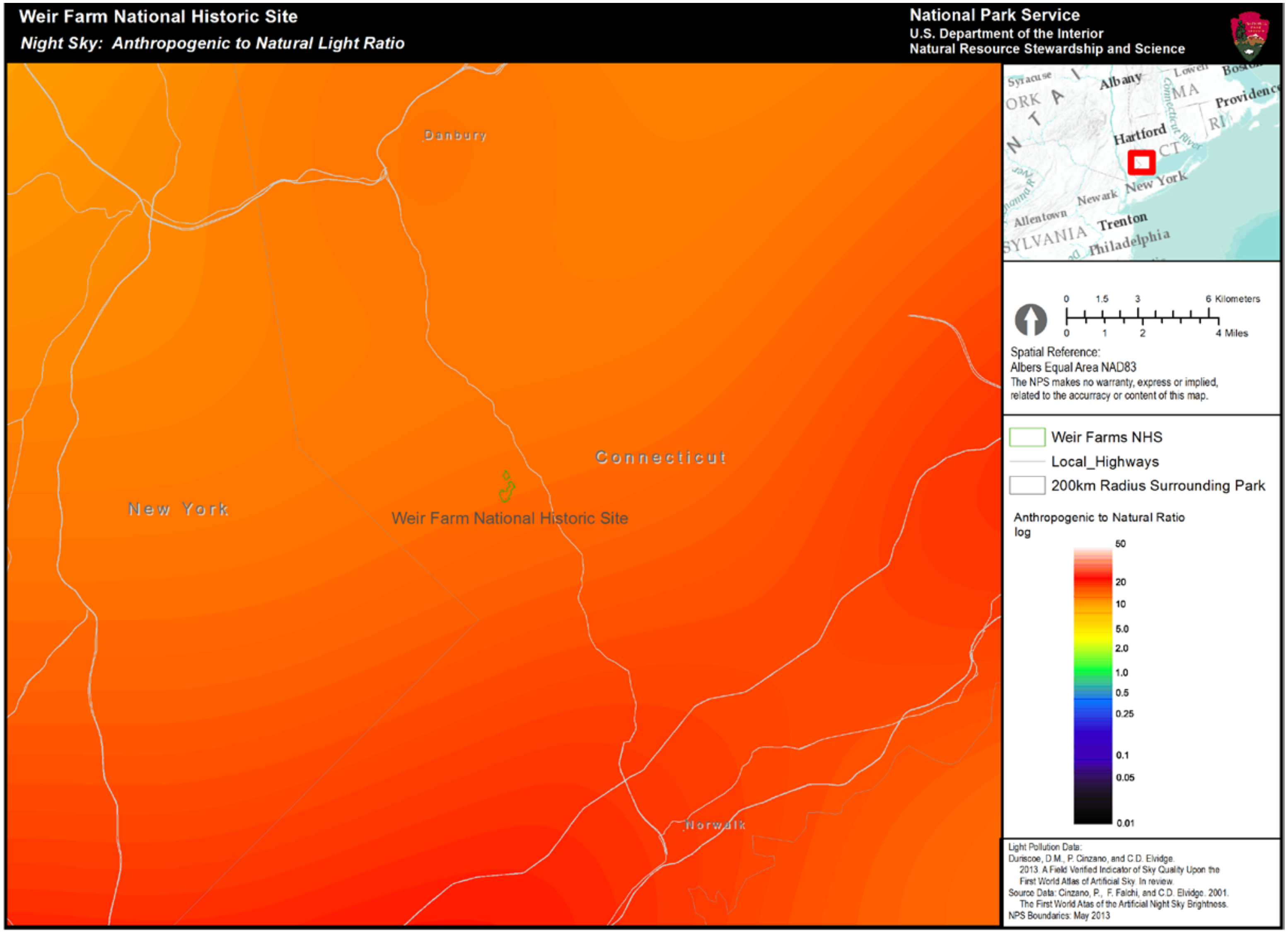
Lightscape

Description and Relevance

Visitors to the national parks may enjoy the star-gazing and natural darkness protected within National Park Units. In addition to having substantial impact on the quality of the visitor experience, natural darkness has ecological value to many species, including species which use darkness to evade predators or which navigate using patterns of light and dark. NPS uses the term "natural lightscape" to describe resources and values that exist in the absence of anthropogenic light at night. The natural lightscape can be compromised by light pollution from sources both within and outside the national parks. NPS management policies require the NPS to “preserve, to the greatest extent possible, the natural lightscapes of parks, which are natural resources and values that exist in the absence of human-caused light” (§ 4.10 in NPS 2006).

Data and Methods

Lightscape data has not been collected at WEFA. However, modeled data were provided by the NPS Natural Sounds & Night Skies Division (NSNSD; Figure 4-11). Using data from the 2001 World Atlas of Night Sky Brightness (Cinzano et al. 2001), NSNSD scientists have modeled a measure of anthropogenic light pollution across the contiguous U.S. This measure, called the anthropogenic light ratio (ALR), is a measure of how much total nighttime sky brightness is elevated over natural nighttime light levels across the entire sky. ALR is calibrated such that a ratio of 0.0 indicates pristine conditions of natural light, while a ratio of 1.0 indicates a sky 100% brighter than a natural sky. Average natural sky luminance is 78 nL (nanolamberts; Moore et al. 2013).



Created by NPS Natural Sounds & Night Skies Division and NPS Inventory and Monitoring Program MAS Group on 20150409

Figure 4-11. Local view of anthropogenic light near Weir Farm NHS. White and red represents more environmental influence from artificial lights while blues and black represent less artificial light (unpublished data provided by NPS NSNSD).

Assessment Points

Lightscape assessment points should consider park management objectives and wilderness status and the impact of light pollution on sensitive species or species of concern. Ideally, condition would be assessed from several lightscape metrics such as maximum vertical illuminance, horizontal illuminance, spectral characteristics, and impacts to wildlife species of concern (Moore et al. 2013).

NPS NSNSD has developed interim guidance to assist Park units in assessing lightscape condition using a single metric (ALR). The suggested assessment points for non-urban parks are applicable to WEFA (Table 4-9). The assessment point between *good condition* and *moderate concern* represents a 33% increase in luminance over a natural sky, and corresponds to a threshold at which the human eye is unable to fully adapt to the dark and some visual sensitivity is lost. The assessment point between *moderate concern* and *significant concern* represents a 200% increase in luminance over a natural sky, and corresponds to a level at which the Milky Way is not fully visible, and full adaptation to darkness is no longer possible by the human eye (Moore et al. 2013).

Table 4-9. Suggested assessment points for lightscape condition in non-urban parks (Moore et al. 2013).

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Median Anthropogenic Light Ratio (ALR)	≤ 0.33	0.33 - 2.0	≥ 2.0

Condition and Trend

The modeled median ALR value at WEFA was 1.14, indicating that anthropogenic light was more than 100% brighter than the natural light from the night sky (NPS NSNSD unpublished data). This corresponds to a rating of *moderate concern*. At these light levels, the Milky Way is visible but has typically lost some of its detail and is not visible as a complete band. Zodiacal light (or “false dawn” which is faint glow at the horizon just before dawn or just after dusk) is rarely seen. Anthropogenic light likely dominates light from natural celestial features and shadows from distant lights may be seen. The trend in lightscape was not assessed.

Data Gaps and Level of Confidence

Confidence in lightscape condition at WEFA is low, because assessment was made from modeled data and did not incorporate onsite monitoring.

Confidence could be increased by onsite monitoring of lightscape parameters, including maximum vertical illuminance, horizontal illuminance, spectral characteristics, impacts to wildlife species of concern, measures in certain quadrants of the sky, and qualitative indices (Moore et al. 2013). NPS has developed a protocol for monitoring park lightscape using automated digital photography (Duriscoe et al. 2007). Alternatively, citizen scientist monitors may be engaged to monitor lightscape using simple star counts, such as in the Globe at Night Program (www.globeatnight.org).

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Geology & Soils

Forest Soil Condition

Description and Relevance

Soil provides the foundation upon which forest ecosystems exist, providing physical structure for anchorage and fine root growth, and nutrients and water for tree growth and maintenance. Forest soil condition is affected by physical disturbance from timber harvest, fire, or trampling, as well as by atmospheric deposition of acidic inputs and other contaminants (Driscoll et al. 2001, Aber et al. 2003). Soil nutrient cycling is also affected by prior land use, weathering of parent material, and by tree species growing on the site, and by interaction of these factors. Tree species vary in their influence on soil nutrient cycling, particularly with respect to nitrogen (N) cycling (Finzi et al. 1998, Lovett and Mitchell 2004). The impacts of atmospheric deposition are of particular concern in the northeastern US, affecting both terrestrial and aquatic ecosystems. Aluminum leached from forest soils by atmospheric inputs enters lakes and streams where it causes toxic impacts to fish and other aquatic organisms.

Data and Methods

Since 2007, NETN has collected composite soil samples from 10 permanent forest plots at WEFA (Miller et al. 2014). Half the plots are monitored during each biennial collection. Soil samples were separated by horizon (O and A) if possible, dried and analyzed for pH, organic matter (as loss on ignition; % LOI), percent total N (% TN) and total carbon (% TC) by combustion, exchangeable acidity in potassium chloride, and exchangeable cations in ammonium chloride (see Miller et al. [2014] for detailed methods). Percent base saturation (% BS) was calculated from milliequivalent levels of base cations and acidity. Herein, condition was determined from the recent data cycle available (2009-2011); trends could not be determined.

Assessment Points

NETN rated soil chemistry based on the ratio of exchangeable calcium to aluminum (Ca:Al), developed as an indicator of acid stress on forest soils (Cronan and Grigal 1995), and the ratio of total C to total N (C:N), a primary indicator of nitrogen status (Aber et al. 2003) as shown in Table 4-10 (Miller et al. 2014). Percent base saturation (%BS) is considered here as a complementary indicator of acid stress (Cronan and Schofield 1990). The USFS has developed a detailed Soil Quality Index (SQI) that integrates 19 physical and chemical properties of forest soils for use in interpreting USFS Forest Inventory and Analysis (FIA) data (Amacher et al. 2007). SQI assessment points were considered to interpret forest soil condition for parameters in addition to those rated in Table 4-10.

Table 4-10. Assessment points for forest soil condition. See text for description.

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Ca:Al	> 4	1 - 4	< 1
C:N	> 25	20 - 25	< 20
% BS	>15%	10-15%	<10%

Condition and Trend

Analysis of soil pH showed forest plots at WEFA to have moderately acid soil (Table 4-11). TN is adequate for plant nutrition, and TC is adequate to excellent. However, low C:N ratios indicate forest soils warrant *significant concern* for vulnerability to N saturation despite the fact that N deposition rates (reported in Section 4.1.2 herein) fell below threshold rates for predicted onset of N saturation (5-18 kg N/ha/yr; Aber et al. 2003). Base cation status is adequate or better at most plots, showing *good condition*. However, aluminum (Al) levels are high, and adverse effects due to Al toxicity warrant *moderate concern*. High sodium (Na) levels indicate possible adverse effects.

Table 4-11. Soil chemistry data from 10 permanent forested NETN plots at WEFA sampled 2009-2011. Interpretation follows the USFS Soil Quality Index (Amacher et al. 2007), unless otherwise cited. Soil parameters are described in text. Cation values are g/kg sample.

Characteristic	Min	Median	Max	Interpretation
pH	4.2	4.5	5.4	Moderately acidic
% TN	0.2	0.4	1.6	Moderate (0.1 to 0.5) to high
% TC	3.2	7.2	28	Moderate (1-5) to high
Ca	56	930	1880	Moderate (101 - 1000) to high
K	84	154	421	Mostly moderate (100 - 500)
Mg	32	175	330	Mostly moderate (50 - 500)
Al	10	283	519	High (> 100)
Fe	1.9	25	90	High (> 10)
Mn	9.0	47	115	Mostly moderate (11 - 100)
Na	4.8	17	57	Possible adverse effects (> 15)
Zn	2.6	5.2	24	Moderate (1 - 10) to high
C:N	13.4	15.7	20.0	*Significant concern* for vulnerability to N saturation (< 20)
Ca:Al	0.1	2.2	124	*Moderate concern* for Al toxicity (1-4)
% BS	13%	65%	99%	*Good condition* (>15%)

Data Gaps and Level of Confidence

Confidence in status assessment is low due to the small sample size and the high variability of soil sampling. Trends were not assessed.

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Water

Water quantity and quality are monitored at a single site in Weir pond (Gawley and Roy 2014). This shallow, artificial pond is about 1.5-ha (3.7-ac) in size and drains an estimated 22.1 ha (54.7-ac) watershed, about half of which occurs within the park boundary (Figure 2-4; HDR, Inc. 2015, Metzler et al. 2009). The area of the Weir Pond watershed outside the park boundary is developed as low density residential land use containing uncurbed road surfaces, lawns and landscaped areas, and septic tanks for leaching of residential sewage (USDA NRCS 1995). The pond is fed by three intermittent streams as well as by groundwater; the outlet from Weir Pond is the park's only perennial stream (USDA NRCS 1995, Farris and Chapman 1999). This unnamed perennial stream traverses the park for 0.27 km (0.17) miles, from Weir Pond to the park border (Gawley et al. 2014).

Water Quantity

Description and Relevance

Weir Pond was created in 1896 when J. Alden Weir blocked a seasonal stream, some springs, and a wetland with an earthen and stone dam (NPS 1990, NPS 1995). At some point the spillway may have been raised, and the dam was partially reinforced at the toe with a concrete retaining wall in 1937 (NPS 1995, Zaitzevsky 2006). The dam is leaking and in need of repair, and the park's GMP/EIS included a recommendation to lower the spillway (USDA NRCS 1995, NPS 1995). This shallow pond is approximately 1.5 m (5 ft.) at its deepest point. It is likely that groundwater contributes a significant portion of Weir Pond's base flow during low runoff periods (USDA NRCS 1995). Surrounding residential development relies on private wells for residential water use in this low-density suburban area (NPS 1995).

Data and Methods

NETN has monitored pond height in Weir Pond monthly (May to October) since 2006 with some missed values (Gawley et al. 2014). A permanent bolt from which to measure pond height was installed in July 2011; thus, data collected prior to installing the bolt may not be accurate.

Assessment Points

Assessment points for water quantity at WEFA have not been set. Minimum values for pond water height may be set in comparison to mean values measured onsite, and with consideration of ecological functioning.

Condition and Trend

Water levels in Weir Pond are typically lowest in late summer and reached their lowest levels on record on October 1, 2007 (Figure 4-12). Data from 2014 fell within the range of values previously recorded; however late summer 2014 values were the lowest recorded since permanent installation of the measuring bolt in 2011. Water quantity condition is unknown due to the lack of established assessment points. Trends were not determined.

Data Gaps and Level of Confidence

Assessment of condition will become possible by determination of appropriate assessment points.

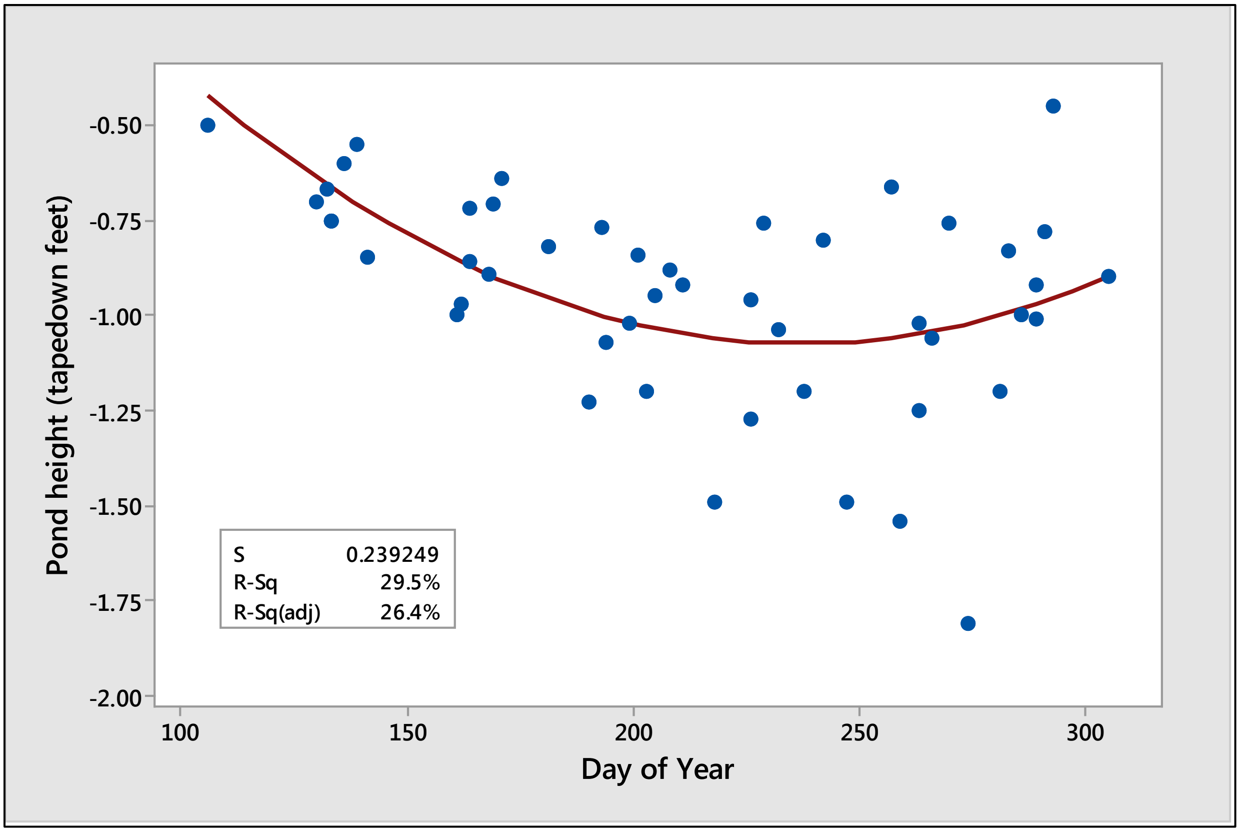

Figure 4-12. Fitted line plot of pond height versus day of year in Weir Pond. Data from NPS NETN 2015.

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Water Chemistry

<u>Description and Relevance</u>

Water chemistry is an essential indicator for determining condition of aquatic resources, providing fundamental information about the quality of the resource and its ability to support aquatic life. Weir Pond is bordered in part by low-density residential development, which may contribute to nutrient loading from on-site residential septic systems and from landscaping activities (Farris and Chapman 1999, G. Waters, personal communication, 23 October 2014). Historically, Weir Pond has ranged between mesotrophic (moderately productive) and eutrophic (highly productive) conditions (Gawley and Roy 2014). Runoff from roads bisecting the park also may impact water quality (Figure 2-4).

According to the State of Connecticut Water Quality Standards, effective February 25, 2011, streams within WEFA are considered class A surface water. Designated uses for class A water include habitat for fish, other aquatic life and wildlife, potential drinking water supply, and recreation. Groundwater beneath WEFA is considered class GA. Designated uses of class GA groundwaters are existing private and potential public or private supplies of water suitable for drinking without treatment and baseflow for hydraulically-connected surface water bodies (CT DEEP 2014).

<u>Data and Methods</u>

NETN has monitored water chemistry at set depths above the deepest point in Weir Pond approximately monthly from May through October since 2006 (Gawley and Roy 2014). In-situ sampling includes the following: pH, specific conductance, temperature, and dissolved oxygen. pH measures the availability of hydrogen ion, which determines acidity, a fundamental property of the sample which is influence by pollution. Temperature affects water chemistry and biology, and temperature is inversely correlated with dissolved oxygen (DO). DO is a critical indicator of water quality because low oxygen levels can kill or stress most aquatic life. A marked increase in specific conductance (a measure of the level of dissolved ions in water) can be an indicator of pollution. Naturally occurring values cover a wide range (less than 20 to more than 1,000 microsiemens per centimeter; μS/cm).

Acid neutralizing capacity (ANC) and nutrients (several forms of nitrogen [N] and total phosphorus [TP]) are monitored twice yearly, once in June and once in August. Reporting of total nitrogen (TN) includes all forms of nitrogen (organic and inorganic). N is an essential plant element and is often the limiting nutrient in terrestrial systems and marine waters, though it can also be limiting in some freshwater systems. P is a major plant nutrient which is typically limiting to plant growth in streams and ponds.

Beginning in 2012, monthly light penetration profiles, and twice-yearly chlorophyll *a*, chloride and sulfate measurements were incorporated into the sampling process. Detailed methods can be found in Gawley et al. (2014).

Water quality condition was assessed from the most recent data year (2014). Nine-year trends in water quality values from May, July, and October samplings were assessed using regression analysis, as were ANC and nutrient values from both June and August samplings.

<u>Assessment Points</u>
Gawley and Roy (2014) assessed Weir Pond water quality using water quality assessment points from the State of Connecticut and the U.S. EPA. State of Connecticut water quality standards define ranges consistent with a particular trophic status, and a water body meets the standard when measured values fall within the range designated for the trophic status considered natural for that water body (Table 4-12). The assessment point for chloride is the chronic exposure assessment point for CT freshwaters. EPA criteria provide assessment points for TN (≤ 320 μg/L), TP (≤ 8 μg/L) and chlorophyll (≤ 2.9 μg/L) developed specifically for Ecoregion 14 (the Eastern Coastal Plain) and represent nutrient conditions that are minimally impacted by human activities (U.S. EPA 2000). The EPA criteria are not regulatory values; they were established based on the lower 25th percentile of lakes and pond, and thus represent the most undisturbed lakes for which data was available (U.S. EPA 2000). Assessment points for specific conductance have not been established; however an increasing trend in specific conductance would warrant concern. For ANC, a minimum assessment point of 100 μeq/L for adequate buffering is suggested (Stoddard et al. 2003).

Table 4-12. Water quality assessment points for WEFA. ND is not determined.

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*	Source
Max Temp (°C)	≤ 29.4	> 29.4	ND	CT
Min DO (mg/L)	≥ 5.0	< 5.0	ND	CT
pH (standard units)	6.5 – 8.0	< 6.5 or > 8.0	ND	CT
TN (µg/L)	≤ 600	600 – 1,000	> 1,000	CT
TP (µg/L)	≤ 30	30 - 50	> 50	CT
Max Chlorophyll a (µg/L)	≤ 15	15 - 30	> 30	CT
Chloride (mg/L)	≤ 230	> 230	ND	CT
ANC (µeq/L)	≥100	< 100	ND	Stoddard et al. 2003

Condition and Trend

Water temperature, dissolved oxygen and specific conductance varied seasonally in Weir Pond (Figure 4-13). Recorded water temperatures in 2014 all fell below the CT state assessment point; however, temperatures exceeded this value at the surface and 0.5 m depth in July 2013. Looking across years at 1 m depth, water temperatures in 2014 fell within the range of values previously recorded.

Weir Pond pH values were moderately basic and typically fell within CT water quality standards (6.5 – 8.0), though August and September 2014 values exceeded this range, as did occasional values in previous years. Most DO measurements fell above the state minimum DO standard (5 mg/L), though values measured at the lowest depth sampled (> 1.3 m) typically fell below this level (data not shown) as expected due to biological activity in pond sediment. Looking across years at 1-m depth, DO values have occasionally dipped below this assessment point, but not in 2014. Inter-annual trends in pH and DO at 1-m depth were unchanging.

Specific conductance values were high in 2014 compared to past years (Figure 4-13). Looking across years at 1-m depth, specific conductance values show a statistically significant, increasing trend in May and October, but not in July.

TN concentrations in Weir Pond varied seasonally with higher values in August while TP concentrations did not vary significantly by season (Figure 4-14). In 2014, values for both nutrients fell within the range previously recorded and in the mesotrophic range. The highest nutrient measurements on record (August 2011) exceeded state guidance for eutrophic ponds for both TN and TP. All TN and TP values recorded in Weir Pond have exceeded the EPA Ecoregion 14 criteria corresponding to minimally-impacted condition (320 µg/L and 8 µg/L, respectively). Nine-year trends in TN and TP were unchanging.

Analysis for ANC showed that Weir Pond was adequately buffered, with all measurements falling above the 100 µeq/L assessment point (Figure 4-14). ANC varied seasonally, as expected, with June values lower than August values. Values from 2014 fell within the range previously recorded, and the lowest value on record (337 µeq/L) was recorded in June 2009. The nine-year trend in ANC was unchanging. Sullivan et al. (2011a and 2011b) found WEFA to have high ecosystem sensitivity to acidification and moderate sensitivity to N enrichment and deposition rates of N and S at WEFA were high enough to warrant significant concern (section 4.1.2). Low C:N and Ca:Al ratios in forest soil also warrant concern for acidification (section 4.2.1). The pH and ANC values reported here indicate adequate buffering of Weir Pond for the time being, but deposition rates and forest soil chemistry both warrant concern for future acidification of Weir Pond.

Chlorophyll *a*, sulfate and chloride were assessed in pond water samples beginning in 2012 to better understand water quality (Figure 4-15). Chlorophyll *a* values in Weir Pond typically fell within the expected range for a mesotrophic water body (2-15 μg/L), and exceeded the EPA Ecoregion 14 criteria for unimpacted lakes (2.9 μg/L). Sulfate levels varied seasonally and fell at the lower end of the usual range of sulfate concentration in natural water (104 μeq/L to 695 μeq/L; Wetzel 1983). However, continued S inputs from current levels of atmospheric deposition warrant concern (section 4.2.1).

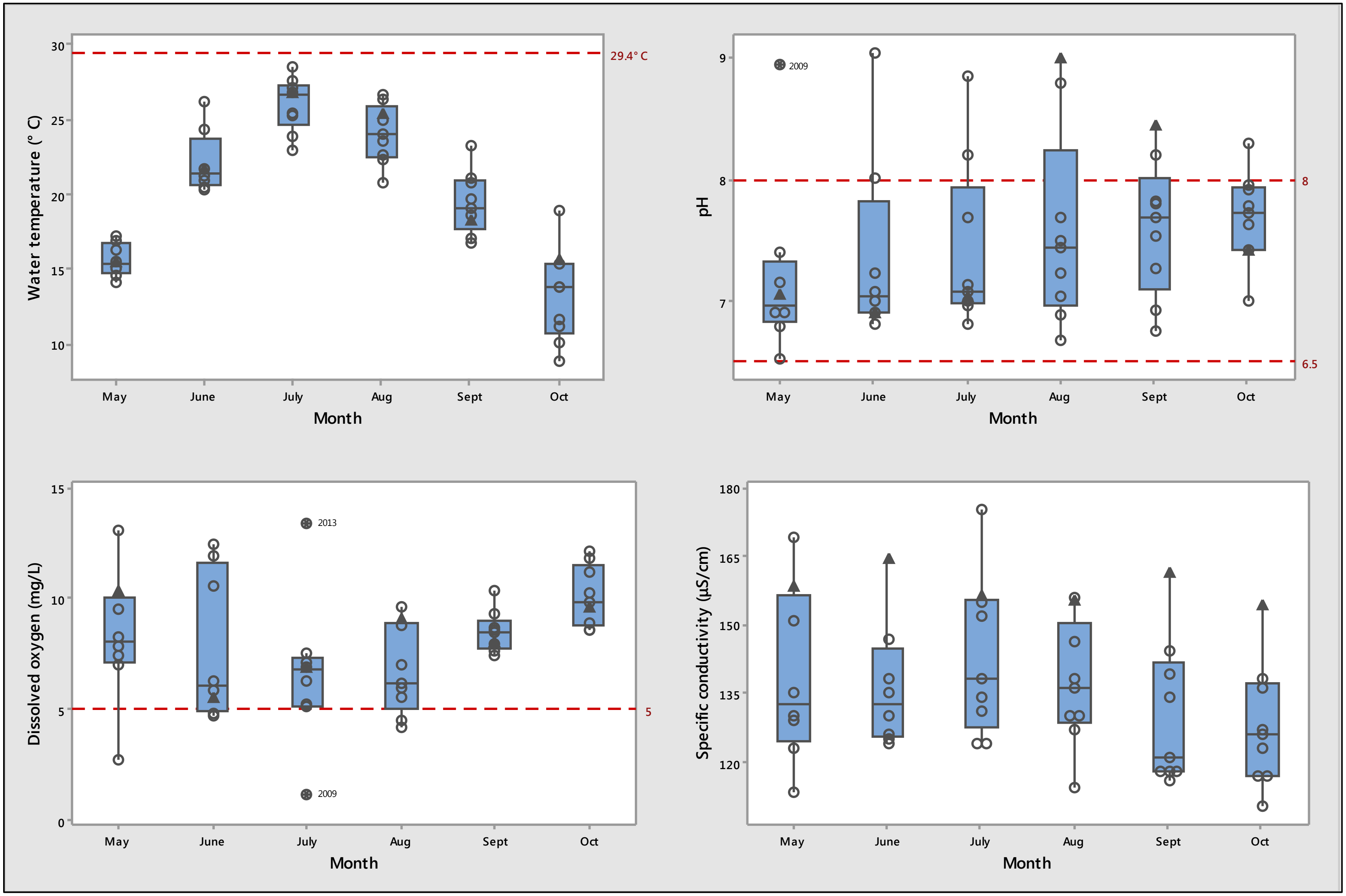

Figure 4-13. Boxplots of monthly temperature, pH, DO, and specific conductance at 1-m depth at a sampling site in Weir Pond in WEFA from 2006-2014. Data are from Gawley (2012), Gawley (2013), Gawley and Roy (2014), and W. Gawley (personal communication, 11 June 2015). Reference lines show CT state assessment points for mesotrophic and eutrophic surface waters. ▲shows 2014 values.

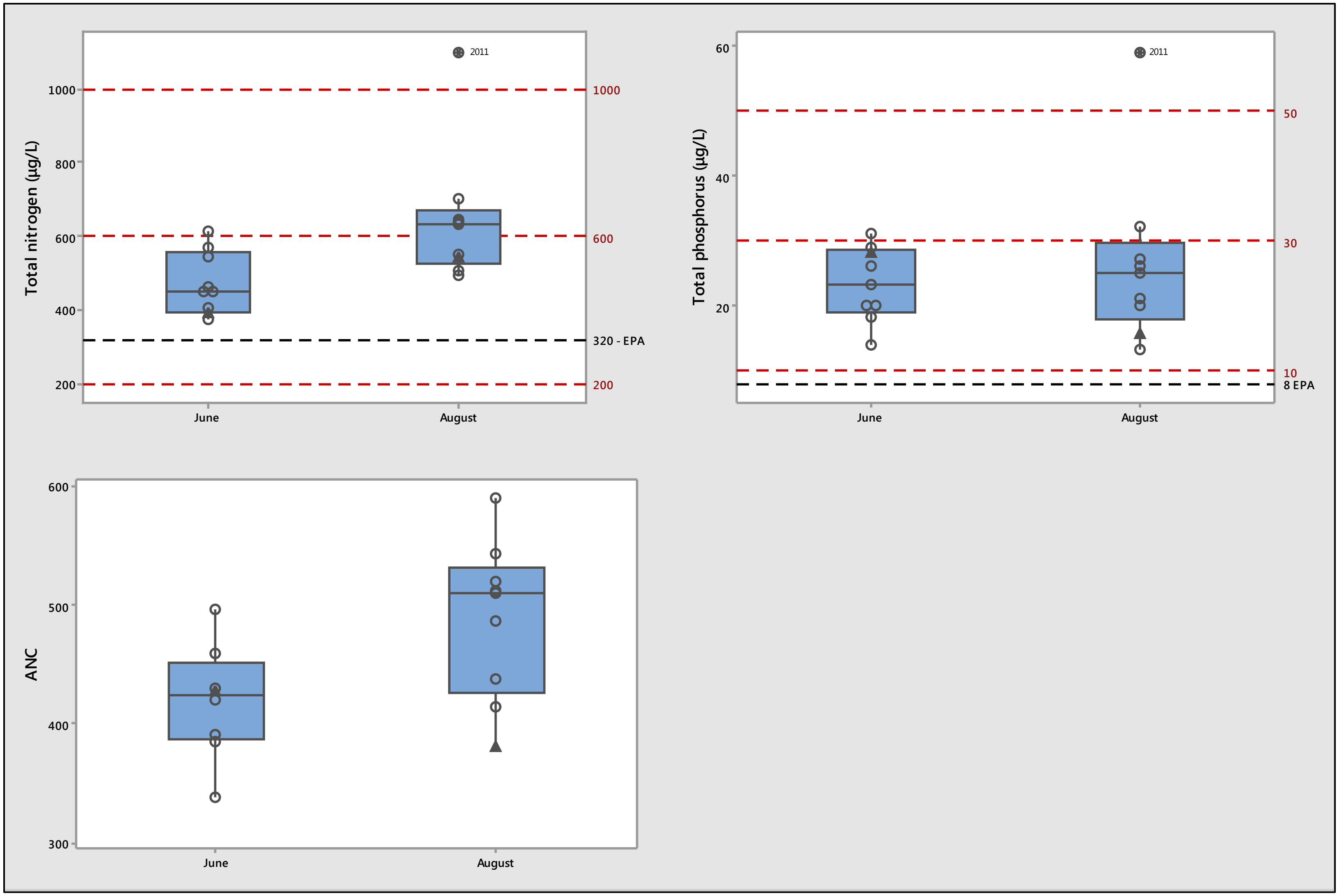

Figure 4-14. Boxplots of total nitrogen, total phosphorus and ANC in water samples collected twice annually from 2006-2014 from Weir Pond in WEFA. Data are from Gawley (2012), Gawley (2013), Gawley and Roy (2014), and W. Gawley (personal communication, 11 June 2015). Reference lines show CT state nutrient ranges for mesotrophic surface waters (lower range) and for eutrophic waters (upper range), and EPA Ecoregion 14 nutrient criteria for minimally impacted surface waters (black line). ▲shows 2014 values.

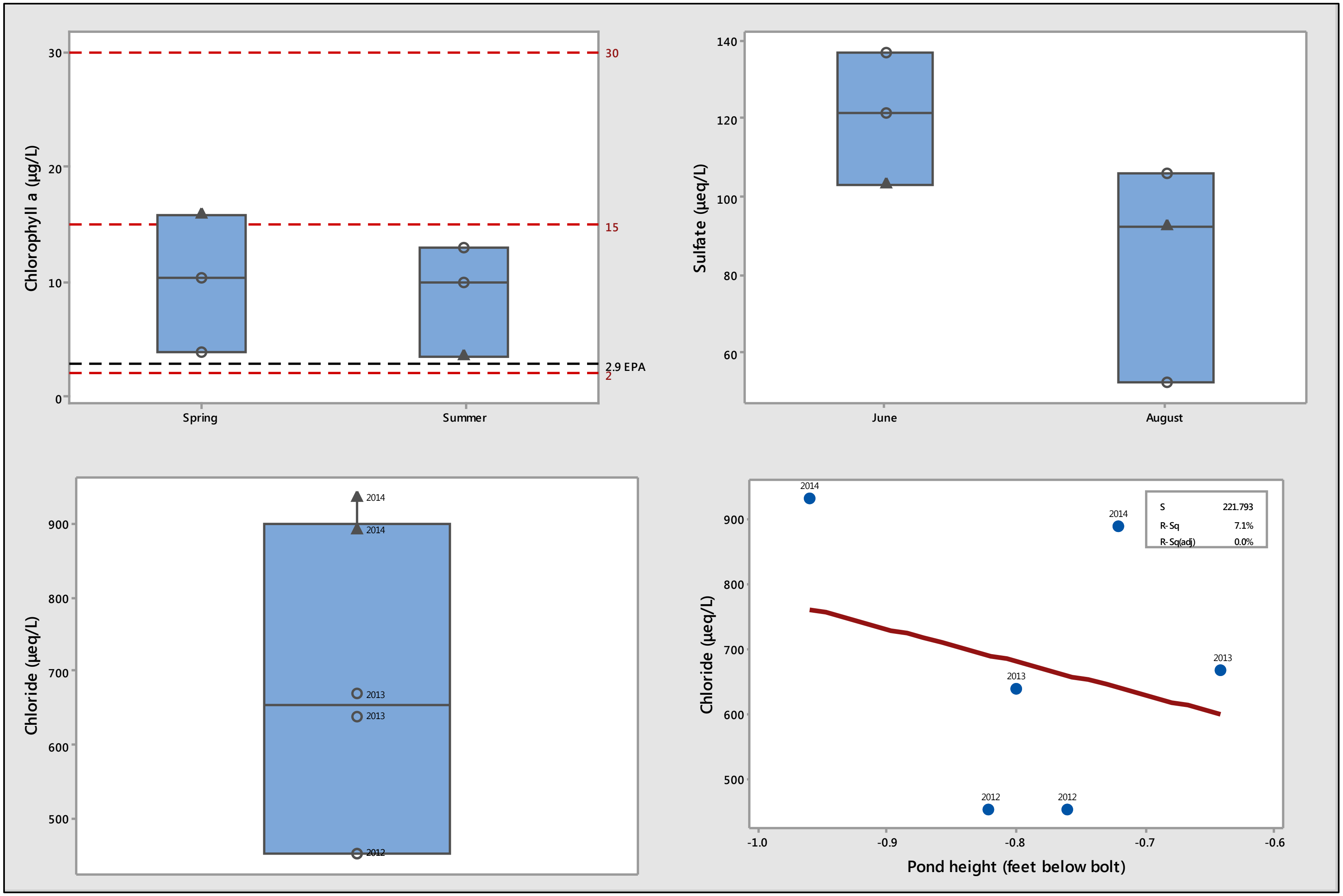

Figure 4-15. Boxplots of chlorophyll a, sulfate and chloride in water samples collected twice annually from 2012-2014 from Weir Pond in WEFA, and fitted line plot of chloride predicted by pond height. Data are from Gawley (2012), Gawley (2013), Gawley and Roy (2014) and W. Gawley (personal communication, 11 June 2015). Reference lines show CT state ranges for mesotrophic surface waters (lower range) and for eutrophic waters (upper range), and EPA Ecoregion 14 criteria for minimally impacted surface waters (black line). ▲shows 2014 values.

Current chloride values of 32 mg/L (910 μeq/L) in 2014 in Weir Pond fell far below the state freshwater assessment point of 230 mg/L (6,480 μeq/L). However, chloride values had large, annual increases from 2012 (the first year of monitoring) to 2013 and again from 2013 to 2014. This steady increase in chloride levels was not explained by pond stage (Figure 4-15). A century ago, chloride levels in groundwater in this location were likely as low as 2.5 – 5 mg/L (70 – 141 μeq/L; Cassanelli and Robbins 2013). However, anthropogenic inputs from road de-icing chemicals, residential water softening systems, agriculture, and other sources have increased chloride levels in groundwater dramatically since the 1950s in CT and elsewhere in the US (McGinley 2008). Cassanelli and Robbins (2013) estimated 2007 chloride levels in groundwater in this region to be 75-150 mg/L (2,110 – 4,230 μeq/L). Possible sources of chloride in this area include contamination from nearby roads and residential sewer systems, as well as from coastal inputs. Continued monitoring of chloride will be important to confirm this trend and inform park managers.

Overall, water chemistry in Weir Pond showed *good condition* for many metrics, but warranted concern for increasing trends in specific conductance and chloride values and for continued inputs of N and S from atmospheric deposition.

Data Gaps and Level of Confidence

Confidence in water quality condition status from a variety of metrics from a single site using established state assessment points is medium. Confidence in nine-year trends is medium. Continued monitoring will allow determination of trends for these important water quality metrics, and will help inform park managers.

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Biological Integrity

Invasive Exotic Plants

Description and Relevance

Invasive exotic species pose a serious threat to native biodiversity across the globe (Mooney et al. 2005). NPS is mandated to preserve native species and it is NPS policy to manage or eradicate invasive exotic species (NPS 2006).

Data and Methods

Invasive exotic plants are surveyed regularly at WEFA using three methods. First, Weir Pond has been surveyed annually since 2006 for invasive aquatic plants on a high priority list which currently includes 11 species, and a secondary priority list of 13 species (Gawley and Roy 2014). The survey encompasses the littoral zone. Second, the NETN forest monitoring crew collects tree, shrub and understory plant data from 10 permanent forests plots at WEFA on a four-year revisit interval

(Section 4.4.4 herein). These data are assessed for frequency and percent cover of 22 key exotic plant species known to be highly invasive in northeastern forest, woodland and successional habitats (Miller et al. 2014). Third, the NETN Invasive Species Early Detection (ISED) program has relied on opportunistic surveys in WEFA since 2010 in order to detect priority pests and exotic plants at early stages of establishment. This program provides park staff, cooperators and others with information describing priority species of concern, and procedures for reporting detections. The 2014 ISED target list for WEFA included 15 terrestrial plant species and ten aquatic plants (Table 4-13; J. Wheeler, personal communication, 21 October 2015). ISED data provides useful information to park managers, but was not used herein to determine condition and trends due to the opportunistic nature of the sampling.

Table 4-13. ISED 2014 target species watch list for Weir Farm National Historic Site.

Lifeform	Species	Common name	WEFA Status
Aquatic	*Didymosphenia geminata*	didymo (alga)	
	Egeria densa	Brazilian waterweed	Fairfield county
	Eichhornia crassipes	water hyacinth	Fairfield county
	Hydrilla verticillata	hydrilla	Fairfield county
	Myriophyllum aquaticum	parrotfeather	
	Myriophyllum heterophyllum	variable watermilfoil	Fairfield county
	Myriophyllum spicatum	Eurasian watermilfoil	Fairfield county
	Najas minor	brittle waternymph	Fairfield county
	Potamogeton crispus	curly pondweed	Fairfield county
	Trapa natans	water chestnut	
Herb	*Fallopia japonica*	Japanese knotweed	In WEFA at low levels
	Heracleum mantegazzianum	giant hogweed	In WEFA at low levels
	Lythrum salicaria	purple loosestrife	In WEFA at low levels
	Oplismenus hirtellus ssp. undulatifolius	wavyleaf basketgrass	-
	Ranunculus ficaria	lesser celandine	-
Shrub	*Elaeagnus umbellata*	autumn olive	In WEFA at low levels
	Rhamnus cathartica	common buckthorn	Fairfield county
	Rhamnus frangula	glossy buckthorn	In WEFA at low levels
	Rubus phoenicolasius [2]	wine raspberry	Established in WEFA
Tree	*Ailanthus altissima*	tree of heaven	In WEFA at low levels
	Paulownia tomentosa	princess tree	Fairfield county
Vine	*Ampelopsis brevipedunculata*	porcelainberry	Fairfield county
	Dioscorea oppositifolia	Chinese yam	Nearby county
	Persicaria perfoliata	mile-a-minute	Near WEFA boundary
	Pueraria montana	kudzu	Fairfield County [1]
	Wisteria floribunda/W. sinensis	Japanese/Chinese wisteria	In WEFA at low levels

[1] Greg Waters noted that Pueraria montana has not been found at WEFA (Greg Waters, personal communication, 1/15/16).

[2] Removed from ISED target list due to establishment of plant at WEFA.

Chlorophyll *a*, sulfate and chloride were assessed in pond water samples beginning in 2012 to better understand water quality (Figure 4-15). Chlorophyll *a* values in Weir Pond typically fell within the expected range for a mesotrophic water body (2-15 µg/L), and exceeded the EPA Ecoregion 14 criteria for unimpacted lakes (2.9 µg/L). Sulfate levels varied seasonally and fell at the lower end of the usual range of sulfate concentration in natural water (104 µeq/L to 695 µeq/L; Wetzel 1983). However, continued S inputs from current levels of atmospheric deposition warrant concern (section 4.2.1).

Current chloride values of 32 mg/L (910 µeq/L) in 2014 in Weir Pond fell far below the state freshwater assessment point of 230 mg/L (6,480 µeq/L). However, chloride values had large, annual increases from 2012 (the first year of monitoring) to 2013 and again from 2013 to 2014. This steady increase in chloride levels was not explained by pond stage (Figure 4-15). A century ago, chloride levels in groundwater in this location were likely as low as 2.5 – 5 mg/L (70 – 141 µeq/L; Cassanelli and Robbins 2013). However, anthropogenic inputs from road de-icing chemicals, residential water softening systems, agriculture, and other sources have increased chloride levels in groundwater dramatically since the 1950s in CT and elsewhere in the US (McGinley 2008). Cassanelli and Robbins (2013) estimated 2007 chloride levels in groundwater in this region to be 75-150 mg/L (2,110 – 4,230 µeq/L). Possible sources of chloride in this area include contamination from nearby roads and residential sewer systems, as well as from coastal inputs. Continued monitoring of chloride will be important to confirm this trend and inform park managers.

<u>Assessment Points</u>

NETN has established condition categories for key invasive exotic plant species (Table 4-14).

Table 4-14. Assessment points for key invasive exotic plant species (Miller et al. 2013).

Metric	***Good Condition***	***Moderate Concern***	***Significant Concern***
Detections	< 0.5 key species / plot	0.5 to < 3.5 key species / plot	3.5 or more key species / plot

<u>Condition and Trend</u>

Annual surveys in Weir Pond have detected no invasive aquatic plants of concern during annual surveys from 2006-2013 (Gawley and Roy 2014). This represents *good condition*. In forest plots, the most recent cycle of data collection (2011-2013) found 4.8 +/- 0.9 invasive indicator species per plot, occupying 2.9 +/- 1.8% cover in quadrats and warranting *significant concern*. The number of invasive indicator species per plot represents a significant increase compared to the first data cycle collected (2007-2009) (Miller et al. 2014). The most common invasive indicator species detected in the park are shown in Table 4-15.

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

Confidence in status assessment is medium. Level of confidence in the four-year increasing trend in forest plots is low, while confidence in the eight-year unchanging trend in Weir Pond is medium.

Table 4-15. Most frequent invasive exotic indicator species detected in NETN forest plots at WEFA (Miller et al. 2014).

Species	Common name	Number of detections
Alliaria petiolata	garlic mustard	5
Berberis thunbergii	Japanese barberry	9
Celastrus orbiculata	Oriental bittersweet	7
Euonymus alatus	burningbush	6
Lonicera japonica	Japanese honeysuckle	4
Rosa multiflora	multiflora rose	6

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Invasive exotic Animals

Description and Relevance

Invasive exotic forest pest species pose enormous threats to forest resources, and several species could cause substantial detrimental impacts on the forests at WEFA should they successfully invade. The Asian longhorned beetle (*Anoplophora glabripennis*) attacks and kills maples and other species including birches, elms, willows and horsechestnut. Eradication programs are underway in New York City and central Long Island, NY, and in Worcester County, Massachusetts (USDA APHIS 2015). A related species, the citrus (or rough shouldered) longhorned beetle (*Anoplophora chinensis*) threatens a wide range of hardwood trees; it has been detected in Georgia and Wisconsin, but not yet in the northeastern US (CAES 2015a). The emerald ash borer (*Agrilus planipennisis*, EAB) a destructive pest that quickly kills all native species of ash (*Fraxinus* spp.); this pest has reached southwestern Connecticut (CAES 2015b). The viburnum leaf beetle (*Pyrrhalta viburni*) can quickly defoliate and kill many species of viburnum. It was first detected in the U.S. in 1994, and is now found throughout NY and the northeast U.S., including Fairfield County CT, as well as other parts of the U.S. (NAPIS

Pest Tracker, Weston and Nuzzo 2008). Early detection of these species is crucial to manage and reduce impacts.

Other destructive forest pests have successfully established in the area. The exotic scale insect (*Cryptococcus fagisuga*) that contributes to beech bark disease is established throughout the states of the Northeastern US, and the hemlock wooly adelgid (*Adelges tsugae*) has been present in Connecticut since 1985. Both are seriously impacting forests in the region.

Data and Methods

The NETN Invasive Species Early Detection (ISED) program serves as the front lines for early detection of exotic forest pests. Since 2010, ISED has maintained a list of high priority forest pests and provided support to park staff, cooperators and others working in the park to facilitate detection of priority pests and exotic plants at early stages of establishment. The ISED target list for WEFA currently includes three forest insect pests: Asian longhorned beetle, emerald ash borer, and viburnum leaf beetle (Wheeler and Miller 2014). Exotic pest detections by county across the nation can be viewed at the National Agricultural Pest Information System (NAPIS) Pest Tracker (http://pest.ceris.purdue.edu/).

Assessment Points

Assessment points are suggested based on proximity of ISED high priority forest pests to WEFA (Table 4-16).

Table 4-16. Suggested assessment points for high priority forest pests. An assessment point for moderate concern has not been identified.

Metric	Good Condition	Moderate Concern	Significant Concern
Detections	No ISED high priority pests in Fairfield County CT or adjacent counties [1]		Detection of ISED high priority pest in Fairfield County CT or adjacent counties.

[1] Counties adjacent to Fairfield County CT are Litchfield and New Haven Counties in Connecticut, and Westchester, Putnam and Dutchess Counties in New York.

Condition and Trend

The emerald ash borer was first detected in Connecticut in 2012 and has been detected in Fairfield County since 2013 (CAES 2015b). The viburnum leaf beetle was first detected in Fairfield County in 2008 (NAPIS Pest Tracker). These detections warrant *significant concern* for early detection and management in WEFA. While not yet detected in Fairfield County or a neighboring county, the proximity of documented occurrences of Asian longhorned beetle in NYC and central Long Island also warrants concern.

Data Gaps and Level of Confidence

Confidence in status assessment is low due to the qualitative dataset and preliminary assessment points. Trends were not determined.

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Wetland Vegetation

Description and Relevance

Freshwater wetlands provide many valuable ecosystem services including surface water detention, sediment retention, and nutrient transformation, in addition to providing critical habitat for many species of plants, insects, amphibians, fish and mammals. At WEFA, the low rolling hills and shallow soils over north-trending bedrock create numerous wetland areas and intermittent streams which dissect the main site (USDA NRCS 1995).

The National Wetlands Inventory uses remotely sensed data to identify likely wetland locations across the U.S. Using 1-meter scale 2010 National Agricultural Image Program (NAIP) imagery, wetlands in this area were identified at a maximum zoom scale of 1:12,000 and delineated at approximately 1:8000. The NWI shows nine seasonal, forested wetlands occurring entirely or partially within the boundary of WEFA, including one small area straddling the boundary of the secondary WEFA site, and two additional seasonal, forest wetlands lying directly adjacent to WEFA (Figure 4-16; U.S. FWS 2010).

Using the standard criteria of hydrology, hydric soils and hydrophytic vegetation, a 1995 Natural Resource Evaluation inventoried, classified and described wetlands at WEFA during a single day's visit in August 1994 (USDA NRCS 1995). This study is the most complete inventory and description of wetland habitat at WEFA, however, no attempt was made to precisely locate wetland boundaries (USDA NRCS 1995). Most of these USDA NRCS wetland locations correspond roughly to those shown on the NWI map (Figure 4-16). However, two small (< 0.1 ha) NWI wetland locations were not noted by the on-site Natural Resource Evaluation (wetlands H and K in Figure 4-16). Likewise, two small wetland areas identified by the on-site Natural Resource Evaluation do not appear on the NWI map (see Figure 4-16).

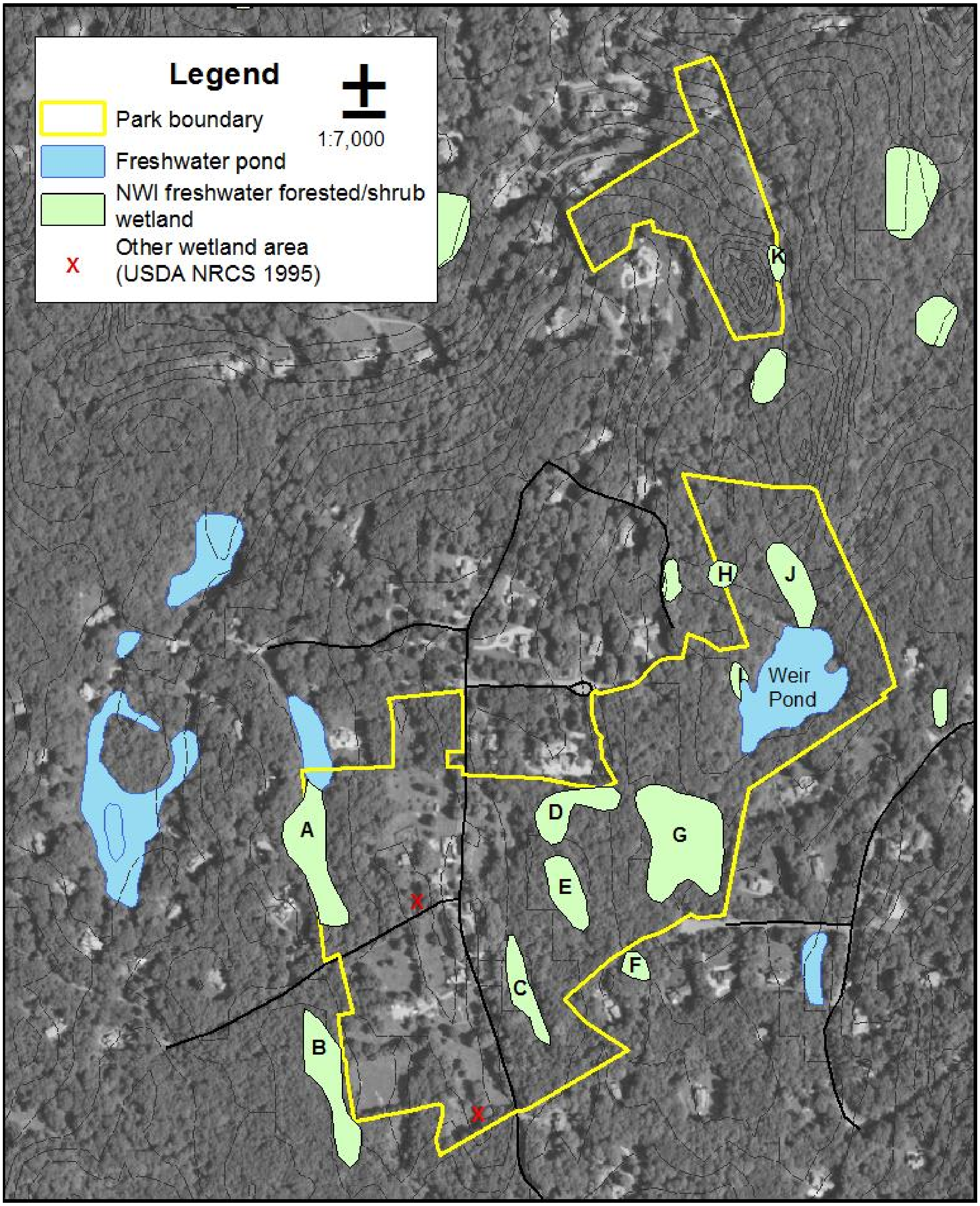

Figure 4-16. Approximate location of wetlands at WEFA (U.S. FWS 2010, USDA NRCS 1995).

The most common wetland type in the park is Southern New England / Northern Piedmont Red Maple Seepage Swamps, occurring in low-lying contours across the site and accounting for just over half of the wetland area at WEFA (Metzler et al. 2009). Other wetland vegetation types occurring at WEFA are Lower New England Red Maple - Blackgum Swamp, Northeastern Buttonbush Shrub Swamp, Blueberry Wetland Thicket, and Old Field Seep (see Table 2-2 in Section 2.2.1 for brief descriptions).

Data and Methods

Status and trends in wetland vegetation is not currently monitored at this park, however, two sources provided some insight into wetland condition. First, several park wetlands (wetlands A, B, C, D, E, and J on Figure 4-16) were sampled for amphibians and reptiles during the park Amphibian and Reptile Inventory (Brotherton et al. 2005).

Second, preliminary assessment of the condition of wetland buffers was assessed from ortho-imagery using the U.S. EPA Rapid Assessment Method (USA-RAM; U.S. EPA 2011). USA-RAM methodology assesses wetland condition and stress based on four components: buffer, hydrology, physical structure and biological structure. NETN draws upon the RAM and other NWCA methods for assessment of wetland vegetation at Acadia National Park (Miller and Mitchell 2013). While most of these components require a site visit, preliminary assessment of the condition of wetland buffers can be assessed using ortho-imagery, and ideally would be confirmed by ground-truthing during a subsequent site visit.

In the present assessment, the six NWI wetlands larger than 0.1 ha and lying at least partly within the WEFA boundary (i.e., wetlands A, C, E, D, G and J in Figure 4-16) were assessed for the condition of wetland buffer from NAIP 2014 ortho-imagery and the WEFA vegetation map, using USA-RAM methods as summarized here (Metzler et al. 2009, U.S. EPA 2011). The wetlands assessment area corresponded to the wetland boundary, and the assessed buffer zone extended 100 m from the wetland boundary. To qualify as wetland buffer, a land cover patch must meet a minimum size requirement (at least 5 m wide and extending at least 10 m along the boundary) and be a natural land cover type. Anthropogenic cover types such as built structures, roads and parking lots, agricultural fields, lawns, and ATV trails do not qualify as wetland buffer. The percent of assessment area having a buffer was visually estimated to the nearest 5%. To estimate buffer width, a central point was selected within each wetland and eight transects were drawn in the 4 cardinal directions (N, S, E, and W) and 4 ordinal directions (NE, SE, SW, and NW). Then, buffer width was measured to the nearest 5 m along each transect, up to a distance of 100 m. The eight measurements were averaged for each wetland. This condition assessment for wetland buffers is considered preliminary because a subsequent site visit for ground-truthing was not part of this assessment.

Assessment Points

Suggested assessment points for determining condition of wetlands from selected USA-RAM metrics are shown in Table 4-17.

Table 4-17. Suggested metrics and assessment points for determining condition of wetlands (adapted from US EPA 2011 and Faber-Langendoen 2009).

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Percent of assessment area having a buffer	> 50 – 100%	25-49%	<25 %
Buffer width (average)	>= 100 m	50 – 99 m	< 50 m
Stress to buffer zone	No stressors affecting >= 1/3 of buffer	At least 1 stressor affecting >= 1/3 of buffer	At least 1 stressor affecting >= 2/3 buffer
Alterations to hydroperiod	Hydroperiod alterations are not severe	At least 1 moderately severe alteration impacting hydroperiod	At least 1 severe alteration impacting hydroperiod
Stress to water quality	Water quality stressors are not severe	At least 1 moderately severe stressor impacting condition	At least 1 severe stressor impacting condition
Habitat/substrate alterations	Substrate alterations are not severe	At least 1 moderately severe alteration impacting substrate	At least 1 severe alteration impacting substrate
Percent cover of invasive plants	0 %	< 5 % in any strata	>= 5 % in any strata
Vegetation disturbance	Vegetation disturbance are not severe	At least 1 moderately severe vegetation disturbance noted	At least 1 severe vegetation disturbance noted

Condition and Trend

Preliminary assessment of the condition of wetland buffers for six NWI wetlands larger than 0.1 ha and lying at least partly within the WEFA boundary showed *good condition* (> 50 to 100%) for percent of assessment area having a buffer, and *moderate concern* (50 – 99 m) for buffer width (Table 4-18). Trends were not assessed.

Table 4-18. Preliminary assessment of wetland buffers for six NWI wetlands lying at least partially within WEFA.

Wetland	Wetland Size (ha)	Buffer Percentage	Average Buffer Width (m)	Rating for Buffer Width
A	0.61	100 %	74	*moderate concern*
C	0.26	100 %	73	*moderate concern*
D	0.34	100 %	85	*moderate concern*
E	0.29	100 %	100	*good condition*
G	1.07	100 %	78	*moderate concern*
J	0.33	100 %	100	*good condition*

The WEFA Amphibian and Reptile Inventory showed that amphibian species sensitive to disturbance and pond-breeding salamanders were well-represented in the amphibian community at WEFA in 2000 (Brotherton et al. 2005; see Section 4.4.7 herein), indicating that park wetlands and vernal pools provide good quality habitat. In particular, wetlands A, B, C and E supported the highest abundance of sensitive species (spotted salamanders [*Ambystoma maculatum*] and wood frogs [*Rana sylvatica]*; Brotherton et al. 2005). The former two wetlands are located near the park's western border, while the latter two lie east of Nod Hill Road. A small wetland noted by the 1995 Natural Resource Inventory lying west of Nod Hill Road at the park's southern border is the location of the only recorded sighting of another sensitive species (marbled salamander [*Ambystoma opacum]*).

Data Gaps and Level of Confidence

Level of confidence in preliminary assessment of wetland buffer condition is low because assessment relied on imagery without ground-truthing. Status and trends in wetland vegetation is a data gap that could be filled by collecting rapid assessment data using USA-RAM (U.S. EPA 2011).

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Forest Vegetation

Description and Relevance

Slightly more than half of WEFA is forested, and these forests consist of five forest associations (Metzler et al. 2009). The matrix forest is a Northeastern Dry Oak - Hickory Forest dominated by northern red oak (*Quercus rubra*), sweet birch (*Betula lenta*), maples (*Acer* spp.), and hickories (*Carya* spp.) with mapleleaf viburnum (*Viburnum acerifolium*) notable in the understory. Embedded within this forest type are patches of Lower New England Slope Chestnut Oak Forest, occurring in small areas where bedrock occurs near the surface, creating drier soil conditions. Dry, rich slopes in two locations at WEFA support a Mesic Sugar Maple - Ash - Oak - Hickory Forest dominated by sugar maple (*Acer saccharum*) with other hardwoods, and with *Carex laxiflora* (broad looseflower sedge) and other sedges in the herb layer. Along streambanks and the border of wetlands receiving groundwater seepage, a Semi-rich Northern Hardwood Forest type is dominated by sugar maple (*Acer saccharum*) and white ash (*Fraxinus americana*), with sparse shrub cover including northern spicebush (*Lindera benzoin*), and a ground cover of ferns. Finally, a Northeastern Modified Successional Forest dominated by sweet birch (*Betula lenta*), with eastern poison ivy (*Toxicodendron radicans*) and dewberry (*Rubus* sp.) in the understory, occurs in two border areas west of Weir Pond.

Data and Methods

Since 2007, NETN has monitored 10 permanent forest plots at WEFA for a suite of stand, tree and understory metrics (Miller et al. 2014). Half the plots are monitored during each biennial collection, yielding two cycles of data separated by a 4-year revisit interval. From this dataset, NETN assesses metrics of forest structure, composition and function. Stand structure assesses the percentage of plots in mature and old-growth structural stages and is indicative of the habitat value of the landscape. Coarse woody debris (CWD) refers to large dead branches and whole downed trees, while snags are standing dead trees. Measuring the abundance of these features provides an indicator of wildlife habitat availability. Tree regeneration assesses the success of tree seedling and sapling establishment and is an early-warning indicator of changes in canopy vegetation. Tree condition qualitatively assesses tree health to identify specific health problems, and tree growth and mortality rates indicate health problems within specific tree species.

For the data reported herein, the current dataset consists of data collected from 2011-2013, while the initial dataset consists of data collected from 2007-2009. Tree growth rates and coarse woody debris were compared with regional mean rates from USFS Forest Inventory and Analysis (FIA) data collected from plots within the same ecoregional Subsection as WEFA (Subsection 221Ae, the Hudson Highlands; Miller et al. 2013). For metrics with sufficient data, trends over the four-year return interval were assessed by comparing the recent with the initial dataset using a paired t-test, using the q-value package in R to reduce the chance of Type 1 errors resulting from multiple comparisons (Miller et al. 2014).

Assessment of exotic plant species, deer-browse impacts, and forest soil chemistry were considered, respectively, in Sections 4.4.1 (Invasive exotic plants), 4.4.5 (White-tailed deer herbivory) and 4.2.1 (Forest soil condition). In addition to the plot measurements, NETN periodically calculates two landscape metrics associated with forest integrity (Forest patch size and Anthropogenic land use). These are reported herein in Section 4.6.1 (Landcover / Ecosystem Cover / Connectivity) and 4.6.2 (Land use).

Assessment Points

NETN has established assessment points for metrics of forest structure, composition and function as shown in Table 4-19 (adapted from Miller et al. 2014).

Table 4-19. Assessment points and ratings for six metrics of forest integrity (adapted from Miller et al. 2014). Medium to large trees are trees >= 30 cm diameter-at-breast-height (dbh). BBD is beech bark disease. ND is not determined.

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Structural stage	≥ 25% late successional structure	< 25% late successional structure	< 25% combined mature and late successional structure
Snag abundance	≥ 10% standing trees are snags and ≥ 10% medium to large trees are snags	< 10% standing trees are snags or < 10% medium to large trees are snags	< 5 medium to large snags/ha
Coarse woody debris ratio	> 15% live tree volume	5 - 15% live tree volume	< 5% live tree volume
Tree regeneration	Seedling ratio ≥ 0	Seedling ratio < 0	Stocking index < 25
Tree condition and forest pests	Foliar problem < 10% and no Priority 1 or 2 pests and BBD ≤ 2	Foliar problem 10 - 50% or Priority 2 pest or BBD > 2	Foliar problem > 50% or Priority 1 pest
Tree growth and mortality rates	Growth ≥ 60% regional mean and Mort ≤ 1.6%	Growth < 60% regional mean or Mort > 1.6%	ND

Condition and Trend

Current NETN data from 10 forest plots at WEFA showed mixed results for forest structural characteristics (Table 4-20; Miller et al. 2015). WEFA forest was comprised of stands with mostly late-successional and mature forest structural stage, falling well above the 25% assessment point for late-successional forest structure based on stand distributions under natural disturbance regimes for the Oak forest type predominant at this park and considered *good condition* (Miller et al. 2014). Levels of standing dead trees (snags) in the park were lower than desired, warranting *moderate concern*, but were sufficient to provide the minimum of 5 medium-large snags/ha based on wildlife needs. Coarse woody debris (CWD) volume remained lower than desired, also warranting *moderate concern* (5 – 15% live tree volume; Table 4-18). Comparing CWD measured at WEFA to data from USFS FIA plots in the surrounding region, Miller et al. (2013) reported that CWD volume in the park may be lower than in surrounding forest (36.2 +/- 13.6 m^3/ha). No significant differences were found in these characteristics between the initial and current datasets collected at WEFA, though condition rating for Snag abundance at the park improved from *significant concern* in the initial dataset to *moderate concern* currently due to a small increase in the abundance of medium-large snags (>= 30 cm diameter-at-breast-height).

Reporting on tree regeneration, Miller et al. (2014) found that low seedling densities at WEFA warranted *significant concern,* and a small increase in small seedlings (15-30 cm) from the initial data cycle to the current data cycle did not represent a significant change. Visual inspection of tree foliage condition showed that most plots had moderate average tree leaf damage (10-50% of tree foliage affected) in both the recent and initial data cycles, warranting *moderate concern* (Miller et al.

2014). Average annual canopy tree growth rates in mature and late-successional forest at WEFA were lower than those calculated from similar FIA plots in the region, warranting *moderate concern*, however Miller et al. (2013) noted that difficulty measuring diameter on trees with vines may have hampered accurate measurements. Yellow birch and red maple both showed low growth rates at WEFA, perhaps due to their landscape position in wet areas (Miller et al. 2014). Also, white ash had particularly low growth rates at WEFA, possibly due to ash yellows which is known to affect ash trees in the area (Pokorny and Sinclair 1994). Average canopy tree mortality rates at WEFA were low, showing *good condition* (Miller et al. 2013). Sufficient data was not yet available to determine trends in growth and mortality rates.

Table 4-20. Status of structural characteristics of forest integrity measured in 10 NETN plots at WEFA during two time periods (adapted from Miller et al. 2014).

Cycle	Stand Structure		Snags		Coarse Woody Debris	
	% late successional	% mature	Snags/ha	Med-large snags/ha	Volume (m^3/ha)	Volume (ft^3/ac)
2007-2009	40	50	30.0	2.5	22.5	321.0
2011-2013	50	40	27.5	5.0	22.2	316.6

Data Gaps and Level of Confidence

Confidence in most condition estimates from quantitative data from 10 plots is medium, while confidence in tree growth metric is low due to the difficulty of establishing meaningful assessment points. Confidence in trend estimates is low because only two cycles of data were available for analysis.

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White-tailed Deer Herbivory

Description and Relevance

White-tailed deer are a "keystone" species in the northeastern US, having a profound effect on the composition, structure and function of the ecosystems they inhabit. Sustained, selective browsing by a historically high population of white-tailed deer is currently impacting understory species composition and tree regeneration in parts of the northeast US (Russell et al. 2001, Rooney and Waller 2003, Cote et al. 2004, Kain et al. 2011). Sustained browsing pressure can result in population reduction or loss of species preferred by deer (such as native perennial forbs) and increases in browse-resistant or non-preferred species (such as grasses and sedges, ferns, and exotic species; Augustine and deCalesta 2003, Balgooyen and Waller 1995, Rooney 2009).

High deer densities in southwestern Connecticut have gained considerable attention from residents and town governments, leading to the formation of a regional deer management working group in 2004 (the Fairfield County Municipal Deer Management Alliance, www.deeralliance.com). Since 2003, the neighboring Weir Preserve has conducted an annual controlled hunt to curb the deer population, typically taking 9 – 13 deer per year (Greg Waters, personal communication, 14 October 2015).

Data and Methods

Local deer population size determines browse pressure on vegetation. The CT DEEP Wildlife Division monitors the deer population within state management zones using several sources including harvest data, deer reported roadkill from deer-vehicle collisions, and aerial deer surveys (LaBonte and Kilpatrick 2014). Beginning in 2009, CT DEEP Wildlife Division has flown biennial, winter aerial deer surveys along six 10-mile transects in Fairfield County, providing estimates in deer population density county-wide (Kilpatrick 2013). These estimates incorporate a correction factor of 2, to account for deer hidden from view.[7] In February 2015, the town of Ridgefield undertook an aerial survey of 6 transects across the town to provide more specific information on deer densities (Reid 2015).

In addition, data on browsing impacts has been collected by NETN as part of the Long-term Forest Monitoring Program (see Section 4.4.4 herein). NETN has monitored frequency of deer-browse indicator species since 2007 in 1-m^2 quadrats within 10 permanent forest plots; these indicator species are plant species known to be preferentially browsed or alternatively avoided by deer. The NETN forest crew also recorded a qualitative assessment of deer-browse impacts at each plot visited since 2010 (Miller et al. 2013).

Assessment Points

Historical densities of white-tailed deer in the eastern US are estimated at 3-4 deer per km^2 (McCabe and McCabe 1997). Negative browse impacts have been documented where deer densities exceed 8

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[7] Observed deer density was multiplied times 2 to yield corrected deer density estimate.

per km^2 for 10 or more years, and severe impacts have been observed with deer densities ≥ 20 per km^2 (Horsley et al. 2003, Augustine and deCalesta 2003).

Condition ratings for white-tailed deer are shown in Table 4-21. For assessing deer-browse impacts on vegetation, NETN assigns ratings based on change over time in browse-sensitive and browse-avoided species as shown (Miller et al. 2013).

Table 4-21. Condition ratings for white-tailed deer population density and browse impacts (Miller et al. 2013).

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Deer population density (deer per km2)	< 8	8 - 20	≥ 20
Deer-browse impacts	No decrease in frequency of most browse-sensitive species	Decrease in frequency of most browsed species or increase in frequency of browse-avoided species	Decrease in frequency of most browsed species and increase in frequency of browse-avoided species

Condition and Trend

Mean county-wide deer density estimates averaged across last three aerial surveys (2011, 2013, 2015) was 21.7 deer/km^2 (56.1 deer/mi^2; M. Gregonis, personal communication, 10/26/15), indicating *significant concern* due to deer density. The February 2015 aerial survey of Ridgefield indicated deer densities in the vicinity of WEFA may be higher than county-wide averages (Reid 2015). Assessment of deer-browse indicator species at WEFA in 10 plots revisited after a 4-yr interval indicated that 50% of browse-preferred species had decreased in abundance and 2/3 of browse-avoided species had increased in abundance. This warrants *moderate concern* that deer-browse pressure may have affected vegetation at WEFA. Qualitative assessment of deer-browse impacts averaged 4.00 +/- 0.26 SE (on a scale of 1 to 5). This level is equivalent to high impacts, described as “Browse evidence common; browse-preferred species rare to absent; non-preferred or browse-resistant vegetation limited in height by browsing” (Miller et al. 2014).

Reported deer roadkill in Fairfield County, and in the Towns of Wilton and Ridgefield (combined) both showed a significant declining trend over the last decade, indicating a declining trend in deer abundance in the area since 2005 (Figure 4-17; LaBonte and Kilpatrick 2014).

Data Gaps and Level of Confidence

Level of confidence in condition estimate from two metrics with established assessment points is medium. Confidence in regional ten-year population trends is high.

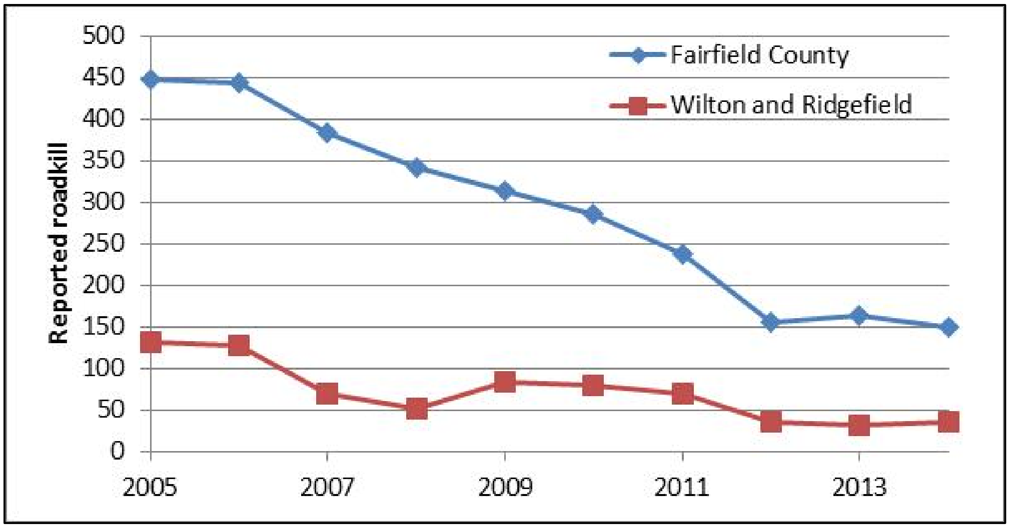

Figure 4-17. Reported deer roadkill by year in Fairfield County and the combined Towns of Wilton and Ridgefield CT.

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Birds

Description and Relevance

Birds are a visible and charismatic faunal group that generates high public interest. They are also useful indicators of habitat fragmentation and anthropogenic change (Robinson et al. 1995, Rosenberg et al. 1999). Birds were selected as a high priority vital sign for monitoring in NETN parks, and the NETN bird monitoring program works collaboratively with volunteers from the local bird community near each monitored park, including WEFA (Mitchell et al. 2006, Faccio and Mitchell 2015).

Data and Methods

The park bird inventory surveyed four forest and two grassland point count stations in WEFA five times annually during the breeding seasons in 2002 and 2003, and detected 65 bird species (Trocki and Paton 2003). Annual forest bird monitoring at WEFA has observed 36 of these 65 species, plus an additional 6 bird species, for a total of 71 bird species documented within the park (Faccio and Mitchell 2015; see Appendix B for full species list). Twenty-three of these bird species are designated by the CT DEEP as CT SGCN,[8] while four species have additional state conservation status and five species have regional conservation status (Table 4-22; CT DEEP 2015). An additional 12 bird species have been noted at the park by observers submitting data to eBird since 2010, including the following species of conservation interest (CT SGCN): the rose-breasted grosbeak

[8] CT SGCN are CT Species of Greatest Conservation Need, defined in Section 2.2.2.

(*Pheucticus ludovicianus*), Northern parula (*Setophaga americana*), Canada warbler (*Wilsonia canadensis*). and common loon (*Gavia immer)* also designated CT Special Concern; eBird 2015).

Table 4-22. Bird species with conservation status documented present in WEFA[1]. PIF is Partners in Flight and UCS is USA/Canada Stewardship Species. CT SGCN are Species of Greatest Conservation Need designated by the CT Department of Energy and Environmental Protection (CT DEEP 2015). Inventory refers to the park bird inventory (Trocki and Paton 2003) and monitor refers to annual park forest bird monitoring (Faccio and Mitchell 2015). See text for additional species of conservation interest at WEFA reported on eBird.

Scientific name	Common name	Conservation Status	Detection
Accipiter striatus	Sharp-shinned hawk	CT Endangered & SGCN	Inventory, eBird
Buteo platypterus	Broad-winged hawk	CT Special Concern & SGCN	Inventory
Catharus fuscescens	Veery	CT SGCN	Inventory, eBird
Certhia americana	Brown creeper	CT SGCN	Inventory, eBird
Coccyzus americanus	Yellow-billed cuckoo	CT SGCN	Inventory
Colaptes auratus	Northern flicker	CT SGCN	Inventory, Monitor, eBird
Contopus virens	Eastern wood pewee	PIF Regional Concern CT SGCN	Inventory, Monitor, eBird
Dendroica caerulescens	Black-throated blue warbler	CT SGCN	Inventory
Empidonax minimus	Least flycatcher	CT SGCN	Inventory
Hylocichla mustelina	Wood thrush	PIF Regional Concern and UCS, CT SGCN	Inventory, Monitor, eBird
Icterus galbula	Baltimore oriole	PIF Regional Concern CT SGCN	Inventory, Monitor, eBird
Mniotilta varia	Black-and-white warbler	CT SGCN	Inventory, eBird
Parkesia (Seiurus) motacilla	Louisiana waterthrush	CT SGCN	Inventory
Parkesia (Seiurus) noveboracensis	Northern waterthrush	CT SGCN	Inventory, eBird
Passerculus sandwichensis	Savannah sparrow	CT Special Concern & SGCN	Inventory
Pipilo erythrophthalmus	Rufous-sided towhee	CT SGCN	Inventory, eBird
Piranga olivacea	Scarlet tanager	PIF Regional Concern CT SGCN	Inventory; Monitor, eBird
Seiurus aurocapilla	Ovenbird	CT SGCN	Inventory, Monitor, eBird
Spizella pusilla	Field sparrow	CT SGCN	Inventory
Tyrannus tyrannus	Eastern kingbird	CT SGCN	Inventory, eBird
Tyto alba	Common barn-owl	CT Endangered & SGCN	Inventory
Vireo flavifrons	Yellow-throated vireo	PIF Regional Concern and UCS	Inventory, Monitor, eBird
Vireo griseus	White-eyed vireo	CT SGCN	Inventory

[1] An additional three species with conservation status are considered by NPS to be "probably present" at WEFA based on nearby sightings. These species are the common nighthawk (*Chordeiles minor*), a CT Endangered species, American woodcock (*Scolopax minor*), and Blue-winged warbler (*Vermivora pinus*). All three are considered CT SGCN.

NETN relies on volunteer monitors to conduct annual forest bird monitoring at WEFA as described here (Faccio and Mitchell 2015). Monitoring has occurred at this park most years since 2006 (but not in 2007, 2008 or 2011) occurring twice per year between late May and June. Volunteers record the species of each individual bird detected during 10-minute point counts at five forested point stations. Data from second surveys were included in the guild-based ecological integrity assessment presented here, but these data were excluded from summaries and trend analysis to facilitate comparison across years (Faccio and Mitchell 2015).

Assessment Points

To assess and interpret condition of forest birds, NETN has developed an avian ecological integrity assessment consisting of 13 guilds in three ecological integrity categories: compositional, functional, and structural (Table 4-23; Faccio et al. 2011, Faccio and Mitchell 2015). Each guild is broadly categorized as "generalist" or "specialist" (i.e., comprised of species with a narrow range of habitat tolerances, or a low intrinsic rate of population growth). In general, the presence of specialist guilds is indicative of high ecological integrity, while generalist guilds indicate low ecological integrity. Bird species from five groups (perching birds or passerines, woodpeckers, cuckoos, swifts and hummingbirds, and doves) were assigned to one or more guilds based on their life history traits, and the proportional species richness of each guild was calculated by dividing the number of guild members detected by the total number of species detected (Faccio et al. 2011, Faccio and Mitchell 2015). Condition was determined using the assessment points shown in Table 4-23. Since some guild members are likely missed during an annual survey, the condition assessment was based on the most recent three-year dataset (2012-2014).

Table 4-23. Forest Avian Ecological Integrity thresholds for 13 response guilds (from Faccio and Mitchell 2015). Percentages are proportional species richness.

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

Condition and Trend

Forty-two bird species have been detected at WEFA during forest bird monitoring since 2006. The most common birds sighted at WEFA during forest bird monitoring include tufted titmouse, white-breasted nuthatch and gray catbird. Relative abundance of forest birds detected at WEFA rebounded in 2014 (6.2 birds per point) from the low levels recorded in 2013 (4.8 birds per point).

Pooling park forest bird monitoring data from the last 3 years (2012-2014), Faccio and Mitchell (2015) reported *good condition* for two (Nest predator/brood parasite and Bark prober) of 13 guilds measuring forest avian ecological condition, while three guilds (Exotic species, Low canopy forager, and Omnivore) warranted *moderate concern*, and the remaining eight guilds warranted *significant concern* (Table 4-24). All four guilds within the structural category at WEFA warrant *significant concern*, indicating limited forest structural diversity at WEFA. Looking at change, Faccio and Mitchell (2015) reported a decline in seven of 13 guilds measuring forest avian ecological condition at WEFA between two time periods (2006-2010[9] and 2012-2014), while five guilds showed no change and one guild (bark prober) showed improved condition (Table 4-19).

Table 4-24. Condition and trends in park-wide Forest Avian Ecological Integrity Assessment for WEFA (adapted from Faccio and Mitchell 2015). Change reports change in condition between two time periods (2006-2010 and 2012-2014).

Biotic Integrity Element	Response Guild Metric	2012-2014 Condition		Change
		Percentage	Rating	
Compositional	Exotic Species	4%	*Moderate concern*	Declining condition
	Nest Predator/Brood Parasite	8%	*Good condition*	No change
	Resident	48%	*Significant concern*	Declining condition
	Single-Brooded	40%	*Significant concern*	No change
Functional	Bark Prober	16%	*Good condition*	Improving condition
	Ground Gleaner	0%	*Significant concern*	Declining condition
	High Canopy Forager	4%	*Significant concern*	Declining condition
	Low Canopy Forager	20%	*Moderate concern*	Declining condition
	Omnivore	44%	*Moderate concern*	No change
Structural	Canopy Nester	20%	*Significant concern*	No change
	Forest-ground Nester	0%	*Significant concern*	Declining condition
	Interior Forest Obligate	8%	*Significant concern*	Declining condition
	Shrub Nester	36%	*Significant concern*	No change

[9] Monitoring did not occur in 2007 or 2008.

Data Gaps and Level of Confidence

Confidence in status assessment of Forest Avian Ecological Integrity from the three-year dataset is medium. Confidence in change between two time periods is medium.

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Amphibians and Reptiles

Description and Relevance

Amphibians and reptiles are valued park resources that may serve as useful bioindicators of environmental stress from changes in wetland extent and quality, atmospheric deposition, climatic change, habitat degradation and habitat loss. At WEFA, key habitats for amphibians include Weir Pond and its fringe wetlands, as well as wetlands along the park’s western and southern borders, and wetlands found east of Nod Hill Road (see Section 4.4.3 herein; Brotherton et al. 2005).

Data and Methods

An inventory of amphibians and reptiles conducted at WEFA in 2000 documented a total of 11 amphibian species (4 salamanders and 7 frogs) and 7 reptiles species (4 turtles and 3 snakes; Table 4-25; Brotherton et al. 2005). Spring peeper (*Pseudacris crucifer)*, red-spotted newt (*Notophthalmus viridescens viridescens)*, painted turtle (*Chrysemys picta)*, and eastern gartersnake (*Thamnophis sirtalis sirtalis*) were the most abundant and widely distributed species encountered. An additional amphibian species, marbled salamander (*Ambystoma opacum*), was recorded incidentally in 1998 by Greg Waters, and is included on the park species list (Brotherton et al. 2005, NPS 2015). Seven of these 19 total herptile species are designated CT SGCN (Table 4-25), one of which is also a CT Special Concern species (Eastern box turtle [*Terrapene carolina carolina]*). These 19 species represent almost 2/3 of the 30 herptile species that may have occurred historically in this area (Brotherton et al. 2005). Two additional snake species, the eastern milk snake (*Lampropeltis triangulum triangulum*) and the worm snake (*Carphophis amoenus*) were observed in or near the park in the 1980s (Klemens 1980, Klemens 1982). More recently, spotted salamander (*A. maculatum*) egg masses were counted in vernal pools at WEFA in 2010 as part of the Ridgefield Natural Resources Inventory (Klemens et al. 2012).

Table 4-25. Amphibian and reptile species present at WEFA, with conservation status and relevant AmphIBI components. Reptiles are not considered by the AmphIBI. See section describing assessment points in text for description of AmphIBI.

Scientific name	Common name	Conservation Status	AmphIBI
Ambystoma maculatum	Spotted salamander		Sensitive, Pond-breeding salamander
Ambystoma opacum	Marbled salamander	CT SGCN	Sensitive, Pond-breeding salamander
Bufo fowleri	Fowler's toad	CT SGCN	Sensitive
Chelydra serpentina serpentina	Common snapping turtle		NA
Chrysemys picta	Eastern painted turtle		NA
Clemmys guttata	Spotted turtle	CT SGCN	NA
Diadophis punctatus edwardsii	Northern ringneck snake		NA
Eurycea bislineata	Northern two-lined salamander		
Hyla versicolor	Gray treefrog	CT SGCN	Sensitive
Nerodia sipedon sipedon	Northern water snake		NA
Notophthalmus viridescens viridescens	Red-spotted newt	CT SGCN	Sensitive, Pond-breeding salamander
Plethodon cinereus	Eastern red-backed salamander		Tolerant
Pseudacris crucifer	Spring peeper		Tolerant
Rana catesbeiana	American bullfrog		Tolerant
Rana clamitans melanota	Northern green frog		Tolerant
Rana palustris	Pickerel frog		Sensitive
Rana sylvatica	Wood frog	CT SGCN	Sensitive, Target species
Terrapene carolina carolina	Eastern box turtle, Woodland box turtle	CT Special Concern & SGCN	NA
Thamnophis sirtalis sirtalis	Common garter snake		NA

Assessment Points

The Ohio Environmental Protection Agency has developed an Amphibian Index of Biotic Integrity (AmphIBI) to assess the quality of forested and shrub wetlands, based on characteristics of the amphibian community (Micacchion 2004). This index provides a tool to assess amphibian community condition (Wagner et al. 2014). AmphIBI assesses condition based on five metrics of amphibian community composition: three metrics assess the relative abundance of sensitive and tolerant amphibian species, one metric assesses the number of pond-breeding salamanders, and one metric assesses the presence or absence of spotted salamanders or wood frogs (vernal pool breeding species correlated with the availability of forested cover). Species sensitivity to disturbance is estimated using a coefficient of conservatism (C of C) ranging from 1 to 10, with higher numbers assigned to sensitive species. A maximum of 10 points is awarded for each metric, which are summed to yield a maximum total index score of 50 points. Micacchion (2011) identified index scores >= 30 as Superior wetland habitat, while scores below 20 are considered Restorable wetland habitat (10-19) or Limited wetland habitat (<10). Accordingly, we suggest assessment points for amphibian community condition as shown in Table 4-26. We suggest *significant concern* below 20, since this is designated by Micacchion as restorable which indicates management is warranted.

Table 4-26. Suggested assessment points for rating amphibian community condition (adapted from Micacchion 2011).

Metric	***Good Condition***	***Moderate Concern***	***Significant Concern***
AmphIBI score	30 – 50	20 - 29	< 20

Condition and Trend

Pooling all data from the park Amphibian and Reptile Inventory (Brotherton et al. 2005), WEFA achieved an overall AmphIBI score of 30, showing *good condition*, with three of five AmphIBI metrics receiving high scores (>=7 out of 10). Amphibian species sensitive to disturbance (wood frog [*Rana sylvatica*], pickerel frog [*R. palustris*], spotted salamander [*Ambystoma maculatum*], red-spotted newt [*Notophthalmus viridescens viridescens*]) and pond-breeding salamanders are well-represented in the amphibian community at WEFA, and vernal-pool breeding species associated with forest cover are present. Abundant individuals of stress-tolerant species (spring peepers [*Pseudacris crucifer*] and northern green frogs [*R. clamitans melanota*]) are also present. Monitoring data was not available to determine trends for this Vital Sign.

Data Gaps and Level of Confidence

Confidence in status assessment based on inventory data collected fifteen years ago is low. Status was based on an assessment tool (AmphIBI) that was developed for assessing the wetlands of Ohio. Trends were not assessed. A monitoring program based on time or spatially constrained search, anuran call counts, coverboards, and aquatic minnow trapping would generate quantitative data useful for trends analysis (Brotherton et al. 2005).

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Bats

Description and Relevance

Since 2006, white-nose syndrome (WNS) has spread across the eastern US and Canada causing major mortality in populations of several species of cave bats (Ingersoll et al. 2013). Three of the five bat species documented at WEFA are species documented to be affected by WNS (Table 4-27). WNS is considered to be among the worst wildlife health crises in recent history.

Weir Barn is believed to be a roost site for a small maternity colony of big brown bats, as indicated by guano accumulations on the barn floor and presence of dead juvenile bats at the barn door (Gates and Johnson 2012).

Table 4-27. Conservation status and detection of bat species in WEFA. Detection status was reported by Gates and Johnson (2012). CT SGCN are Species of Greatest Conservation Need designated by the CT Department of Energy and Environmental Protection (CT DEEP 2015a).

Scientific name	Common name	Conservation Status [1]	Detection during 2010 WEFA Inventory
Eptesicus fuscus	Big brown bat [2]	CT SGCN	Capture, Acoustic
Lasiurus borealis	Eastern red bat	CT Special Concern & SGCN	Capture, Acoustic
Lasiurus cinereus	Hoary bat	CT Special Concern & SGCN	Acoustic
Myotis lucifugus	Little brown myotis [2]	CT Endangered & SGCN	Captures, Acoustic
Myotis septentrionalis	Northern long-eared myotis [2]	US Threatened, CT Endangered & SGCN	Captures

[1] CT DEEP 2015a and 2015b.

[2] Affected by WNS (Blehert et al. 2009).

Data and Methods

No bat monitoring data is available for WEFA, but a Park bat inventory conducted in 2010 documented five species of bats using a combination of mist nets and acoustic monitoring (Table 4-28). Bat activity centered around Weir Pond, with the big brown bat (*Eptesicus fuscus*) accounting for 70% of mist-net captures and 76% of acoustic detections (Gates and Johnson 2012). Capture rates of little brown myotis (*Myotis lucifugus*) at WEFA were relatively high compared to other northeastern NPS units inventoried in 2010 (Gates and Johnson 2012). The Connecticut Department of Energy and Environmental Protection (CT DEEP) monitors winter bat populations in caves known to be hibernacula in the state.

Assessment Points

Monitoring data is not currently available to assess bat condition for WEFA. If bat monitoring is undertaken, the assessment points shown in Table 4-28 could be used to interpret bat condition from acoustic monitoring data, using recorded calls per hour as an index of bat activity and the 2010 park inventory as a baseline for comparison.

Table 4-28. Proposed assessment points for bat condition.

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Bat activity	>= 80% of baseline	50% to 80% of baseline	< 50% of baseline

Condition and Trend

Monitoring data was not available to determine bat condition or trends at WEFA. The CT DEEP has reported catastrophic declines in winter populations of the state's three most common cave-dwelling bat species (*Myotis lucifugus, M. septentrionalis,* and *Perimyotis subflavus*) since the onset of WNS (CT CEQ 2015).

Data Gaps and Level of Confidence

Bat condition at WEFA is a priority data gap, given the conservation status of bat species occurring at WEFA. If additional inventory and monitoring of bats occurs at WEFA, sampling during spring and fall migration, in addition to the summer breeding season, would target potential rare and endangered species and common species not documented in the 2010 inventory (Gates and Johnson 2012).

Any efforts to exclude bats from the Weir Barn should be mitigated by establishing bat houses nearby as alternative roosts (Gates and Johnson 2012). Retention of snags, particularly those with exfoliating bark, and live trees with exfoliating bark (e.g., shagbark hickory), would also improve potential roosting habitat for several bat species (Gates and Johnson 2012).

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Mammals

Description and Relevance

National park units provide important habitat for native mammal species, which in turn play important roles in park ecosystems as consumers of park vegetation and as predators. Data describing the status and trends in key mammal populations provide valuable information to park managers.

Data and Methods

Mammal monitoring data is not available for WEFA, but a mammal inventory conducted at WEFA in 2004 surveyed the mammal community at 16 sampling points (8 traps and 8 indirect measure sites such as camera or trackplate) within four community types (riparian, wetland, field, and deciduous forest; Gilbert et al. 2008). They detected 15 native mammal species at WEFA (Table 4-29) as well as the domestic cat (*Felis silvestris*). In addition, the WEFA bat inventory detected five bat species and observed a southern flying squirrel (*Glaucomys volans*) at Weir Pond dam, increasing the total native mammal species detected in the park to 21 (Gates and Johnson 2012). The domestic cat and raccoon (*Procyon lotor*) were the most commonly detected medium-sized mammals by Gilbert et al. (2008) during the winter sampling session at WEFA, while the Virginia opossum (*Didelphis virginiana*) and raccoon were the most commonly detected medium-sized mammals during the summer sampling session. White-footed mouse (*Peromyscus leucopus*) was the most commonly detected small mammal, followed by the deer mouse (*P. maniculatus;* Gilbert et al. 2008). As noted in Section 4.4.8 Bats above, all five bat species found in WEFA have state or federal conservation designation. Two additional mammals, the woodland vole (*Microtus pinetorum*) and deer mouse (*Peromyscus maniculatus*) found in WEFA are CT SGCN (CT DEEP 2015).

Table 4-29. Native mammal species documented to be present within WEFA. CT SGCN are Species of Greatest Conservation Need designated by the CT Department of Energy and Environmental Protection (CT DEEP 2015).

Latin name	Common name	Source	Conservation Status
Blarina brevicauda	Northern short-tailed shrew	Gilbert et al. 2008	
Canis latrans	Coyote	Gilbert et al. 2008	
Castor canadensis	Beaver	Gilbert et al. 2008	
Didelphis virginiana	Virginia opposum	Gilbert et al. 2008	
Eptesicus fuscus	Big Brown bat	Gates and Johnson 2012	CT SGCN
Glaucomys volans	Southern flying squirrel	Gates and Johnson 2012	
Lasiurus borealis	Red bat	Gates and Johnson 2012	CT SC & SGCN
Lasiurus cinereus	Hoary bat	Gates and Johnson 2012	CT SC & SGCN
Marmota monax	Woodchuck	Gilbert et al. 2008	
Mephitis mephitis	Striped skunk	Gilbert et al. 2008	
Microtus pinetorum	Woodland vole	Gilbert et al. 2008	CT SGCN
Mustela vison	Mink	Gilbert et al. 2008	
Myotis lucifugus	Little brown myotis	Gates and Johnson 2012	CT E & SGCN
Myotis septentrionalis	Northern long-eared myotis	Gates and Johnson 2012	US T, CT E & SGCN
Odocoileus virginianus	White-tailed deer	Gilbert et al. 2008	
Peromyscus leucopus	White-footed mouse	Gilbert et al. 2008	
Peromyscus maniculatus	Deer mouse	Gilbert et al. 2008	CT SGCN
Procyon lotor	Raccoon	Gilbert et al. 2008	
Sciurus carolinensis	Gray squirrel	Gilbert et al. 2008	
Tamias striatus	Eastern chipmunk	Gilbert et al. 2008	
Vulpes vulpes	Red fox	Gilbert et al. 2008	

Several mammal species which have not been documented in the park may be present, based on known population ranges and habitat requirements of these species. These include several species of shrew (*Sorex cinereus*, *S. fumeus* and *S. palustris*), two moles (*Condylura cristata* and *Scalopus aquaticus*), meadow vole (*Microtus pennsylvanicus*), gray fox (*Urocyon cinereoargenteus*), and long-tailed weasel (*Mustela frenata*; Gilbert et al. 2008).

Assessment Points

Assessment points for mammal species other than bat species and white-tailed deer have not been defined. Suggested assessment points for mammal condition could be set based on population monitoring of key species.

Condition and Trend

Mammal condition and trends at WEFA were not determined due to lack of monitoring data.

Data Gaps and Level of Confidence

Mammal condition and trends are data gaps at WEFA.

Literature Cited

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Terrestrial Invertebrates

Description and Relevance

Invertebrates can be useful indicators of biological condition due to their diversity, abundance, and sensitivity to environmental change (Gerlach et al. 2013). Bees can be useful indicators of environmental condition (Porrini et al. 2003, Rabea et al. 2010). Researcher Sam Droege (sdroege@usgs.gov) with the Patuxent Wildlife Research Center has collaborated with the U.S. Forest Service to develop methods for monitoring native bees. Butterflies are charismatic invertebrates which have been observed in the park, and surveyed in Ridgefield as well as in locations across the state during the Connecticut Butterfly Atlas Project. A variety of terrestrial invertebrate taxa may serve as useful indicators of the ground layer (including ants, millipedes, snails, ground beetles, harvestmen and gnaphosid spiders), or the foliage layer (including ants, chrysomelid leaf beetles, theridiid spiders and arctiid moths) while isopods may be useful soil indicator species (Gerlach et al. 2013).

Data and Methods

Informal observation of butterfly species collected in the park in 2009, 2011 and 2012 identified 21 species of butterflies present in the park (Table 4-30; Greg Waters, personal communication, 26 May 2015). The Connecticut Butterfly Atlas Project, undertaken 1955-1959, identified 55 species of butterflies in Ridgefield CT; 25 butterfly species were observed in Ridgefield in 2009 (Klemens et al. 2012). The Butterflies and Moths Database of North America (BAMONA) lists 109 species of butterflies and 65 species of moths known to occur in Fairfield County CT.

Table 4-30. Butterfly species observed in Weir Farm National Historic Site 2009-2011. Numbers of individuals observed is shown for 2010-2011.

Latin name	Common name	6/27/2009 - 7/11/09	7/9/2011	7/7/2012
Celastrina ladon	Summer azure	x		
Cercyonis pegala	Common wood nymph		7	1
Colias eurytheme	Orange sulphur		2	
Colias philodice	Clouded sulphur	x	1	8
Danaus plexippus	Monarch	x	1	
Epargyreus clarus	Silver-spotted skipper	x		
Lycaena phlaeas	American copper			1
Megisto cymela	Little wood-satyr	x	2	1
Papilio glaucus	Eastern tiger swallowtail	x		2
Papilio troilus	Spicebush swallowtail		1	
Phyciodes tharos	Pearl crescent		3	4
Pieris rapae	Cabbage white	x	5	4
Poanes hobomok	Hobomok skipper	x		
Polites mystic	Long dash		1	
Polites themistocles	Tawny-edged skipper	x		1
Polygonia interragationis	Question mark	x		
Pompeius verna	Little glassywing	x	23	3
Speyeria cybele	Great spangled fritillary	x	8	
Thymelicus lineola	European skipper		1	
Vanessa cardui	Painted lady		1	
Wallengrenia egeremet	Northern broken dash			2

Assessment Points
Assessment points have not been defined.

Condition and Trend
Condition and trends cannot be assessed at this time.

Data Gaps and Level of Confidence
This data gap could be filled if funding permits.

Literature Cited
Gerlach, J., M. Samways, and J. Pryke. 2013. Terrestrial invertebrates as bioindicators: an overview of available taxonomic groups. J Insect Conserv 17:831–85.

Klemens, M.W., E.R. Davison, and B. K. Oko. 2012. Ridgefield Natural Resource Inventory. Prepared for the Ridgefield Conservation Commission. April 2012.

Porrini, C., A. G. Sabatini, S. Girotti, S. Ghini, P. Medrzycki, F. Grillenzoni, L. Bortolotti, E. Gattavecchia, and G. Celli. 2003. Honey bees and bee products as monitors of the environmental contamination. Apicata 38:63–70.

Rabea, E. I., H. M. Nasr, M. E. I. Badawy. 2010. Toxic effect and biochemical study of chlorfluazuron, oxymatrine, and spinosad on honey Bees (Apis mellifera). Arch Environ Contam Toxicol 58:722–732.

Human Use

Visitor Usage

Description and Relevance
Visitor use has been recognized as a Vital Sign directly related to park management (Mitchell et al. 2006). Visitors to WEFA typically engage in tours of the park buildings and grounds, art and photography (with permit), hiking and dog-walking, and nature study. Dogs are allowed in the park, but must be leashed. Cross-country skiing and fishing are also allowed. Hunting, camping and horseback riding are not allowed; and bicycles and motorized vehicles (other than Segways and motorized wheelchairs) are not allowed on park grounds and trails. A geocache is located on the path around Weir Farm.

Data and Methods
The park counts visitors in several classes: 1) an automatic counter operates in the parking lot; 2) visitors to the Burlingham House visitor center are estimated by rangers using hand counters; 3) visitors on Weir House tours are recorded; and 4) visitors to the Young and Weir Studios are estimated by docents using hand counters (NPS 2015, Greg Waters personal communication 1/15/16).

Visitors traveling off established trails may trample vegetation and the forest floor. NETN forest crews have visually assessed trampling in 10 permanent forest plots during visits every four years since 2007 (Tierney et al. 2015); visible trampling may be caused by visitors, park management, or by wildlife such as white-tailed deer.

Assessment Points

Assessment points have not been established for numbers of visitors. Trampling condition was rated using the assessment points shown in Table 4-31.

Table 4-31. Assessment points for trampling condition (Tierney et al. 2015).

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Trampling	< 1% trampled ground cover	1 - 5% trampled ground cover	> 5% trampled ground cover

Condition and Trend

WEFA has hosted more than 300,000 recreational visitors since establishment in 1990 (Figure 4-18). Visitation rates are typically highest June through October and lowest during winter. The number of annual visitors has increased over time, averaging about 24,000 from 2010 – 2014. In May 2014, after a decade of restoration, the park celebrated a grand opening of the Weir House, Weir Studio, and Young Studio. Visitation rates in 2014 were 40% higher than in 2013, and visitation rates thus far in 2015 have exceeded rates in 2014 (NPS 2015).

Observed trampling of NETN forest plots was negligible (<1% cover) in six of the ten plots in the current data cycle (2011-2013); this indicates *good condition*. The trend in visible trampling was unchanging between the initial (2007-2009) and current data collections.

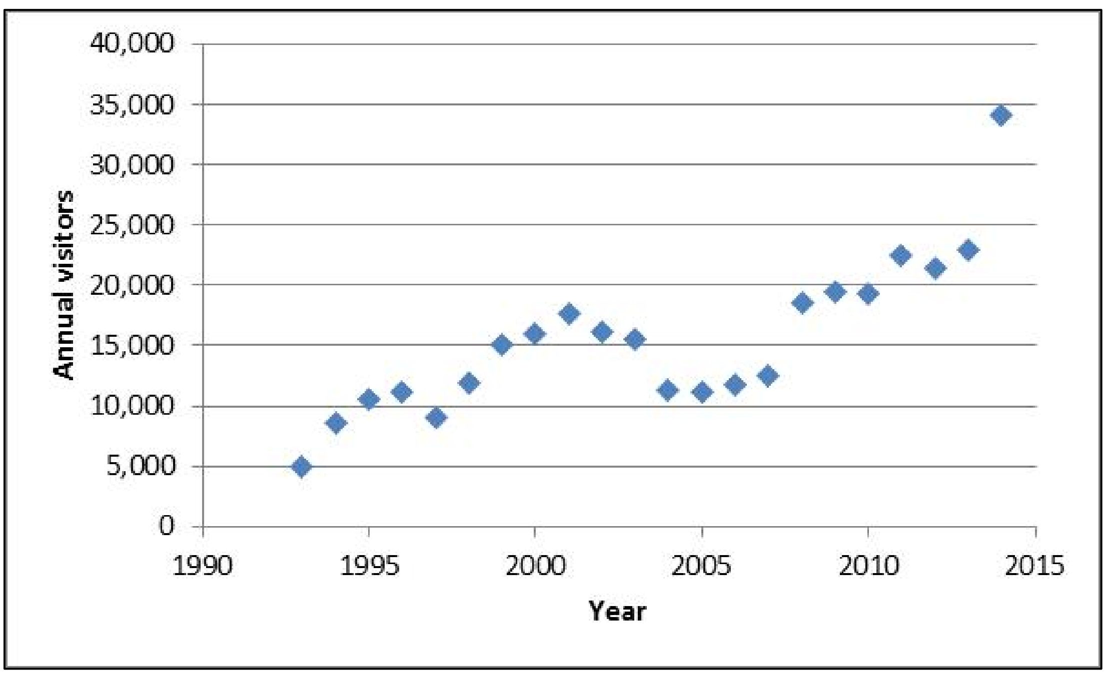

Figure 4-18. Annual visitation to Weir Farm NHS.

Data Gaps and Level of Confidence

Level of confidence in park visitor estimates by rangers and automatic counters is medium. Automatic counters may over count visitors (who may pass by counters more than once) and park log books may undercount visitors (who may fail to sign in). Level of confidence in trampling status assessment is low due to the small sample size and low frequency of assessment (every four years). Patterns of visitor trampling could be better characterized by visual assessment of selected off-trail locations adjacent to major trails and Weir Pond.

Literature Cited

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, Vermont.

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Landscapes

Landcover / Ecosystem Cover / Connectivity

Description and Relevance

Habitat fragmentation is a key threat to biodiversity. In general, large forest patches disproportionately support larger populations of fauna and more native, specialist, and forest interior species (Harris 1984, Forman 1995). The impacts of fragmentation have been especially well documented upon avian communities, and population declines of a variety of forest interior avian species are linked to habitat fragmentation (Austen et al. 2001, Boulinier et al. 2001). National historic parks and sites such as WEFA are particularly vulnerable to impacts from fragmentation due to their relatively small size and layout, typically determined by the location of historical features; both of these factors can increase vulnerability to fragmentation beyond park borders. These parks may also be more vulnerable to fragmentation due to their mandate to preserve and interpret historical features, which may include fragmented landscapes.

Data and Methods

Data to interpret the condition of landcover at WEFA came from several sources. Wang and Nugranad-Marzilli (2009) used Landsat remote sensing data with ground-truthing to assess landcover change within a 5-km (3.1-mile) buffer surrounding WEFA from 1973 to 2002. Within this 5-km (3.1-mile) WEFA buffer, they found little change in amount of deciduous forest over the 29-year study period, but decreases in the amount of coniferous and mixed forest led to an overall decrease in forest vegetation of about 15%, or 1180 ha (2916 ac).

Miller et al. (2011) assessed forest patch size at WEFA in 2010 using recent, leaf-on 1:6,000 scale orthophotography (Figure 4-19; Miller et al. 2011). This analysis will be repeated periodically to update status and determine trends.

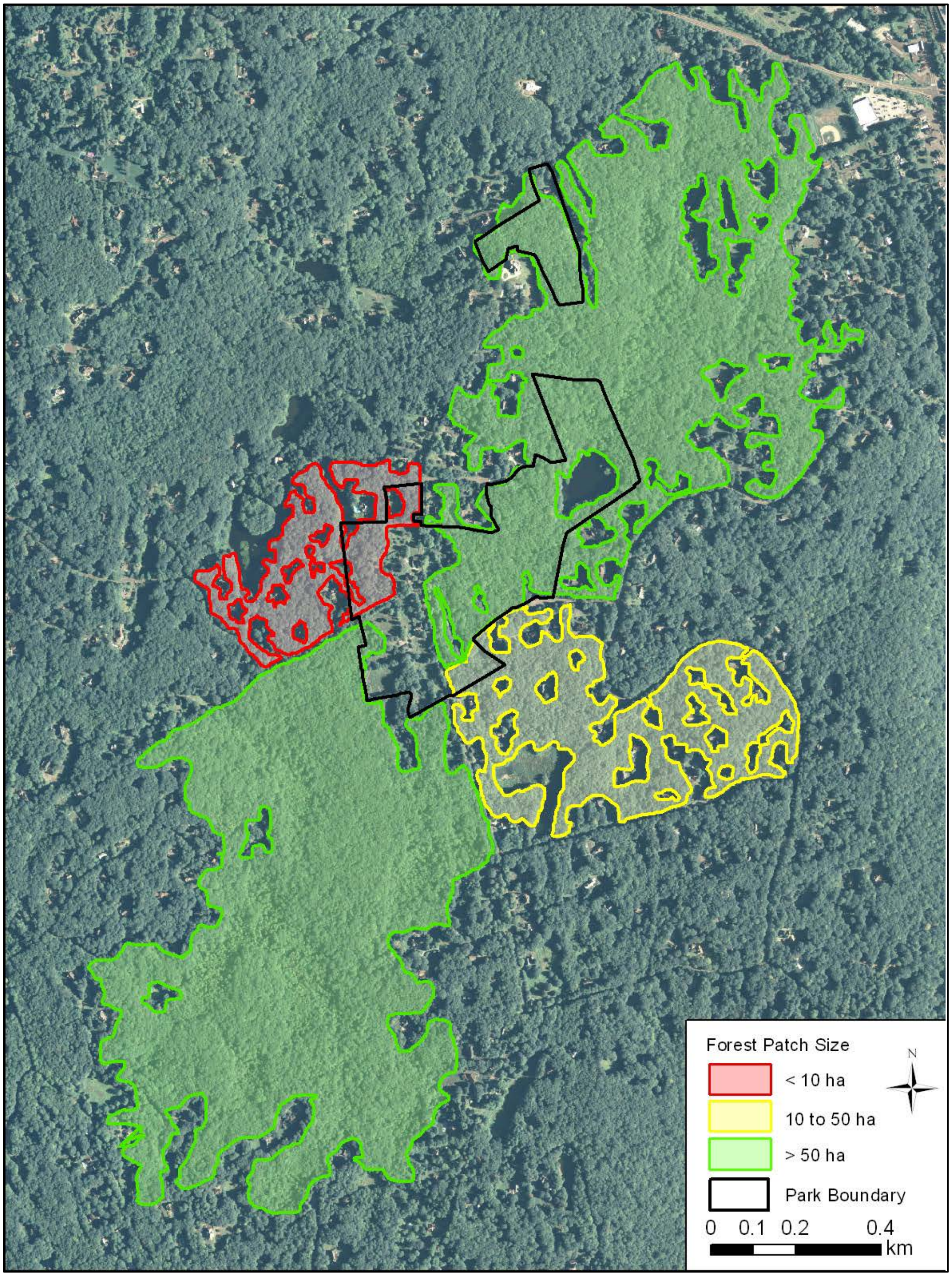

Figure 4-19. Forest patch size delineated at Weir Farm National Historic Site (excerpted from Miller et al. 2011).

The NPScape program provides several sources of data for assessing status and trends in landscape dynamics within national parks. Using the 2011 National Land Cover Database (NLCD), NPScape has provided coverage of Anderson level 2 landcover categories (Figure 4-20), as well as forest density within 30 m pixels (Figure 4-21; NPS 2015). Forest density (p) was estimated using an automated moving window analysis within seven categories: intact ($p = 1.0$), interior ($0.9 \leq p < 1.0$), dominant ($0.6 \leq p < 0.9$), transitional ($0.4 \leq p < 0.6$), patchy ($0.1 \leq p < 0.4$), rare ($0.0 \leq p < 0.1$) and none ($p = 0.0$; Riitters 2011).

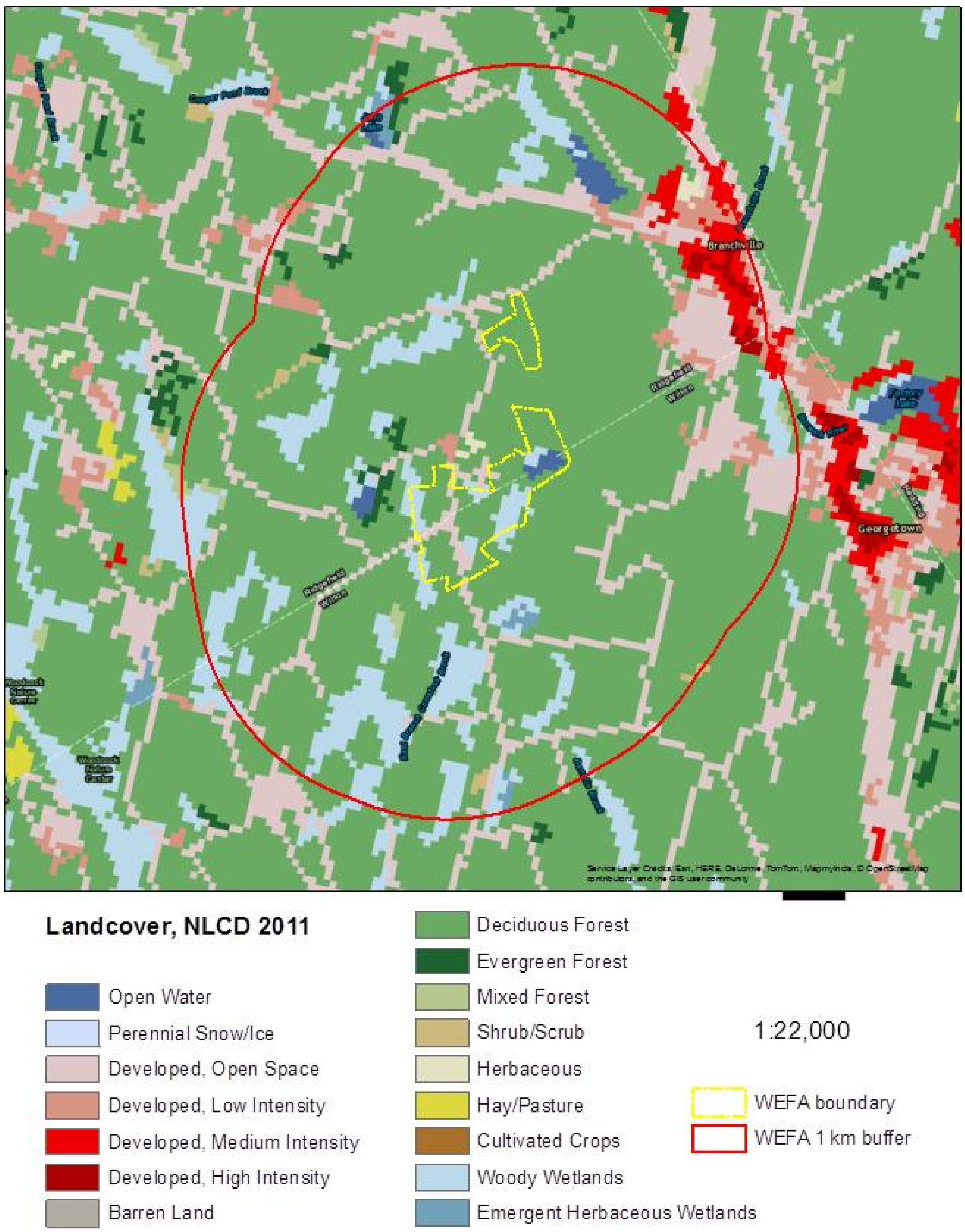

Figure 4-20. Andersen level 2 land cover categories at Weir Farm NHS (data from NPS 2015).

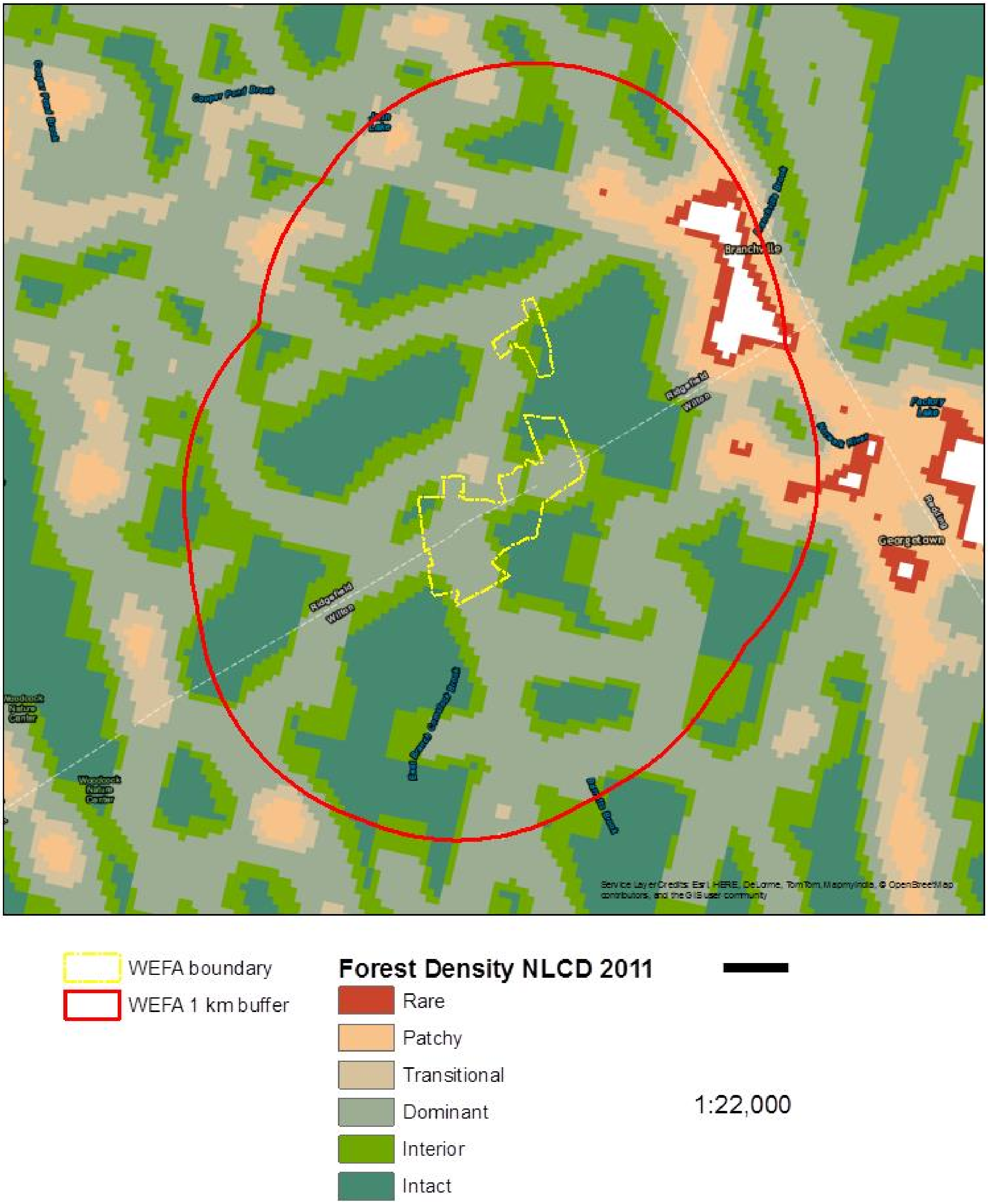

Figure 4-21. Forest density at Weir Farm National Historic Site (data from NPS 2015).

Finally, a state-wide study undertaken by the Center of Land Use Education and Research (CLEAR) at the University of Connecticut provided data on forest fragmentation in the Norwalk River Valley (UCONN CLEAR 2015).

Assessment Points

Miller et al. (2011) assessed ecological integrity of forest patch size based on the needs of invertebrates, small mammals and many bird species dependent upon intact forest habitat (Kennedy et al. 2003). WEFA is too small to support large mammal populations, so the needs of large mammals were not factored into the assessment points for this metric. Thus patch size range considered *good condition* may be smaller than those recommended by other studies, such as UCONN CLEAR (2015). Assessment points based on forest density classes are suggested as shown in Table 4-32.

Table 4-32. Assessment points for forest patch size and forest density.

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Forest patch size	> 50 ha	10-50 ha	< 10 ha
Forest density	Forested area is predominantly interior or intact class	Forested area is predominantly dominant class	Forested area is predominantly transitional or less dense class

Condition and Trend

Miller et al. (2011) delineated WEFA and the surrounding land into four forest patches which are separated by roads and fields and perforated by residential lawns (Figure 4-19). Over 80% of the park's forested area, fell within relatively large (>50 ha) but perforated patches. Interpretation of forest density from NLCD 2011 imagery shows WEFA to be mostly dominant forest class with small areas of interior and intact forest, warranting *moderate concern* (Figure 4-21; NPS 2015). Trends for WEFA have not yet been assessed.

The CLEAR dataset showed the Norwalk River watershed, within which WEFA lies, to be less forested and more fragmented than the state overall, and has lost core forest at a greater rate over the study period than the state as a whole. The Norwalk River Watershed was about 50% forested in 2006, with only 20% of the forested area comprised of core forest, almost entirely within the small core forest category (<100 ha [147 ac]; Figure 4-22; UCONN CLEAR 2015). Within this watershed, the amount of core forest declined by about 24% from 1985 to 2006, while the amount of perforated and patch forest increased (by about 29% and 10%, respectively; UCONN CLEAR 2015).

Data Gaps and Level of Confidence

Assessment of condition from two data sources with established assessment points is medium. Trends in condition were not assessed; confidence in regional trends is high.

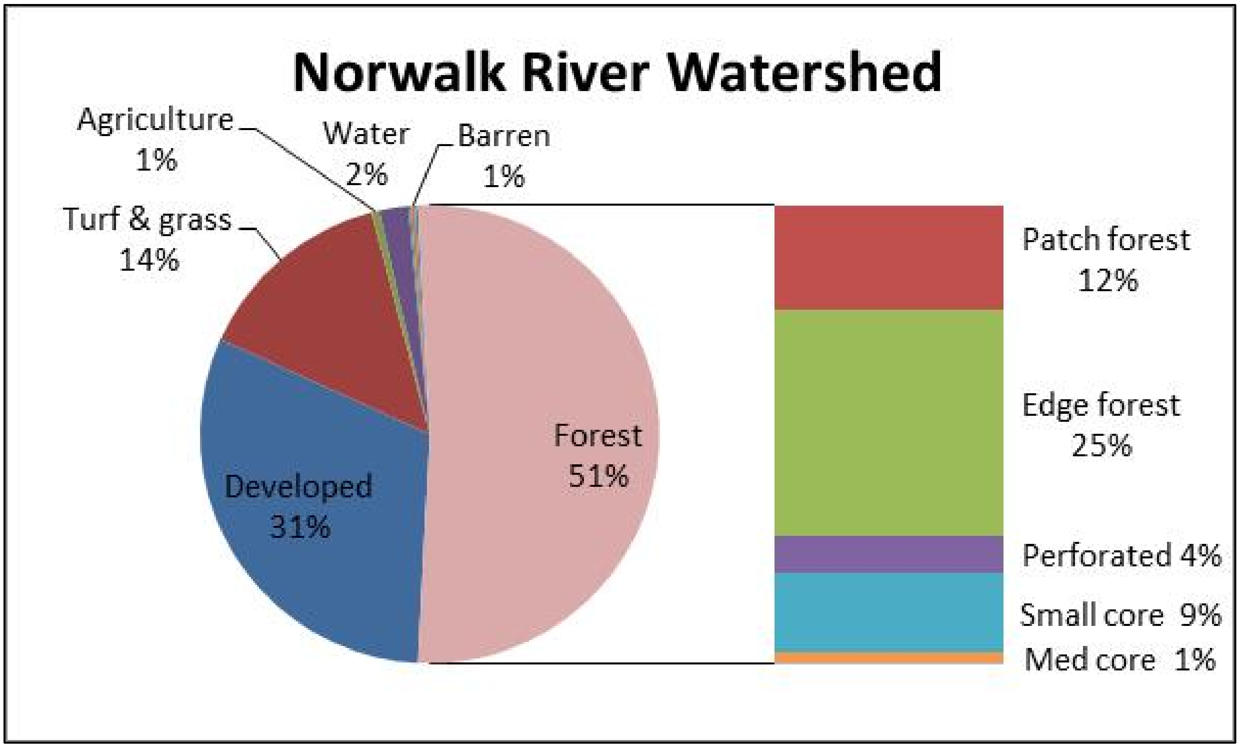

Figure 4-22. Percent cover of land use and forest fragmentation classes in the Norwalk River Watershed in 2006 (adapted from UCONN CLEAR 2015). Small core forest is <100 ha and medium (med) core forest is 100-200 ha in size. See text for other definitions.

<u>Literature Cited</u>

Austen, M. J. W., C. M. Francis, D. M. Burke, and M. S. W. Bradstreet. 2001. Landscape context and fragmentation effects on forest birds in southern Ontario. *Condor* 103:701-714.

Boulinier, T., J. D. Nichols, J. E. Hines, and others. 2001. Forest fragmentation and bird community dynamics: Inference at regional scales. *Ecology* 82:1159-1169.

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Harris, L. 1984. The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity. University of Chicago Press, Chicago, IL.

Kennedy, C., J. Wilkinson, and J. Balch. 2003. Conservation Thresholds for Land Use Planners. Environmental Law Institute, Washington, DC.

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Land Use

Description and Relevance

Land conversion to anthropogenic uses eliminates and fragments wildlife habitat and increases sources of local pollution and pathways for invasive exotic species. Land conversion to impervious surfaces increases runoff and reduces water quality and watershed buffering. Small parks such as WEFA are particularly vulnerable to land conversion that occurs outside park borders, particularly conversion occurring upstream of park wetlands and water courses.

Data and Methods

Data to assess land use at WEFA comes from several sources. Wang and Nugranad-Marzilli (2009) assessed landcover change within a 5-km buffer surrounding WEFA from over the 29-year period from 1973 to 2002. Within the 5-km park buffer, they found a large increase (1454 ha [3592 ac] or 460%) in urban land from 1973 to 2002. This increase may in part be an artifact created by the increase in resolution and spectral bands of later Landsat sensors.

Miller et al. (2011) assessed the percentage of anthropogenic versus natural land use within a 100-m radius circle surrounding each WEFA forest plot (Figure 4-23). Using the 2011 NLCD, NPScape has provided data describing coverage by impervious surfaces (Figure 4-24; NPS 2015).

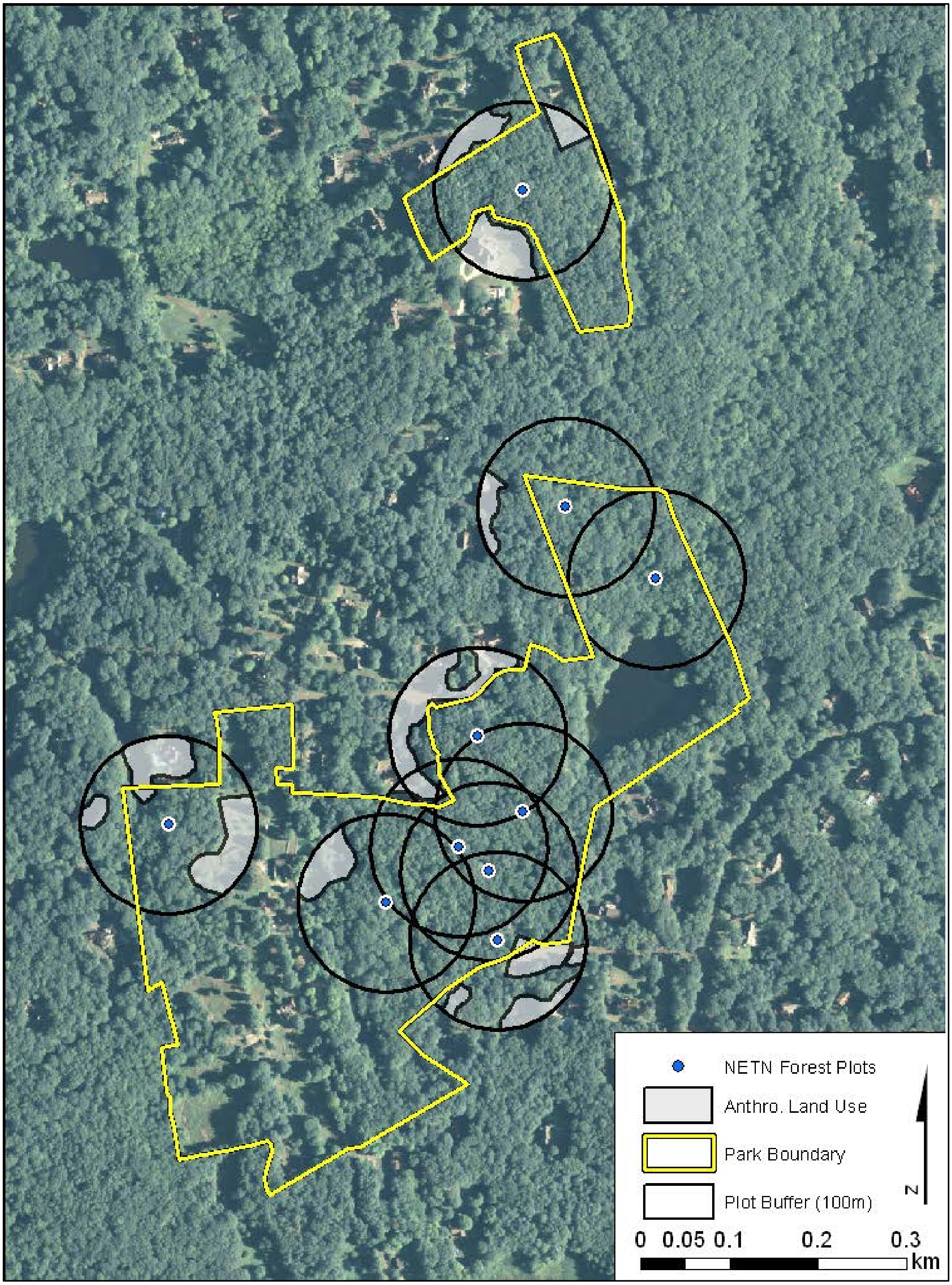

Figure 4-23. Anthropogenic land use surrounding forest plots at Weir Farm NHS (excerpted from Miller et al. 2011).

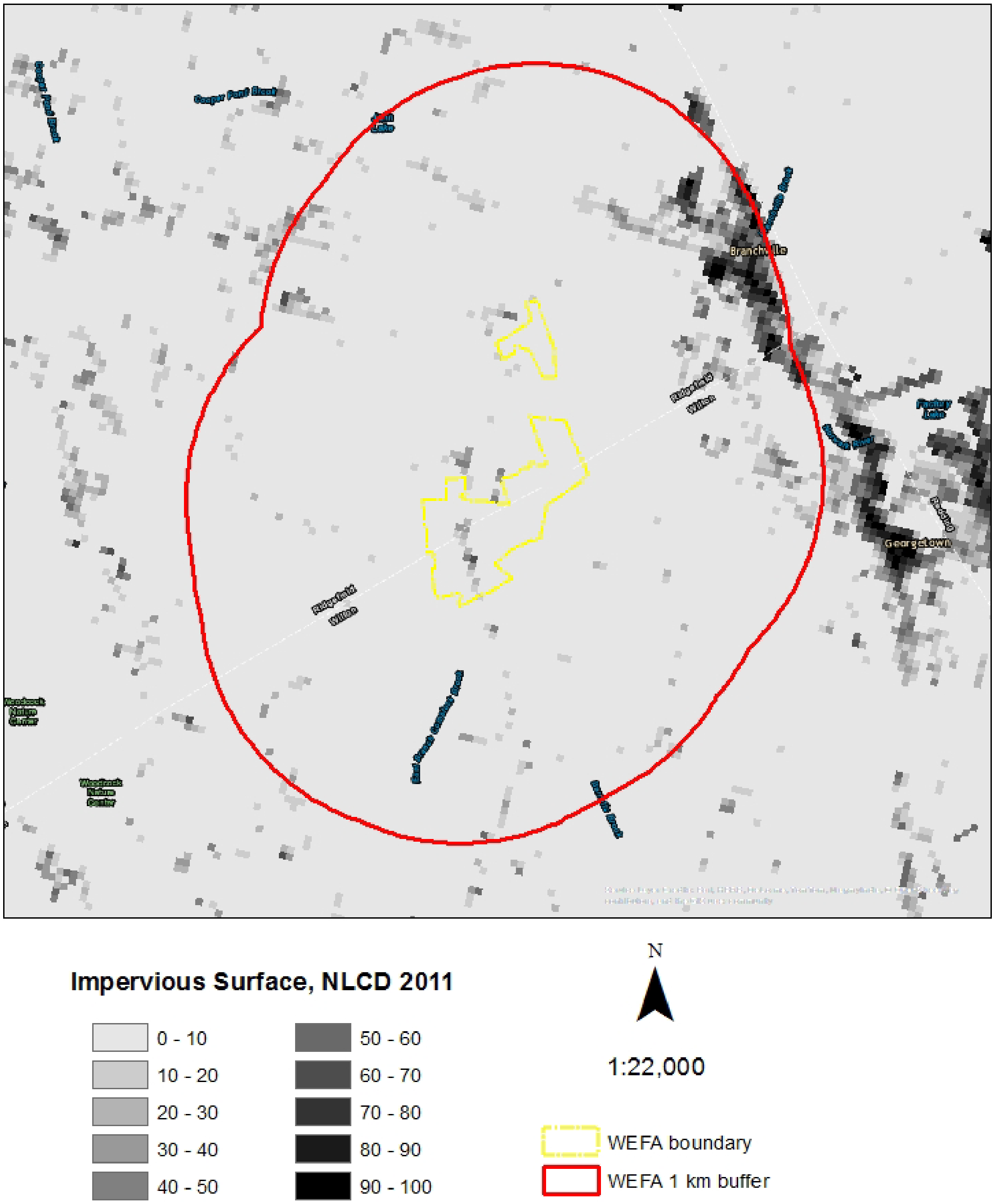

Figure 4-24. Impervious surfaces at Weir Farm NHS (data from NPS 2015).

<u>Assessment Points</u>

Miller et al. (2011) assessed anthropogenic land use (ALU) using the assessment points shown in Table 4-33, based on theoretical models that examined the combined impacts of habitat loss and fragmentation (McIntyre and Hobbs 1999, O'Neill et al. 1997). Wagner et al. (2014) suggested the *good condition* assessment point for impervious cover (IC) used here, based on impacts to water quality and habitat (Goetz et al. 2003, Schiff and Benoit 2007), as well as a second assessment point for *significant concern*.

Table 4-33. Assessment points for land use condition based on anthropogenic land use and impervious cover.

Metric	*Good Condition*	*Moderate Concern*	*Significant Concern*
Anthropogenic land use	< 10%	10 – 40%	> 40%
Impervious cover	< 10%	11 – 25%	> 25%

Condition and Trend

Anthropogenic land use (ALU) within a 100 m radius surrounding NETN forest plots at WEFA averaged 10.5%, just over the 10% assessment point and warranting *moderate concern*. The most common ALUs were residential lawns. Coverage by impervious surfaces within the WEFA boundary is minimal, falling below the 10% assessment point to warrant *good condition*. Within a 1 km boundary surrounding WEFA, the developed area known as Branchville along the Route 7 corridor northeast of the park corresponds to a larger area of impervious surface. This area is located downstream from WEFA and does not impact water quality in the park.

Data Gaps and Level of Confidence

Assessment of park land use condition based two metrics with established assessment points is medium. Trends were not assessed.

Literature Cited

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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.

Discussion

Overall, assessment of natural resource condition at WEFA reflects condition supportive of a wide variety of native flora and fauna within the park ecosystems: Weir Pond, wetlands and forests.

Weir Pond remains uninvaded by invasive exotic aquatic plants and showed *good condition* for water chemistry, but is notable for recent increases in specific conductivity and chloride. Establishment of water quantity assessment points will allow determination of water quantity condition in future assessments.

Wetland vegetation is a data gap that could be filled using rapid assessment methods noted below. Limited cover by impervious surfaces in the park results in good infiltration. At the time of the park amphibian and reptile inventory in 2000, the park amphibian community showed good representation by sensitive species, pond-breeding salamanders and vernal pool-breeding amphibians. However, herptile species monitoring data is not available and represents a data gap.

Assessed for ecological integrity, forest vegetation at WEFA showed *good condition* for stand structure, but warranted *moderate concern* for tree condition and lower than desired levels of snags and CWD, and warranted *significant concern* for low tree regeneration. Forest soils showed *good condition* for base saturation, but warranted *moderate concern* for aluminum toxicity and *significant concern* for nitrogen saturation. Forest patch size is sufficiently large to support invertebrates, small mammals and many bird species dependent upon forest habitat, but a pattern of perforation reduces the amount of forest interior habitat available. Forest bird populations warranted *significant concern* for ecological integrity, and trends appear to be deteriorating. The regional white-tailed deer population remains dense enough to warrant *significant concern* for browse impacts, but an improving trend (i.e., reduced white-tailed deer population density) over the last decade is promising. Invasive exotic plants and forest pests both pose *significant concern*s to park forest habitats. Forest plots showed little indication of trampling, but more targeted monitoring at key sites could detect more specific problems.

Soundscape and lightscape were both assessed using modeled data, and appeared to warrant concern.

Some notable problem areas reflect regional trends outside of the control of park managers. Within the air quality category, Ozone, Acidic deposition & stress, and Climate & phenology all warranted *significant concern*. Park managers can continue to monitor impacts and work collaboratively with federal, state and local partners to reduce regional air pollution. Likewise, the approach of invasive exotic forest pests and terrestrial plant invaders is largely beyond the control of park managers, but managers can continue to focus on early detection and eradication within the park. WNS is a regional wildlife health crisis that is outside the control of park staff; however, establishing an annual bat monitoring program as outlined below may provide useful data on populations of several rare species.

Status and trends in park natural resource condition at WEFA are summarized in report card format in Appendix C.

Data gaps

NPS staff and collaborators have collected data which has provided a detailed picture of natural resource condition for many of the 23 Vital Signs considered here. However, this assessment revealed several data gaps which could be filled by additional park monitoring if funding permits. These gaps and potential additional monitoring activities are summarized in Table 5-1.

Table 5-1. Data gaps and potential monitoring activities at Weir Farm NHS.

Data gap	Potential monitoring activities
Climate change	Expand efforts to identify and monitor status and trends of key indicators of climate change, and to identify and monitor valued park resources at high risk to climate change impacts.
Contaminants	Consider participating in NPS Dragonfly Mercury Project, using citizen scientists to collect dragonfly larvae for mercury analysis. http://www.nature.nps.gov/air/studies/air_toxics/dragonfly/index.cfm
Visibility	Consider monitoring key landscape scenes using time-lapse photography. The resulting dataset could be evaluated by a professional landscape artist to assign ratings for light quality, and further investigation could determine if the artist's light quality ratings were correlated with monitored visibility metrics or other extractable metrics from the photo dataset.
Lightscape	Monitor with automated photography using NPS methods (Duriscoe et al. 2007) or with simple star counts using citizen scientists.
Soundscape	Monitor with automated recorders using NPS methods (NPS NSNSD 2013).
Wetland vegetation	Monitor key sites using USA-RAM methods (US EPA 2011).
Amphibians and reptiles	Monitor community with annual acoustic surveys, vernal pool egg mass counts, coverboard transects, and monitoring of stream salamanders.
Bats	Monitor community with annual, automated acoustic monitoring. Follow up with mist-netting at key sites to confirm status of rare species.
Mammals	Monitor small mammals using live-trapping grids.
Terrestrial invertebrates	Consider monitoring pollinators or butterflies and moths.
Trampling at key locations	Monitor key locations using visual assessment.

Management recommendations

To protect park wetlands, water courses and Weir pond from chloride, the park could incorporate and publicize best practices for de-icing and water softening. These include limiting the use of de-icers and water softeners, use of appropriate products such as sand/road salt mixtures and on-demand water softeners, and off-site disposal of brine if possible (Hunt et al. 2012; RI DEM 2012). Any new transportation projects within the park watershed, including a revival of the "Super Seven Expressway" project, should receive careful attention by park staff for impacts to park wetlands and Weir Pond.

Continuing the use of careful mowing practices in the park to protect turtles and snakes is beneficial; these practices include performing annual mowing at times when turtles and snakes are less active (i.e., November), minimizing threats from more frequent trail mowing by slow and careful mowing, preferably with someone walking ahead of the mower, and mowing during times of drought and high heat intensity, when turtles avoid open areas (Brotherton et al. 2005).

Park forests are substantially affected by white-tailed deer herbivory, forest pests and invasive exotic species. Park managers could consider deer exclosures in key areas to facilitate tree regeneration, and should continue to work with local and regional organizations to reduce the regional deer herd to levels which have lower negative impacts on forest resources. Early detection of key forest pests and rapid response must continue to be a high priority for the park, and continued diligence in detecting and eradicating exotic plant invasions is warranted.

Low levels of standing dead trees (snags) and coarse woody debris (CWD) limit the availability of valuable habitats in the park. Park managers may allow these structural features to continue to accumulate by leaving snags and CWD in place whenever possible. Retention of snags, particularly those with exfoliating bark, and live trees with exfoliating bark (e.g., shagbark hickory), would also improve potential roosting habitat for several bat species (Gates and Johnson 2012). In addition, park managers could consider establishing bat houses as alternative roosts, particularly if efforts are made to exclude bats from Weir barn (Gates and Johnson 2012).

Literature Cited

Brotherton, D. K., R. P. Cook, J. L. Behler. November 2005. Weir Farm National Historic Site Amphibian and Reptile Inventory March – September 2000. Technical Report NPS/NER/NRTR—2005/029. National Park Service. Boston, MA.

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Appendix A: Additional Maps of WEFA Region

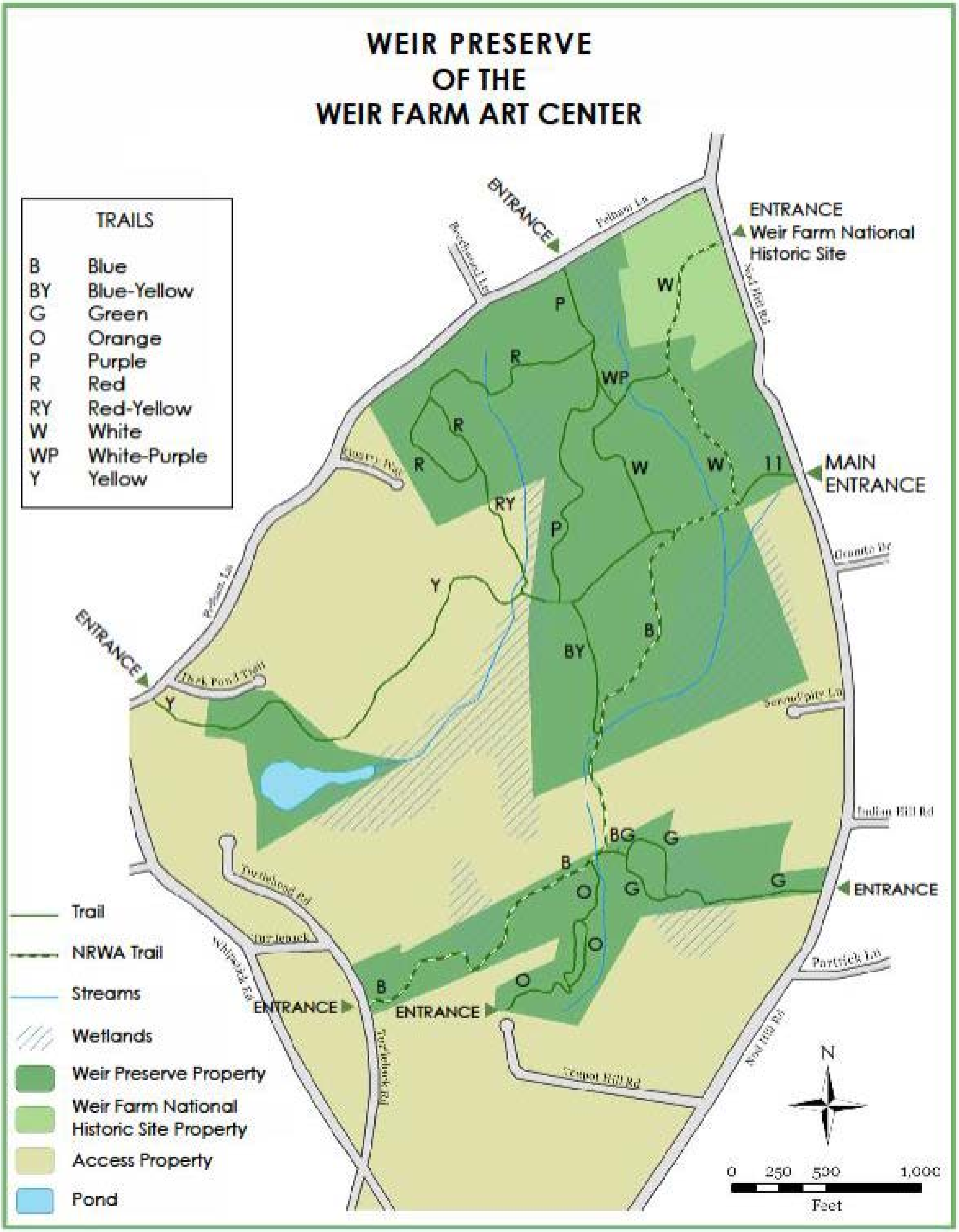


Figure A-1. Map of the Weir Preserve, adjacent to Weir Farm National Historic Site, in Wilton, CT.

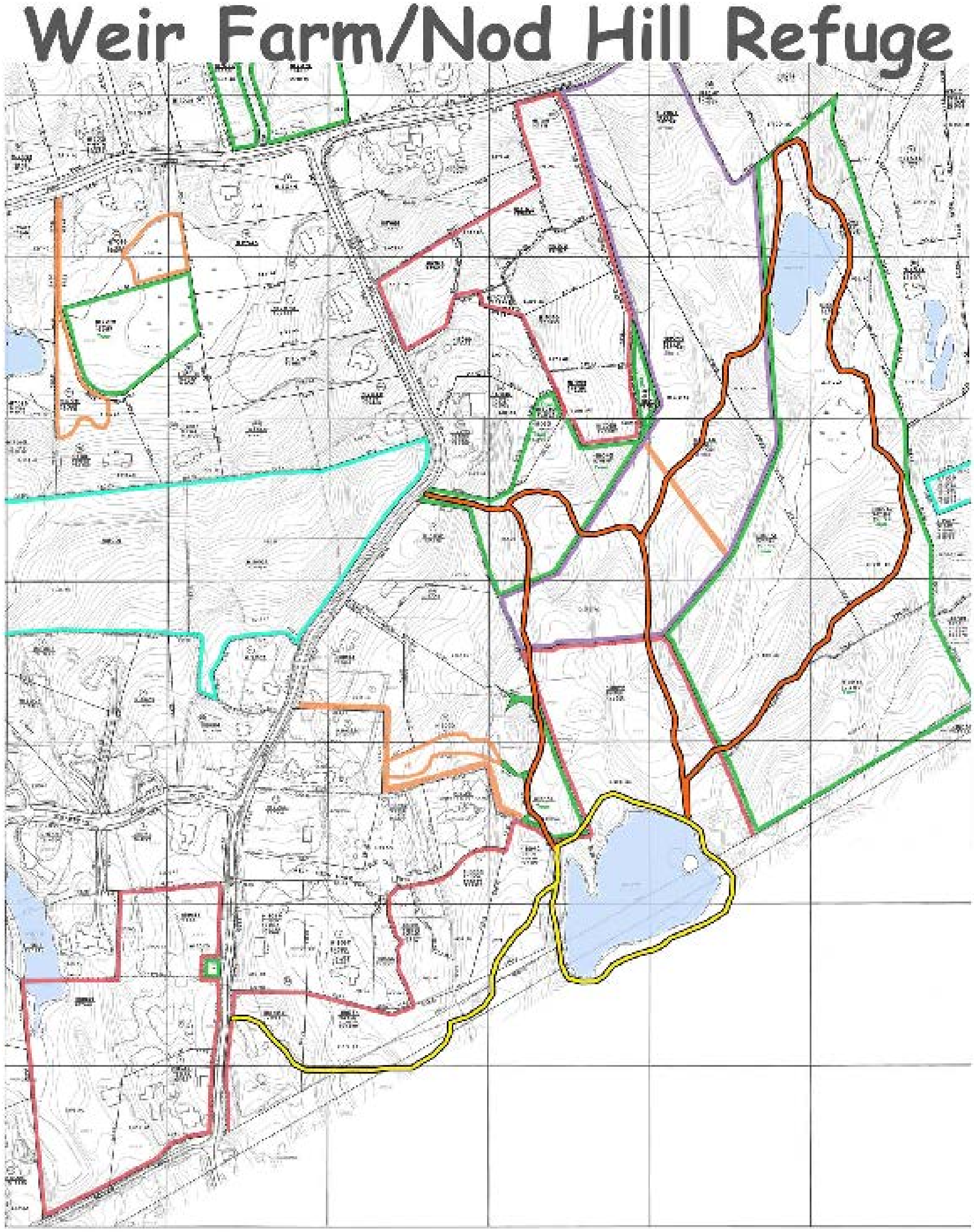


Figure A-2. Section of Ridgefield, CT surrounding Weir Farm National Historic Site. The Ridgefield section of WEFA is outlined in red, the Town of Ridgefield Nod Hill Preserve is outlined in green, and State of Connecticut land is outlined in purple. Hiking trails are show in in yellow and orange (with black outline)

Appendix B: Wildlife Species List for Weir Farm NHS

Table B-1. Wildlife species documented present or probably present in WEFA. Cite is noted if other than the official park list. Regional concern and UCS (USA/Canada Stewardship Species) are designations by Partners in Flight, and CT SGCN are Species of Greatest Conservation Need designated by the CT Department of Energy and Environmental Protection.

Category	Scientific Name	Common Names	Conservation Status	Comment	Cite
Amphibian	*Ambystoma maculatum*	Spotted Salamander		Breeder	
Amphibian	*Ambystoma opacum*	Marbled Salamander	CT SGCN		
Amphibian	*Bufo fowleri*	Fowler's Toad	CT SGCN	Resident	
Amphibian	*Eurycea bislineata*	Northern Two-lined Salamander			
Amphibian	*Hyla versicolor*	Gray Treefrog	CT SGCN	Breeder	
Amphibian	*Notophthalmus viridescens viridescens*	Red-spotted Newt	CT SGCN	Breeder	
Amphibian	*Plethodon cinereus*	Eastern Red-backed Salamander		Resident	
Amphibian	*Pseudacris crucifer*	Spring Peeper		Breeder	
Amphibian	*Rana catesbeiana*	American Bullfrog		Breeder	
Amphibian	*Rana clamitans melanota*	Northern Green Frog		Breeder	
Amphibian	*Rana palustris*	Pickerel Frog		Breeder	
Amphibian	*Rana sylvatica*	Wood Frog	CT SGCN	Breeder	
Bird	*Accipiter striatus*	Sharp-shinned Hawk	CT Endangered & SGCN		Trocki and Paton 2003
Bird	*Agelaius phoeniceus*	Red-winged Blackbird			
Bird	*Aix sponsa*	Wood Duck			
Bird	*Archilochus colubris*	Ruby-throated Hummingbird			
Bird	*Bombycilla cedrorum*	Cedar Waxwing		Breeder	
Bird	*Branta canadensis*	Canada Goose		Breeder	
Bird	*Buteo jamaicensis*	Red-tailed Hawk		Breeder	
Bird	*Buteo lineatus*	Red-shouldered Hawk			
Bird	*Buteo platypterus*	Broad-winged Hawk	CT Special Concern & SGCN		Trocki and Paton 2003
Bird	*Cardinalis cardinalis*	Northern cardinal			
Bird	*Carduelis tristis*	American Goldfinch		Breeder	
Bird	*Carpodacus mexicanus*	House Finch		Breeder	

Category	Scientific Name	Common Names	Conservation Status	Comment	Cite
Bird	*Catharus fuscescens*	Veery	CT SGCN		Trocki and Paton 2003
Bird	*Certhia americana*	Brown Creeper	CT SGCN	Breeder	Trocki and Paton 2003
Bird	*Ceryle alcyon*	Belted Kingfisher			
Bird	*Chaetura pelagica*	Chimney Swift			
Bird	*Chordeiles minor*	Common nighthawk	CT Endangered & SGCN	Probably Present	
Bird	*Coccyzus americanus*	Yellow-billed Cuckoo	CT SGCN	Rare	Trocki and Paton 2003
Bird	*Colaptes auratus*	Northern flicker	CT SGCN		Trocki and Paton 2003
Bird	*Contopus virens*	Eastern Wood Pewee	Regional Concern, CT SGCN	Breeder	Trocki and Paton 2003
Bird	*Corvus brachyrhynchos*	American crow			
Bird	*Cyanocitta cristata*	Blue jay			
Bird	*Dendroica caerulescens*	Black-throated Blue Warbler	CT SGCN	Migratory	Trocki and Paton 2003
Bird	*Dendroica magnolia*	Magnolia Warbler		Migratory	
Bird	*Dendroica pinus*	Pine Warbler			
Bird	*Dryocopus pileatus*	Pileated Woodpecker		Breeder	
Bird	*Dumatella carolinensis*	Gray catbird			
Bird	*Empidonax minimus*	Least Flycatcher	CT SGCN	Breeder	Trocki and Paton 2003
Bird	*Geothlypis trichas*	Common yellowthroat		Probably Present	
Bird	*Hirundo rustica*	Barn swallow		Probably Present	
Bird	*Hylocichla mustelina*	Wood Thrush	Regional Concern, UCS, CT SGCN	Breeder	Trocki and Paton 2003
Bird	*Icterus galbula*	Baltimore Oriole, Northern Oriole	Regional Concern, CT SGCN		Trocki and Paton 2003
Bird	*Iridoprocne bicolor*	Tree swallow		Probably Present	

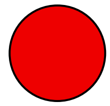
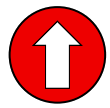
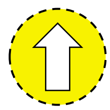
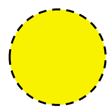
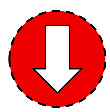
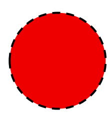
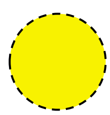
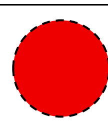
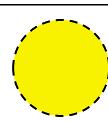
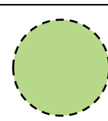
Category	Scientific Name	Common Names	Conservation Status	Comment	Cite
Bird	*Melanerpes carolinus*	Red-bellied Woodpecker		Breeder	
Bird	*Meleagris gallopavo*	Wild Turkey		Breeder	
Bird	*Melospiza melodia*	Song sparrow			
Bird	*Mimus polyglottos*	Northern Mockingbird		Breeder	
Bird	*Mniotilta varia*	Black-and-white warbler	CT SGCN	Probably Present	Trocki and Paton 2003
Bird	*Molothrus ater*	Brown-headed cowbird			
Bird	*Myiarchus crinitus*	Great Crested Flycatcher		Breeder	
Bird	*Parkesia (Seiurus) motacilla*	Louisiana Waterthrush	CT SGCN	Breeder	
Bird	*Parkesia (Seiurus) noveboracensis*	Northern Waterthrush	CT SGCN		
Bird	*Parus atricapillus*	Black-capped chickadee			
Bird	*Parus bicolor*	Tufted titmouse			
Bird	*Passer domesticus*	House Sparrow		Breeder	
Bird	*Passerculus sandwichensis*	Savannah Sparrow	CT Special Concern & SGCN		Trocki and Paton 2003
Bird	*Picoides pubescens*	Downy Woodpecker		Breeder	
Bird	*Picoides villosus*	Hairy Woodpecker		Breeder	
Bird	*Pipilo erythrophthalmus*	Rufous-sided towhee	CT SGCN		Trocki and Paton 2003
Bird	*Piranga olivacea*	Scarlet Tanager	Regional Concern, CT SGCN	Breeder	Trocki and Paton 2003
Bird	*Quiscalus quiscula*	Common grackle			
Bird	*Sayornis phoebe*	Eastern phoebe			
Bird	*Scolopax minor*	American woodcock	CT SGCN	Probably Present	
Bird	*Seiurus aurocapilla*	Ovenbird	CT SGCN		Trocki and Paton 2003
Bird	*Setophaga petechia*	Yellow warbler			Faccio and Mitchell 2015
Bird	*Setophaga ruticilla*	American redstart			Faccio and Mitchell 2015

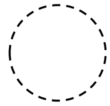
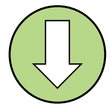
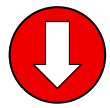
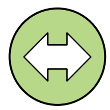
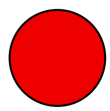
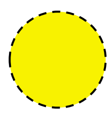
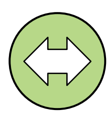
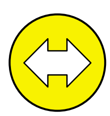
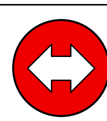
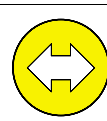
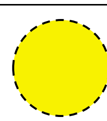
Category	Scientific Name	Common Names	Conservation Status	Comment	Cite
Bird	*Setophaga striata*	Blackpoll warbler			Faccio and Mitchell 2015
Bird	*Setophaga virens*	Black-throated green warbler			Faccio and Mitchell 2015
Bird	*Siala sialis*	Eastern bluebird			
Bird	*Sitta carolinensis*	White-breasted nuthatch			
Bird	*Spizella passerina*	Chipping Sparrow		Breeder	
Bird	*Spizella pusilla*	Field sparrow	CT SGCN		Trocki and Paton 2003
Bird	*Strix varia*	Barred owl			Faccio and Mitchell 2015
Bird	*Sturnus vulgaris*	Common Starling, European Starling		Breeder	
Bird	*Troglodytes aedon*	House wren			
Bird	*Troglodytes ludovicianus*	Carolina wren			
Bird	*Turdus migratorius*	American robin			
Bird	*Tyrannus tyrannus*	Eastern Kingbird	CT SGCN		Trocki and Paton 2003
Bird	*Tyto alba*	Barn Owl, Common Barn-Owl	CT Endangered & SGCN	Breeder	Trocki and Paton 2003
Bird	*Vermivora pinus*	Blue-winged warbler	CT SGCN	Probably Present	
Bird	*Vireo flavifrons*	Yellow-throated Vireo	Regional Concern, UCS		Trocki and Paton 2003
Bird	*Vireo gilvus*	Warbling vireo			Faccio and Mitchell 2015
Bird	*Vireo griseus*	White-eyed Vireo	CT SGCN		Trocki and Paton 2003
Bird	*Vireo olivaceus*	Red-eyed Vireo			
Bird	*Vireo solitarius*	Blue-headed Vireo, Solitary Vireo			
Bird	*Wilsonia pusilla*	Wilson's Warbler		Migratory	
Bird	*Zenaida macroura*	Mourning dove			
Fish	*Anguilla rostrata*	American eel	CT SGCN	Rare, Vagrant	

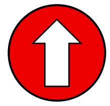
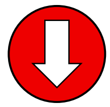
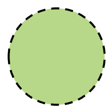
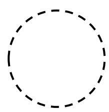
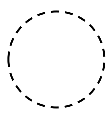
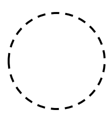
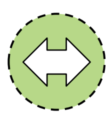
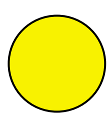
Category	Scientific Name	Common Names	Conservation Status	Comment	Cite
Fish	*Lepomis gibbosus*	Kiver, Pumpkinseed	CT SGCN	Breeder	
Fish	*Micropterus salmoides*	Largemouth bass		Non-native resident	
Insect - butterfly	*Celastrina ladon*	summer azure			Park files
Insect - butterfly	*Cercyonis pegala*	common wood nymph			Park files
Insect - butterfly	*Colias eurytheme*	orange sulphur			Park files
Insect - butterfly	*Colias philodice*	clouded sulphur			Park files
Insect - butterfly	*Danaus plexippus*	monarch			Park files
Insect - butterfly	*Epargyreus clarus*	silver-spotted skipper			Park files
Insect - butterfly	*Lycaena phlaeas*	American copper			Park files
Insect - butterfly	*Megisto cymela*	little wood-satyr			Park files
Insect - butterfly	*Papilio glaucus*	eastern tiger swallowtail			Park files
Insect - butterfly	*Papilio troilus*	spicebush swallowtail			Park files
Insect - butterfly	*Phyciodes tharos*	pearl crescent			Park files
Insect - butterfly	*Pieris rapae*	cabbage white			Park files
Insect - butterfly	*Poanes hobomok*	hobomok skipper			Park files
Insect - butterfly	*Polites mystic*	long dash			Park files
Insect - butterfly	*Polites themistocles*	tawny-edged skipper			Park files
Insect - butterfly	*Polygonia interragationis*	question mark			Park files
Insect - butterfly	*Pompeius verna*	little glassywing			Park files
Insect - butterfly	*Speyeria cybele*	great spangled fritillary			Park files
Insect - butterfly	*Thymelicus lineola*	European skipper			Park files
Insect - butterfly	*Vanessa cardui*	painted lady			Park files
Insect - butterfly	*Wallengrenia egeremet*	northern broken dash			Park files
Mammal	*Blarina brevicauda*	Northern Short-tailed shrew			Gilbert et al. 2008
Mammal	*Canis latrans*	Coyote			Gilbert et al. 2008
Mammal	*Castor canadensis*	Beaver			Gilbert et al. 2008
Mammal	*Didelphis virginiana*	Virginia opposum			Gilbert et al. 2008
Mammal	*Eptesicus fuscus*	Big Brown bat	CT SGCN	Breeder	Gates and Johnson 2012
Mammal	*Glaucomys volans*	Southern flying squirrel			Gates and Johnson 2012

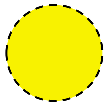
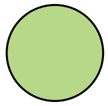
Category	Scientific Name	Common Names	Conservation Status	Comment	Cite
Mammal	*Lasiurus borealis*	Red bat	CT Special Concern & SGCN		Gates and Johnson 2012
Mammal	*Lasiurus cinereus*	Hoary bat	CT Special Concern & SGCN		Gates and Johnson 2012
Mammal	*Marmota monax*	Woodchuck		Resident	
Mammal	*Mephitis mephitis*	Striped skunk			Gilbert et al. 2008
Mammal	*Microtus pinetorum*	Woodland vole	CT SGCN		Gilbert et al. 2008
Mammal	*Mustela vison*	Mink			Gilbert et al. 2008
Mammal	*Myotis lucifugus*	Little brown myotis	CT Endangered & SGCN		Gates and Johnson 2012
Mammal	*Myotis septentrionalis*	Northern long-eared myotis	US Threatened, CT Endangered & SGCN		Gates and Johnson 2012
Mammal	*Odocoileus virginianus*	White-tailed deer		Resident	
Mammal	*Peromyscus leucopus*	White-footed mouse			Gilbert et al. 2008
Mammal	*Peromyscus maniculatus*	Deer mouse	CT SGCN		Gilbert et al. 2008
Mammal	*Procyon lotor*	Raccoon			Gilbert et al. 2008
Mammal	*Sciurus carolinensis*	Gray squirrel		Resident	
Mammal	*Tamias striatus*	Eastern chipmunk		Resident	
Mammal	*Vulpes vulpes*	Red fox			Gilbert et al. 2008
Reptile	*Chelydra serpentina serpentina*	Common Snapping Turtle		Resident	
Reptile	*Chrysemys picta*	Eastern Painted Turtle		Resident	
Reptile	*Clemmys guttata*	Spotted Turtle	CT SGCN	Resident	
Reptile	*Diadophis punctatus edwardsii*	Northern Ringneck Snake		Resident	
Reptile	*Nerodia sipedon sipedon*	Northern Water Snake		Breeder	
Reptile	*Terrapene carolina carolina*	Eastern Box Turtle, Woodland Box Turtle	CT Special Concern & SGCN		
Reptile	*Thamnophis sirtalis sirtalis*	Common Garter Snake		Breeder	

Appendix C: Vital Sign Report for Weir Farm NHS

Category	Vital Sign	Condition & Trend	Findings
Air and Climate	Ozone		Ozone pollution warrants *significant concern* for human health, and *moderate concern* for vegetation. Ozone pollution reflects regional trends resulting from activities occurring outside NPS boundaries.
	Acidic deposition & stress		Acidic deposition rates for both N and S have improved, but remain at levels which may cause harm to park ecosystems. Acidic deposition reflects regional trends resulting from activities occurring outside NPS boundaries.
	Visibility & particulate matter		Impaired visibility of park views due to anthropogenic haze warrants *moderate concern*. Natural light quality is an important data gap at WEFA. Visibility is impaired by pollution from activities primarily occurring outside NPS boundaries.
	Contaminants		Mercury deposition and transformation may cause harm to park ecosystems. Mercury deposition reflects regional trends resulting from activities occurring outside NPS boundaries.
	Climate & Phenology		Changes in temperature and precipitation over the historical record warrant *significant concern*. Climate change reflects global and regional trends resulting from activities occurring outside NPS boundaries.
	Soundscape		Modeled data suggest anthropogenic sound such as automobile traffic and aircraft overflights may reduce park listening area ≥ 50%. Soundscape is affected activities originating from both within and outside NPS boundaries.
	Lightscape		Modeled data suggest anthropogenic light sources visibly impact park views of the night sky. Lightscape is affected by sources originating from both within and outside NPS boundaries.
Geology and soils	Forest soil condition: Nitrogen saturation		Forest soil analysis warrants *significant concern* for nitrogen saturation, *moderate concern* for aluminum toxicity, and shows *good condition* for Base saturation. Forest soil condition is affected by activities occurring both within and outside NPS boundaries.
	Forest soil condition: Aluminum toxicity		
	Forest soil condition: Base saturation		

Category	Vital Sign	Condition & Trend	Findings
Water	Water quantity		Assessment points for water quantity are not defined. Water quantity is affected by factors originating from both within and outside NPS boundaries.
	Water chemistry		Water quality in Weir Pond shows *good condition*, but warrants concern for deteriorating trends in chloride and specific conductivity. Water chemistry is affected by activities originating from both within and outside NPS boundaries.
Biological Integrity	Invasive exotic plants: Forest		Invasion by exotic plants warrants *significant concern* in forest habitats and shows a deteriorating four-year trend. Weir Pond remains free of invasive exotic plants. The spread of invasive exotic plants is affected by activities occurring both within and outside NPS boundaries.
	Invasive exotic plants: Weir Pond		
	Invasive exotic animals		Detections of emerald ash borer and viburnum leaf beetle in Fairfield County warrant *significant concern*, and the Asian longhorned beetle also poses enormous threats to park forest resources. The spread of invasive exotic animals reflects regional trends resulting from activities occurring outside NPS boundaries.
	Wetland vegetation		Wetland vegetation is not monitored. However, preliminary assessment of wetland buffers indicated *moderate concern* for buffer width. Wetland monitoring could fill this data gap.
	Forest vegetation: Stand structure		WEFA forest is comprised primarily of mature and late-successional forest, which is considered *good condition*. Low levels of standing dead trees (snags) and coarse woody debris (CWD) warrant *moderate concern*. Low tree seedling densities warrant *significant concern*. Moderate tree foliage damage warrants *moderate concern*. Low tree growth rates may warrant *moderate concern*. Confidence in trends is low because plots have only been resampled once. Forest condition is affected by activities occurring both within and outside NPS boundaries
	Forest vegetation: Snags and CWD		
	Forest vegetation: Tree regeneration		
	Forest vegetation: Tree condition		
	Forest vegetation: Tree growth and mortality		

Category	Vital Sign	Condition & Trend	Findings
Biological Integrity	White-tailed deer herbivory		High deer density in Fairfield County warrants *significant concern* for impacts to vegetation. Assessment of deer-browse indicator species in forest plots indicated *moderate concern*. Roadkill data show an improving trend in deer density. White-tailed deer herbivory reflects regional trends resulting from activities occurring both within and outside NPS boundaries.
	Forest birds		Eight of thirteen forest bird condition metrics warranted *significant concern* for ecological integrity. Seven of thirteen metrics showed deteriorating trends. Bird condition reflects regional trends resulting from activities occurring both within and outside NPS boundaries.
	Amphibians and reptiles		Sensitive species, pond-breeding salamanders and vernal pool-breeding amphibians were well represented in the amphibian community at the time of the park inventory in 2000. However, monitoring data is not available and represents a data gap. Herptile condition reflects regional trends resulting from activities occurring both within and outside NPS boundaries.
	Bats		Population trends of bat species are an important data gap.
	Mammals		Population trends of select mammal species are a data gap.
	Terrestrial invertebrates		Population trends of select invertebrate taxa are a data gap.
Human Use	Visitor usage		Forest plots showed little sign of trampling. The four-year trend is unchanging.
Landscapes	Landcover / ecosystem cover / connectivity		Landcover was assessed for ecological integrity. Forest patch size is sufficient to support invertebrates, small mammals and many bird species but patch configuration and perforation has reduced the amount of interior or intact forest habitat. Landcover condition is affected by activities occurring both within and outside NPS boundaries.

Category	Vital Sign	Condition & Trend	Findings
Landscapes (continued)	Land use: Anthropogenic cover		Levels of anthropogenic land use surrounding forest plots may be a *moderate concern*. Coverage by impervious surfaces in the park is minimal. Land use condition is affected by activities occurring both within and outside NPS boundaries.
	Land use: Impervious surface		

NPS 413/133675, August 2016

National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov