National Park Service
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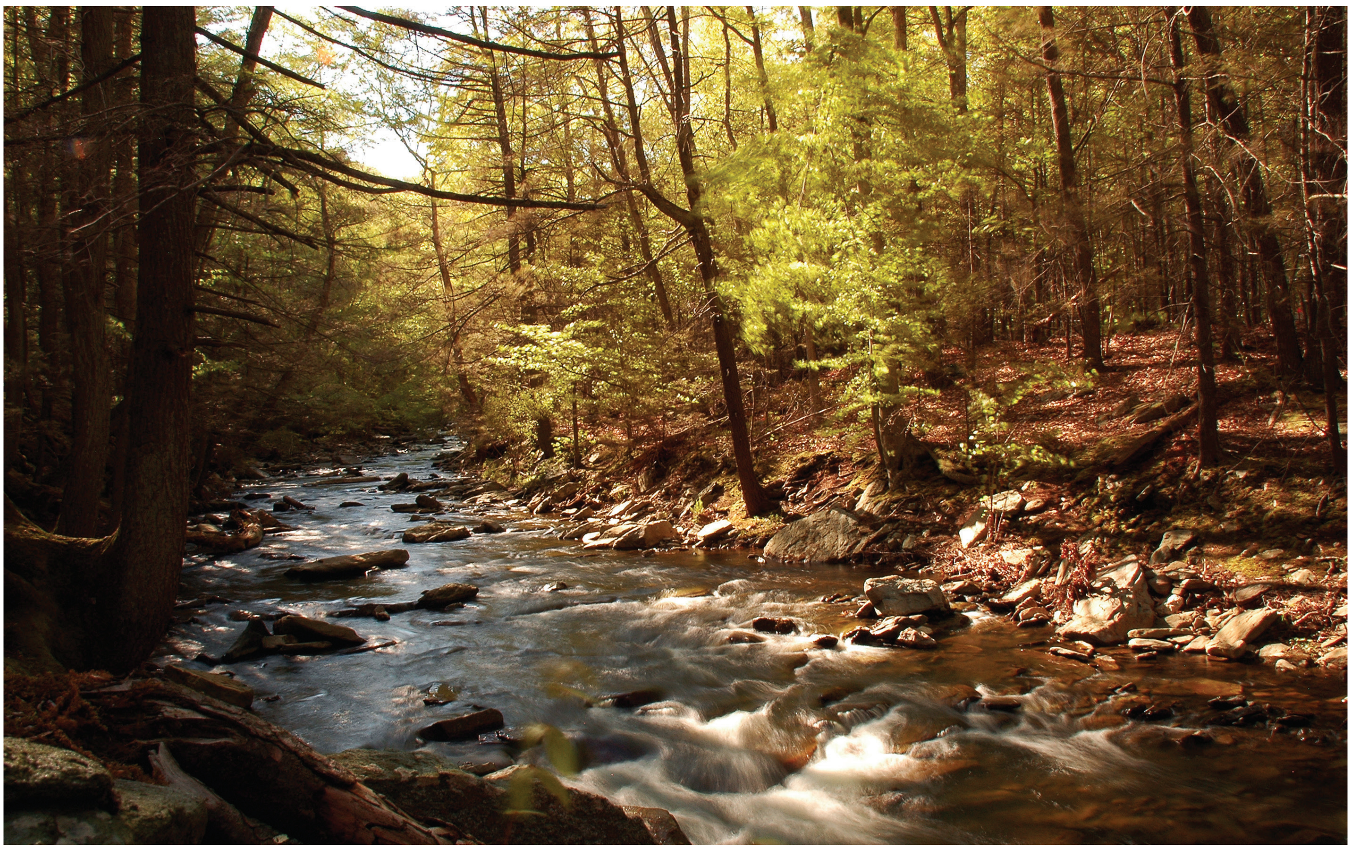
Natural Resource Stewardship and Science

Catoctin Mountain Park Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/CATO/NRR—2013/745



ON THE COVER

Catoctin stream.
Photo by Melanie Lukesh.

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Natural Resource Report NPS/CATO/NRR—2013/745

Jane E. Thomas, Simon D. Costanzo, R. Heath Kelsey, William C. Dennison
Integration & Application Network
University of Maryland Center for Environmental Science
PO Box 775
Cambridge, MD 21613

Patrick Campbell, Mark Lehman, Megan Nortup
National Capital Region Inventory & Monitoring
National Park Service
4598 MacArthur Blvd NW, Washington, DC 20007

P. Scott Bell, Becky Loncosky, Lindsey Donaldson
Catoctin Mountain Park
National Park Service
6602 Foxville Road
Thurmont, MD 21788-1598

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The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

This report is available from the National Capital Region Network website (*http://science.nature.nps.gov/im/units/ncrn/index.cfm*) and the Natural Resource Publications Management website (*http://www.nature.nps.gov/publications/NRPM*) on the Internet. To receive this report in a format optimized for screen readers, please email *irma@npa.gov*.

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Executive Summary

BACKGROUND

Emerging as a 10,000-acre Recreational Demonstration Area (RDA) out of New Deal legislation in the 1930s, Catoctin was transferred to the National Park Service by Executive Order 7496 dated November 14, 1936. Public Law 2852 dated June 6, 1942 required that all RDA project areas be maintained for “public park, recreational and conservation purposes”. Despite mostly forested land use surrounding the park, there are threats to the park from exotic species, nearby development, and regionally poor air quality.

Catoctin Mountain Park provides a wealth of natural resource values, largely resulting from the maintenance of forest and wetland habitats. The secondary growth forest, dominated by mixed oak–hickory communities, functions as a regional refuge for native flora and fauna.

Catoctin Mountain Park’s natural resources are challenged by multiple regional and local stressors. Air pollution from power plants, industry, and vehicle emissions result in reduced air quality through large regions of the central eastern seaboard of North America. The park is therefore subjected to high ozone and atmospheric deposition, potentially impacting flora, fauna, and park visitors. Watershed-wide urbanization and development result in challenges to water quality. Increased nutrients, pollutants, and flashiness of river flow can result in impacts to wetland flora and fauna as well as streambank erosion.

NATURAL RESOURCE CONDITION ASSESSMENT

Assessment of natural resource condition within Catoctin Mountain Park was carried out using the Inventory and Monitoring Program Vital Signs ecological monitoring framework. Twenty-five metrics were synthesized in four categories: Air Quality, Water Resources, Biological Integrity, and Landscape Dynamics. The assessment of condition was based on the comparison of available data collected between 2000 and 2011 to justified ecological threshold values.

Overall, the natural resources of Catoctin Mountain Park were in *moderate condition*.

ECOLOGICAL MONITORING FRAMEWORK

The Vital Signs framework showed that air quality condition was generally very degraded, water resources condition was generally very good, biological integrity condition was variable but moderate overall, and landscape dynamics condition was generally very good.

All air quality metrics were evaluted to be in conditions of significant concern, except particulate matter which was in moderate condition. All water resources metrics scored as very good, except total phosphorus which was very degraded, Benthic Index of Biotic Integrity which was good, and Physical Habitat Index which was partially degraded. Specific conductance showed a significant degrading trend. Biological integrity results were very variable. The park scored as very good condition for area of exotic trees and saplings, medium integrity for the Bird Community Index, moderate or fair condition for forest pests and Fish Index of Biotic Integrity, degraded condition for cover of exotic herbaceous species, and very degraded condition for the seedling stocking index and deer density. The park scored as very good for all landscape dynamics metrics except forest interior area at the 5x park area scale (good condition) and road density at the 5x park area scale (very degraded condition).

RECOMMENDATIONS AND DATA GAPS

Air quality was in a very degraded condition. Degraded air quality is a problem throughout the eastern United States, and while the causes of degraded air quality are out of the park’s control, the specific implications to the habitats and species in the

Natural resoures in Catoctin Mountain Park are in moderate condition overall but are under threat from surrounding land use, regionally poor air quality, and overpopulation of deer. Climate change is predicted to negatively affect many of the natural resources of the park.

park are less well known. Gaining a better understanding of how reduced air quality is impacting sensitive habitats and species within the park would help prioritize management efforts.

Despite mercury wet deposition data being available, there is no published reference condition for wet deposition. The only available reference condition for mercury is for fish tissue concentration—a human health threshold. As fish tissue concentrations are not regularly monitored, establishment of a wet deposition reference condition would give a better picture of the effect of mercury in the ecosystem.

Water resources were in very good condition overall. However, total phosphorus was in a very degraded condition, which is similar to results found in parks throughout the region. Specific conductance is currently in very good condition but is showing a general degrading trend, also in keeping with trends throughout the region. The Physical Habitat Index is on the borderline of being classified as being in degraded condition, so more data about sensitive locations and which parts of the index are failing would be informative. Data gaps and research recommendations revolve around maintaining good water quality by identification of nutrient sources and sensitive organisms

Biological integrity was in a moderate condition overall,although results for individual metrics were variable. Deer density and the seedling stocking index were both in very degraded condition. Studies show a relationship between high deer density and poor forest regeneration and as such, deer management should continue to be a top priority. Other monitoring recommendations include exotic species monitoring and education, and continuing to monitor pests and diseases. Data gaps and research needs include developing a bird index for non-forest species and modeling the effects of climate change and other stressors on the region's forests.

Landscape dynamics were in a very good condition overall. Forest interior area, forest cover, and impervious surface (at both spatial scales) were all in good or very good condition, as was road density within the park. This is due at least in part to the proximity of several protected areas—Cunningham Falls State Park immediately to the south of Catoctin Mountain Park, South Mountain Park to the north-east, and Seymour B. Cooper Memorial Wildlife Sanctuary to the east of the park. However, road density adjacent to the park was in very degraded condition, mostly due to the proximity of the towns of Thurmont to the south-east of the park and Cascade to the north of the park.

CONCLUSIONS

Natural resoures in Catoctin Mountain Park are in moderate condition overall but are under threat from surrounding land use, regionally poor air quality, and overpopulation of deer. Climate change is predicted to negatively affect many of the natural resources of the park, including increasing ozone levels and particle pollution, raising the water temperature of these cold-water, trout-supporting streams, changing forest composition, and affecting exotic species and forest pests and diseases.

Acknowledgements

Geoff Sanders, John Paul Schmit, Jim Pieper, Marian Norris, and NPS National Capital Region Inventory & Monitoring, who provided data support. Mel Poole, Superintendent at Catoctin Mountain Park. Holly Salazer, Air Resources Coordinator, Northeast Region and Ellen Porter, Drew Bingham, and John Ray, NPS Air Resources Division, for advice on air quality metrics. Katie Foreman, Chesapeake Bay Program for assistance with benthic metrics. Staff at the Center for Urban Ecology who assisted with data sourcing, scoping, and proofing. Tim Carruthers, Joanna Woerner, and Melissa Andreychek at the Integration and Application Network for assistance with project scoping and initiation.

Chapter 1: NRCA background information

1.1 NRCA BACKGROUND INFORMATION

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

NRCAs 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 logical reference conditions/values to compare current condition data against;[3,4]
- emphasize spatial evaluation of conditions and GIS (map) products;[5]
- summarize key findings by park areas;[6] and
- follow national NRCA guidelines and standards for study design and reporting products.

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

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "vital signs" monitoring indicators. They can also

***NRCAs strive to provide** credible condition reporting for a subset of important park natural resources and indicators*

Important NRCA success factors

Obtaining good input from park and other NPS subjective matter experts at critical points in the project timeline.

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

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

1. However, 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.
4. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management 'triggers').
5. As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products.
6. 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.

bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

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

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[7] and help parks report to government accountability measures.[8]

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

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

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA[9] Program information is posted at: *http://nature.nps.gov/water/nrca/index.cfm*

NRCA reporting products *provide a credible snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:*

- *Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)*
- *Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values*

7. NRCAs are an especially useful lead-in to working on a park Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project.
8. 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.
9. Acronyms are defined in Table B-3 in Appendix B.

Chapter 2: Introduction and resource setting

2.1 INTRODUCTION

Catoctin Mountain Park encompasses 2,376 ha (5,872 acres) of forested landscape located in the mountains of the Catoctin Ridge in north-central Maryland. It originated as a Recreation Demonstration Area under the National Industrial Recovery Act of 1933, and was transferred to the National Park Service in 1936. Catoctin Ridge is part of the Blue Ridge Mountains which are in turn part of the larger Appalachian Mountain chain.

The park area has witnessed Native American use, European settlement for subsistence and commercial farming, iron production and other industry, tourism, recreational hunting, and military usage (both during the Civil War and World War II).

The first wave of European settlers to Catoctin in the 1740s cleared forest land to farm small grains and livestock. Mountain and burned over land provided huckleberries, strawberries, grapes, and cherries (Wehrle 2000). An 1841 article in *The Baltimore Phoenix and Budget* newspaper recalled the idyllic state of the mountain and environs in the late eighteenth century: "At that period…almost uninterrupted forest; and game of various descriptions…the frightful shrieks of the howling wolf were heard at night." But "a few years brought the woodman's axe in fearful conflict with the mighty oak that had withstood the blasts of many winter, and the majestic trees whose towering height almost pierced the clouds all were laid low."

Farming, charcoal-making, timbering for sawmills, and wood-cutting to fuel iron production and other industry in the first 100 years of settlement decimated many tracts of old-growth forest and forest extraction continued into the 1920s. An operation making barrel staves and pins for mining cars closed in 1926 or 1927 after they finished cutting the last usable timber off Catoctin Mountain (Kirconnell 1988). Underbrush took over and the berries were gone. American Chestnut trees, decimated by chestnut blight, were gone completely from Frederick County by the early 1920s (Wehrle 2000).

Chimney Rock in Catoctin Mountain Park. Photo by NPS.

In 1935, as part of a New Deal program to develop recreation areas near urban populations and address the problem of farmers working "submarginal land," the federal government began purchasing mountain land at Catoctin for a planned "recreational demonstration area." Catoctin Mountain was considered a top candidate for redevelopment because of its "good roads," proximity to the nearby Appalachian trail, Hunting Creek (Wehrle 2000), and the cities of Washington, D.C. and Baltimore.

However, the acquisition and construction process of the park was anything but smooth. Local businessmen, vacationers, well-to-do fruit growers, and others owned mountain tracts alongside subsistence farmers. Government officials trying to purchase land experienced resistance to their efforts (Wehrle 2000).

Eventually though, purchase of land was completed. The new 10,000-acre Catoctin Recreation Demonstration Area (RDA) consisted, according to a NPS official, of an estimated 90% cut over forest tracts, and

10% "tillable land and pasture." Only a few inaccessible tracts still contained marketable timber. Between the tree harvesting and recent chestnut blight, the wooded areas on the mountain were in poor condition (Wehrle 2000).

Initial work by the Work Progress Administration (WPA) and the Civilian Conservation Corps (CCC) focused on blazing trails, reforestation, and improving Hunting and Owen's Creeks by clearing obstructions and building small dams for fishing. Miles of old roads and fences (made of stones wrapped in wire) had to be obliterated, thousands of blighted chestnut trees were to be removed, and farm buildings awaited demolition. Then came tree planting and the construction of new roads, trails, and structures for the RDA (Wehrle 2000).

In 1942, in light of WWII, the park was chosen to serve new federal uses. A presidential retreat (known as Shangri-La) was established at Camp Hi-Catoctin, formerly a family camp for federal employees. It not only offered the president a respite from Washington's humid summers, but became a protected meeting place for Churchill and Roosevelt. In spring of the same year, Camp Greentop, originally built as a camp for handicapped children, was taken over by the Office of Strategic Services (OSS) for use as a spy training site. Public use of the park was closed to civilians but later restored after the war's end.

Like other RDAs across the nation, the federal government had the expressed intention of eventually returning Catoctin to the state of Maryland. However with the establishment of the presidential retreat, plans changed. In 1951, a compromise agreement allowed the National Park Service to retain a large portion of the originally-purchased area, while the state of Maryland took over the southern portion of the park below Route 77 (Wehrle 2000).

The park today still sits within a relatively rural landscape. Cunningham Falls State Park (originally the southern half of Catoctin RDA) adjoins the park. Second-growth forests continue to regenerate from previous eras of exploitation. Yet recoveries cannot undo all the loss. Records summarized in the park's 1998 Resource Management Plan state that "of the native animal species known to historically range within the area of Catoctin Mountain Park, the bison, elk, gray wolf, eastern cougar, porcupine, and fisher have been extirpated."

Still the park offers much to visitors and remains a secluded escape from nearby urban areas.

2.1.1 Park enabling legislation

Several laws and documents guide natural resource management for Catoctin Mountain Park—the National Park Service Organic Act of 1916 ("Organic Act," Ch. 1, 39 Stat 535), and Public Law 594 on the use of Recreation Demonstration Areas (1942). Other guidance documents include the NPS Management Policies (U.S. Dept of Interior 2006) and the 1998 Catoctin Mountain Park Resource Management Plan.

The Organic Act that established the National Park Service (NPS) on August 25, 1916 provides the primary mandate NPS has for natural resource protection within all national parks. It states,

> *"the Service thus established shall promote and regulate the use of Federal areas known as national parks, monuments and reservations . . . by such means and measures as conform to the fundamental purpose of the said parks, monuments and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."*

Consequently, like all parks in the National Park system, one of Catoctin Mountain Park's chief mandates is to preserve the scenery and the natural and cultural resources of the park. Any visitor activities associated with enjoyment can occur only to the extent that they do not impair the scenery and the natural resources for future generations.

The park exists in its present state due to a series of unique circumstances. There is no legislation establishing the area as a "national park" (NPS 1988). The original authority to acquire Catoctin's lands began with the Emergency Relief and Construction Act of 1932. That legislation authorized the acquisition of land for "… emergency construction of public building projects outside the District of Columbia…" with the intention that this "…be used in furnishing relief and work relief to needy and distressed people and in relieving the hardship resulting from unemployment…" Originally 4,050 ha (10,000 acres) were designated as Catoctin Recreation Demonstration Area under the National Industrial Recovery Act on February 7, 1935. In 1936, the RDA was transferred from the Resettlement Administration to the National Park Service via Executive "Order # 7496.

Public Law 594 of June 6, 1942, provides general guidelines that the recreation demonstration area should be used, exclusively for "public park, recreational, and conservation purposes."

RDAs were originally intended to revert to the state, but due to the presence of the presidential retreat, only a partial transfer of 1,799 ha (4,446 acres) was made to the state of Maryland (the present day Cunningham Falls State Park). The rest of the RDA was kept in federal hands and was renamed Catoctin Mountain Park. Although officially recognized, there was no enabling legislation passed for the park or mission statement completed (NPS 1988).

According to the park's draft Foundation Document (NPS 2012c), the purpose of Catoctin Mountain Park is

> *to provide quality recreational opportunities in the Catoctin Mountains and serve as a setting and buffer for the presidential retreat, while protecting and conserving the park's natural and cultural environments as envisioned by New Deal conservation programs.*

Blue Blazes Creek in Catoctin Mountain Park. Photo by NPS.

2.1.2 Geographic setting

Park description

Catoctin Mountain Park (CATO) is located in Frederick County, MD (with the extreme western edge of the park being located in Washington County) in north-central Maryland (Figure 2.1). It is situated on the eastern slopes of Catoctin Mountain in the northern end of the Blue Ridge physiographic province of the Appalachian Mountains, which extends from Georgia to Pennsylvania (Thorneberry–Ehrlich 2009).

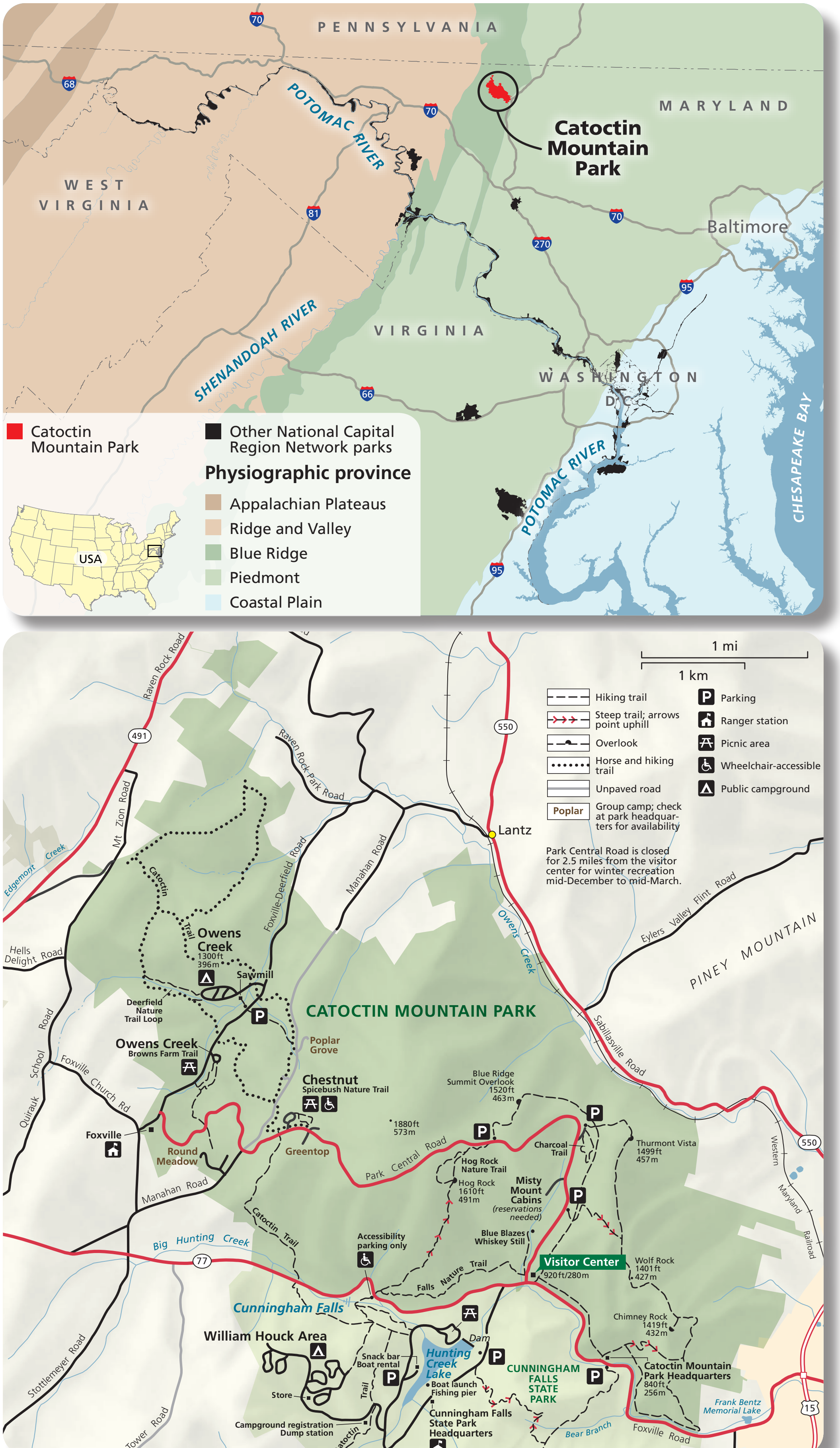
The park is largely composed of hills, ridges, valleys, and ravines, and nearly 97% of the park is forested although in most places, the forest is less than 100 years old. Other habitats include wetlands and streams, as well as approximately 120 ha (300 acres) of developed zones (NPS 2008a).

Land use

Land use in a 30-km radius around CATO is mostly forested to the north and southwest of the park, due to the presence of municipal and state parks in both Maryland and Pennsylvania along the mountains of the Blue Ridge (Figure 2.2).

To the east and west is a mixture of agricultural (pasture/hay and crops) and developed lands (namely the cities of Frederick to the south and Hagerstown to the west) (Figure 2.3).

Figure 2.1. Location of CATO in northern Maryland.



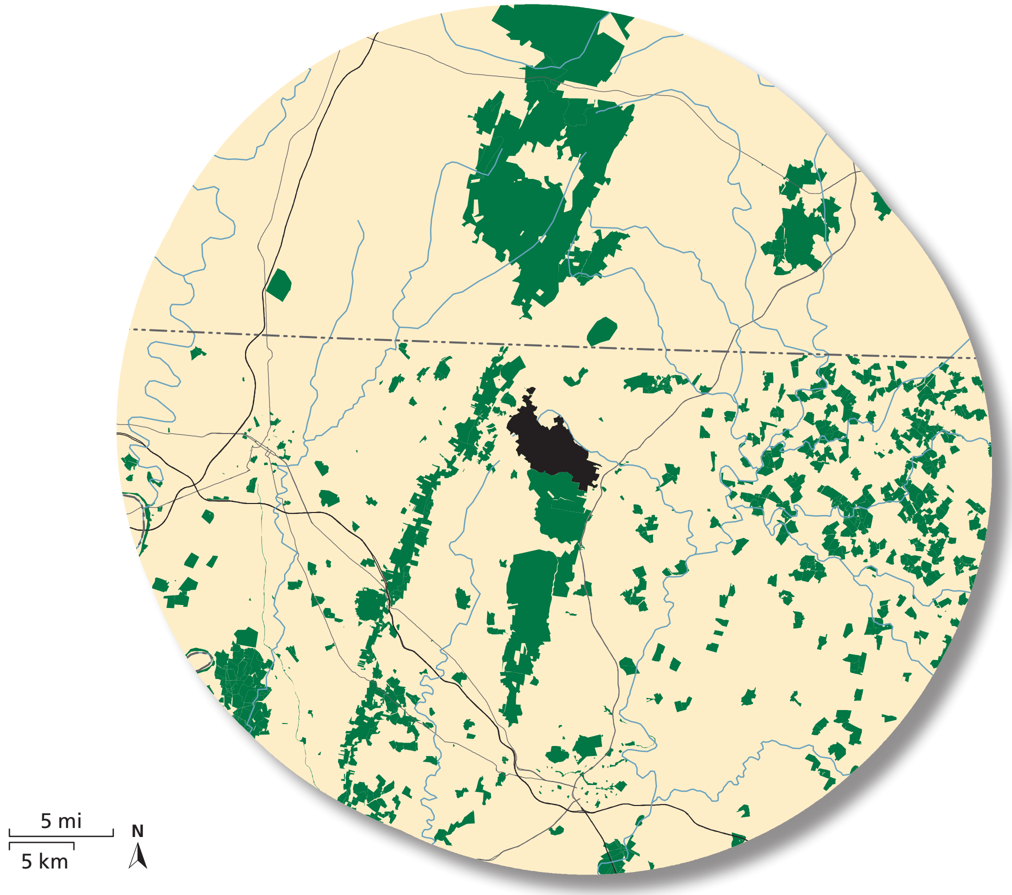


Figure 2.2. Protected areas within a 30-km area surrounding CATO in 2011 (NPS 2010a, 2011, USGS 2011).

Protected areas

- Protected areas
- Streams and waterbodies
- State boundaries
- Interstates
- Highways
- CATO boundary

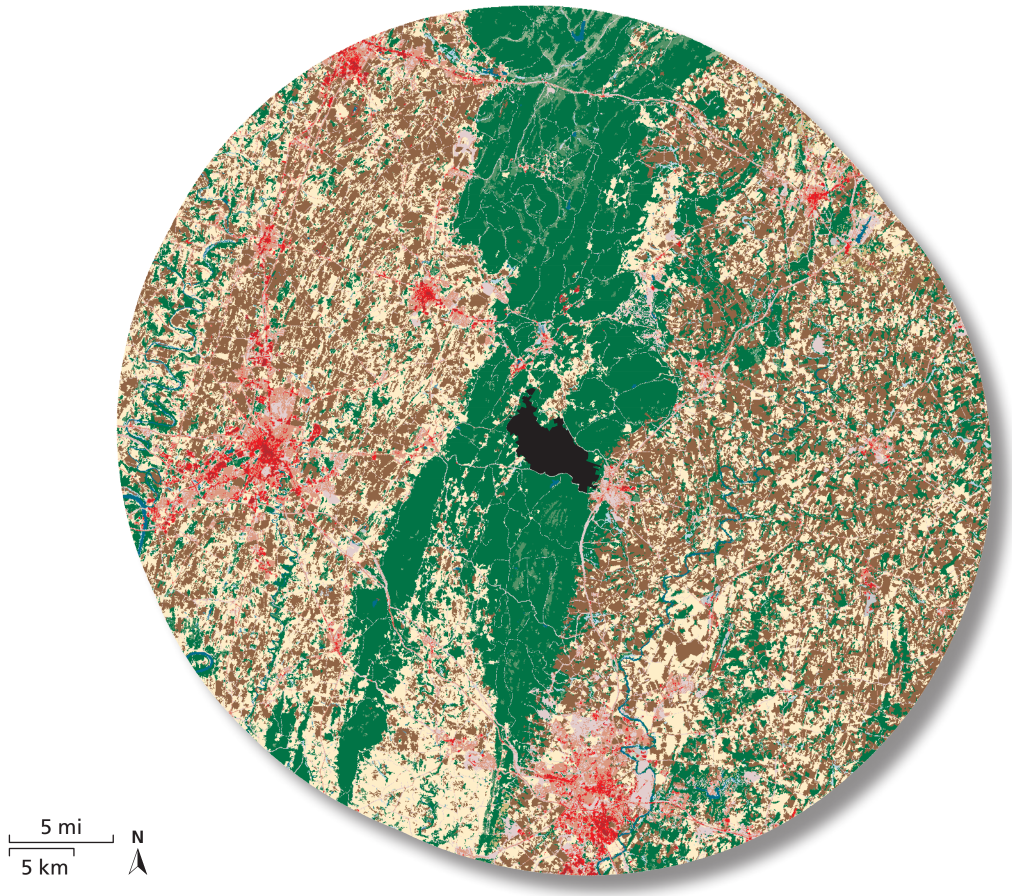


Figure 2.3. Land use within a 30-km area surrounding CATO in 2006 (Fry et al. 2011, NPS 2011).

Land use

- Open water
- Developed, open space
- Developed, low intensity
- Developed, medium intensity
- Developed, high intensity
- Barren land (rock/sand/clay)
- Deciduous forest
- Evergreen forest
- Mixed forest
- Shrub/scrub
- Grassland/herbaceous
- Pasture/hay
- Cultivated crops
- Woody wetlands
- Emergent herbaceous wetlands

- CATO boundary

Population

Frederick County's population has grown considerably in recent years, increasing 19.5% between 2000 (population of 195,277) and 2010 (population 233,385), compared to 9.0% statewide, making it the third-fastest-growing county in Maryland (U.S. Bureau of the Census 2012a). The population in adjacent Washington County has also undergone considerable growth, increasing 11.8% between 2000 and 2010, from 131,923 to 147,430 (U.S. Bureau of the Census 2012b). To the north of the park, Adams County, PA has grown 11.1% during the period 2000–2010, compared with 3.4% statewide (U.S. Bureau of the Census 2012c). This has led to an increase in both housing and population density surrounding the park (Figures 2.4, 2.5).

Climate

Catoctin Mountain Park and the surrounding area generally experience a mild, four-season climate, but can experience extreme weather at times. The park averages 1.3 m (50 inches) of precipitation annually, with monthly distribution being fairly even throughout the year (Western Regional Climate Center 2012a). Average snowfall is 80 cm (32 inches) per year (Western Regional Climate Center 2012b).

Summers are warm, with high temperatures averaging around 27°C (80°F) but can exceed 32°C (90°F). Winter lows average around 4.5°C (24°F) but lows have been recorded at –28°C (–18°F) (The Weather Channel 2012).

2.1.3 Visitation statistics

Annual visitation to CATO has declined in recent years, numbering 263,105 in 2012, down from a high of nearly 700,000 in 2004 (NPS 2010c) (Figure 2.6). Visitation to the park is highest from May through October, reflecting the popularity of spring flower viewing, hiking, and viewing fall foliage. Seasonal events hosted by park staff, particularly in the spring and fall, may also be responsible for higher visitation during these months (Le and Littlejohn 2003, NPS 2008a).

A 2002 visitor study found that the most common activities undertaken by visitors to CATO were viewing wildlife and scenery, driving through, hiking, picnicking, photography, and camping. The most-visited areas of the park were the Visitor Center, Chimney Rock Vista, and Hog Rock Vista (NPS 2002).

2.2 NATURAL RESOURCES

2.2.1 Resource descriptions

Natural resources in the park, and threats to those resources, are depicted in Figure 2.7.

Geology

Catoctin Mountain forms the easternmost portion of the Blue Ridge physiographic province of Maryland and northern Virginia as a belt of Lower Cambrian sediments and older metamorphosed volcanic rocks (Thorneberry–Ehrlich 2009). The topography in the park consists of rolling hills and narrow ridgetops separated by steep-sloped valleys and ravines. The landscape within the park is largely a function of the different types of underlying bedrock. The ridgetops are composed of resistant late Precambrian to early Paleozoic metamorphic rocks of the Catoctin Formation and Chilhowee Group (Loudoun, Weverton, Harpers, and Antietam formations) (Figure 2.8). The Catoctin Formation contains metamorphosed volcanic rocks associated with ancient continental rifting. The quartz-rich rocks of the Chilhowee Group began as fluvial sediments deposited atop the volcanic rocks. Valleys separate the ridgetops now that less resistant units have eroded. Relief varies from lower elevations of approximately 190 m (620 ft) above sea level in the southeast of the park to nearly 488 m (1,600 ft) at Hog Rock and 573 m (1,880 ft) at Camp 3 (Trombley and Zynjuk 1985). Catoctin Mountain rises to 579 m (1,900 ft) outside the park (Thorneberry–Ehrlich 2009) (Figure 2.9).

Soils

Soils on the eastern slope of Catoctin Mountain within and surrounding the park were derived from erosion of the Weverton Formation (quartzite) (Figure 2.10). They are acidic, thin, sandy loams with high permeability. In contrast, soils derived from the Catoctin Formation (greenstone), typical on the western side of the park, are deeper and more moist, orange, clayey, and rich in calcium and magnesium (Southworth and Denenny 2006).

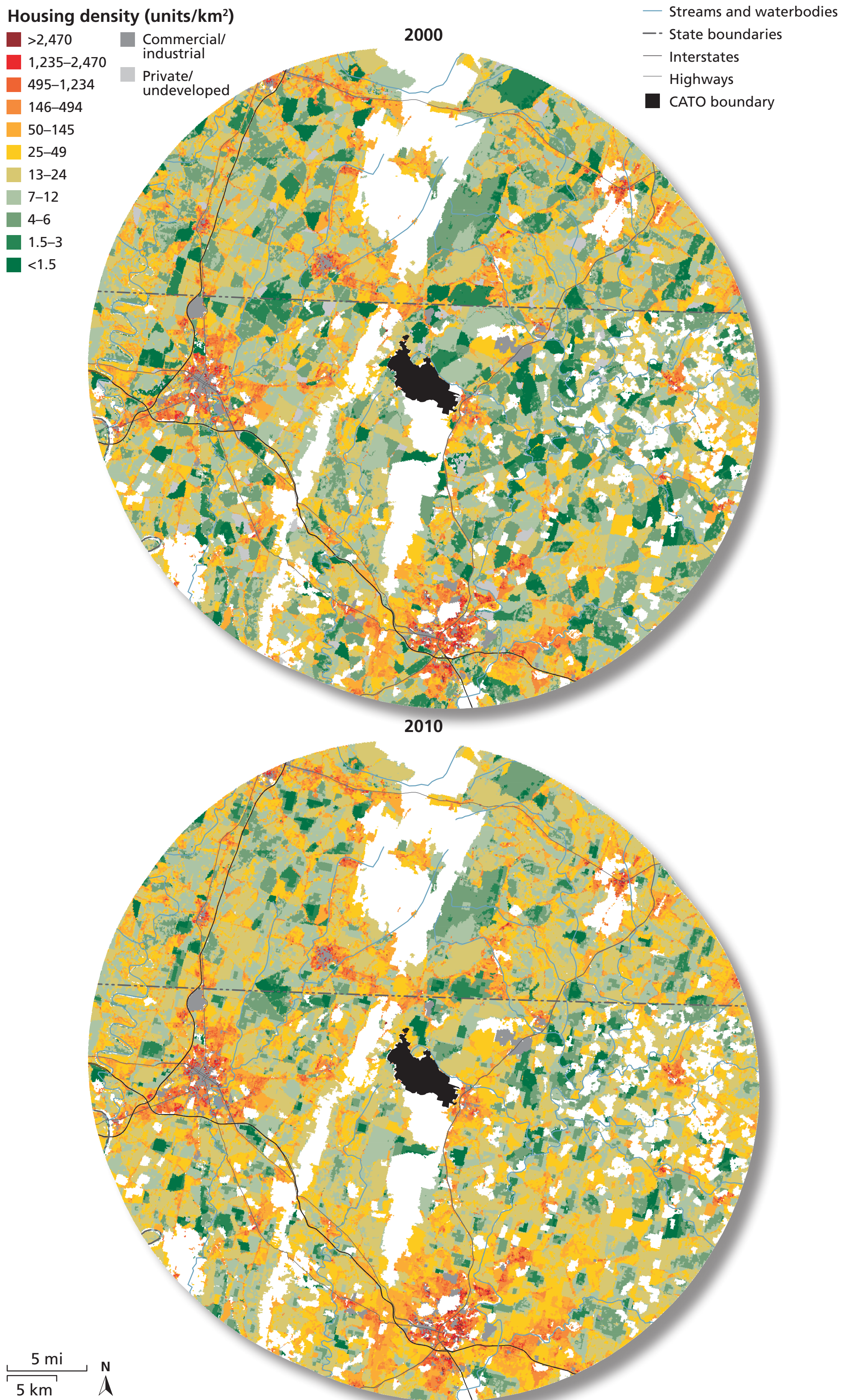
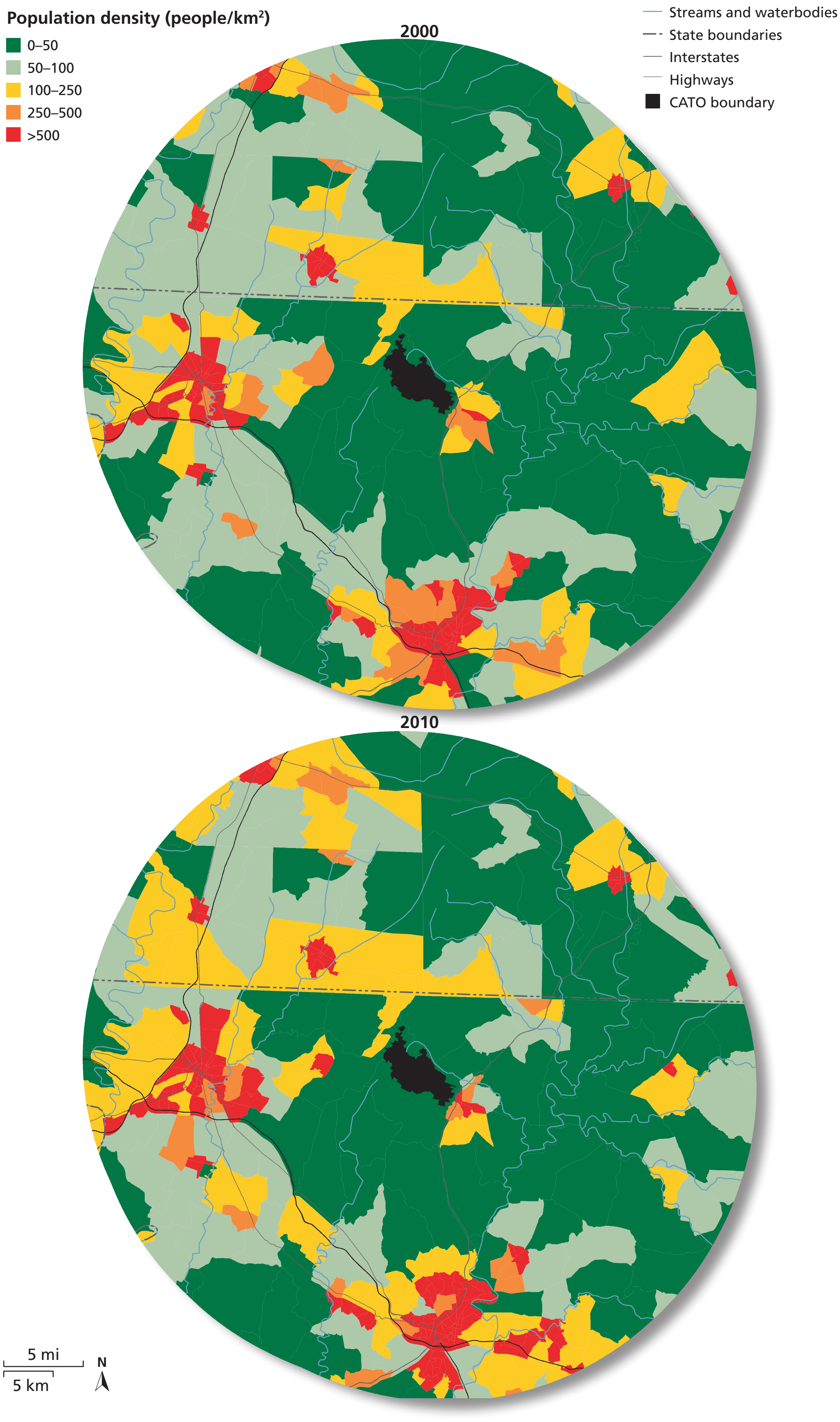
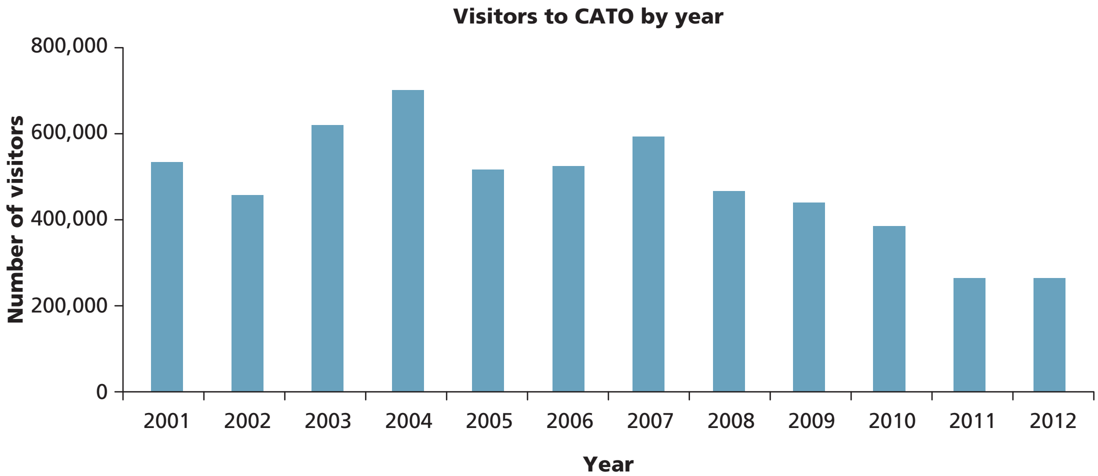


Figure 2.4. Housing density within a 30-km area surrounding CATO in 2000 and 2010 (NPS 2010a, 2011).

Figure 2.5. Population density within a 30-km area surrounding CATO in 2000 and 2010 (NPS 2010a, 2011).





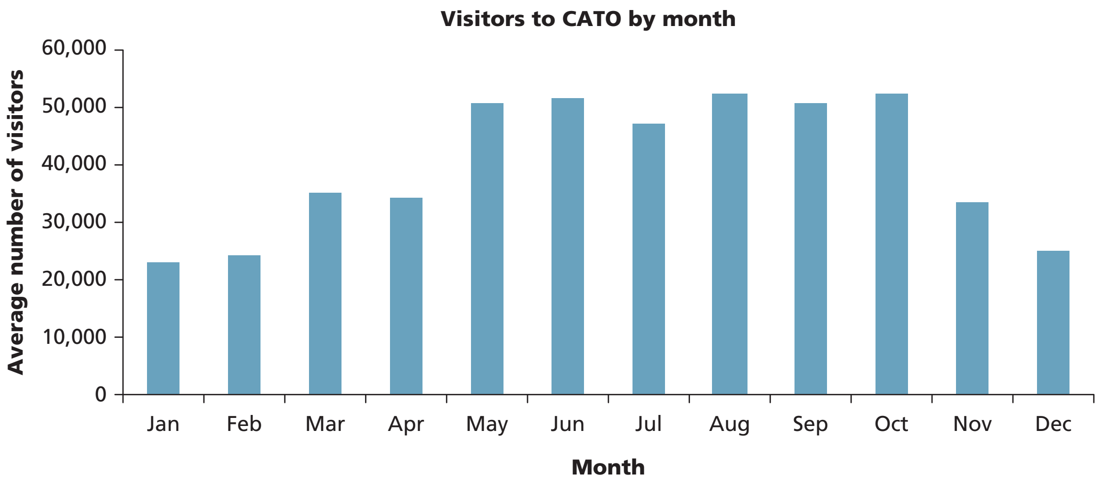


Figure 2.6. Visitors to CATO over the past decade by year and by month (NPS 2010c).

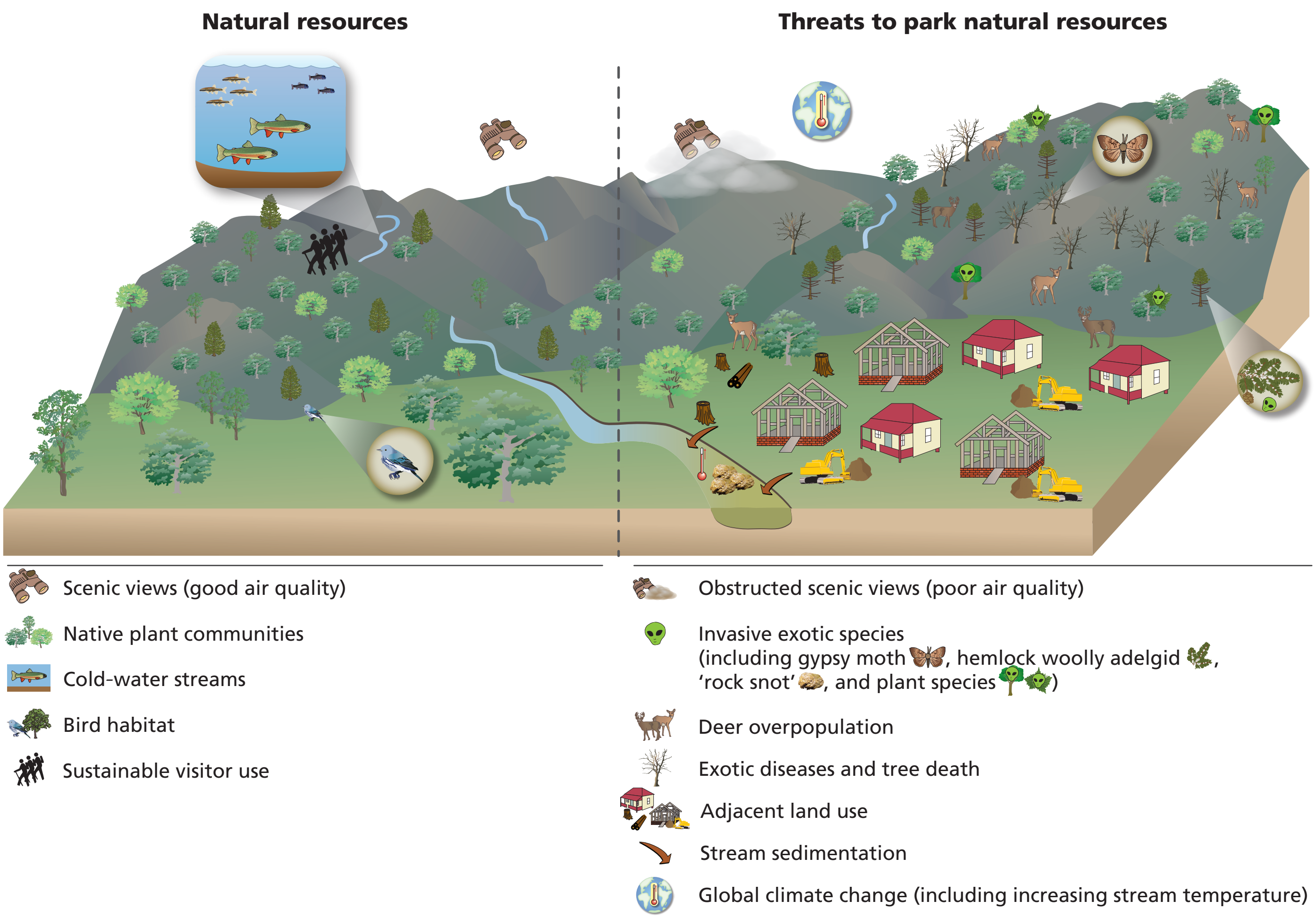


Figure 2.7. Features of and threats to the natural resources of Catoctin Mountain Park.

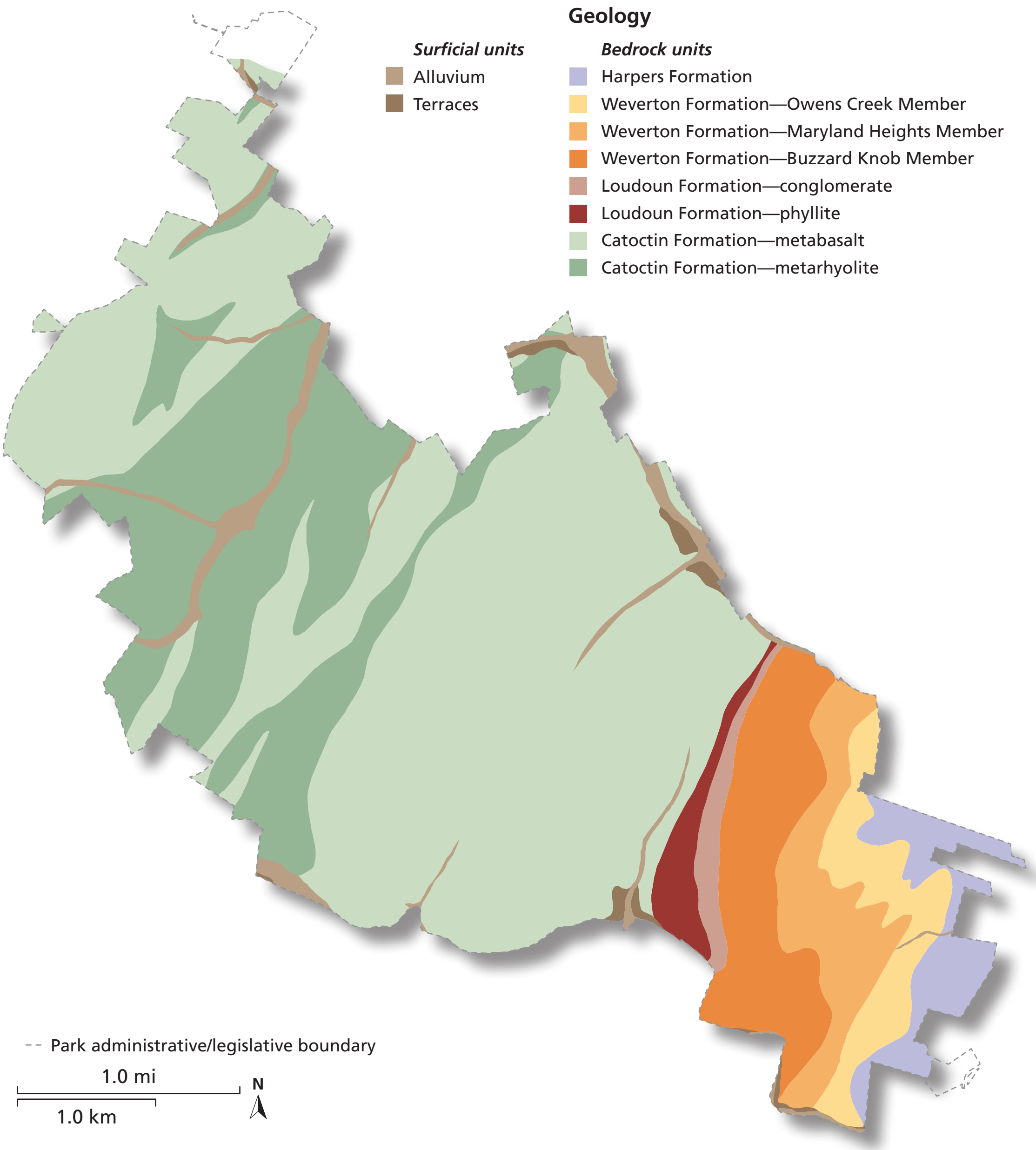
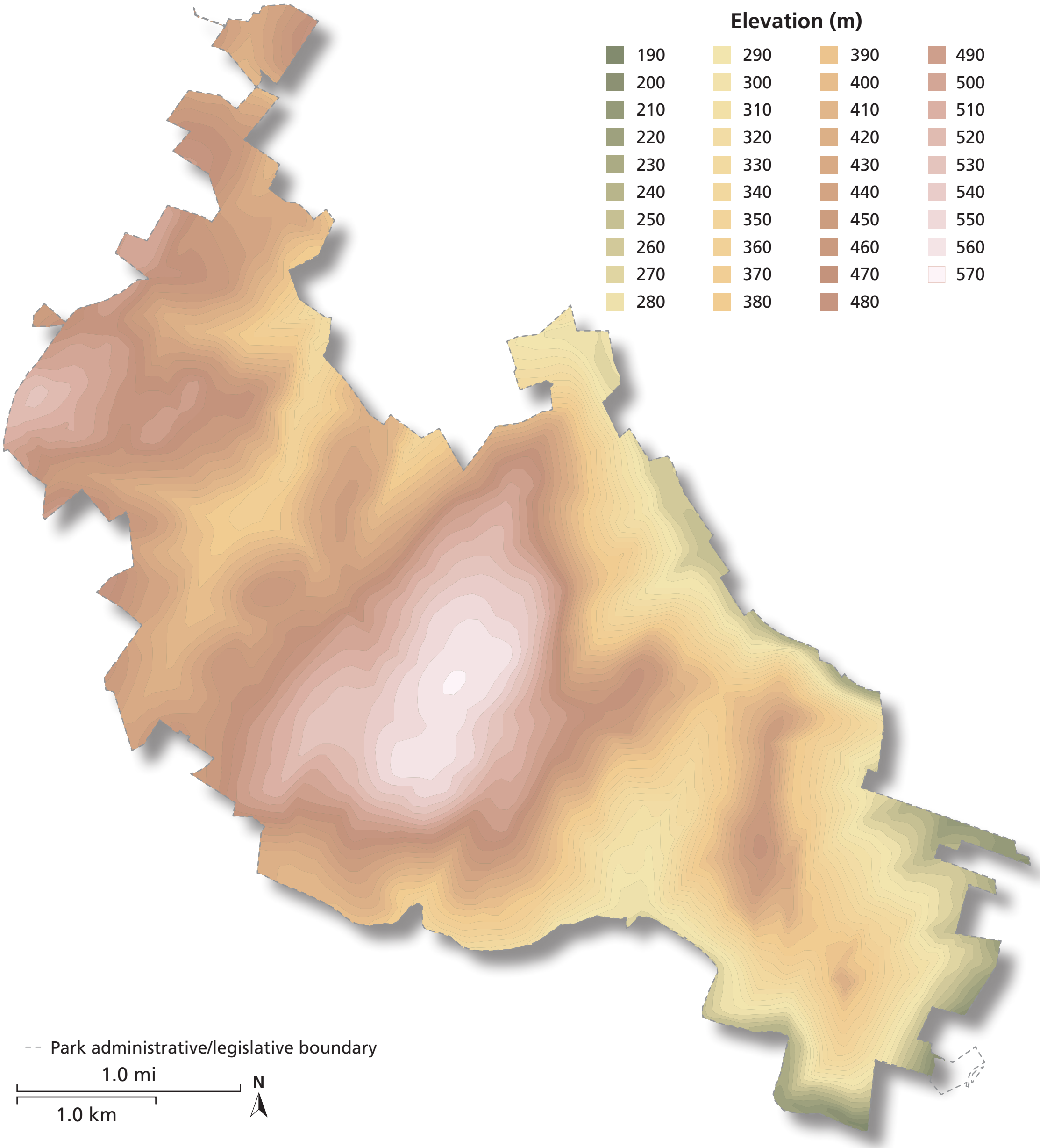


Figure 2.8. Geology of CATO (Thorneberry–Ehrlich 2009).

Figure 2.9. Topographic elevation of CATO (Gesch 2007).



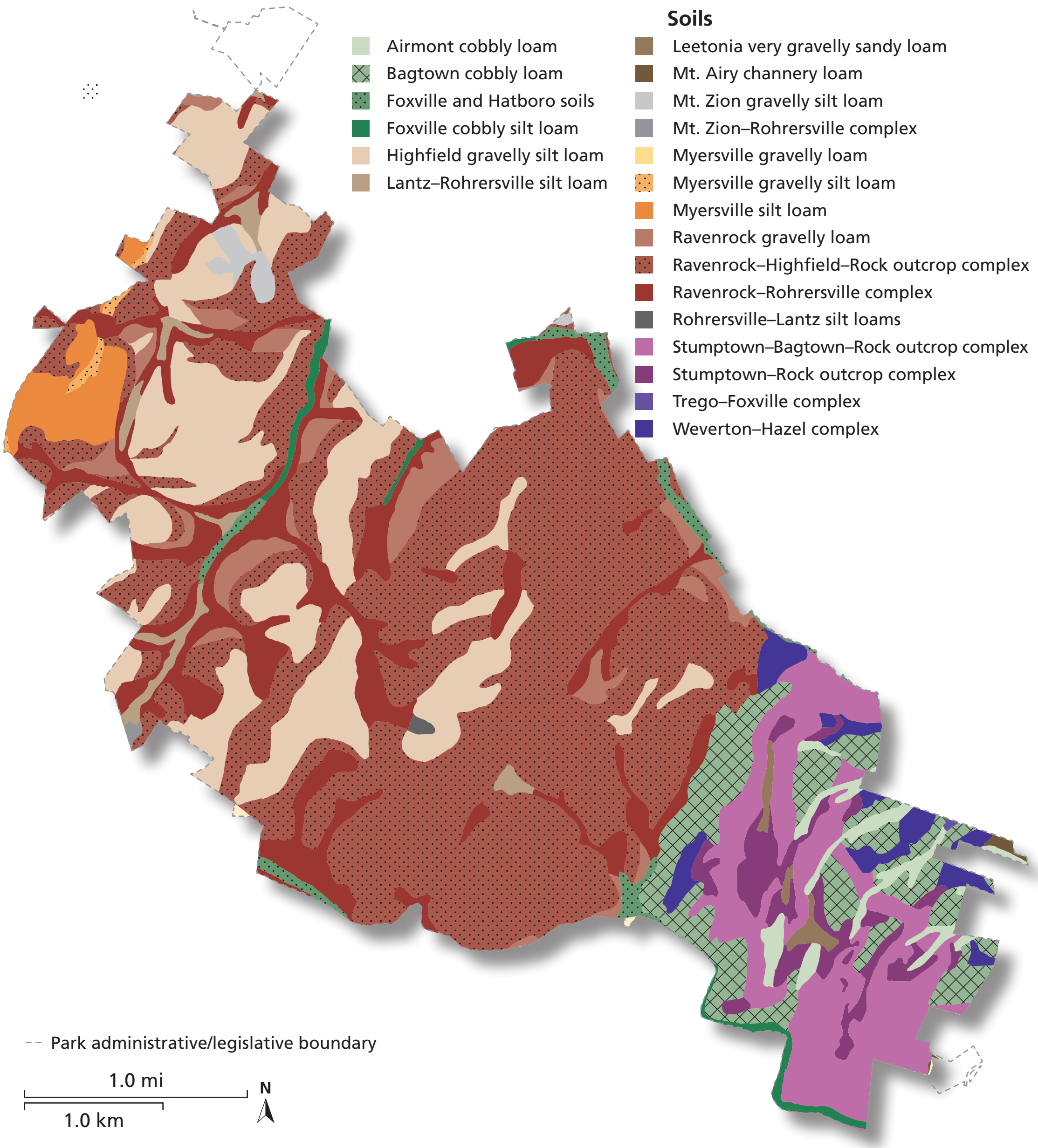


Figure 2.10. Soils of CATO (NPS 2008b, National Cooperative Soil Survey 2009).

Figure 2.11. Watersheds of the major streams within CATO (USGS EDNA watersheds, ESRI).

Waterways

Two main perennial streams flow through the park and drain its two principal watersheds—Big Hunting Creek and Owens Creek (Figure 2.11). These creeks drain to the Monocacy River and ultimately the Potomac River, Chesapeake Bay, and the Atlantic Ocean (Figure 2.12).The water quality in these streams is very good and both are classified by the state as Class III-P: Nontidal Cold Water and Public Water Supply. This indicates that the waters are suitable for the growth and propagation of trout, capable of supporting self-sustaining trout populations and their associated food organisms, and suitable for use as a public water supply (COMAR 2007a, b).

Big Hunting Creek consists of four perennial tributaries and numerous intermittent, unnamed tributaries. Although the park comprises only 7% of the Big Hunting Creek drainage basin, the creek drains 34.5% of the park (NPS 1998). The rest of the watershed lies outside park boundaries. Developed areas in the park occurring within the creek's watershed include Camp Greentop, Camp Round Meadow, and Camp Misty Mount; the maintenance yard; the visitor center; and the administration office. Runoff from these areas enters Big Hunting Creek, as does runoff from Park Central Road, Maryland Route 77, and Camp 3 (NPS 2008a).

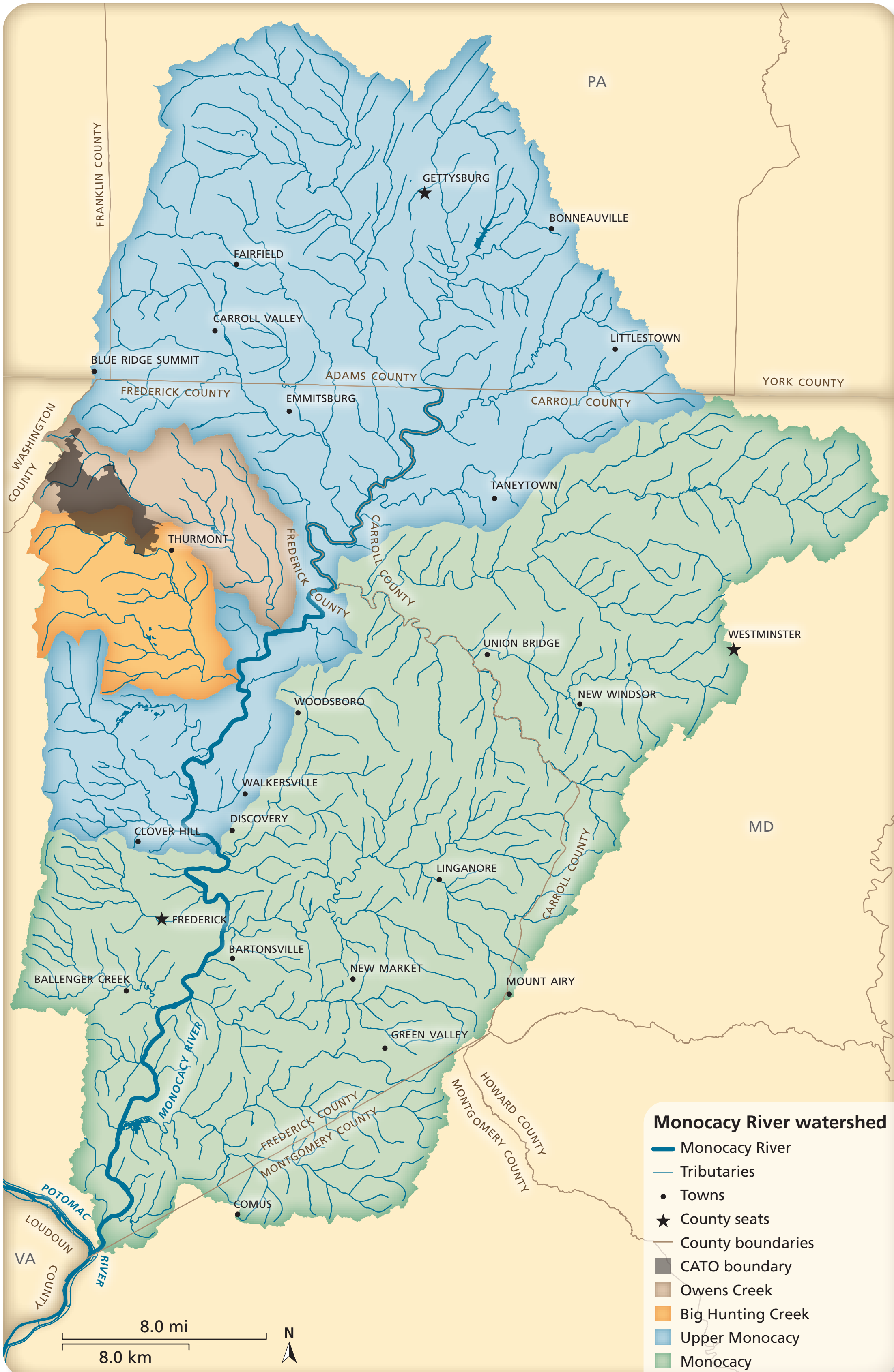


Figure 2.12. Watersheds of the major streams within CATO (USGS EDNA watersheds, ESRI).

Catoctin stream. Photo by M. Valcarcel.

The gradient of Big Hunting Creek varies greatly. From its headwaters outside the park to Cunningham Falls, the gradient is low and the stream is little more than finger-like rivulets that run down from the farms and lots bordering the park to the west and southwest (NPS 1998). From the falls to the east boundary of the park, the gradient is very steep, and the stream is full of large rocks and boulders with many clean gravel bars. In a few places, the stream bottom is bedrock with little gravel or sediment (NPS 2008a). The gradient of the last section of stream before leaving the park is moderate.

Blue Blazes Creek, a small tributary of Big Hunting Creek, lies entirely in the park and contains a small population of brook trout. Very little understory or ground cover occurs in this stream valley, with an obvious deer browsing line and a fair amount of sediment in the stream (NPS 2008a).

Owens Creek consists of six perennial tributaries and numerous, intermittent, unnamed tributaries. Owens Creek drains 64% of the park, equivalent to 14.5% of its total watershed (NPS 1998). Developed park areas that drain into Owens Creek include Camp Round Meadow, Camp 3, both government housing facilities, the Owens Creek and Chestnut picnic areas, and the Owens Creek campground (NPS 2008a). A park wastewater treatment plant at the head of the creek discharges directly into the stream and wetlands area where Owens Creek originates (NPS 1998).

A moderate gradient stream, Owens Creek contains a healthy population of brook trout. This creek begins primarily on the park's west side and flows north, where it leaves the park and flows through an agricultural area before briefly entering the park again for 400 m (0.25 mile). The creek skirts the park boundary for three kilometers (two miles). The general terrain of Owens Creek is not as rocky as Big Hunting Creek, and the bottom is a combination of silt, gravel, and small rocks. There is a fair amount of bank erosion, and the stream channel is changing. The most prominent tributary of Owens Creek within the park, Ike Smith Creek, has significant erosion problems (NPS 2008a).

In 1978, Catoctin Mountain Park began a long-term water quality monitoring program to closely monitor for signs of pollution and other problems within Big Hunting and Owens Creeks. The program entails analyzing monthly water samples from nine locations within the park for temperature, dissolved oxygen, pH, ammonia, salinity, specific conductivity, turbidity, and alkalinity (see section *4.2—Water Resources*). Turbidity is an indirect measure of sediment in the water and can be an indicator of problems with soil erosion.

Turbidity levels in Owens and Big Hunting creeks are very low. As a general guide, water begins to appear cloudy when the turbidity is greater than 5 NTU (nephelometric turbidity unit). Since monitoring began on a monthly basis in 1978, turbidity levels in the two creeks has exceeded 5 NTU in 7.8% (114) of the water samples, with only 11 samples exceeding 5 NTU since the beginning of 2000.

Biologists from the Maryland Department of Natural Resources have conducted macroinvertebrate sampling on Owens Creek and Big Hunting Creek since 1981. Aquatic macroinvertebrates are organisms highly sensitive to environmental factors, and the sampling of these animals can offer additional information about water quality and the impacts of pollution. These organisms can be seen with the naked eye and include insects, crustaceans, mollusks, and annelids. The sampling program reflects the high diversity of these organisms in both Owens Creek and Big Hunting Creek, including more than 90 taxa of insects (NPS 2000a), indicating very good water quality in the two streams.

Wetlands

Wetlands are interspersed with the forest environments at Catoctin Mountain Park. Wetlands sustain significant biodiversity and are vital components of healthy ecosystems. They provide unique habitat, help control erosion and regulate flooding, and recharge groundwater and streamflow in drought years. Wetlands also act as natural filters for impurities and pollution in the water. To be classified as a wetland, an area must meet three criteria: (1) include hydric soils (be waterlogged for at least one to two weeks per year); (2) contain more than 50% of its total vegetation as designated wetland plants; and (3) possess signs of hydrology, including, but not limited to, drift lines, flow patterns, flood-related tree debris, and muddy substrate. There are 18 wetland areas at Catoctin Mountain Park, covering nearly 58 ha (143 acres) adjacent to streams.

The Owens Creek and Hog Rock wetlands are considered sensitive habitats due to the occurrence of sensitive plant species and high plant diversity (NPS 2008a).

The Owens Creek wetland is an approximately 5-ha (12-acre) area that occurs in association with a riparian habitat along Owens Creek. The wetland occurs at an elevation of 400 m (1,300 ft) and is between the Owens Creek picnic area and campground. The Nature Conservancy designated the wetland an outstanding Maryland natural area in 1983 due to its unique assemblage of plants (NPS 1994). At least three state-listed plant species occur in the wetland, including long-bracted orchid (*Coeloglossum viride*), which is state-endangered, and large purple-fringed orchid (*Platanthera grandiflora*) and leatherwood (*Dirca palustris*), which are state-listed threatened species. Other common plant species occurring within the Owens Creek wetland are listed in Table 2.1.

The approximately 0.1-ha (0.3-acre) Hog Rock wetland is adjacent to Hog Rock at an elevation of 500 m (1,660 ft), making it the highest wetland habitat in the park. There are no known state-listed species in the wetland, but the high diversity of plant species in this small habitat makes the area unique. Table 2.2 lists the plant species occurring within the Hog Rock wetland area.

Flora

Native flora

The forest at Catoctin Mountain Park in most places is less than 100 years old, with plant communities reflecting the park's varying past uses, as well as the natural influences of soil and exposure on vegetation types (Hickey 1975). Over 700 species of vascular plants have been recorded in the park, including 60 tree species and 50 shrub species (Warner 1972; Hickey 1975; Anderson et al. 1976; NPS 1996). Approximately 100 non-native plants have been identified (NPS 2008a).

Most of the park is covered by eastern deciduous forest, containing a mixture of oaks (*Quercus* spp.), hickories (*Carya* spp.), maples (*Acer* spp.), and tulip poplars (*Liriodendron tulipifera*) (NPS 2012a). Until the chestnut blight reduced the chestnut to second growth around old stumps, the region's forest was classified as oak–chestnut (Braun 1950). A few large chestnut logs remain, but most have decayed beyond recognition or were used for fuel soon after they fell (Hickey 1975); some were salvaged for construction of the cabin camps in the 1930s.

Vegetation communities are largely controlled by the underlying geology and soils and the park has two distinct vegetation zones that follow the park's predominant geologic strata, which divide the park into eastern and western forest communities (Hickey 1975, Thorneberry–Ehrlich 2009). The eastern portion of the park has thin

Table 2.1. Owens Creek wetland plant species.

Common name	Scientific name
Trout lily	*Erythronium americanum*
Witch hazel	*Hamamelis virginiana*
Jewelweed	*Impatiens* spp.
Sensitive fern	*Onoclea sensibilis*
Cinnamon Fern	*Osmunda cinnamomea*
Interrupted fern	*Osmunda claytoniana*
Canada clearweed	*Pilea pumila*
Eastern swamp saxifrage	*Saxifraga pensylvanica*
Greenbrier	*Smilax* spp.
Skunk cabbage	*Symplocarpus foetidus*
Fox grape	*Vitis labrusca*
Spicebush	*Lindera benzoin*

Table 2.2. Hog Rock wetland plant species.

Common name	Scientific name
Red maple	*Acer rubrum*
Jack-in-the-pulpit	*Arisaema triphyllum*
Smallspike falsenettle	*Boehmeria cylindrica*
Buttonbush	*Cephalanthus occidentalis*
Water hemlock	*Cicuta maculata*
American beech	*Fagus grandifolia*
Ash	*Fraxinus* spp.
Tulip poplar	*Liriodendron tulipifera*
Japanese stiltgrass	*Microstegium vimineum*
Black gum	*Nyssa sylvatica*
Sensitive fern	*Onoclea sensibilis*
Cinnamon fern	*Osmunda cinnamomea*
Royal fern	*Osmunda regalis*
Virginia creeper	*Parthenocissus quinquefolia*
Canada clearweed	*Pilea pumila*
Lady's thumb	*Polygonum persicaria*
Arrowleaf tearthumb	*Polygonum sagittatum*
Pickerelweed	*Pontederia cordata*
Sassafras	*Sassafras albidum*
Mad Dog skullcap	*Scutellaria lateriflora*
Greenbrier	*Smilax* spp.
Skunk cabbage	*Symplocarpus foetidus*
Poison ivy	*Toxicodendron radicans*
Bellwort	*Uvularia perfoliata*
Blueberry	*Vaccinium* spp.
Sedges	*Carex* spp.
Oak species	*Quercus* spp.
Grasses	No identification of species were made

sandy-loam soils that are highly permeable and therefore well drained. Tree species such as chestnut oak (*Quercus prinus*), table mountain pine (*Pinus pungens*), and pitch pine (*Pinus rigida*) can be found on the drier ridge tops. On lower slopes and ravines, where soil is richer, white oak (*Quercus alba*), tulip poplar, red maple (*Acer rubrum*), black birch (*Betula lenta*), American beech (*Fagus grandifolia*), sour gum (*Nyssa sylvatica*), and eastern hemlock (*Tsuga canadensis*) can be found. The western portion of the park has deeper, richer, and moister soils. Most of the trees here are larger and the forest contains more species. Trees found here include sugar maple (*Acer saccharum*), basswood (*Tilia americana*), hickories, hornbeam (*Carpinus caroliniana*), white ash (*Fraxinus americana*), beech, and tulip poplar. In the higher ridge areas chestnut oak trees dominate. Floodplain areas contain trees that do not grow in drier areas such as elm (*Ulmus* spp.), yellow birch (*Betula alleghaniensis*), and sycamore (*Platanus occidentalis*) (NPS 2012a).

There were approximately 200 acres of eastern hemlock forest within Catoctin, primarily along Big Hunting and Owens Creeks (NPS 2008a). These acres are currently threatened by diseases specific to hemlocks including elongate hemlock scale (*Fiorinia externa*) and hemlock woolly adelgid (*Adelges tsugae*). The hemlock forests, particularly along Big Hunting Creek, consist of dense stands of small trees, 4–10 feet in height, with a mixture of a few larger trees. Hemlocks are limited to these shaded moist areas because of their very shallow roots. Hemlock trees in the park play a vital role in the ecology of Big Hunting Creek. The dense hemlock canopy helps provide shade and keep water temperatures cool in the summer, facilitating the survival of cold-water organisms, like the brook (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*). Natural hemlock stands typically grow in or close to riparian areas that are often classified as wetlands or floodplains (NPS 2003).

The shrubs are generally found in the forest understory or along the forest edge. The most common shrubs include mountain laurel (*Kalmia latifolia*), spicebush (*Lindera benzoin*), lowbush blueberry (*Vaccinum angustifolium*), witch-hazel (*Hamamelis virginiana*), and viburnum (*Viburnum* spp.) (NPS 2012a, Schmit et al. 2012). The shrub layers of the east and west portions of the park are quite different. Acid-loving shrubs, like lowbush blueberry and mountain laurel, mark the eastern area and are less common in the western area. Additionally, deerberry (*Vaccinium stamineum*) and black huckleberry (*Gaylussacia baccata*) are abundant in the east but essentially absent in the west (NPS 2008a). Shrubs in the western portion of the park are varied, consisting primarily of spicebush in moist areas, along with wild grape vines (*Vitis* spp.) and Virginia creeper (*Parthenocissus quinquefolia*). Flowering dogwood (*Cornus florida*) was once abundant in the western area, but nearly absent from the east (Hickey 1975).

The majority of the plants known to occur in the park are herbaceous, including ferns, grasses, and wildflowers (NPS 2008a). Over 700 plant species have been inventoried in the park (Hickey 1975), and over 33 different species of fern have been reported. Some of Catoctin's wildflowers include spring beauties (*Claytonia virginica*), cut-leaf toothwort (*Cardamine concatenate*), wild geranium (*Geranium maculatum*), bloodroot (*Sanguinaria* spp.), wild ginger (*Asarum canadense*), rue anemone (*Isopyrum biternatum*), wood anemone (*Anemone quinquefolia*), yellow violet (*Viola pubescens*), yellow adders tongue (*Erythronium americanum*), cardinal flower (*Lobelia cardinalis*), hepatica (*Hepatica* spp.), jack-in-the-pulpit (*Arisaema triphyllum*), mayapple (*Podophyllum peltatum*), and several species of orchid (NPS 2012a).

In addition to the native forest, there are areas of open woodland and landscape plantings around the old mountain homesteads and developed areas within the park. Some clearings near homesteads are still evident, but most are grown over with sour gum, tulip poplars, white ash, oaks, and hickories (NPS 2008a). Remnant orchard trees and white pine plantations mark several previously cultivated areas (Hickey 1975). Catoctin Mountain Park also manages approximately 120 ha (300 acres) of developed zones. Vegetation within these zones has been altered from its natural state and consists of lawns, shrubbery, and trees, which have been planted and are maintained primarily for historic, aesthetic, or erosion control purposes (NPS 1994).

Jack-in-the-pulpit. Photo by Jason Hollinger

Park wetlands contain many special status species, and two of these areas (the Owens Creek and Hog Rock wetlands) are recognized as rare plant habitats. In 1983 the Nature Conservancy designated Owens Creek Swamp as an outstanding Maryland natural area because of its unique assemblage of plants (NPS 1994). These two areas and their associated wetland vegetation are discussed earlier in this section.

Rare, threatened, and endangered plants

No federally listed plant species have been documented in the park (NPS 2008a). The Maryland Department of Natural Resources' Wildlife and Heritage Service identifies six plant species as potentially occurring in or in the vicinity of the park—large purple-fringed orchid (*Platanthera grandiflora*), leatherwood (*Dirca palustris*), Torrey's mountain-mint (*Pycnanthemum torrei*), long-bracted orchid (*Coeloglossum viride*), large-leaved white violet (*Viola incognita*), and herb-robert (*Geranium robertianum*) (NPS 2008a).

In 1989, 12 remaining large purple-fringed orchids were discovered in the park, and the following year the park located and installed wire cages around all known occurrences of large purple-fringed orchids and leatherwood (NPS 2000a). These species are still protected by the park.

Table 2.3 lists the species of special concern identified by the Maryland Department of Natural Resources and Catoctin Mountain Park staff. Where information was available, the table also provides the state status or rank for the species, and preferred habitat (NPS 2008a).

Fauna

Catoctin's forested ecosystem is habitat for more than 280 species of animals (exclud-

Table 2.3. Plant species of special concern in Catoctin Mountain Park.

Common name	Scientific name	State listing	Confirmed occurrence in park	General habitat
Plants (Maryland Department of Natural Resources)				
Herb-robert	*Geranium robertianum*	Highly rare	No	Woods and gravelly shores (Brown and Brown 1984)
Large-leaved white violet	*Viola blanda* var. *palustriformis*	Highly rare	Yes	Rich, deciduous woods (Brown and Brown 1984)
Eastern leatherwood	*Dirca palustris*	Threatened	Yes	Rich woods and stream banks in midland and mountain zones
Long-bracted orchid	*Coeloglossum viride*	Endangered	Yes	Moist, rich deciduous woods, frequently on steep slopes
Small purple-fringed orchid	*Platanthera psycodes*	Endangered extirpated	No	Moist fields and moist open woods
Torrey's mountain-mint	*Pycnanthemum torrei*	Endangered	Yes	Dry woods and thickets (Brown and Brown 1984)
Additional plant species (Catoctin Mountain Park)				
American chestnut	*Castanea dentata*	State rare/Watch list	Yes	Forest tree, most abundant on poor, or dry, acid soils (Brown and Brown 1984)
American ginseng	*Panax quinquefolius*	Watch list	Yes	Rich deciduous woods (Brown and Brown 1984)
White bergamot	*Monarda clinopodia*	Watch list	Yes	Low woods and thickets (Brown and Brown 1984)
Butternut	*Juglans cinerea*	State rare/Watch list	Yes	Rich soils usually in the woods or along fence rows; most commonly in the mountains (Brown and Brown 1984)
False pennyroyal	*Isanthus brachiatus*	Watch list	Yes	Prefers open areas in dry soils
Large purple-fringed orchid	*Platanthera grandiflora*	Threatened	Yes	Rich moist woods and meadows (Brown and Brown 1984)
Nodding trillium	*Trillium cernuum*	Watch list	Yes	Moist woods in midlands and mountain zones (Brown and Brown 1984)
Pale corydalis	*Corydalis sempervirens*	Watch list	Yes	Rock crevices, talus, forest clearings, open woods, and on burned or otherwise disturbed areas in shallow, often dry soil
Red turtlehead	*Chelone obliqua*	Threatened	Yes	Wet woods (Brown and Brown 1984)
Whorled milkweed	*Asclepias verticillata*	Watch list	Yes	Dry woodlands, field, and roadsides

ing invertebrates), most of which are resident and migratory birds (NPS 2012a).

Mammals

Common mammals in the park include skunk (*Mephitis mephitis*), groundhog (*Marmota monax*), squirrel (*Sciurus carolinensis*), several varieties of vole, mole, mouse, and shrew, Eastern cottontail rabbit (*Sylvilagus floridanus*), Eastern chipmunk (*Tamias striatus*), opossum (*Didelphis virginiana*), raccoon (*Procyon lotor*), white-tailed deer (*Odocoileus virginianus*), and red fox (*Vulpes vulpes*) (McShea and O'Brien 2003). Six bat species have also been documented in the park—little brown bats (*Myotis lucifugus*), northern myotis (*Myotis septentrionalis*), big brown bats (*Eptesicus fuscus*), eastern red bats (*Lasiurus borealis*), hoary bats (*Lasiurus cinereus*), and eastern pipistrelles/tricolor bats (*Pipistrellus subflavus/Perimyotis subflavus*) (Gates and Johnson 2005).

Recent sightings of beaver (*Castor canadensis*), mink (*Neovison vison*), and black bear (*Ursus americanus*) indicate that populations of these mammals have returned to the area, and coyotes (*Canis latrans*), which had never before been documented at Catoctin, have also recently become established in the park (NPS 2012a). Of the native mammal species known historically to range within the area of Catoctin, bison (*Bison bison*), elk (*Cervus elaphus*), gray wolf (*Canis lupus*), eastern cougar (*Felis concolor*), porcupine (*Erethizon dorsatum*), and fisher (*Martes pennanti*) have been extirpated (NPS 2012a).

Birds

Approximately 109 species of birds are thought to occur in the park during some part of the year. The ten most common birds at Catoctin are red-eyed vireo (*Vireo olivaceus*), scarlet tanager (*Piranga olivacea*), wood thrush (*Hylocichla mustelina*), white-breasted nuthatch (*Sitta carolinensis*), American robin (*Turdus migratorius*), eastern wood-pewee (*Contopus virens*), downy woodpecker (*Picoides pubescens*), blue jay (*Cyanocitta cristata*), eastern tufted titmouse (*Baeolophus bicolor*), and red-bellied woodpecker (*Melanerpes carolinus*) Sinclair et al. 2004, Ladin and Shriver 2013). The wood thrush is a species of conservation concern, being designated a 'watchlist species' by the Partners in Flight program (*http://www.partnersinflight.org*). The fact that it makes Catoctin's top 10 list means that this vulnerable species is finding valuable habitat in the park.

Other species found include great horned owls (*Bubo virginianus*), wild turkeys (*Meleagris gallopavo*), pileated woodpeckers (*Dryocopus pileatus*), hawks, and a variety of songbirds such as crows, warblers, sparrows, and finches (Sinclair 2002, Sinclair et al. 2004, NPS 2012a).

The state-rare common raven (*Corvus corax*) was found in the park during the 2010 National Capital Region Network monitoring (Ladin and Shriver 2013).

Herpetofauna

Of the 14 species of snakes found in the park only two of them, the copperhead (*Agkistrodon contortrix*) and timber rattlesnake (*Crotalus horridus*), are venomous. Other snakes in the park are the northern black racer (*Coluber constrictor*), northern ring neck (*Diadophis punctatus edwardsii*), black rat (*Pantherophis obsoletus*), hognose (*Heterodon platirhinos*), eastern milk (*Lampropeltis triangulum*), queen (*Regina septemvittata*), northern water snake (*Nerodia sipedon*), brown water snake (*Nerodia taxispilota*), green snake (*Opheodrys* spp.), and eastern garter (*Thamnophis sirtalis*). The turtle that is most commonly seen in the forest is the eastern box turtle (*Terrapene carolina carolina*). The wood turtle (*Glyptemys insculpta*), recognized by its distinctive sculptured shell, is the other terrestrial turtle found in the park. The more aquatic turtles, such as the snapping turtle (*Chelydra serpentina serpentina*), spotted turtle (*Clemmys guttata*), and painted turtle (*Chrysemys picta picta*), are found closer to streams and ponds. Lizards make up the largest group of living reptiles, numbering about 3,000 species worldwide. However, Catoctin Mountain Park is home only to two species, the five-lined skink (*Eumeces fasciatus*) and the northern fence lizard (*Sceloporus undulatus*). There is a possibility that the broadhead skink may be in the park, but that is yet to be confirmed (Pauley et al. 2005, NPS 2012a).

There are 22 known species of salamanders, frogs, and toads at Catoctin Mountain Park. There are eight species of salamander found at Catoctin: spotted salamander (*Ambystoma maculatum*), northern dusky salamander (*Desmognathus fuscus*), northern two-lined salamander (*Eurycea bislineata*), longtail salamander (*Eurycea longicauda*), northern spring salamander (*Gyrinophilus p. porphyriticus*), eastern red-backed salamander (*Plethodon cinereus*), northern slimy salamander (*Plethodon glutinosus*), and northern red salamander (*Pseudotriton r. ruber*) (Pauley et al. 2005).

The frogs and toads that can be heard, and sometimes seen, at Catoctin include the eastern American toad (*Bufo a. americanus*), Fowler's toad (*Bufo fowleri*), gray treefrog (*Hyla versicolor*), northern spring peeper (*Pseudacris c. crucifer*), northern green frog (*Rana c. melanota*), American bullfrog (*Rana catesbeiana*), pickerel frog (*Rana palustris*), and wood frog (*Rana sylvatica*) (Pauley et al. 2005).

Fishes

Trout are the big game of Catoctin Mountain Park's streams. They are the pinnacle species in the food chain, but also the top prize of anglers. Trout are members of the Salmonidae family, which includes salmon, char, whitefish, graylings, and true trout. They are mostly predatory, eating anything they can swallow. They prefer cold, swift waters. Big Hunting Creek has enjoyed protection since 1933, longer than any other stream in Maryland. Private anglers' societies regularly stock the stream (outside the park boundaries) to maintain it as one of the region's premier fishing streams. Other waters in the park do not receive direct stocking, so that native brook trout may thrive and spawn naturally (NPS 2012a).

Brook trout (*Salvelinus fontinalis*) in Catoctin. Photo by NPS.

Rainbow trout (*Oncorhynchus mykiss*) are native to the western states. The Maryland Department of Natural Resources stocks them annually in Big Hunting Creek Lake, Frank Bentz Memorial Lake, and Owens Creek. The Potomac Valley Fly Fishermen stock them in Big Hunting Creek. They are prized for their fighting agility and their excellent taste. Within Catoctin Mountain Park, fish counts reveal populations in Big Hunting Creek, but not typically in Owens Creek (NPS 2012a).

Brown trout (*Salmo trutta*) are native to Europe, northern Africa, and western Asia. They tolerate more silt than other trout, so they often survive where rainbow or brook trout cannot. They were once found in great numbers in Big Hunting Creek, but numbers have declined since they are no longer stocked (NPS 2012a).

The brook trout (*Salvelinus fontinalis*) is the only trout native to Catoctin Mountain streams. It is a member of the char genus, more closely related to lake trout, bull trout, and arctic char than to the rainbow or brown trout.

Besides insect larvae, the trouts' prey includes small fish such as the mottled sculpin (*Cottus bairdii*), longnose dace (*Rhinichthys cataractae*), roseyside dace (*Clinostomus funduloides*), blacknose dace (*Rhinichthys atratulus*), and fantail darter (*Etheostoma flabellare*). Other small fish, such as the white sucker (*Catostomus commersonii*), cutlips minnow (*Exoglossum maxillingua*), creek chub (*Semotilus atromaculatus*), and common shiner (*Luxilus cornutus*), inhabit portions of Owens Creek that border private land (NPS 2012a).

The American eel (*Anguilla rostrata*) spawns in the open ocean of the Sargasso Sea and migrates to estuarine and freshwater streams to mature. They are the only North American fish with this unusual life cycle. American eels have been observed in both Owens Creek and Big Hunting Creek.

Invertebrates

Several state-listed odonates (dragonflies and damselflies) are found in the park—brown spiketail (*Cordulegaster bilineata*), sable clubtail (*Gomphus rogersi*), southern pygmy clubtail (*Lanthus vernalis*), and mocha emerald (*Somatochlora linearis*). 250 species of butterflies and moths and 103 species of ground beetles have also been identified (NPS 2008a, Fritzler and Strazanac 2012).

Soundscapes and lightscapes

The soundscape within a park comprises both natural ambient sounds and human-made sounds. Natural sounds include geophysical (e.g., wind, rain, running water) and biological sounds (e.g., insects, frogs, birds) (Pijanowski et al. 2011). This natural ambient environment enhances visitor experience of the natural park landscape (Miller 2008). The natural darkness associated with the night sky is an important natural, scientific, and cultural resource valued by the National Park Service and has been identified as an important resource/value in Catoctin Mountain Park (NPS 2012b, c). Natural darkness is important to wildlife for mating, migration, sleep, foraging, orientation, and other aspects of their life cycle. Nocturnal animals, such as bats, rely on the cover of darkness to forage for prey. The night sky is important for preserving the sense of place and time inherent to the site.

Providing quality recreational opportunities and facilities is one of the three major purposes of Catoctin Mountain Park (NPS 2008a). It is a prime example of the diversity of an eastern deciduous forest and provides outstanding scenic beauty for all to enjoy. Visitors come to Catoctin to seek a variety of experiences which are mostly related to the natural soundscapes and lightscapes found in the park. A sense of adventure while hiking a trail, solitude while watching a sunset from a scenic overlook, listening to the chorus of songbirds, the silence of new-fallen snow, the smell of the forest after a gentle rain, and the annual display of fall colors. All experiences that visitors to Catoctin value. A 2002 visitor study revealed that 80% or more of visitors come to view wildlife and scenery with 61% exploring by automobile and another 68% hiking for one hour or more (NPS 2002). Visitors also said that the element that detracted from their experience the most was unnatural noise (20%). Visitors rated the importance of several park elements. With 50% rating viewing the night sky as extremely important, 58% rating solitude as extremely important, and 73% rating natural quiet/sounds of nature as extremely important, it is evident that visitors come to Catoctin not only to hike, camp, view wildlife, but to experience the park fully through all their senses.

2.2.2 Resource issues overview

Natural resources in the park, and threats to those resources, are depicted in Figure 2.7.

Internal park threats

Exotic species

Exotic plants and diseases are prevalent within CATO. Approximately 100 invasive species of plants have been documented within the park. Many of these species are also invasive and outcompete and displace native species. Many thrive on disturbances created within the ecosystem, such as fragmentation, blow-downs, or flooding. When native species are displaced by these disturbances, invasive species can more rapidly colonize the area, further facilitating competition for resources. This changes habitat structure and the composition of vegetation communities, which can affect nutrient cycling, water resources, and habitat quality for wildlife.

Multiflora rose (*Rosa multiflora*) and Japanese barberry (*Berberis thunbergii*) occur throughout much of the park. They are exotic species that were introduced by humans. Spiked with thorns, these shrubs crowd out native plants (NPS 2012a).

Other non-native plants found in the park include tree of heaven (*Ailanthus altissima*) and the herbaceous species garlic mustard (*Alliaria petiolata*), ground ivy (*Glechoma hederacea*), Japanese honeysuckle (*Lonicera japonica*), Japanese stiltgrass (*Microstegium vimineum*), Oriental ladysthumb (*Polygonum caespitosum*), mile-a-minute

(*Polygonum perfoliatum*), and wineberry (*Rubus phoenicolasius*) (Schmit et al. 2007, 2008, 2009, 2010).

Several pests and diseases threaten forest resources, among them the gypsy moth (*Lymantria dispar*), hemlock woolly adelgid (*Adelges tsugae*), Dutch elm disease, and dogwood anthracnose (NPS 2012b). Gypsy moths, by defoliating oak trees, open the forest canopy and facilitate invasion by non-native vegetation. Repeated defoliation can cause oak tree mortality—oaks are the dominant tree species in several forest community assemblages. Hemlock woolly adelgid, first discovered in the park in 1992, has largely decimated eastern hemlock (*Tsuga canadensis*) trees. Dutch elm disease is an introduced fungus that destroys American elm trees, transmitted by the elm bark beetle (native and European species). Dogwood anthracnose is a disease caused by the fungus *Discula destructiva* and has devastated the flowering dogwood (*Cornus florida*) trees in the park. In 1991, it was esimated that 79% of the park's dogwoods were dead, with no sign of regeneration. However, a few dogwood trees have been discovered at Catoctin that show resistance to the disease. Cuttings from one of these trees were used to produce a flowering dogwood that is resistant to the blight. These dogwoods are sold as "Appalachian Spring". Some of these trees have been planted in the park in the hope of restoring this species (NPS 2012a).

'Rock snot' is another invasive species found in the park. The diatom is a single-celled alga also known as Didymo (*Didymosphenia geminata*). It forms mats that cover and suffocate stream bottoms, and can damage macroinvertebrate and other algal communities (U.S. EPA 2006).

Deer overpopulation

White-tailed deer (*Odocoileus virginianus*) densities have risen rapidly in the past few decades in response to lack of natural predators, increased forage area due to land fragmentation for suburban growth, and declines in hunting outside the park (Bates 2009). High populations of native white-tailed deer heavily browse the vegetation in the park. This deer overbrowsing is causing an extremely open understory and lack of small trees in Catoctin (Schmit et al. 2012).

Numerous plant species have been extirpated or are at risk of being extirpated from the park's plant community due to excessive deer browsing in the park. Since the early 1980s, park staff have noted the effects of deer browsing on vegetative species, and a 2000 report lists browsing impacts to 24 species of plants, including American ginseng (*Panax quinquefolius*), large purple-fringed orchid (*Platanthera grandiflora*), long-bracted orchid (*Coleoglossum viride*), and leatherwood (*Dirca palustris*) (NPS 2000b, 2008a).

Langdon (1985) noted that deer impacts on plant communities consist of three primary effects: (1) failure to reproduce, especially in slowly maturing woody species where seedlings are killed, (2) alteration of species composition, which occurs where deer remove preferred browse species and indirectly create opportunities for less preferred or unpalatable species to proliferate, and (3) extirpation of highly palatable plants, especially those that were naturally uncommon or of local occurrence in the park (Langdon 1985). Among the direct impacts described by Langdon and later observed by park staff were the loss of mountain laurel (*Kalmia latifolia*) from stands that occurred on the eastern ridge of the park and the browsing of white pines so that all saplings accessible to deer were severely injured or dead (NPS 2008a).

Deer also carry disease, such as Lyme disease—which is spread through deer ticks—and chronic wasting disease.

Stream water temperature

Both Big Hunting Creek and Owens Creek are classified by the state as Class III-P: Natural Trout Waters, or Nontidal Cold Water and Public Water Supply. This indicates that the waters are suitable for the growth and propagation of trout, capable of supporting self-sustaining trout populations and their associated food organisms, and suitable for use as a public water supply (COMAR 2007a, b). Brook trout are sensitive to several water quality parameters, including water temperature. Studies have shown that brook trout cannot tolerate sustained water temperatures exceeding 25°C and prefer water temperatures less than 20°C. Trees growing in riparian buffers provide shade that keeps the streams cool. The dam on Big Hunting Creek releases water from the bottom of the lake in the summer to help lower temperatures (NPS 2012a). Maintaining an intact riparian buffer will help sustain trout populations by keeping stream temperatures cooler and preventing streambank erosion.

Other threats

There is also a wastewater treatment plant located near the headwaters of Owens Creek that could threaten water quality if there is a malfunction (NPS 1998).

Deer browse line visible in a Catoctin forest. Photo by NPS.

Regional threats

Surrounding land use

Frederick County, where 98.5% of Catoctin Mountain Park's nine square miles is located, is the third-fastest-growing county in Maryland (U.S. Bureau of the Census 2012a). Threats from adjacent development include habitat fragmentation and introduction of exotic and invasive species.

NPS believes that Frederick County has done a very good job of buffering the park from development but is concerned over the Residential and Village Center zoning which threatens the headwaters of Big Hunting Creek. An additional concern is over lands within the park's viewshed (Piney Mountain, Harbaugh Valley, and Sabillasville) that could sustain future visually intrusive development. Foxville is a small unincorporated community on the southwest boundary that contains approximately 50 dwellings with residential zoning (R-1). One building site currently holds commercial zoning, Village Center (VC) that impacts the headwaters and aquifer recharge areas of Big Hunting Creek, a major trout stream in the state of Maryland.

The western town boundary of Thurmont shares a portion of the park's eastern boundary. There is some concern that the western town boundary which abuts the park with agricultural and low density residential lands could be converted to more intensive residential development. This could increase land use impacts such as wildlife habitat fragmentation and the potential for wildland fire interface. Compact settlement patterns around designated growth centers is also encouraged by the county comprehensive plan.

Sedimentation

Nearby development and increased runoff due to impervious surfaces are a large source of sedimentation. Heavy deer browsing leads to reduced vegetative ground cover and erosion, also resulting in sedimentation in Owens and Big Hunting Creeks (NPS 2008a).

Air quality

Air pollution originates from several different types of sources—stationary sources, such as factories, power plants, and smelters; mobile sources, such as cars, trains, and airplanes; and naturally occurring sources, such as windblown dust (U.S. EPA 2011). The most commonly found air pollutants are particulate matter, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead, the former two of which are the most widespread human health threats (U.S. EPA 2011). The East Coast has some of the worst air pollution in the country, characterized by low visibility, elevated ozone concentrations, and elevated rates of atmospheric nitrogen and sulfur deposition.

Elevated ozone levels have been shown to cause premature defoliation in plants; high levels of nitrogen deposition acidify and fertilize soils and waters, thereby affecting nutrient cycling, vegetation composition, biodiversity, and eutrophication. Air pollution can be transported over long distances, making management difficult at the local scale.

Emerging threats

The rusty crayfish (*Orconectes rusticus*) is a large, aggressive species of freshwater crayfish that is native to Indiana, Kentucky, Ohio, and Tennessee but has been rapidly expanding its range throughout North America. It is present in Big Hunting Creek in Thurmont, just downstream from CATO. Invasions by the rusty crayfish have resulted in the loss of native crayfish. They are also known to feed upon fish eggs and can reduce the quality of habitat available to many fishes and other invertebrates. Rusty crayfish also feed on freshwater mussels, 70% of which are threatened or endangered (MD DNR 2007).

Another emerging threat is emerald ash borer (*Agrilus planipennis*). The emerald ash borer is a beetle native to Asia that was first found in North America in 2002 (Michigan State University 2010). In North America, it has only been found in ash trees (*Fraxinus* spp.). The beetle destroys the water- and nutrient-conducting tissues (xylem and phloem) under the bark, resulting in the dieback and eventual death of the tree. Emerald ash borer has been discovered in Washington County, MD, less than 20 miles from the park (Maryland Dept of Agriculture, 2012).

A future threat to park resources is increasing stream water temperature. Low temperatures are essential to the survival and growth of trout and other animals in the streams. Factors such as climate change may increase stream water temperature, as will the reduction of stream shading due to loss of hemlock trees from the forest pest hemlock woolly adelgid and loss of forest cover from deer overbrowse.

2.3 RESOURCE STEWARDSHIP

2.3.1 Management directives and planning guidance

Park purpose

According to the park's draft Foundation Document (NPS 2012c), the purpose of Catoctin Mountain Park is

> *to provide quality recreational opportunities in the Catoctin Mountains and serve as a setting and buffer for the presidential retreat, while protecting and conserving the park's natural and cultural environments as envisioned by New Deal conservation programs.*

Park significance

Statements of significance clearly define the importance or distinctiveness of the park's resources. Their purpose is to help managers make decisions that preserve the resources and values present and represented in Catoctin Mountain Park (NPS 2012c). Catoctin Mountain Park is significant because it:

1. is an early and continuing example of conservation practices resulting in the regeneration of an eastern deciduous forest.
2. provides outstanding scenic values at the transition of the Monocacy River Valley and the Catoctin Mountains in the Piedmont Plateau and Blue Ridge geologic provinces.
3. provides diverse outdoor recreation opportunities in a mountain setting near the population centers of the mid-Atlantic region.
4. provides exceptional aquatic habitat for fishing and other recreational activities.
5. serves as a setting for the presidential retreat—a place where international leaders convene to discuss world peace and international diplomacy.
6. was one of 46 recreational demonstration areas established in the 1930s, and represents an outstanding example of New Deal era programs to restore the landscape for conservation and recreation purposes.
7. is the site of the oldest operating cabin camps in the nation, constructed especially for persons with disabilities, and

is one of the original locations that the Office of Strategic Services trained.
8. protects the cultural heritage of the Catoctin Mountains that dates back 3,500 years, ranging from stone tool making to agriculture to charcoal production.

Other important resources and values of the park are natural sounds/air quality/night sky, campground and picnic areas, the trail system, water quantity and quality, and the presidential retreat (NPS 2012c).

A draft Resource Stewardship Strategy (NPS 2012d) is currently in review and will ultimately provide guidance for the research, resource management, and resource education programs of the National Park Service at CATO.

2.3.2 Status of supporting science

Inventory and Monitoring Program

The Inventory and Monitoring (I&M) Program was formed in response to the Natural Resource Challenge of 1999, which led to the formation of the I&M Program. The goals of the Program are to (NPS 2013):

1. Inventory the natural resources under National Park Service stewardship to determine their nature and status.
2. Monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments.
3. Establish natural resource inventory and monitoring as a standard practice throughout the National Park system that transcends traditional program, activity, and funding boundaries.
4. Integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision making.
5. Share National Park Service accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives.

In addition to conducting baseline inventories, I&M monitors Vital Signs that are indicators of ecosystem health. Vital Signs include:

1. physical, chemical, and biological elements and processes of park ecosystems;
2. known or hypothesized effects of stressors; and/or
3. elements that have important human values (Fancy et al. 2009).

CATO is one of 11 parks served by the National Capital Region I&M Network (NCRN I&M). Numerous baseline inventories have been conducted at Catoctin (Table 2.4) and NRCN Vital Signs monitoring makes up a large portion of the natural resource data described in this report. The long-term monitoring of these vital signs is meant to serve as an 'early warning system' to detect declines in ecosystem integrity and species viability before irreversible loss has occurred (Fancy et al. 2009).

Research at the park

The National Park Service has performed its own research and collaborated with a variety of outside researchers and to fill gaps in knowledge and have a better understanding of baseline conditions of park resources. Collaborators have included various state and federal government agencies, The University of Maryland, Hood College, The University of Arkansas, and non-government organisations. A partial bibliography of research that has been completed at CATO can be seen in Table 2.5.

Table 2.4. Status of NCRN I&M inventories at Catoctin Mountain Park.

Inventory	Description	Status
Soil Resources	The Soil Resources Inventory (SRI) includes maps of the locations and extent of soils in a park; data about the physical, chemical, and biological properties of those soils; and information regarding the potential use and management of each soil. The SRI adheres to mapping and database standards of the National Cooperative Soil Survey (NCSS) and meets the geospatial requirements of the Soil Survey Geographic (SSURGO) database. SRI data are intended to serve as the as the official database for all agency applications regarding soil resources.	Completed 2008
Base Cartography Data	The Base Cartography inventory is one of 12 core inventories identified by the National Park Service as essential to effectively manage park natural resources. Base cartographic information from this inventory provides geographic information systems (GIS) data layers to National Park resource management staff, researchers, and research partners.	Completed 2010
Air Quality Related Values	Air quality related values are resources sensitive to air quality, including vegetation, wildlife, water quality, and soils. This inventory identifies whether categories of these values are sensitive for a given park.	Completed 2010
Geologic Resources Inventory	The Geologic Resources Inventory aims to raise awareness of geology and the role it plays in the environment, and to provide natural resource managers and staff, park planners, interpreters, and researchers with information that can help them make informed management decisions. A part of the program's mission is to provide more than 270 parks with digital geologic-GIS data and a geology report.	Completed 2006
Natural Resource Bibliography	The Natural Resource Bibliography, one of the 12 core NPS natural resource inventories, was developed to catalog and manage natural resource-related information sources pertaining to national parks. The bibliography has been managed in several different systems in the past, including NPBib and NatureBib. In 2010 all records were migrated to the NPS Data Store, part of the IRMA data system.	Completed 2008
Climate Inventory	One of the 12 natural resource inventories, the primary objective of the Climate Inventory is to obtain park-relevant baseline climate data useful to NPS biologists, hydrologists and resource managers.	Completed 2006
Baseline Water Quality Inventory	This inventory documents and summarizes existing, readily-available digital water quality data collected in the vicinity of national parks.	Completed 2007
Air Quality Data	One of the 12 core natural resource inventories, the Air Quality Inventory objective is to provide actual-measured or estimated concentrations of indicator air pollutants such as ozone, wet deposition species (NO_3, SO_4, NH_4, etc.), dry deposition species (NO_3, SO_4, HNO_3, NH_4, SO_2), and visibility (extinction for 20% cleanest days and 20% worst days for visibility).	Completed 2006
Vegetation Mapping	The Vegetation Inventory Program (VIP) is an effort by the National Park Service (NPS) to classify, describe, and map detailed vegetation communities in more than 270 national park units across the United States. Stringent quality control procedures ensure the reliability of the vegetation data and encourage the use of resulting maps, reports, and databases at multiple scales.	In progress

Table 2.5. A partial bibliography of research that has been completed at Catoctin Mountain Park.

Study topic	Reference
Mammals	Cox 1983, Fenwick and Dobey 1984, Kerstner 1984, Cherry 1985, McShea and O'Brien 2003, Gates and Johnson 2005, Rattner and Ackerson 2006, Bates 2009.
Birds	Clarke 1984, Boone and Dowell 1986, Sinclair et al. 2004, Rattner and Ackerson 2006, Ladin and Shriver 2013*.
Fish	Frederickson 2011.
Herpetofauna	Pauley et al. 2005, Rattner and Ackerson 2006, Valencia and Donaldson 2011.
Insects	Mt. St. Mary's 1985, Orr 2010, Fritzler and Strazanac 2012.
Plants	Hickey 1975, Kyde and Boucher 2000, Engelhardt et al. 2008.
Geology & Soils	National Cooperative Soil Survey 2009, Thorneberry–Ehrlich 2009.
Hydrology	NPS 1995.
Water Quality	Norris and Pieper 2010*.
Habitat	Schmit and Campbell 2007*, 2008*, Schmit et al. 2009*, 2010*.
Fungi	Hawkins and Brantley 2007, Stephenson 2008, Barron and Emery 2009.

*Publications describing results of ongoing monitoring by the NCRN I&M program.

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Chapter 3: Study scoping and design

3.1 PRELIMINARY SCOPING

3.1.1 Park involvement

Scoping for the assessment of Catoctin Mountain Park (CATO) began in December 2010 with a meeting at Harpers Ferry National Historical Park to start the Natural Resource Condition Assessment (NRCA) process for Catoctin Mountain Park, Harpers Ferry National Historical Park, and Chesapeake and Ohio Canal National Historical Park. In attendance were staff from the three parks, the NPS National Capital Region Network (NCRN) Inventory and Monitoring (I&M) Program, and the University of Maryland Center for Environmental Science Integration and Application Network (UMCES-IAN) (Table 3.1). Data for park resources from CATO and NCRN I&M were organized into an electronic library comprised of management reports, hard data files, and geospatial data, which provided the primary sources for the assessment. Additional datasets were obtained from the NPS Air Resources Division (ARD) and the Interagency Monitoring of Protected Visual Environments (IMPROVE).

Several follow-up meetings with staff from CATO, NCRN I&M, and UMCES-IAN were used to identify and locate key resources for completing the assessment, to present work and calculations already completed, and to outline and brainstorm content conclusions and recommendations.

Strong collaboration with park natural resource staff was essential to the success of this assessment, and key park staff invested significant time to assist in the development of reference conditions, calculation of metrics, and interpretation of calculated results.

3.2 STUDY DESIGN

3.2.1 Reporting areas

The focus of the reporting area for the NRCA was the Catoctin Mountain Park administrative boundary. An area five times the total area of the park (evenly distributed around the entire park boundary) was examined for landscape dynamic metric analysis. Lands within 30 km (19 mi) of the park boundary were examined for context (Budde et al. 2009) but not included in the formal assessment.

3.2.2 Indicator framework

The framework utilized for presenting assessment data in Chapter 4 was the Vital Signs categorization developed by NPS I&M (Fancy et al., 2008). Metrics included in this assessment were sorted into their respective Vital Signs categories so that they could be utilized in future studies (Figure 3.1). Fancy *et al*. (2008)identified the key challenge to large scale monitoring programs is the development of information products which integrate and translate large amounts of complex scientific data into highly aggregated metrics for communication to policymakers and non-scientists. Aggregated indices were developed and presented within the current natural resource assessment for Catoctin Mountain Park.

3.2.3 General approach and methods

The approach taken to assess natural resource condition was to determine indicators of current status within each habitat, establish a reference condition for each indicator, and then assess the percentage attainment of reference condition. Details of approach, background, and justification are provided on a metric-by-metric basis in Chapter 4. Once attainment was calculated for each indicator, an unweighted mean was calculated to determine the condition for each Vital Sign category and then similarly to combine Vital Sign categories to calculate an overall park assessment.

3.2.4 Condition assessment calculations

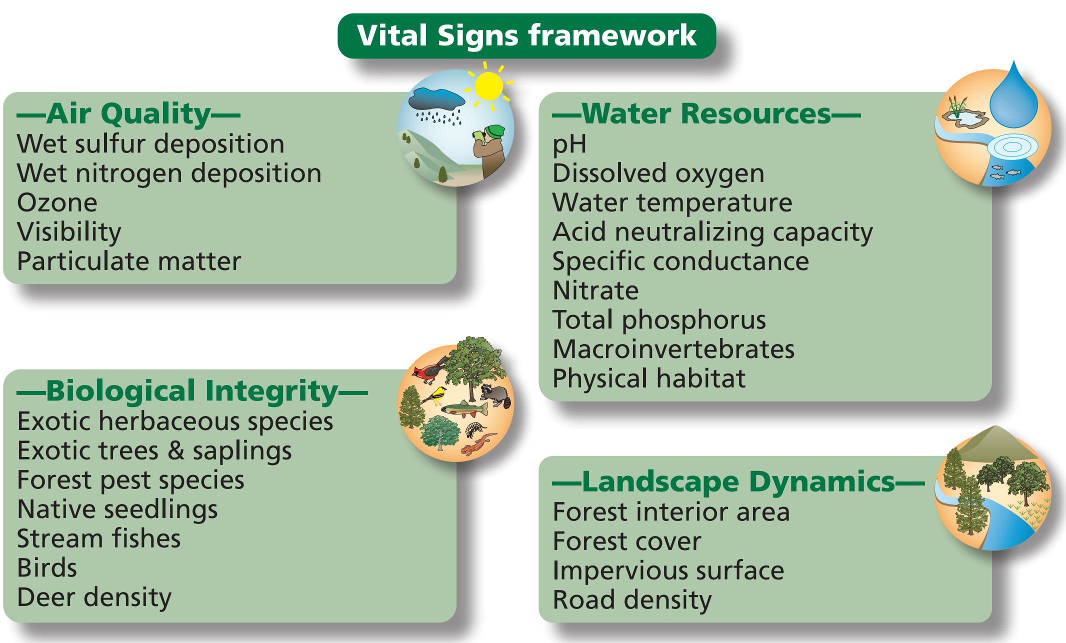
A total of 25 metrics were used to determine the natural resource condition of

Table 3.1. Ecological monitoring framework data provided by agencies and specific sources included in the assessment of Catoctin Mountain Park.

Date	Meeting type	Topics discussed	Attendees
12/10/2010	Phone call	Overall project timeline	NCRN I&M: Patrick Campbell, Megan Nortrup. UMCES-IAN: Tim Carruthers, Jane Thomas.
12/17/2010	In person	Introduce NRCA project and timeline.	CATO: Scott Bell, Becky Loncosky. CHOH: Brian Carlstrom, Chris Stubbs, John Hitchcock, Michelle Carter. HAFE: Mia Parsons, Rebecca Harriet, Dale Nisbet, Andrew Lee. NCRN I&M: Pat Campbell, Mark Lehman, Megan Nortrup. UMCES-IAN: Tim Carruthers, Jane Thomas.
3/10/2011	In person	Compile resources for Chapter 2, compile a list of potential metrics for the NRCA, and to achieve a consensus on which park boundary to use for the NRCA.	CATO: Becky Loncosky. NCRN I&M: Pat Campbell, Mark Lehman, Megan Nortrup. UMCES-IAN: Heath Kelsey, Jane Thomas, Joanna Woerner.
7/5/2011	Phone call	Progress on the NRCA and next steps.	NCRN I&M: Patrick Campbell, John Paul Schmit, Mark Lehman, Megan Nortrup. UMCES-IAN: Heath Kelsey, Jane Thomas.
9/2/2011	Phone call	Landscape Dynamics metrics analyses.	University of Richmond: Todd Lookingbill. NCRN I&M: John Paul Schmit, Mark Lehman, Megan Nortrup. UMCES-IAN: Heath Kelsey, Jane Thomas.
11/1/2011	Phone call	Progress on the NRCA and next steps.	NCRN I&M: Patrick Campbell, John Paul Schmit, Mark Lehman, Megan Nortrup. UMCES-IAN: Heath Kelsey, Jane Thomas.
12/5/2011	In person	Present NRCA drafts to park staff and discuss progress and next steps.	CATO: Scott Bell, Becky Loncosky, Lindsey Donaldson. CHOH: Brian Carlstrom, John Hitchcock, Michelle Carter. HAFE: Mia Parsons, Dale Nisbet. NCRN I&M: Pat Campbell, Mark Lehman, Megan Nortrup. UMCES-IAN: Bill Dennison, Simon Costanzo, Jane Thomas.
12/3/2012	In person	Draft conclusions and recommendations for Chapter 5.	CATO: Scott Bell, Becky Loncosky, Lindsey Donaldson. NCRN I&M: Pat Campbell, Mark Lehman, Megan Nortrup. UMCES-IAN: Bill Dennison, Simon Costanzo, Jane Thomas.

CATO—Catoctin Mountain Park; CHOH—Chesapeake & Ohio Canal National Historical Park; HAFE—Harpers Ferry National Historical Park; NCRN I&M—National Capital Region Network Inventory and Monitoring; NRCA—Natural Resource Condition Assessment; UMCES-IAN—University of Maryland Center for Environmental Science Integration & Application Network.

Figure 3.1. Vital Signs framework used in this assessment.



Catoctin Mountain Park. The approach for assessing resource condition within CATO required establishment of a reference condition (i.e., threshold) for each metric. Thresholds ideally were ecologically based and derived from the scientific literature. However, when data were not available to support peer-reviewed ecological thresholds, regulatory and management-based thresholds were used.

Due to the wide range of data values for some of the metrics, medians were presented as the overall result instead of the mean.

Threshold attainment of metrics was calculated based on the percentage of sites or samples that met or exceeded threshold values set for each metric. A metric attainment score of 100% reflected that the metric at all sites and at all times met the threshold identified to maintain natural resources. Conversely, a score of 0% indicated that no sites at any sampling time met the threshold value. Once attainment was calculated for each metric, the median was calculated to determine the condition of each Vital Sign. Attainment scores were categorized on a scale from very good to very degraded. Attainment scores for each metric are presented in Chapter 4.

The four Vital Signs scores were then averaged to produce a single assessment score for the entire park. Key findings, conclusions, and recommendations were also given for each Vital Sign and for the park as a whole in Chapter 5.

3.3 LITERATURE CITED

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Fancy, S.G., J.E. Gross, and S.L. Carter. 2008. Monitoring the condition of natural resources in US national parks. Environmental Monitoring and Assessment: Electronically published May 29, 2008.

Chapter 4: Natural resource conditions

4.1 AIR QUALITY

4.1.1 Air quality summary

Five metrics were used to assess air quality in Catoctin Mountain Park (CATO)—wet sulfur (S) deposition, wet nitrogen (N) deposition, ozone (ppb and W126), visibility, and particulate matter. A sixth metric (ozone [W126]) was analyzed but not included in the overall assessment due to an ozone metric (ppb) already being included in the assessment. A seventh metric (mercury deposition) was included for informational purposes but not included in the overall assessment. Data used for the assessment of current condition of wet sulfur and nitrogen deposition, ozone, and visibility were obtained from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2011a, b, c) (Table 4.1). These data were calculated by the ARD on a national scale between 2005 and 2009 using an interpolation model based on monitoring data. The values for individual parks were taken from the interpolation at the park centroid, which is a location near the center of the park and within the park boundary (Figure 4.1). Data for the other two metrics

Table 4.1. Ecological monitoring framework data for Air Quality provided by agencies and specific sources included in the assessment of CATO.

Metric	Agency	Reference/source
Wet sulfur deposition	NPS ARD	NPS ARD 2011a, *http://nadp.sws.uiuc.edu/sites/ntnmap.asp*
Wet nitrogen deposition	NPS ARD	NPS ARD 2011a, *http://nadp.sws.uiuc.edu/sites/ntnmap.asp*
Ozone (ppb and W126)	NPS ARD	NPS ARD 2011b
Visibility	NPS ARD	NPS ARD 2011c
Particulate matter (PM 2.5)	IMPROVE	*http://www.epa.gov/airdata/*
Mercury deposition	MDN-NADP	*http://nadp.sws.uiuc.edu/mdn/*

Table 4.2. Air Quality reference conditions for CATO.

Metric	Reference conditions	Sites	Samples	Period
Wet sulfur deposition (kg/ha/yr)	< 1; 1–3; > 3	Whole park	N/A*	2005–2009
Wet nitrogen deposition (kg/ha/yr)	< 1; 1–3; > 3	Whole park	N/A*	2005–2009
Ozone (ppb)	≤ 60; 60.1–75; > 75	Whole park	N/A*	2005–2009
Ozone (W126; ppm-hrs)	< 7; 7–13; > 13	Whole park	N/A*	2005–2009
Visibility (dv)	< 2; 2–8; > 8	Whole park	N/A*	2005–2009
Particulate matter (PM2.5; μg/m³)	≤ 12; 12.1–15; > 15	2	5,476	2001–2010
Mercury deposition (ng/L)	N/A	2	701	2001–2011

* One interpolated value represents a five-year average of weekly measurements at multiple sites.

Table 4.3. Categorical ranking of the reference condition attainment categories for Air Quality metrics.

Metric reference conditions					Attainment of reference condition	Natural resource condition
S & N deposition (kg/ha/yr)	Ozone (ppb)	Ozone (W126)	Visibility (dv)	Particulate matter (μg/m³)		
< 1	≤ 60	< 7	< 2	≤ 12	100%	Good
1–3	60.1–75	7–13	2–8	12.1–15	0–100% (scaled)	Moderate
> 3	> 75	> 13	> 8	> 15	0%	Significant concern

(particulate matter and mercury deposition) were obtained from national monitoring network sites (Table 4.1).

Reference conditions were established for each metric (Table 4.2) and the data were compared to these reference conditions to obtain the percent attainment and converted to the condition assessment for that metric (Table 4.3). Multiple reference condition categories were used in accordance with the NPS ARD documentation (NPS ARD 2011d) (Table 4.2).

To assess trends, data from the NPS ARD report were used where possible (NPS ARD 2010). Otherwise, monitoring sites used were those closest to CATO from the National Atmospheric Deposition Program (NADP) and Interagency Monitoring of Protected Visual Environments (IMPROVE) program (Figure 4.1).

CATO scored 0% attainment (or conditions of significant concern) for all air quality metrics except particulate matter (65% attainment) which scored as moderate (Table 4.4). This resulted in an overall air quality condition attainment of 13%, or very degraded condition.

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NPS ARD (National Park Service, Air Resources Division). 2010. Air quality in National Parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, CO.

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Table 4.4. Summary of resource condition assessment of Air Quality in CATO.

Metric	Result	Reference conditions	% attainment	Condition	Air Quality condition
Wet sulfur deposition (kg/ha/yr)	5.40	< 1; 1–3; > 3	0	Significant concern	13% Very degraded
Wet nitrogen deposition (kg/ha/yr)	4.65	< 1; 1–3; > 3	0	Significant concern	
Ozone (ppb)	75.9	≤ 60; 60.1–75; > 75	0	Significant concern	
Ozone (W126; ppm-hrs)	12.6	< 7; 7–13; > 13	6.7	Moderate	
Visibility (dv)	13.0	< 2; 2–8; > 8	0	Significant concern	
Particulate matter (PM2.5; µg/m^3)	13.1	≤ 12; 12.1–15; > 15	65	Moderate	
Mercury deposition (ng/L)	9.1	N/A	N/A	N/A	

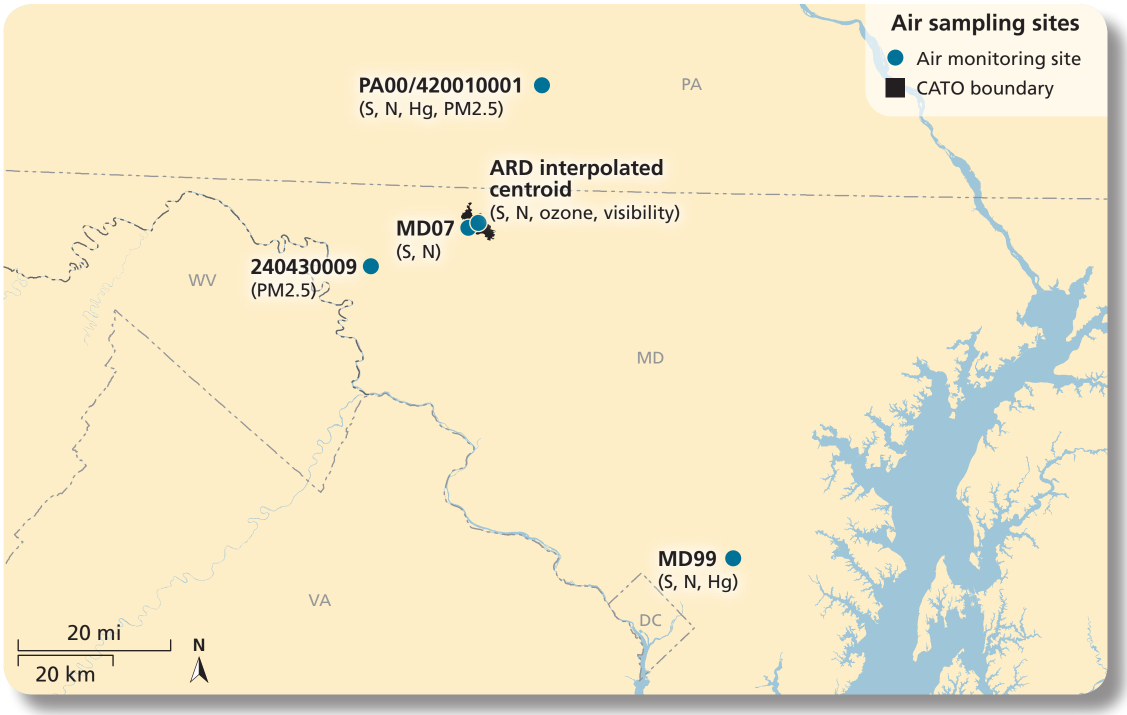

Figure 4.1. Regional air quality monitoring sites for wet deposition of sulfur and nitrogen, ozone, visibility, particulate matter, and mercury deposition. Wet deposition, ozone, and visibility condition data for 2005–2009 were interpolated by NPS ARD to estimate mean concentrations for CATO.

wet deposition estimates. NPS Air Quality Estimates. Accessed April 9, 2013. *http://www.nature.nps.gov/air/Maps/AirAtlas/IM_materials.cfm*

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4.1.2 Wet sulfur deposition

Description

Emissions of sulfur dioxide (SO_2) in the U.S. increased from nine million metric tons in 1900 up to 28.8 million metric tons by 1973, with 60% of these emissions coming from electric utilities. Geographically, 41% came from the seven Midwest states centered on the Ohio Valley (Driscoll et al. 2001). Largely as a result of the Clean Air Act, emissions of SO_2 had reduced to 17.8 million metric tons by 1996 and while large areas of the eastern U.S. had annual sulfur wet deposition loads > 30 kg/ha/yr over the period 1983–1985, these areas were mostly < 25 kg/ha/yr by the period 1995–1997 (Driscoll et al. 2001). Once in the atmosphere, SO_2 is highly mobile and can be transported distances greater than 500 km (311 miles) (Driscoll et al. 2001).Wet sulfate (SO_4^{2-}) deposition is significant in the eastern parts of the United States (Figure 4.2).

Data and methods

The reference condition for total sulfur wet deposition is ecological. Natural background total sulfur deposition in the east of the U.S. is 0.5 kg/ha/yr which equates to a wet deposition of approximately 0.25 kg/ ha/yr (Porter and Morris 2007, NPS ARD 2011b).

The wet sulfur deposition data used for the assessment of current condition were taken from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2011a) (Table 4.1). These estimates were calculated on a national scale between 2005 and 2009 using an interpolation model based on monitoring data. The value for CATO was taken from the interpolation at the park centroid, which is a location near the center of the park (Figure 4.1).

NPS ARD has established wet sulfur deposition guidelines as < 1 kg/ha/yr indicating good condition (or 100% attainment of reference condition) and > 3 kg/ha/yr indicating significant concern (or 0% attainment). Concentrations of 1–3 kg/ha/yr were considered in moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (Figure 4.3, Table 4.5). For the current assessment, the reported wet deposition value was assessed against these guidelines (NPS ARD 2011a, b) (Tables 4.2, 4.3).

This analysis meant that there was only one value reported for wet sulfur deposition for

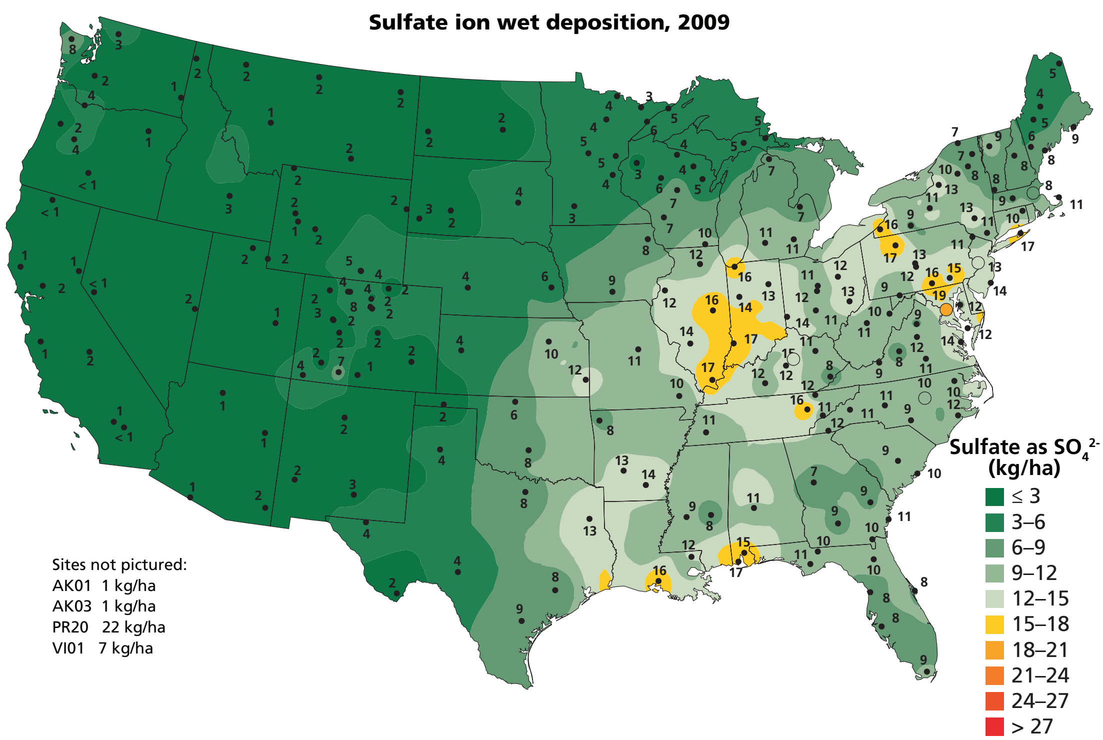

Figure 4.2. Total wet deposition of sulfate (SO_4^{3-}) for the continental United States in 2009 (NADP/NTN 2010).

CATO, so this value was assessed against the three reference condition ranges described above.

Additionally, National Atmospheric Deposition Program (NADP) data from the three monitoring sites closest to CATO were used—site MD07 within the park, and sites PA00 and MD99 nearby (Table 4.1, Figure 4.1).

Condition and trend

Interpolated wet sulfur deposition between 2005 and 2009 for CATO was 5.40 kg/ha/yr which resulted in 0% attainment of reference condition, or a condition of significant concern (NPS ARD 2011a) (Table 4.4). In a national assessment that ranked parks according to relative risk from sulfur (and nitrogen) acidification effects, CATO was ranked at very high risk (Sullivan et al. 2011a, b), suggesting that streams and soils in the park are very vulnerable to acidification. At this time, however, park streams are not showing signs of acidification (see section *4.2—Water Resources*).

CATO is included in the national assessment of current air quality conditions by NPS ARD but has not yet been included in the country-wide trends analyses. However, when deposition data were analyzed from the three sites closest to the park, site MD07 (within the park) showed a significant improvement of wet deposition over the past decade (p-value < 0.01) (Figure 4.4). The other two sites nearest the park (PA00 and MD99) did not show such a trend.

Sources of expertise

Air Resources Division, National Park Service. *http://www.nature.nps.gov/air*

National Atmospheric Deposition Program. *http://nadp.sws.uiuc.edu*

Drew Bingham, Geographer, NPS Air Resources Division.

Ellen Porter, NPS Air Resources Division.

Holly Salazer, NPS Air Resources Coordinator for the Northeast Region.

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Driscoll, C.T., G.B. Lawrence, A.J. Bulger, T.J. Butler, C.S. Cronan, C. Eagar, K.F. Lambert, G.E. Likens, J.L. Stoddard, and K.C. Weathers. 2001. Acidic deposition in the northeastern United States: sources and inputs, ecosystem

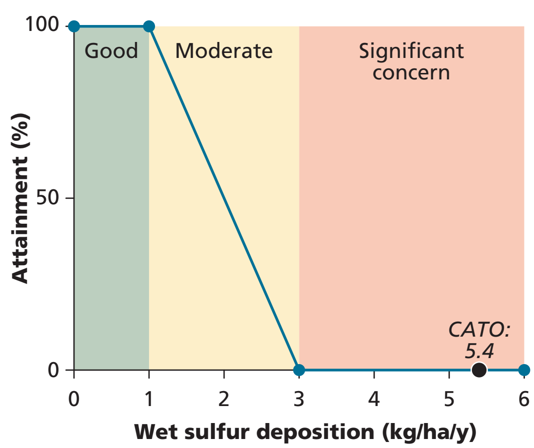

Figure 4.3. Application of the percent attainment categories to the wet sulfur deposition value categories. Wet sulfur deposition at CATO was 5.4 kg/ha/y which equated to 0% attainment of the reference condition.

Table 4.5. Wet sulfur deposition categories, percent attainment, and condition assessment.

S deposition (kg/ha/yr)	% attainment	Condition
< 1	100%	Good
1–3	0–100% (scaled)	Moderate
> 3	0%	Significant concern

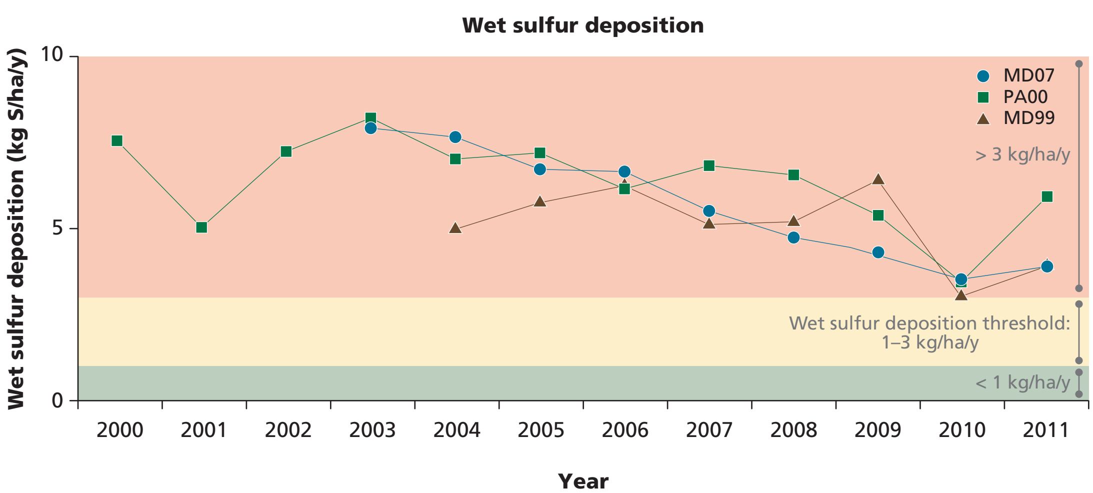

Figure 4.4. Annual wet deposition of sulfate (kg SO_4/ha/yr) at the three sites closest to CATO. Data were reported as SO_4 deposition; these data were converted to total S deposition using atomic weights (multiplying by 0.333). Reference conditions are shown in gray.

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NADP/NTN. 2010. *http://nadp.sws.uiuc.edu*

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Porter, E., K. Morris. 2007. Wet Deposition Monitoring Protocol: Monitoring Atmospheric Pollutants in Wet Deposition. Natural Resource Technical Report NPS/NRPC/ARD/NRTR—2007/004. National Park Service, Fort Collins, CO.

Sullivan, T.J., G.T. McPherson, T.C. McDonnell, S.D. Mackey, and D. Moore. 2011a. Evaluation of the sensitivity of Inventory and Monitoring National Parks to acidification effects from atmospheric sulfur and nitrogen deposition: main report. Natural Resource Report NPS/NRPC/ARD/NRR—2011/349. National Park Service, Denver, CO.

Sullivan, T.J., G.T. McPherson, T.C. McDonnell, S.D. Mackey, and D. Moore. 2011b. Evaluation of the sensitivity of Inventory and Monitoring National Parks to acidification effects from atmospheric sulfur and nitrogen deposition: National Capital Region Network (NCRN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/367. National Park Service, Denver, CO.

4.1.3 Wet nitrogen deposition

Description

During the 1940s and 1950s, it was recognized in the United States and Great Britain that emissions from coal burning and large-scale industry such as power plants and steel mills were causing severely degraded air quality in major cities. This resulted in severe human health impacts and by the early 1970s, the U.S. Environmental Protection Agency had established the National Ambient Air Quality Standards (NAAQS) (Porter and Johnson 2007). Since 1970, in addition to human health effects, it was increasingly recognized that there were significant ecosystem impacts of atmospheric nitrogen deposition, including acidification and nutrient fertilization of waters and soils (NPS ARD 2011a). These impacts included such measurable effects as the disruption of nutrient cycling, changes to vegetation structure, loss of stream biodiversity, and the eutrophication of streams and coastal waters (Driscoll et al. 2001, Porter and Johnson 2007). Wet nitrogen deposition is significant in the eastern parts of the United States (Figure 4.5).

Data and methods

The reference condition for total nitrogen wet deposition is ecological. Natural background total nitrogen deposition in the east of the U.S. is 0.5 kg/ha/yr which equates to a wet deposition of approximately 0.25 kg/ha/yr (Porter and Morris 2007, NPS ARD 2011a). Some sensitive ecosystems, such as coastal and estuarine waters and upland areas, show responses to wet nitrogen deposition rates of 1.5 kg/ha/yr, while there is no evidence of ecosystem harm at deposition rates less than 1 kg/ha/yr (Fenn et al. 2003).

The wet nitrogen deposition data used for the assessment of current condition were taken from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2011b) (Table 4.1). These estimates were calculated on a national scale between 2005 and 2009 using an interpolation model based on monitoring data. The value for CATO was taken from the interpolation at the park centroid, which is a location near the center of the park (Figure 4.1).

NPS ARD has established wet nitrogen deposition guidelines as < 1 kg/ha/yr indicating good condition (or 100% attainment of reference condition) and > 3 kg/ha/yr indicating significant concern (or 0% attainment). Concentrations of 1–3 kg/ha/yr were considered in moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (Figure 4.6, Table 4.6). For the current assessment, the reported wet deposition value

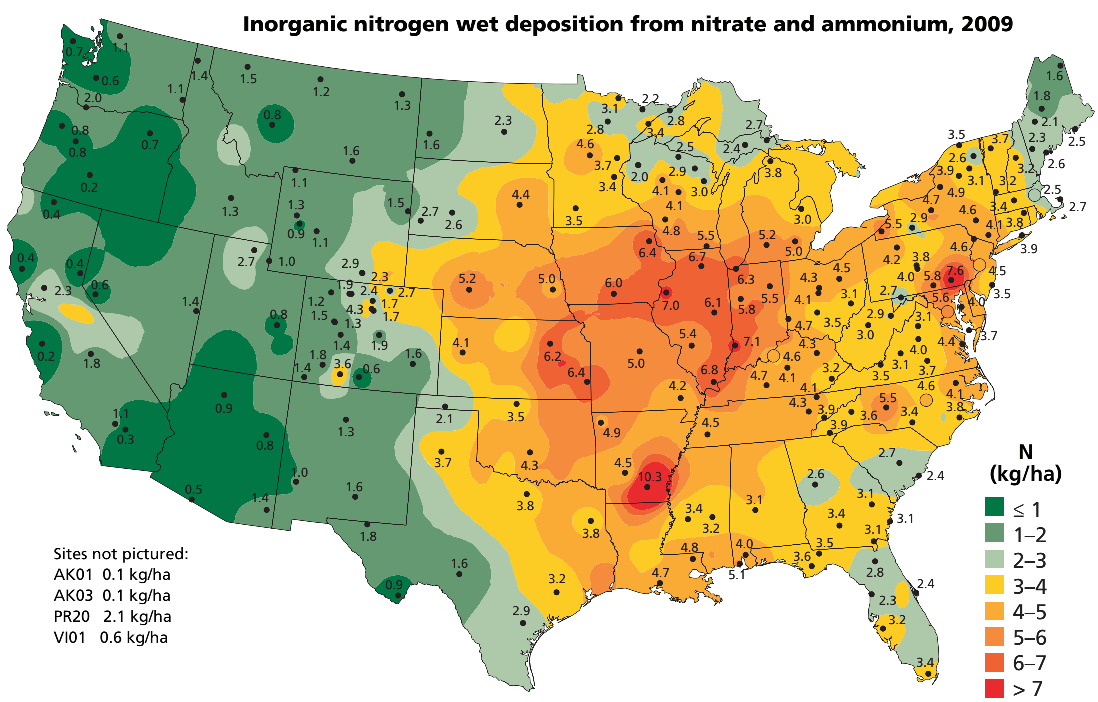

Figure 4.5. Total wet deposition of nitrate (NO_3^-) and ammonium (NH_4^+) (kg/ha) for the continental United States in 2009 (NADP/NTN 2010).

was assessed against these guidelines (NPS ARD 2011a, b) (Tables 4.2, 4.3).

This analysis meant that there was only one value reported for wet nitrogen deposition for CATO, so this value was assessed against the three reference condition ranges described above.

Additionally, National Atmospheric Deposition Program (NADP) data from the three monitoring sites closest to CATO were used—site MD07 within the park, and sites PA00 and MD99 nearby (Table 4.1, Figure 4.1).

Figure 4.6. Application of the percent attainment categories to the wet nitrogen deposition value categories. Wet nitrogen deposition at CATO was 4.65 kg/ha/y which equated to 0% attainment of the reference condition.

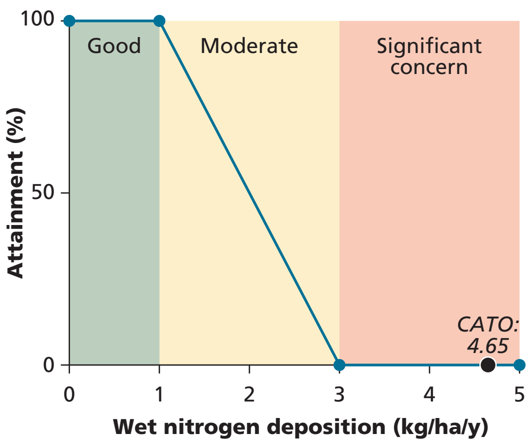

Table 4.6. Wet nitrogen deposition categories, percent attainment, and condition assessment.

N deposition (kg/ha/yr)	% attainment	Condition
< 1	100%	Good
1–3	0–100% (scaled)	Moderate
> 3	0%	Significant concern

Condition and trend

Interpolated wet nitrogen deposition between 2005 and 2009 for CATO was 4.65 kg/ha/yr which resulted in 0% attainment of reference condition, or a condition of significant concern (NPS ARD 2011b) (Table 4.4). In a national assessment that ranked parks according to relative risk from nutrient nitrogen effects, CATO was ranked at moderate risk (Sullivan et al. 2011a, b).

CATO is included in the national assessment of current air quality conditions by NPS ARD but has not yet been included in the country-wide trends analyses. However, when deposition data were analyzed from the three sites closest to the park, none of the sites showed a significant improvement of wet deposition over the past decade (p-value > 0.01) (Figure 4.7).

Sources of expertise

Air Resources Division, National Park Service. *http://www.nature.nps.gov/air*

National Atmospheric Deposition Program. *http://nadp.sws.uiuc.edu*

Drew Bingham, Geographer, NPS Air Resources Division.

Ellen Porter, NPS Air Resources Division.

Holly Salazer, NPS Air Resources Coordinator for the Northeast Region.

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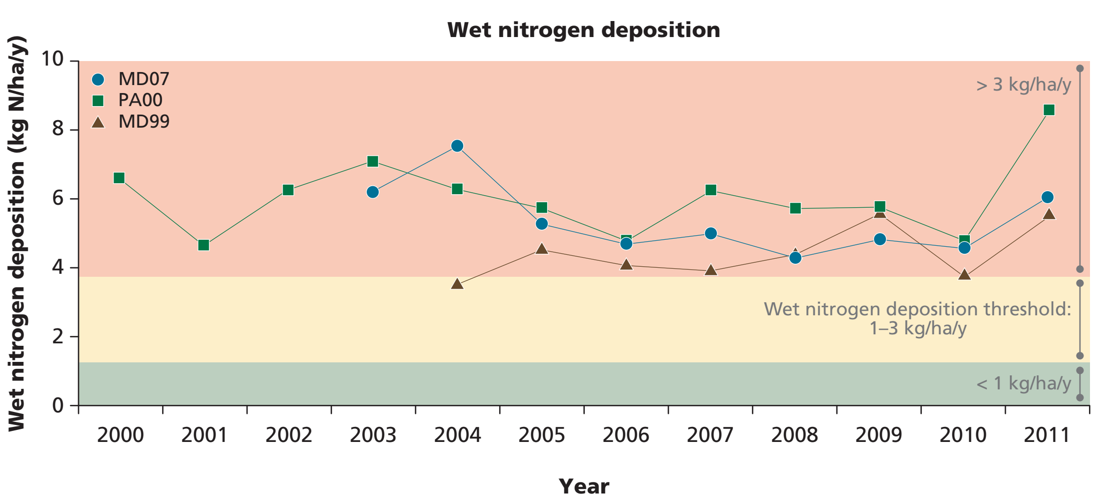
Figure 4.7. Annual wet deposition of total nitrogen (kg N/ha/yr) at the three sites closest to CATO. Reference conditions are shown in gray.



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4.1.4 Ozone

Description

Ozone is a secondary atmospheric pollutant, meaning it is not directly emitted but rather is formed by a sunlight-driven chemical reaction on nitrogen oxides and volatile organic compounds emitted largely from burning fossil fuels (Haagen–Smit and Fox 1956). In humans, ozone can cause a number of health-related issues such as lung inflammation and reduced lung function, which can result in hospitalization. Although adverse health effects can occur in very sensitive groups at levels below 60 ppb, the U.S. EPA's 2007 review of the standard concluded that levels between 60 and 70 ppb would likely be protective of most of the population (U.S. EPA 2007). In 2010, the U.S. EPA proposed establishing a separate secondary standard to protect vegetation, based on an ecologically relevant metric, the W126, which is explained in more detail in the following section. Some plant species are more sensitive to ozone than humans. These sensitive plants can develop foliar injury from elevated ozone exposure levels especially when soil moisture levels are moderate to high. Under these conditions, plants have their stomata open, allowing gas exchange for photosynthesis, but also allowing ozone to enter.

Data and methods

Ground-level ozone is regulated under the Clean Air Act and the U.S. EPA is required to set standard concentrations for ozone (U.S. EPA 2004). The current National Ambient Air Quality Standards (NAAQS) standard is 75 ppb, based on the three-year average annual fourth-highest daily maximum eight-hour ozone concentration at a monitor (NAAQS 2008). Both the three-year average annual fourth-highest daily maximum eight-hour concentration (averaged over five years) and the plant-exposure metric, the W126, are incorporated into the benchmarks to assess ozone condition within National Park units by the National Park Service Air Resources Division (NPS ARD 2011a).

The ozone concentration data used for the assessment of current condition were taken from the NPS ARD Air Quality Estimates (NPS ARD 2011b) (Table 4.1). These estimates were calculated on a national scale between 2005 and 2009 using an interpolation model based on monitoring data. The value for CATO was taken from the interpolation at the park centroid, which is a location near the center of the park (Figure 4.1).

NPS ARD has established ozone concentration (three-year average fourth-highest daily maximum eight-hour ozone concentration, averaged over five years) guidelines as ≤ 60.0 ppb (set as 80% of the current standard of 75 ppb) indicating good condition (or 100% attainment of reference condition) and > 75 ppb indicating significant concern (or 0% attainment) (U.S. EPA 2007, NPS ARD 2011a). Concentrations of 60.1–75.0 ppb were considered in moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (Figure 4.8, Table 4.7). For the current assessment, the reported visibility value was assessed against these guidelines (NPS ARD 2011a, b) (Tables 4.2, 4.3).

NPS ARD also looks at the W126 standard to assess the risk for ozone-induced foliar damage to sensitive plants. W126 provides an index of the cumulative ozone exposure to plants during daylight hours. The W126 weights higher ozone concentration more heavily because they are more likely to cause injury. Values less than 7 parts per million-hour (ppm-hrs) are considered safe for sensitive plants (or 100% attainment of reference condition) and > 13 ppm-hrs is considered a significant concern for very

Table 4.7. Ozone deposition categories, percent attainment, and condition assessment.

Ozone (ppb)	Ozone (W126)	% attainment	Condition
≤ 60	< 7	100%	Good
60.1–75	7–13	0–100% (scaled)	Moderate
> 75	> 13	0%	Significant concern

sensitive plant species (or 0% attainment). Values of 7–13 ppm-hrs represents a moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (NPS ARD 2010, 2011c) (Figure 4.9, Table 4.7). Although the W126 metric was analyzed and the attainment was calculated, the score was omitted from the overall assessment due to the ozone (ppb) metric already being included in the assessment.

This analysis meant that there was only one value reported for ozone concentration for CATO, so this value was assessed against the three reference condition ranges described above.

Condition and trend

Interpolated fourth-highest daily maximum eight-hour ozone concentration between 2005 and 2009 for CATO was 75.9 ppb which resulted in 0% attainment of reference condition, or a condition of significant concern (NPS ARD 2011a) (Table 4.4). In addition, the U.S. EPA has announced its intention to designate Frederick County, MD, which encompasses CATO, as nonat-

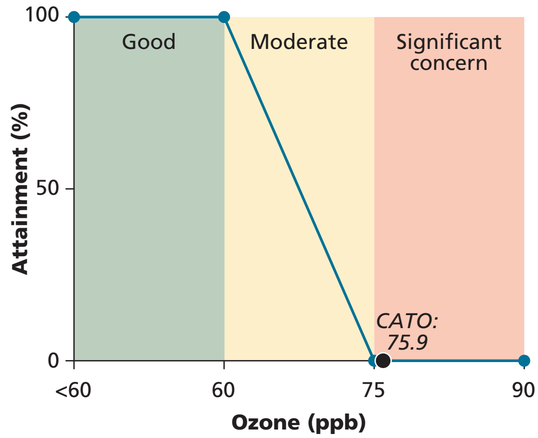

Figure 4.8. Application of the percent attainment categories to the ozone (ppb) value categories. Ozone at CATO was 75.9 ppb which equated to 0% attainment of the reference condition.

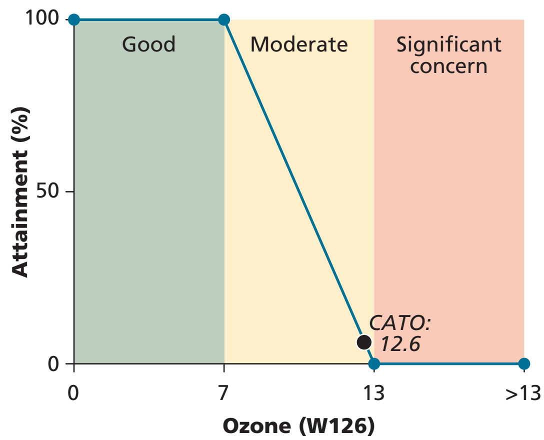

Figure 4.9. Application of the percent attainment categories to the ozone (W126) value categories. W126 at CATO was 12.6 which equated to 6.7% attainment of the reference condition.

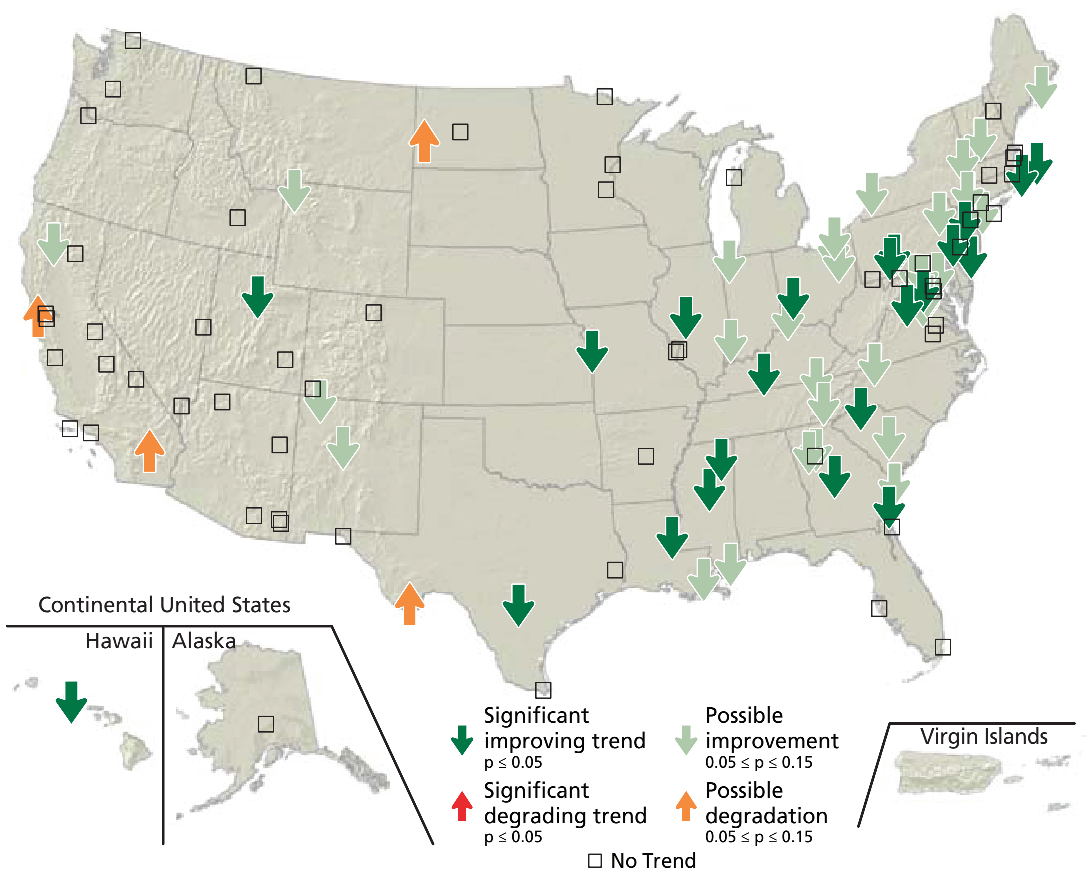

Figure 4.10. Trends in annual fourth-highest eight-hour ozone concentration (ppb), 1999–2008 (NPS ARD 2010).

tainment for ozone (U.S. EPA 2011) because of violations of the 75 ppb standard, recognizing that air quality is unhealthy at times in the area.

Interpolated W126 value between 2005 and 2009 for CATO was 12.6 ppm-hrs which resulted in 6.7% attainment of reference condition, or very degraded conditions (NPS ARD 2011a) (Table 4.4). A national assessment concluded that vegetation at CATO was at high risk of injury from ozone, which can cause visible foliar injury and reduced growth and reproduction (Kohut 2007).

Although the trend in CATO was not individually assessed, a country-wide assessment of ozone trends within 159 park units found that in the eastern U.S., ozone trends are generally improving over the past 10 years, largely influenced by the implementation of the NOX State Implementation Plan (SIP) Call rule (EPA 2010, NPS ARD 2010) (Figure 4.10).

The overall ozone condition at CATO is of significant concern, as the interpolated estimate of the eight-hour ozone average exceeds the human health standard of 75 ppb. Additionally, the park is located in Frederick County, MD, which is considered nonattainment for the standard.

Sources of expertise

Air Resources Division, National Park Service. *http://www.nature.nps.gov/air*

Drew Bingham, Geographer, NPS Air Resources Division.

Ellen Porter, NPS Air Resources Division.

Holly Salazer, NPS Air Resources Coordinator for the Northeast Region.

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4.1.5 Visibility

Description

The presence of sulfates, organic matter, soot, nitrates, and soil dust can impair visibility. In the eastern U.S., the major cause of reduced visibility is sulfate particles formed from SO_2 emitted from coal combustion (National Research Council 1993). The Clean Air Act includes visibility as one of its national goals as it is an indicator of emissions (U.S. EPA 2004).

Data and methods

Air pollution causes haze and reduces visibility. Visibility is measured using the Haze Index in deciviews (dv). As the Haze Index increases, the visibility worsens. Conditions for visibility are based on five-year average visibility minus estimated average natural visibility, where average visibility is the mean of visibility between 40th and 60th percentiles (U.S. EPA 2003, NPS ARD 2011a). Interpolated five-year averages are used within the contiguous U.S. The visibility condition is expressed as:

Visibility Condition = average current visibility – estimated average natural visibility

The reference condition for visibility is based on the national goal of restoring natural visibility. The Regional Haze Rule requires remedying existing and preventing any future visibility impairment in the nation's largest parks and wilderness areas, known as the 'Class I' areas (NPS ARD 2010). NPS has adopted this goal for all parks, including CATO and all others designated as Class II under the Clean Air Act.

The haze index data used for the assessment of current condition were taken from the NPS Air Resources Division (ARD) Air Quality Estimates (NPS ARD 2011b) (Table 4.1). These estimates were calculated on a national scale between 2005 and 2009 using an interpolation model based on monitoring data. The value for CATO was taken from the interpolation at the park centroid, which is a location near the center of the park (Figure 4.1).

NPS ARD has established visibility guidelines as ≤ 2 dv above natural conditions indicating good condition (or 100% attainment of reference condition) and ≥ 8 dv above natural conditions indicating significant concern (or 0% attainment). Concentrations of 2–8 dv above natural conditions were considered in moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (Figure 4.11, Table 4.8). For the current assessment, the reported visibility value was assessed against these guidelines (NPS ARD 2011a, b) (Tables 4.2, 4.3).

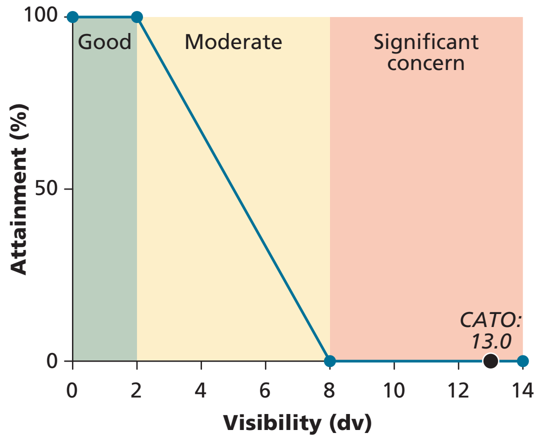

Figure 4.11. Application of the percent attainment categories to the visibility value categories. Visibility at CATO was 13.0 dv which equated to 0% attainment of the reference condition.

Table 4.8. Visibility categories, percent attainment, and condition assessment.

Visibility (dv)	% attainment	Condition
< 2	100%	Good
2–8	0–100% (scaled)	Moderate
> 8	0%	Significant concern

This analysis meant that there was only one value reported for the haze index for CATO, so this value was assessed against the three reference condition ranges described above.

Condition and trend

Interpolated haze index between 2005 and 2009 for CATO was 13.0 dv, which resulted in 0% attainment of reference condition, or a condition of significant concern (NPS ARD 2011a) (Table 4.4).

A country-wide assessment of visibility trends between 1999 and 2008 within 157 parks found that CATO was one of only 10 parks showing a significant improvement of visibility on the haziest days (NPS ARD 2010) (Figure 4.12). However, when trends for the clearest days and haziest days were

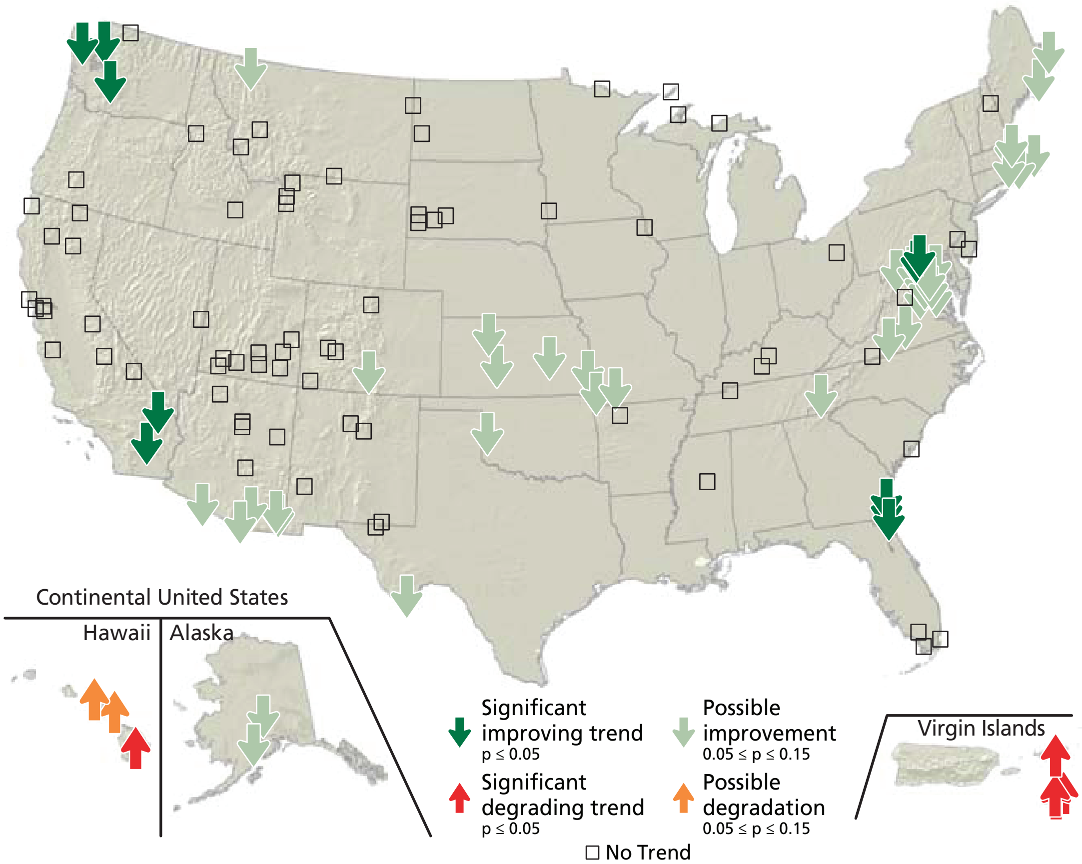

Figure 4.12. Visibility trends measured by the haze index (deciview) on haziest days, 1999–2008 (NPS ARD 2010).

examined together, there was no significant trend in visibility for CATO (NPS ARD 2010).

Sources of expertise

Air Resources Division, National Park Service. *http://www.nature.nps.gov/air*

Drew Bingham, Geographer, NPS Air Resources Division.

Ellen Porter, NPS Air Resources Division.

Holly Salazer, NPS Air Resources Coordinator for the Northeast Region.

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4.1.6 Particulate matter

Description

Fine particles less than 2.5µm diameter (PM 2.5) are emitted as smoke from power plants, gasoline and diesel engines, wood combustion, steel mills, and forest fires. Fine particles are also created when emissions of sulfur dioxide and nitrogen dioxide transform in the atmosphere to sulfate and nitrate particles. These fine particles have multiple human health impacts and can aggravate lung disease and cause non-fatal heart and asthma attacks, acute bronchitis, respiratory infection, coughing, wheezing, shortness of breath, and changes in lung function (U.S. EPA 2006). In recognition of these significant health impacts, ground-level particulate matter is regulated under the Clean Air Act and the U.S. EPA is required to set standard concentrations for airborne particulates (U.S. EPA 2004a).

Data and methods

Data was obtained from the Interagency Monitoring of Protected Visual Environments (IMPROVE) database through the U.S. EPA's AirData interface (Table 4.1) for the two sampling locations closest to CATO: sites 240430009 near St. James in Washington County, MD and 420010001 in Arendtsville in Adams County, PA (Figure 4.1, Table A-1).

The current National Ambient Air Quality Standards (NAAQS) particulate matter regulatory threshold is a concentration of 35 µg/m³ (NAAQS 2008). There are two primary standards for PM 2.5. The annual standard is met (air condition is considered acceptable) when the three-year average of the annual mean concentration is ≤ 15.0 µg/m³, and the 24-hour or 'daily' standard is met when the three-year average of the annual 98th percentile is ≤ 65.0 µg/m³ (NAAQS 2008). The annual standard (≤ 15.0 µg/m³) was used as the reference condition in the current assessment (Tables 4.2, 4.3).

In keeping with the NPS ARD calculation of multiple thresholds for ozone (NPS ARD 2011), good condition (or 100% attainment) for particulate matter represents

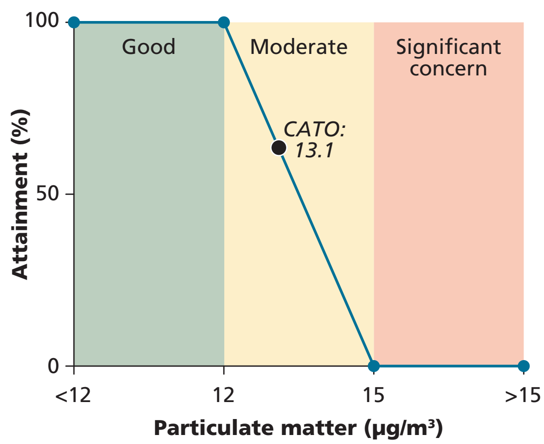

Figure 4.13. Application of the percent attainment categories to the particulate matter value categories. Particulate matter at CATO was 13.1 µg/m³ which equated to 65% attainment of the reference condition.

Table 4.9. Particulate matter categories, percent attainment, and condition assessment.

Particulate matter (µg/m³)	% attainment	Condition
≤ 12	100%	Good
12.1–15	0–100% (scaled)	Moderate
> 15	0%	Significant concern

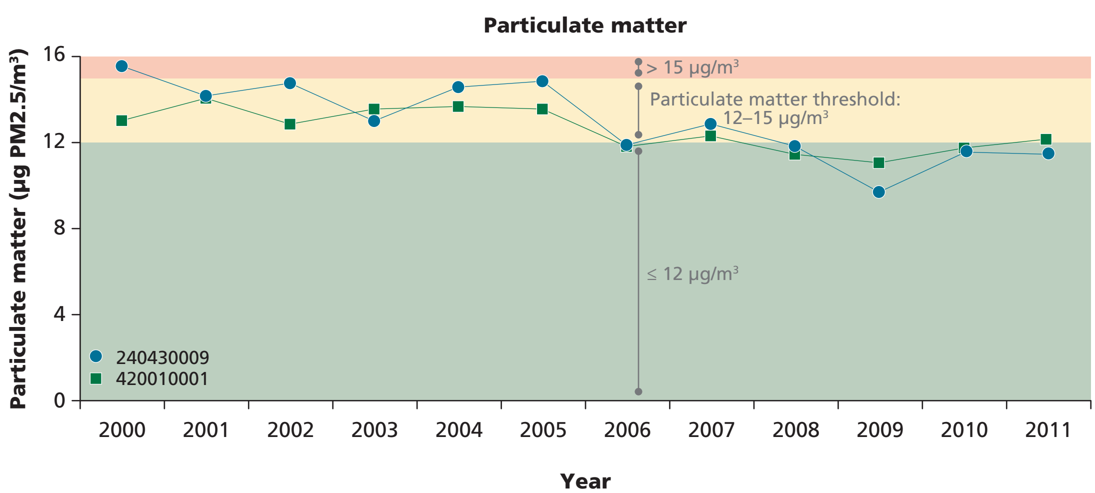

Figure 4.14. Particulate matter (µg PM2.5/m³) at the two sites closest to CATO. Reference conditions are shown in gray. Data show the annual mean concentrations.

80% or less (or ≤12.0 μg/m^3) of the current standard. Values > 15 μg/m^3 indicated significant concern (or 0% attainment). Values of 12.0–15.0 μg/m^3 indicated moderate condition, and attainment scores were scaled linearly from 0 to 100% between these two reference points (Figure 4.13, Tables 4.2, 4.3, 4.9).

Data were 24-hour averages; three-year averages of the annual mean concentrations were calculated. The median of all these values was taken and assessed against the three reference condition ranges described above.

Condition and trend

The two sites closest to CATO had a median of 13.1 μg/m^3 between 2001 and 2010, with 65% attainment of the reference condition, or moderate condition (Figure 4.14, Table 4.4). Both sites showed a significant improving trend of particulate matter over the past decade (p-value < 0.01) (Figure 4.14).

Sources of expertise

Interagency Monitoring of Protected Visual Environments (IMPROVE). *http://vista.cira.colostate.edu/improve/Data/IMPROVE/improve_data.htm*

U.S. EPA PM Standards. *http://epa.gov/ttn/naaqs/standards/pm/s_pm_index.html*

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4.1.7 Mercury deposition

Description

Atmospheric mercury (Hg) comes from natural sources, including volcanic and geothermal activity, geological weathering, anthropogenic sources such as burning of fossil fuels, processing of mineral ores, and incineration of certain waste products (UNEP 2008). At a global scale, annual anthropogenic emissions of mercury approximately equal all natural marine and terrestrial emissions, with anthropogenic emissions in North America being 153 metric tons in 2005 (UNEP 2008). Exposure of humans and other mammals to mercury in utero can result in developmental disabilities, cerebral palsy, deafness, blindness, and dysarthria (speech disorder), and exposure as adults can lead to motor dysfunction and other neurological and mental impacts (U.S. EPA 2001). Avian species' reproductive potential is negatively impacted by mercury, and measured trends in mercury deposition, from west to east across North America, can also be measured in the common loon (*Gavia immer*), and throughout North America in mosquitoes (Evers et al. 1998, Hammerschmidt and Fitzgerald 2006). Mercury is also recorded to have a toxic effect on soil microflora, although no ecological depositional threshold is currently established (Meili et al. 2003).

Data and methods

Data was obtained from the National Atmospheric Deposition Program, Mercury Deposition Network (Table 4.1) for two sites: Arendtsville (PA00) in Adams County, PA, and Beltsville (MD99) in Prince Georges County, MD (Figure 4.1). Samples are collected weekly and within 24 hours of a precipitation event and analyzed for mercury concentration, measured in nanograms (ng) of Hg/L. Annual mean mercury concentrations were calculated for each sampling site.

There are no published thresholds for wet deposition of mercury, so this metric was not included in the overall assessment of CATO, but was included for informational purposes only.

Condition and trend

Annual median mercury concentrations in precipitation from two sites in the region of CATO over the past decade range from ~7–13 ng/L (Figure 4.15, Table 4.4) and the Mid-Atlantic region in general has relatively low levels of mercury deposition (Figure 4.16). If it is assumed that precipitation constitutes much of the flow in streams in the parks, then it can be assumed that mercury concentrations in streams would be comparable to the range observed in precipitation. The U.S. EPA does provide National Recommended Water Quality Criteria for the protection of aquatic life. Criteria for total dissolved mercury are 1,400 ng/L (acute criteria) and 770 ng/L (chronic criteria) (U.S. EPA 2012). These criteria values are 1–2 orders of magnitude greater than what has been recorded in rainfall in the region, suggesting a low risk to aquatic life. However, mercury concentrations in streams within the region are not

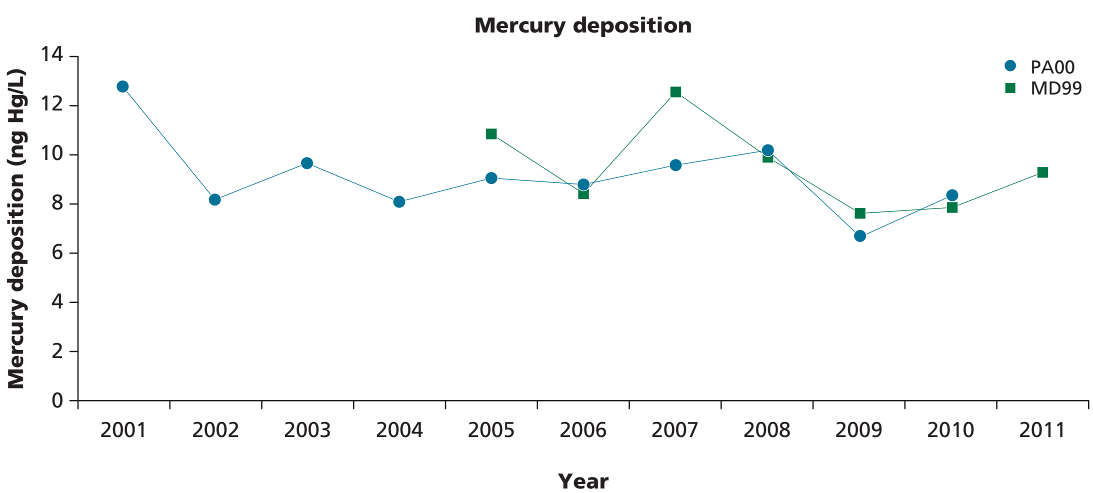

Figure 4.15. Median annual mercury concentrations (ng Hg/L) in precipitation from two sites in the region of CATO.

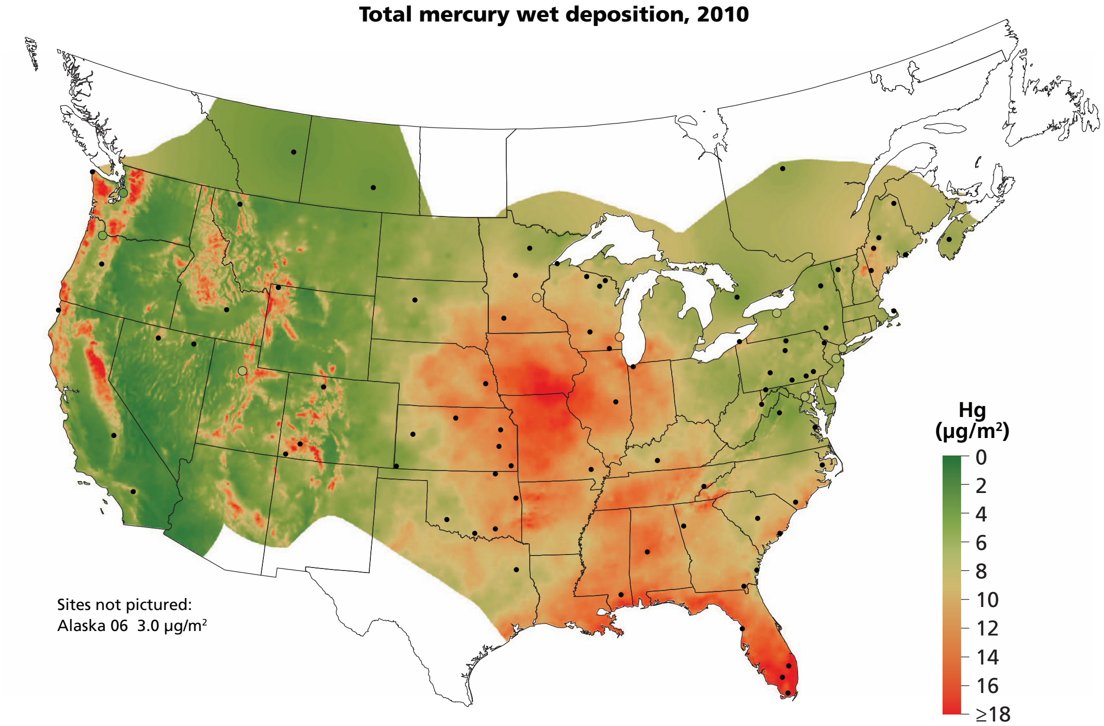

Figure 4.16. Total mercury wet deposition across the United States in 2010 (NADP/MDN 2012).

available. Experimental research in boreal lakes in Canada has shown a linear relationship between mercury deposition and accumulation in biota, using similar deposition values as seen in the National Capital Region (Orihel et al. 2007). However, due to the lack of research in the region linking mercury deposition to accumulation in fish, mercury was not included in the overall assessment.

Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.15).

Sources of expertise

National Atmospheric Deposition Program, Mercury Deposition Network. *http://nadp.sws.uiuc.edu/MDN*

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4.2 WATER RESOURCES

4.2.1 Water resources summary

Nine metrics were used to assess water resources in CATO—pH, dissolved oxygen, water temperature, acid neutralizing capacity, salinity/specific conductance, nitrate, total phosphorus, Benthic Index of Biotic Integrity (BIBI), and Physical Habitat Index (PHI) (Table 4.10). Data were collected by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff and CATO park staff. Water quality monitoring sites are shown in Figure 4.17 and BIBI and PHI monitoring sites are shown in Figure 4.18.

Reference conditions were established for each metric (Table 4.11) and the data were compared to these reference conditions to obtain the percent attainment and converted to the condition assessment for that metric (Table 4.12). Single reference conditions were used for pH, dissolved oxygen, temperature, acid neutralizing capacity, specific conductance, nitrate, and total phosphorus, while multiple reference conditions were used for BIBI and PHI (Tables 4.11, 4.12a, 4.12b).

CATO scored as very good (88–100% attainment) for all water quality metrics except total phosphorus (0% attainment or very degraded condition), BIBI (83% attainment or good condition), and PHI (66% attainment or partially degraded condition) (Table 4.13). This resulted in an overall water resources condition attainment of 80%, or very good condition.

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Table 4.10. Ecological monitoring framework data for Water Resources provided by agencies and specific sources included in the assessment of CATO.

Metric	Agency	Reference/source
pH	NCRN I&M	Pieper et al. 2012, Norris et al. 2011
Dissolved oxygen	NCRN I&M	Pieper et al. 2012, Norris et al. 2011
Water temperature	NCRN I&M	Pieper et al. 2012, Norris et al. 2011
Acid neutralizing capacity	NCRN I&M	Pieper et al. 2012, Norris et al. 2011
Specific conductance	NCRN I&M	Pieper et al. 2012, Norris et al. 2011
Nitrate	NCRN I&M	Pieper et al. 2012, Norris et al. 2011
Total phosphorus	NCRN I&M	Pieper et al. 2012, Norris et al. 2011
Benthic Index of Biotic Integrity	NCRN I&M, MBSS	Norris and Sanders 2009, MBSS
Physical Habitat Index	NCRN I&M, MBSS	Norris and Sanders 2009, MBSS

Table 4.11. Water Resources reference conditions for CATO.

Metric	Reference condition/s	Sites	Samples	Period
pH	$6.5 \leq pH \leq 8.5$	12	1,014	2000–2011
Dissolved oxygen (mg/L)	≥ 5.0	12	960	2000–2011
Water temperature (°C)	≤ 20.0	12	1,083	2000–2011
Acid neutralizing capacity (µeq/L)	≥ 200	3	204	2005–2011
Specific conductance (µS/cm)	≤ 500	12	986	2000–2011
Nitrate (mg/L)	≤ 2	12	201	2005–2011
Total phosphorus (mg/L)	≤ 0.01	3	156	2007–2011
Benthic Index of Biotic Integrity	1.0–1.9; 2.0–2.9; 3.0–3.9; 4.0–5.0	4	4	2006–2010
Physical Habitat Index	0–50; 51–65; 66–80; 81–100	4	4	2006–2010

Norris, M.E., J.M. Pieper, T.M. Watts, and A. Cattani. 2011. National Capital Region Network Inventory and Monitoring Program water chemistry and quantity monitoring protocol version 2.0: Water chemistry, nutrient dynamics, and surface water dynamics vital signs. Natural Resource Report NPS/NCRN/ NRR—2011/423. National Park Service, Fort Collins, CO.

Pieper, J., M. Norris, and T. Watts. 2012. National Capital Region Network FY 2010 water resources monitoring data report. Natural Resources Data Series NPS/NCRN/ NRDS—2012/381. Natural Resources Program Center, Fort Collins, CO.

Table 4.12a. Categorical ranking of reference condition attainment categories for pH, dissolved oxygen, temperature, acid neutralizing capacity, specific conductance, nitrate, and total phosphorus.

Attainment of reference condition	Natural resource condition
80–100%	Very good
60–<80%	Good
40–<60%	Moderate
20–<40%	Degraded
0–<20%	Very degraded

Table 4.12b. Categorical ranking of the reference condition attainment categories for the Benthic Index of Biotic Integrity and the Physical Habitat Index.

Reference conditions	Attainment of reference condition	Natural resource condition
Benthic Index of Biotic Integrity (BIBI)		
4.0–5.0	100%	Good
3.0–3.9	↑ scaled	Fair
2.0–2.9	linearly ↓	Poor
1.0–1.9	0%	Very poor

Reference conditions	Attainment of reference condition	Natural resource condition
Physical Habitat Index (PHI)		
81–100	75–100% (scaled)	Minimally degraded
66–80	50–75% (scaled)	Partially degraded
51–65	25–50% (scaled)	Degraded
0–50	0–25% (scaled)	Severely degraded

Table 4.13. Summary of resource condition assessment of Water Resources in CATO.

Metric	Result	Reference condition	% attainment	Condition	Water resources condition
pH	7.6	6.5–8.5	99.7	Very good	**80% Very good**
Dissolved oxygen (mg/L)	9.8	≥ 5.0	99.4	Very good	
Water temperature (°C)	11.0	≤ 20.0	98	Very good	
Acid neutralizing capacity (μeq/L)	564	≥ 200	100	Very good	
Specific conductance (μS/cm)	112	≤ 500	88	Very good	
Nitrate (mg/L)	1.0	≤ 2	98	Very good	
Total phosphorus (mg/L)	0.08	≤ 0.01	0	Very degraded	
Benthic Index of Biotic Integrity	4.3	1.0–1.9; 2.0–2.9; 3.0–3.9; 4.0–5.0	83	Good	
Physical Habitat Index	66	0–50; 51–65; 66–80; 81–100	50	Partially degraded	

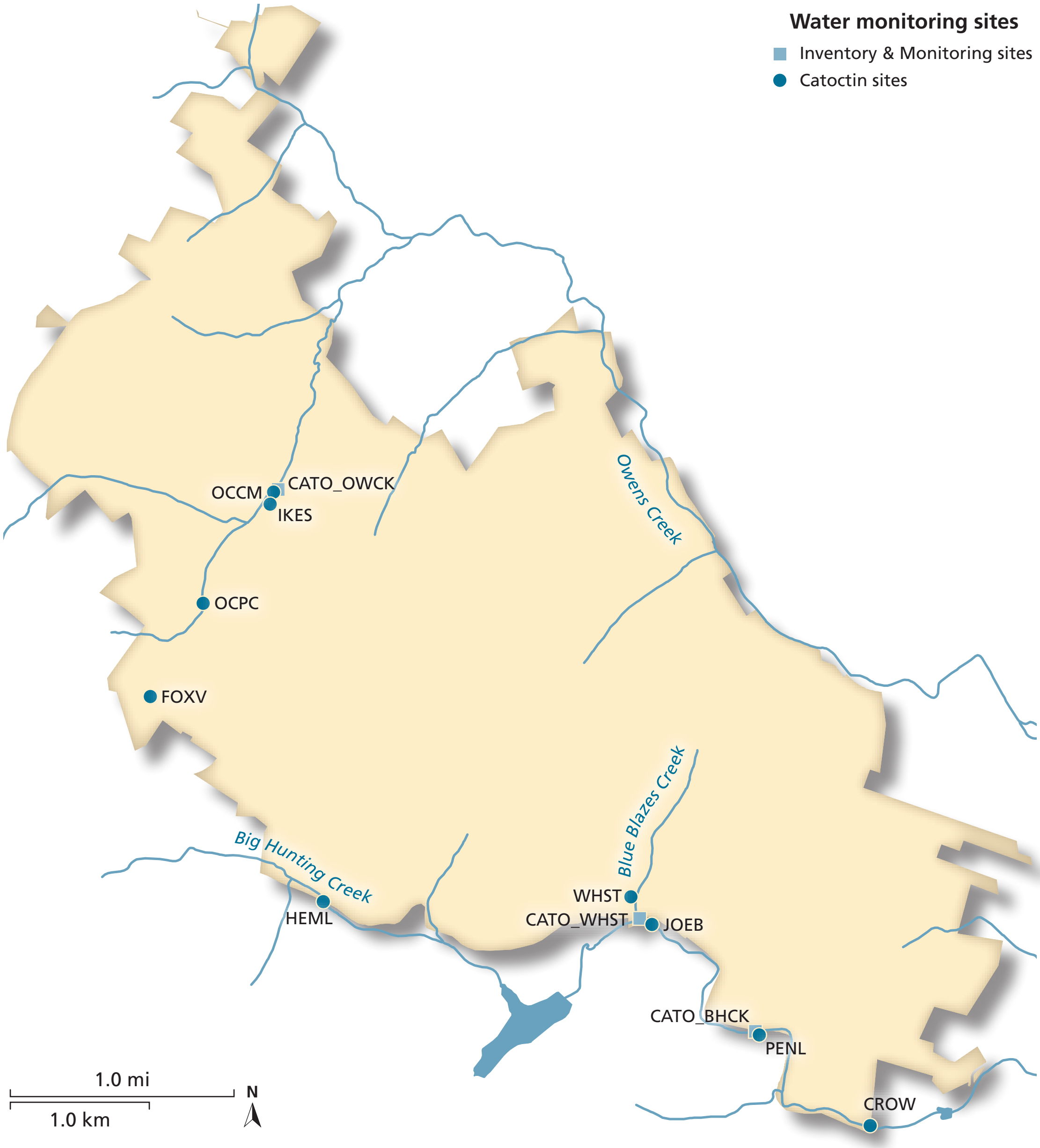

Figure 4.17. Stream sampling locations in CATO used for long-term water quality monitoring (Norris et al. 2007).

Figure 4.18. Stream sampling locations in CATO monitored for stream macroinvertebrates, physical habitat, and stream fishes.

4.2.2 Water pH

Description

The streams in and adjacent to CATO are an important and unique habitat for plants, invertebrates, fish, and amphibians, as well as an important water source for mammals and birds. Deposition of atmospheric sulfate and nitrogen are a significant regional concern, and freshwater habitats may be impacted by acidification (Sardinski and Dunson 1992, NPS ARD 2010). Salamanders and fish are susceptible to extreme pH values and can be limited by food availability even at less extreme acidification by, for example, reduced zooplankton and periphyton communities (Sadinski and Dunson 1992, Barr and Babbitt 2002). Reduced pH can result in reduced salamander hatching success, suppression of larval newt survival, and impacts upon frog metamorphosis (Sadinski and Dunson 1992).

Data and methods

The data analyzed were collected monthly between 2000 and 2011 at nine sites by CATO staff and monthly between 2000 and 2011 at three sites by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff (Pieper et al. 2012) (Figure 4.17, Table 4.10, Table A-2). NCRN followed the sampling protocol specified in Norris et al. 2011.

A reference condition pH range of 6.5–8.5 was used for this assessment, which is the Maryland criteria for Designated Use III-P: Nontidal Cold Water and Public Water Supply (COMAR 2007a, 2007b, 2007c) (Table 4.11). Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment (Table 4.12a).

Condition and trend

Condition of pH in CATO between 200 and 2011 was very good, with a median pH of 7.6 and 99.7% of data points attaining the reference condition of 6.5–8.5 (Figures 4.19, 4.20, Tables 4.13, 4.14). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.20).

Table 4.14. Median results for pH at each site. Locations of monitoring sites are shown in Figure 4.17.

Site	Median
CATO_BHCK	7.63
CATO_OWCK	7.52
CATO_WHST	7.64
CROW	7.69
FOXV	7.55
HEML	7.61
IKES	7.63
JOEB	7.55
OCCM	7.48
OCPC	7.54
PENL	7.65
WHST	7.64

Sources of expertise

James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

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Barr, G.E. and K.J. Babbitt. 2002. Effects of biotic and abiotic factors on the distribution and abundance of larval two-lined salamanders (Eurycea bislineata) across spatial scales. Oecologia 133: 176–185.

COMAR (Code of Maryland Regulations). 2007a. 26.08.02.02: Designated Uses. Title 26: Maryland Department of the Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality.

COMAR (Code of Maryland Regulations). 2007b. 26.08.02.03-3: Water Quality Criteria Specific to Designated Uses. Title 26: Maryland Department of the Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality.

COMAR (Code of Maryland Regulations). 2007c. 26.08.02.08: Stream Segment Designations. Title 26: Maryland Department of the Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality.

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

Norris, M.E., J.M. Pieper, T.M. Watts, and A. Cattani. 2011. National Capital Region Network Inventory and Monitoring Program water chemistry and quantity monitoring protocol version 2.0: Water chemistry, nutrient dynamics, and surface water dynamics vital signs. Natural Resource Report NPS/NCRN/ NRR—2011/423. National Park Service, Fort Collins, CO.

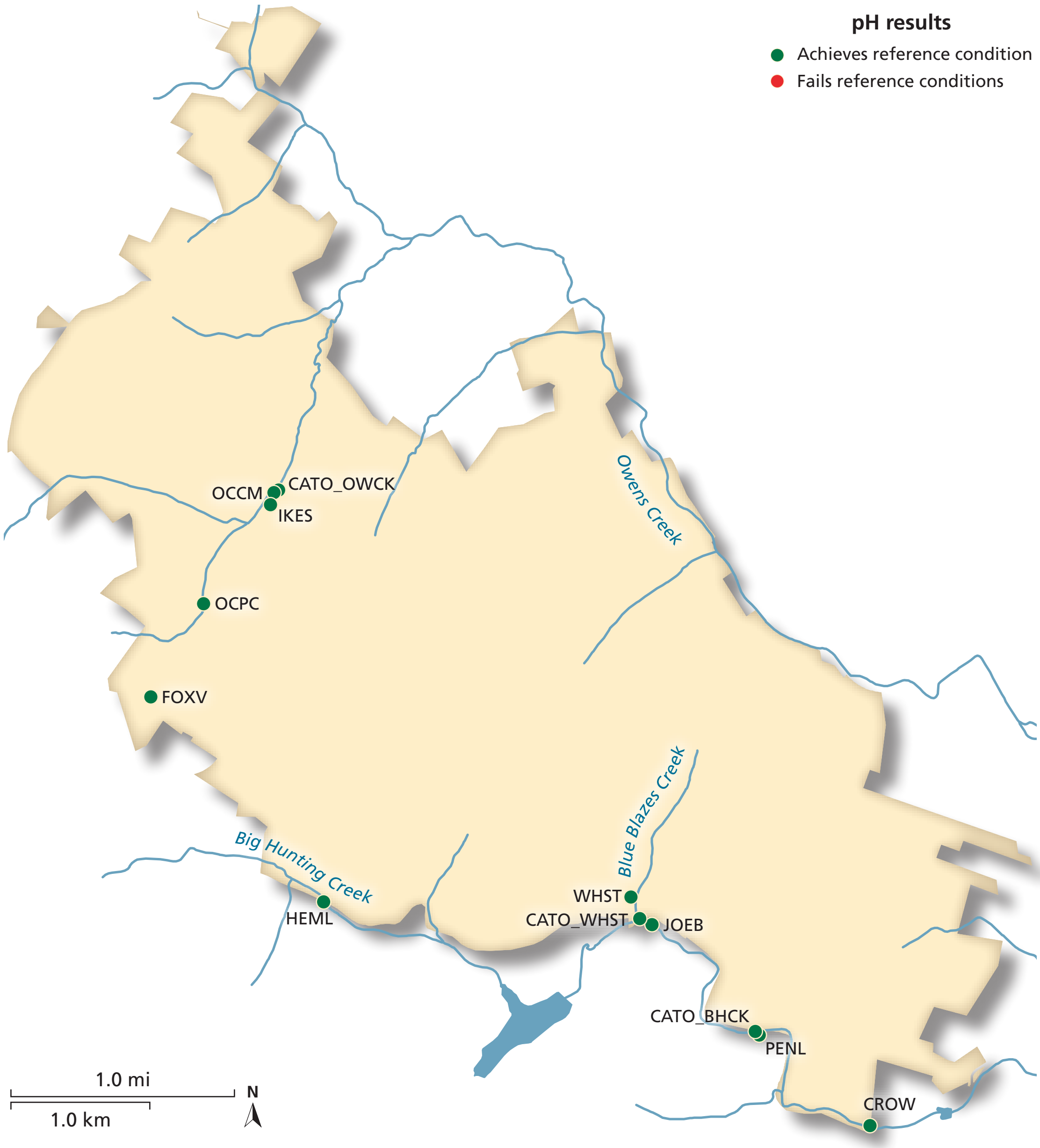

Figure 4.19. Attainment of pH reference condition by site for CATO. Site medians were used for this analysis.

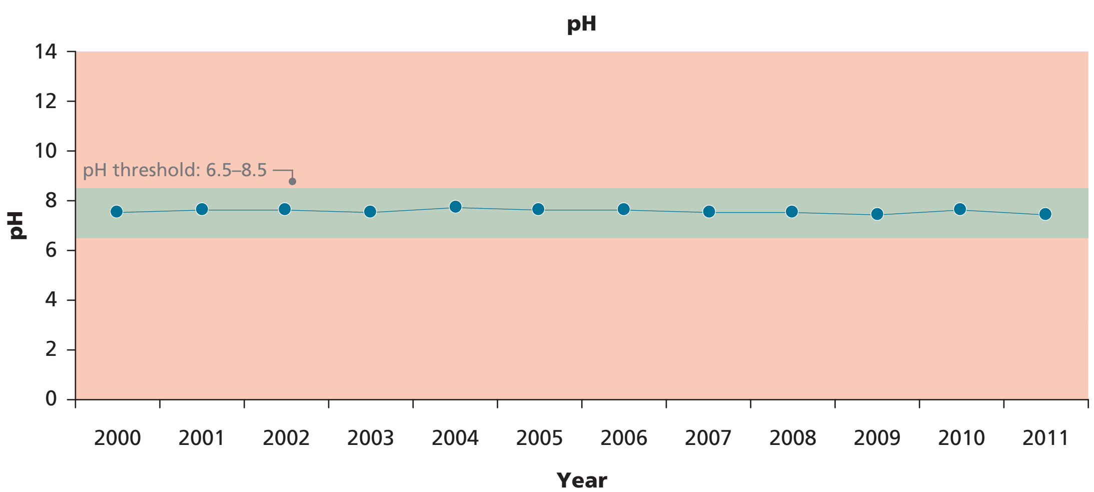

Figure 4.20. Annual median pH values from 2000 to 2011 for 12 stream sampling locations in CATO. Reference condition (6.5 ≤ pH ≤ 8.5) is shown in gray.

Pieper, J., M. Norris, and T. Watts. 2012. National Capital Region Network FY 2010 water resources monitoring data report. Natural Resources Data Series NPS/NCRN/NRDS—2012/381. Natural Resources Program Center, Fort Collins, CO.

Sadinski, W.J. and W.A. Dunson. 1992. A multilevel study of effects of low pH on amphibians of temporary ponds. Journal of Herpetology 26: 413–422.

4.2.3 Dissolved oxygen

Description

Dissolved oxygen (DO) concentration in water is often used as an indicator to gauge the overall health of the aquatic environment. It is needed to maintain suitable habitat for the survival and growth of fish and many other aquatic organisms (USGS 2013). Low DO is of great concern due to detrimental effects on aquatic life. Conditions that generally contribute to low DO levels include warm temperatures, low flows, water stagnation and shallow stream gradients, organic matter inputs, and high respiration rates. Decay of excessive organic debris in the water column from aquatic plants, municipal or industrial discharges, or storm runoff can also cause DO concentrations to be undersaturated or depleted. Insufficient DO can lead to unsuitable conditions for aquatic life and its absence can result in the unpleasant odors associated with anaerobic decomposition. Minimum required DO concentration to support fish varies because the oxygen requirements of fish vary with a number of factors, including the species and age of the fish, prior acclimatization, temperature, and concentration of other substances in the water.

Brook trout (*Salvelinus fontinalis*) are Maryland's only native salmonid species, and are found in the streams of CATO. Optimum oxygen levels for brook trout are not well documented but appear to be ≥ 7 mg/L at temperatures < 15 °C and ≥ 9 mg/L at temperatures ≥ 15 °C (Raleigh 1982).

Data and methods

The data analyzed were collected monthly between 2000 and 2011 at nine sites by CATO staff and monthly between 2000 and 2011 at three sites by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff (Norris and Pieper 2010) (Figure 4.17, Table 4.10, Table A-2). NCRN followed the sampling protocol specified in Norris et al. 2011.

A reference condition of ≤ 5.0 mg DO/L was used for this assessment, which is the Maryland criteria for Designated Use III-P: Nontidal Cold Water and Public Water Supply (COMAR 2007a, 2007b, 2007c) (Table 4.11). Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment (Table 4.12a).

Table 4.15. Median results for dissolved oxygen at each site. Locations of monitoring sites are shown in Figure 4.17.

Site	Median
CATO_BHCK	9.68
CATO_OWCK	9.05
CATO_WHST	9.03
CROW	10.55
FOXV	9.40
HEML	10.38
IKES	9.78
JOEB	9.95
OCCM	10.10
OCPC	10.55
PENL	10.40
WHST	9.90

Condition and trend

Condition of dissolved oxygen in CATO between 2000 and 2011 was very good, with a median DO of 9.8 mg/L and 99.4% of data points attaining the reference condition of ≥ 5.0 mg/L (Figures 4.21, 4.22, Tables 4.13, 4.15). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.22).

Sources of expertise

James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

Literature cited

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COMAR (Code of Maryland Regulations). 2007b. 26.08.02.03-3: Water Quality Criteria Specific to Designated Uses. Title 26: Maryland Department of the Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality.

COMAR (Code of Maryland Regulations). 2007c. 26.08.02.08: Stream Segment Designations. Title 26: Maryland Department of the

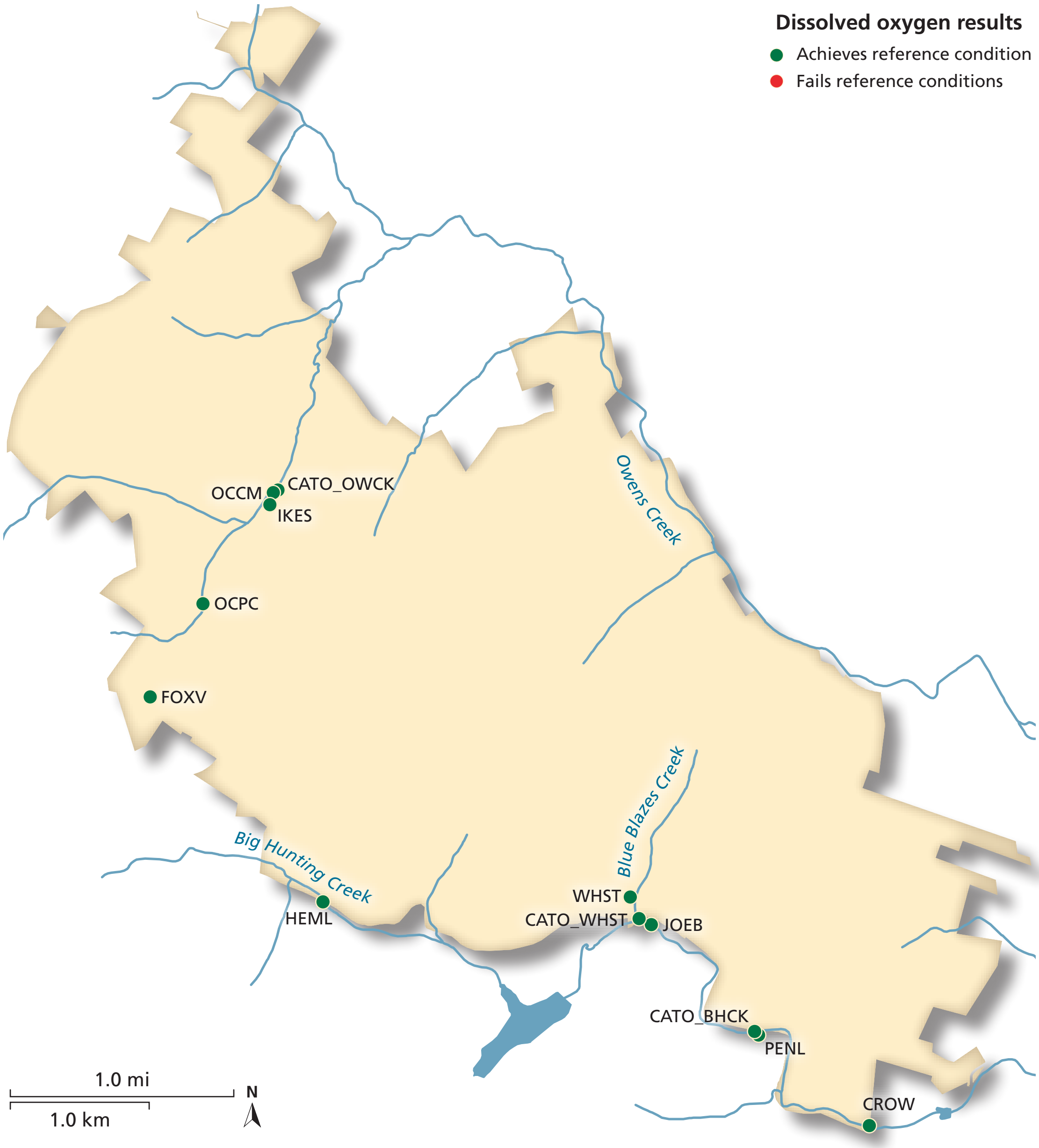

Figure 4.21. Attainment of dissolved oxygen reference condition by site for CATO. Site medians were used for this analysis.

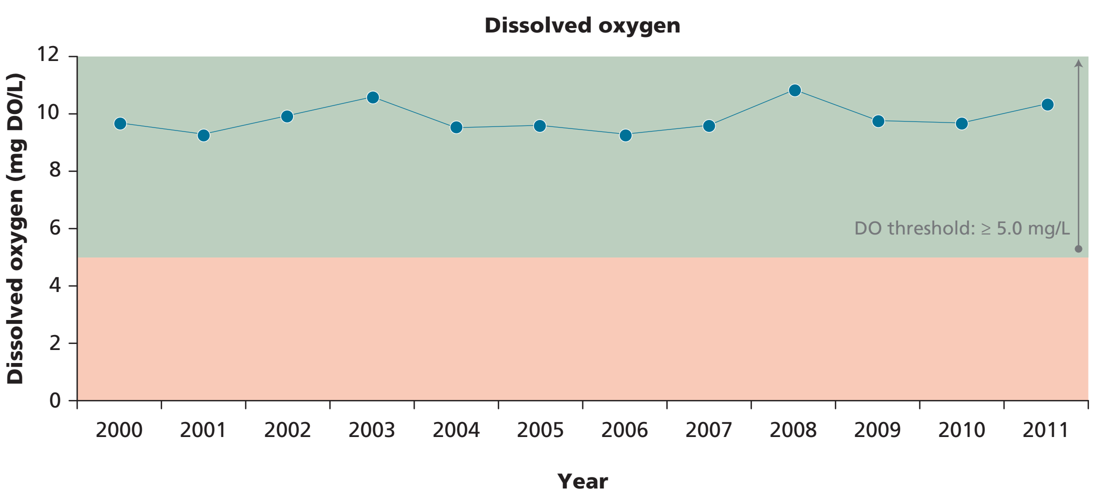

Figure 4.22. Annual median dissolved oxygen concentrations (mg/L) from 2000 to 2011 for 12 stream sampling locations in CATO. Reference condition (DO ≥ 5.0 mg/L) is shown in gray.

Environment. Subtitle 08: Water Pollution. Chapter 02: Water Quality.

Norris, M. and J. Pieper. 2010. National Capital Region Network 2009 water resources monitoring report. Natural Resources Data Series. Natural Resources Program Center, Fort Collins, CO.

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Raleigh, R.F. 1982. Habitat suitability index models: Brook trout. U.S. Department of the Interior, Fish and Wildlife Service FWS/ OBS-82/10.24.

USGS (United States Geological Survey). 2013. Dissolved oxygen, from USGS Water Science for Schools: All about water. Accessed April 23, 2013. *http://ga.water.usgs.gov/edu/ dissolvedoxygen.html*

4.2.4 Water temperature

Description

Aquatic organisms are dependent on certain temperature ranges for optimal health. Temperature affects many other parameters in water, including the amount of dissolved oxygen available, the types of plants and animals present, and the susceptibility of organisms to parasites, pollution, and disease (USGS 2013). Causes of temperature changes in the water include weather conditions, shade, and discharges into the water from urban sources or groundwater inflows.

Summer stream temperature is the most important single factor influencing brook trout distribution and production (Creaser 1930, MacCrimmon and Campbell 1969). Upper and lower temperature limits for adult brook trout vary according to acclimation differences that result from seasonal temperature cycles. The literature suggests that very brief exposure to water temperatures up to 22°C may be tolerated. However, populations are more stable and productive when water temperatures don't exceed 19°C (Heft 2006). In addition, previous studies established that optimal brook trout spawning (which occurs in the fall) occurs near 6°C, spawning does not occur at 16°C, and that 75% of the viable eggs were spawned at temperatures 11.7°C or below (Hokanson et al. 1973).

Data and methods

The data analyzed were collected monthly between 2000 and 2011 at nine sites by CATO staff and monthly between 2005 and 2011 at three sites by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff (Pieper et al. 2012) (Figure 4.17, Table 4.10, Table A-2). NCRN followed the sampling protocol specified in Norris et al. 2011.

A reference condition of ≤ 20°C temperature was used for this assessment, which is the Maryland criteria for Designated Use III-P: Nontidal Cold Water and Public Water Supply (COMAR 2007a, 2007b, 2007c) (Table 4.11). Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment (Table 4.12a).

Condition and trend

Condition of water temperature in CATO between 2000 and 2011 was very good, with a median temperature of 11°C and 98% of data points attaining the reference condition of ≤ 20°C (Figures 4.23, 4.24, Tables 4.13, 4.16). Over the data range available, no significant trend was present for any season (p-value > 0.01) (Figure 4.24).

However, a snapshot assessment of thermal suitability for brook trout reproduction of

Table 4.16. Median results for water temperature by season at each site. Locations of monitoring sites are shown in Figure 4.17.

Site	Winter	Spring	Summer	Fall
CATO_BHCK	3.72	12.10	17.90	9.35
CATO_OWCK	3.90	12.08	17.60	9.60
CATO_WHST	4.50	11.95	19.00	9.90
CROW	1.65	10.85	19.14	9.45
FOXV	4.00	11.00	19.00	8.00
HEML	2.00	10.00	18.90	7.10
IKES	3.75	9.80	16.50	8.00
JOEB	4.00	12.00	17.00	9.00
OCCM	3.00	10.00	17.10	7.50
OCPC	2.00	10.00	18.00	7.10
PENL	3.85	12.00	18.00	9.00
WHST	3.00	11.00	19.00	8.75

Figure 4.23. Attainment of water temperature reference condition by site for CATO. Site medians were used for this analysis.

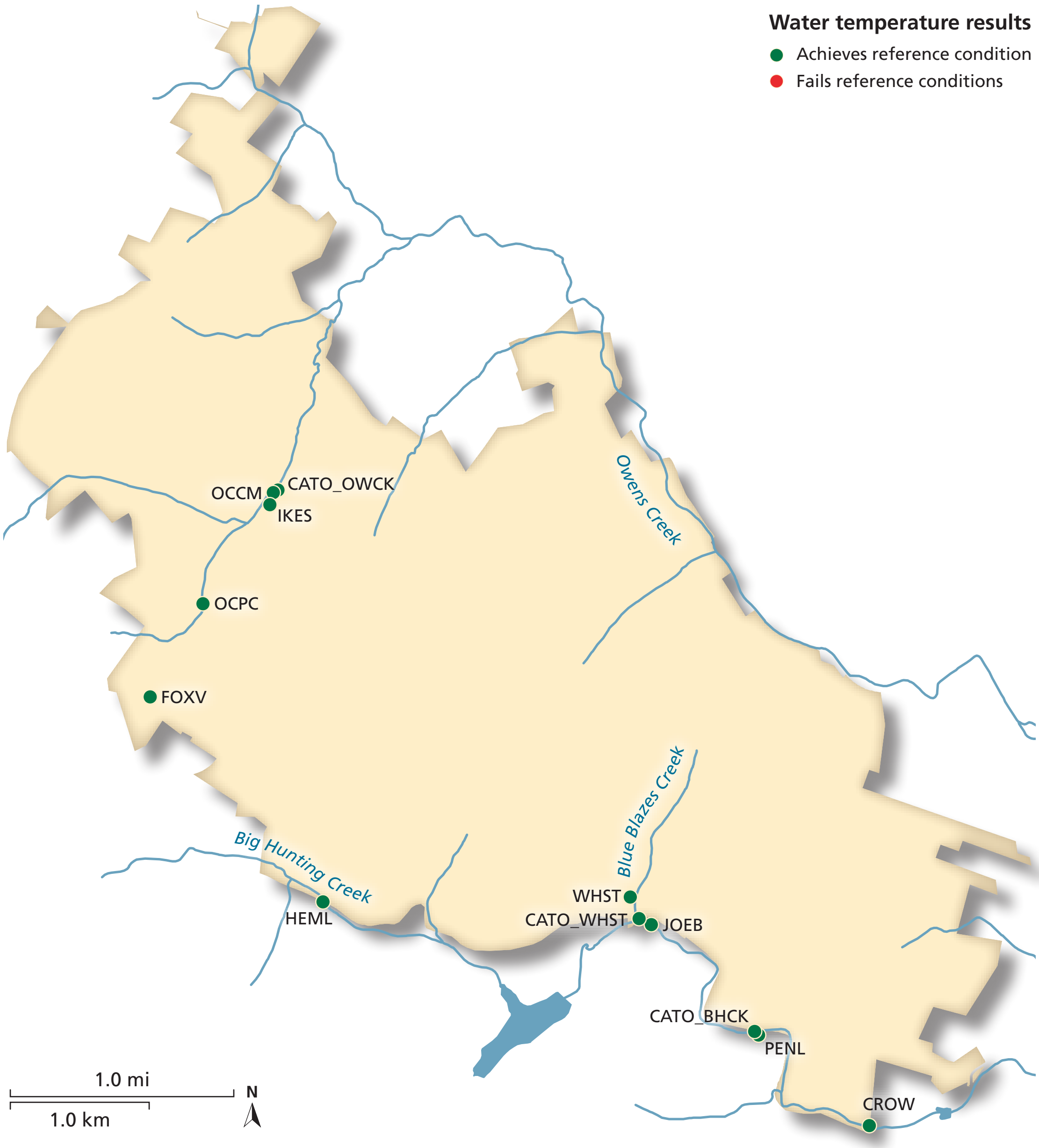
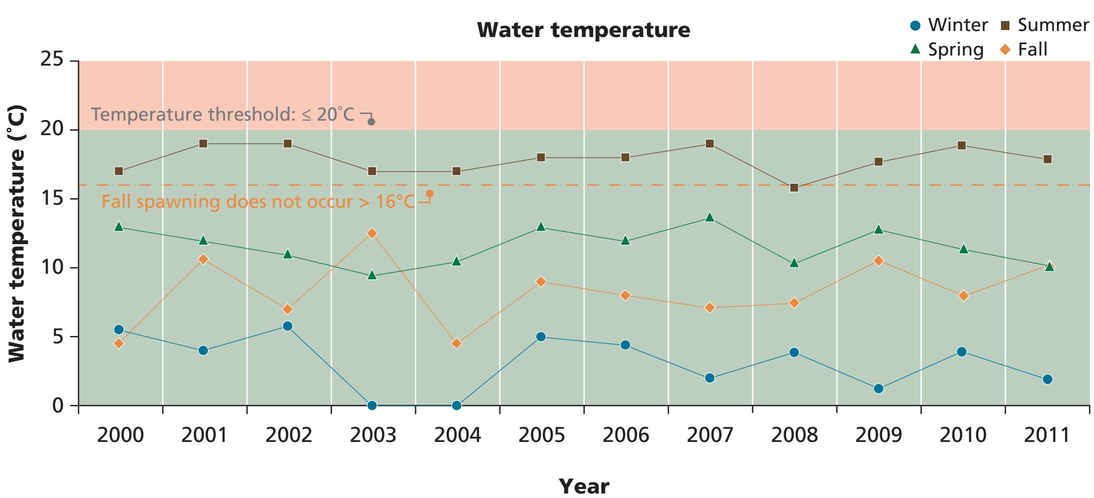


Figure 4.24. Seasonal median water temperature values (°C) from 2000 to 2011 for 12 stream sampling locations in CATO. Reference condition (temperature ≤ 20.0°C) is shown in gray.



10 stream locations within CATO in 2011 showed that during the summer months, four of those sites fail the temperature threshold more than 50% of the time (Frederickson 2011) (Figure 4.25, Table 4.17). The same study predicts that if air temperatures increase by 3.8°C (4.1°C in July and August), that only two of the 10 sites would be thermally suitable for brook trout habitation. This has implications for the long-term sustainability of the trout populations (Frederickson 2011).

Table 4.17. Median results for water temperature (°C) at 11 sites monitored continuously during the summer of 2011. Attainment refers to the percent of time that site attained the reference condition of ≤ 20.0°C. Locations of monitoring sites are shown in Figure 4.25.

Site	Median	% attainment
AFPD	21.3	33.0
BFPD	19.5	59.7
DFNT	17.3	94.8
HEML	20.7	35.7
IKES	17.0	99.1
LZMR	22.1	24.1
OCEP	19.3	61.5
OCHW	20.3	46.0
PENL	19.7	61.7
WHST	19.7	57.7

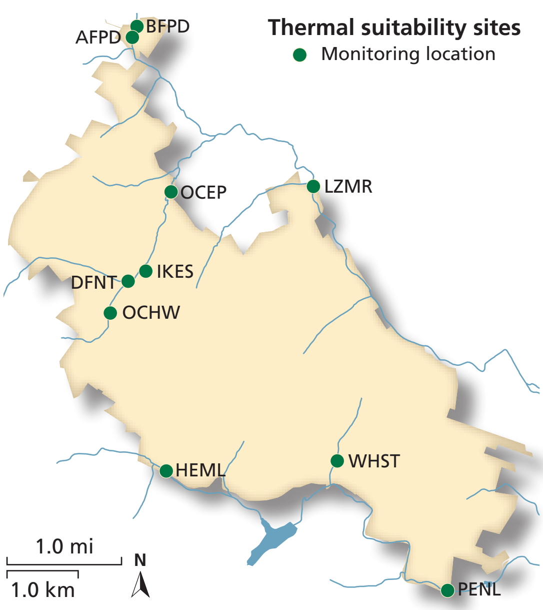


Figure 4.25. Site locations used for the thermal suitability study.

Sources of expertise

James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

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USGS (United States Geological Survey). 2013. Temperature – water properties. USGS Water Science School. Accessed April 23, 2013. *http://ga.water.usgs.gov/edu/temperature.html*

4.2.5 Acid neutralizing capacity

Description

Acid neutralizing capacity (ANC) is the prime indicator of a waterbody's susceptibility to acid inputs. ANC is a measure of the amount of carbonate and other compounds in the water that neutralize low (acidic) pH. Streams with higher ANC levels (better buffering capacity) are affected less by acid rain and other acid inputs than streams with lower ANC values (Welch et al. 1998).

Data and methods

The data analyzed were collected monthly at three sites between 2005 and 2011 by Inventory & Monitoring staff (Pieper et al. 2012) (Figure 4.17, Table 4.10, Table A-2). NCRN followed the sampling protocol specified in Norris et al. 2011.

The acid neutralizing capacity (ANC) threshold was developed by the Maryland Biological Stream Survey (MBSS) program after their first round of sampling (1995–1997). The MBSS data were used to detect stream degradation so as to identify streams in need of restoration and to identify 'impaired waters' candidates (Southerland et al. 2007). A total of 539 streams that received a fish or benthic index of biotic integrity (FIBI or BIBI) rating of poor (2) or very poor (1) were pooled and field observations and site-specific water chemistry data were used to determine stressors likely causing degradation.

The resulting ANC threshold linked to degraded streams was values less than 200 µeq/L, which was used as the threshold in this assessment (where 1 mg/L [1 ppm] CaCO3 = 20 µeq/L) (Southerland et al. 2007, Norris and Sanders 2009) (Table 4.11). A less conservative threshold of 50 µeq/L has also been suggested by some authors (Hendricks and Little 2003, Schindler 1988). Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment (Table 4.12a).

Condition and trend

Condition of ANC in CATO between 2005 and 2011 was very good, with a median ANC of 564 µeq/L and 100% of data points attaining the reference condition of ≥ 200 µeq/L (Figures 4.26, 4.27, Tables 4.13, 4.18). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.27).

Table 4.18. Median results for acid neutralizing capacity at each site. Locations of monitoring sites are shown in Figure 4.17.

Site	Median
CATO_BHCK	518
CATO_OWCK	590
CATO_WHST	618

Sources of expertise

James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

Literature cited

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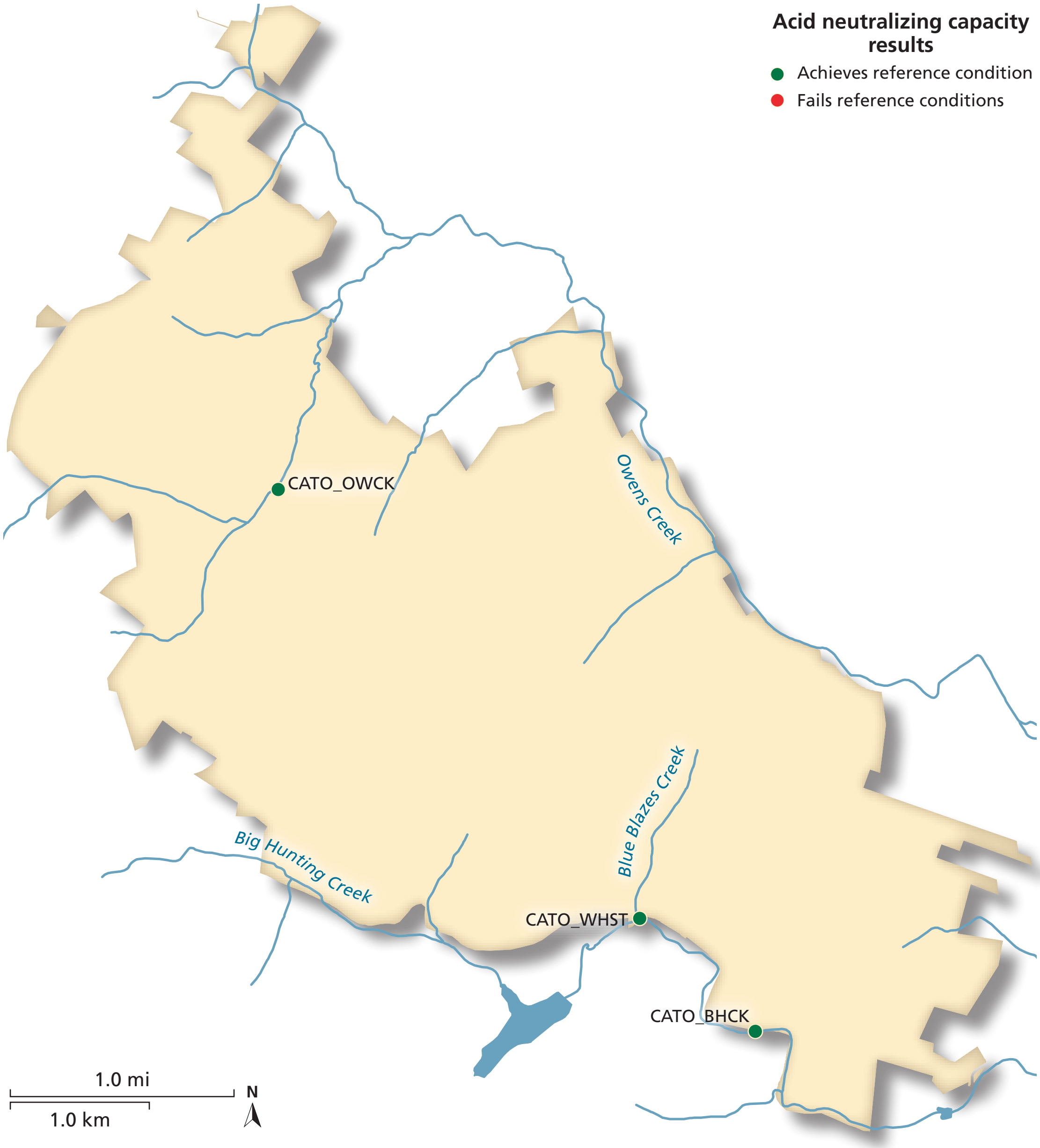

Figure 4.26. Attainment of acid neutralizing capacity reference condition by site for CATO. Site medians were used for this analysis.

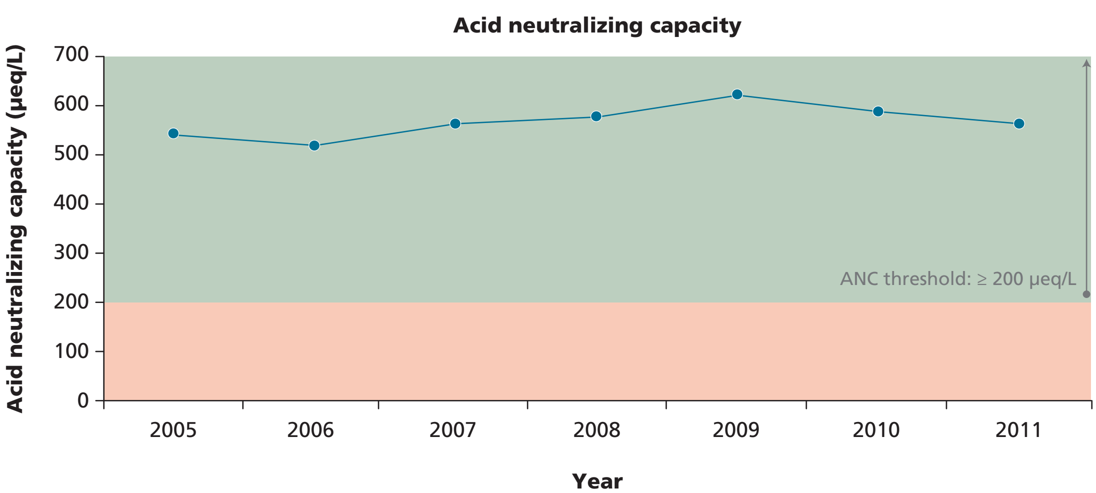

Figure 4.27. Median acid neutralizing capacity values (µeq/L) from 2005 to 2011 for three stream sampling locations in CATO. Reference condition (ANC ≥ 200 µeq/L) is shown in gray.

4.2.6 Specific conductance

Description

Salinity is a measurement of the mass of dissolved salt in a given body of water. Salinity is an important property of industrial and natural waters. Collectively, all substances in solution exert osmotic pressure on the organisms living in it, which in turn adapt to the condition imposed upon the water by its dissolved constituents. With excessive salts in solution, osmotic pressure becomes so high that water may be drawn from gills and other delicate external organs resulting in cell damage or death of the organism (USGS 1980, Stednick and Gilbert 1998, NPS 2002).

Electrical conductivity is related to salinity and is a measure of water's ability to conduct electricity, and therefore a measure of the water's ionic activity and content. The higher the concentration of ionic (dissolved) constituents, the higher the conductivity (Radtke et al. 1998). As conductivity changes with temperature, conductivity can be normalized to a temperature of 25° C and reported as specific conductance to enable comparisons.

Common sources of pollution that can affect specific conductance are deicing salts, dust-reducing compounds, agriculture (primarily from the liming of fields), and acid mine drainage associated with mining operations (USGS 1980, Stednick and Gilbert 1998, NPS 2002). Deicing compounds alone are significantly elevating the specific conductance of some streams in the northeast during winter periods (Kaushal et al. 2005, Allan and Castillo 2007).

Data and methods

The data analyzed were collected monthly between 2000 and 2011 at nine sites by CATO staff and monthly between 2005 and 2009 at three sites by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff (Pieper et al. 2012) (Figure 4.17, Table 4.10, Table A-2). NCRN followed the sampling protocol specified in Norris et al. 2011.

The reference condition for specific conductance was ≤ 171 µS/cm, above which conditions are said to be degraded (Morgan et al. 2007) (Table 4.11). Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment (Table 4.12a).

Table 4.19. Median results for specific conductance at each site. Locations of monitoring sites are shown in Figure 4.17.

Site	Median
CATO_BHCK	137
CATO_OWCK	148
CATO_WHST	104
CROW	128
FOXV	222
HEML	110
IKES	131
JOEB	100
OCCM	108
OCPC	128
PENL	100
WHST	80

Condition and trend

Condition of specific conductance in CATO between 2000 and 2011 was very good, with a median conductance of 112 µS/cm and 88% of data points attaining the reference condition of ≤ 171 µS/cm (Figures 4.28, 4.29, Tables 4.13, 4.19). However, there was a significant degrading trend (increasing specific conductance) over all sites over the past decade (p-value < 0.01) (Figure 4.29).

Sources of expertise

Kate Foreman, Water Quality Analyst, Chesapeake Bay Program.

James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

Literature cited

Allan, J.D. and M.M. Castillo. 2007. Stream ecology: structure and function of running waters. Springer, Dordrecht, The Netherlands.

Kaushal, S.S., P.M. Groffman, G.E. Likens, K.T. Belt, W.P. Stack, V.R. Kelly, L.E. Band, and G.T. Fisher. 2005. Increased salinization of fresh water in the northeastern United States. Proceedings of the National Academy of Sciences of the United States of America 102: 13517.

Morgan II, R.P., K.M. Kline, and S.F. Cushman. 2007. Relationships among nutrients,

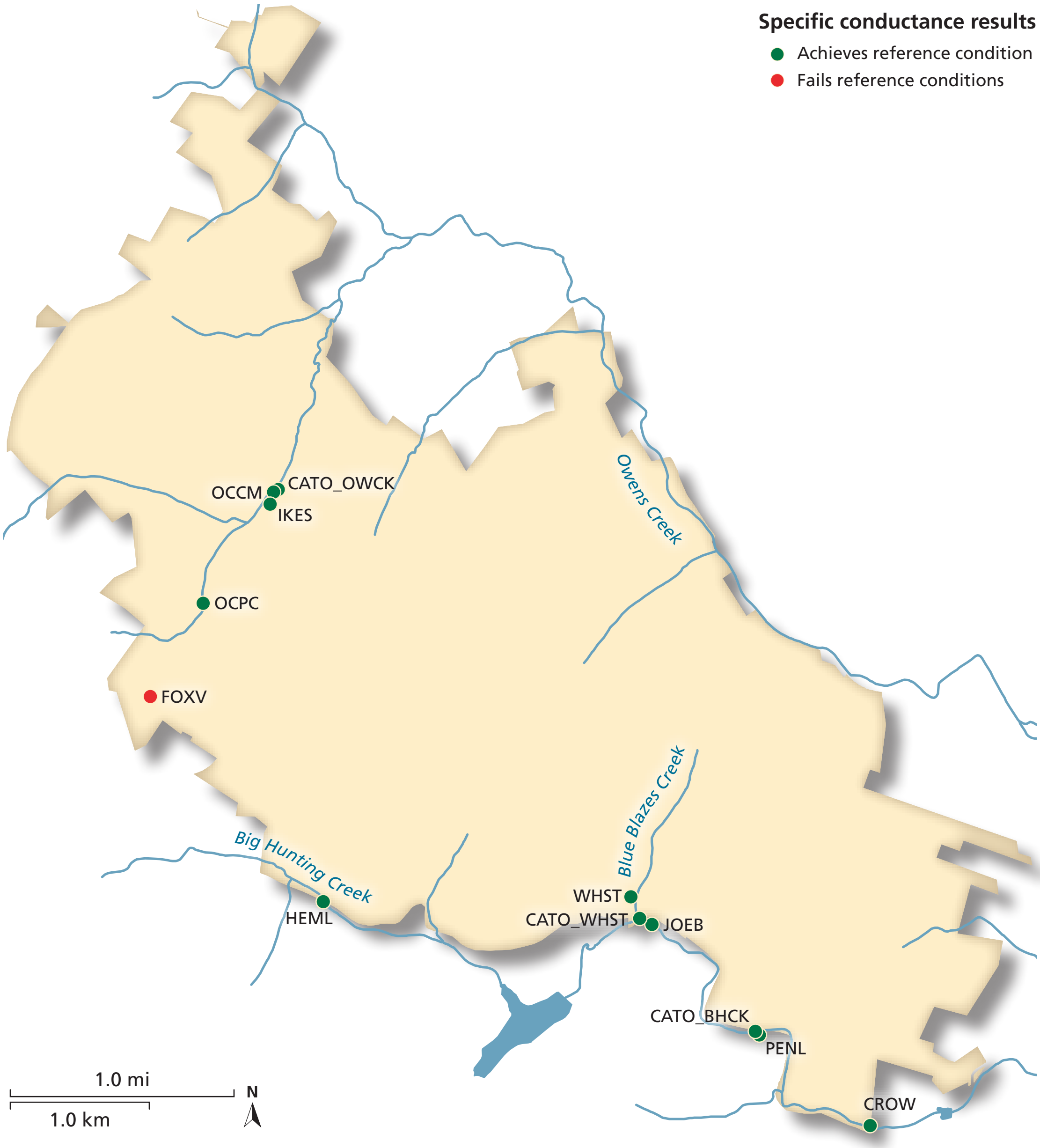

Figure 4.28. Attainment of specific conductance reference condition by site for CATO. Site medians were used for this analysis.

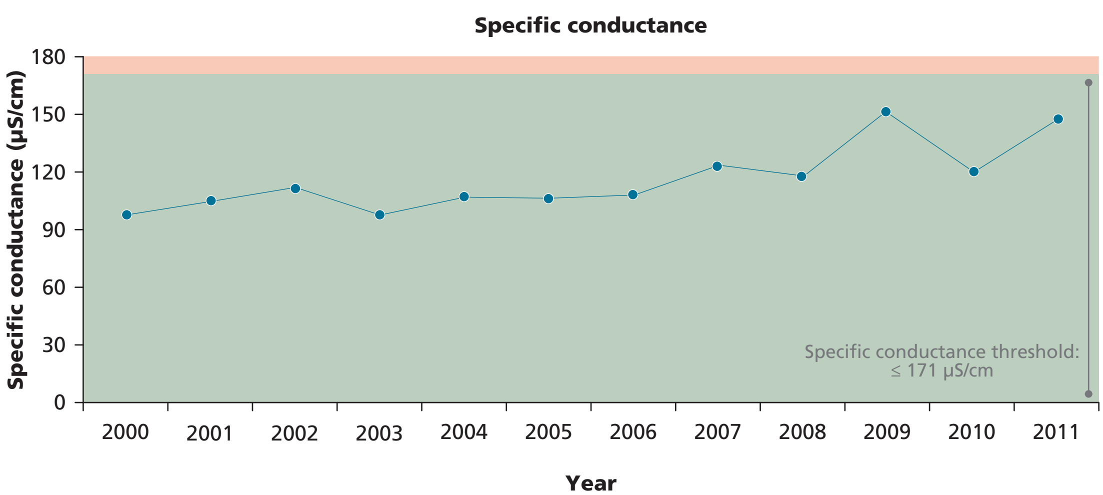

Figure 4.29. Annual median specific conductance values (µS/cm) from 2000 to 2011 for 12 stream sampling locations in CATO. Reference condition (specific conductance ≤ 171 µS/cm) is shown in gray.

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Radtke, D.B., Davis, J.V., and Wilde, F.D, 1998, Specific electrical conductance. In: Wilde, F.D., and D.B. Radtke (eds.). 1998. Field measurements, in national field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6.3, 22 p.

Stednick, J.D. and D.M. Gilbert. 1998. Water quality inventory protocol: riverine environments. NPS/NRWRD/NRTR—98/177, National Park Service, Servicewide Inventory and Monitoring Program, Fort Collins, CO.

USGS (United States Geological Survey). 1980. Surfacewater. National handbook of recommended methods for water-data acquisition. U.S. Geological Survey.

4.2.7 Nitrate

Description

Nitrate (NO_3) is a form of nitrogen which aquatic plants can absorb and incorporate into proteins, amino acids, nucleic acids, and other essential molecules. Nitrate is highly mobile in surface and groundwater and may seep into streams, lakes, and estuaries from groundwater enriched by animal or human wastes, commercial fertilizers, and air pollution. High concentrations of nitrate can enhance the growth of algae and aquatic plants in a manner similar to enrichment in phosphorus and thus cause eutrophication of a water body. Nitrate is typically indicative of agricultural pollution. Nitrate in surface water may occur in dissolved or particulate form resulting from inorganic sources. The dissolved, inorganic forms of nitrogen are most available for biological uptake and chemical transformation. Nitrate also travels freely through soil and therefore may pollute groundwater (USGS 2013).

Data and methods

The data analyzed were collected monthly between 2005 and 2011 at three sites by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff (Pieper et al. 2012) (Figure 4.17, Table 4.10, Table A-2). NCRN followed the sampling protocol specified in Norris et al. 2011.

It should be noted that the current methodology for measuring nitrate has been in use since July 2007. During the month of July 2007, a different method was used after an equipment malfunction. A third method was utilized prior to July 2007 (Norris and Pieper 2010).

The nitrate concentration threshold was developed by the Maryland Biological Stream Survey (MBSS) program after their first round of sampling as described for the ANC threshold. The MBSS determined that a nitrate concentration of 2 mg NO_3/L (2 ppm) and above indicated stream degradation (Southerland et al. 2007, Norris and Sanders 2009), so this was used as the reference condition in this assessment (Table 4.11). Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment (Table 4.12a).

Table 4.20. Median results for nitrate at each site. Locations of monitoring sites are shown in Figure 4.17.

Site	Median
CATO_BHCK	1.00
CATO_OWCK	1.20
CATO_WHST	0.80

Condition and trend

Condition of nitrate in CATO between 2005 and 2011 was very good, with a median nitrate concentration of 1.0 mg/L and 98% of data points attaining the reference condition of 2 mg/L (Figures 4.30, 4.31, Tables 4.13, 4.20). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.30).

Sources of expertise

James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

Literature cited

Norris, M.E. and J. Pieper. 2010. National Capital Region Network 2007–2008 water resources monitoring data report. Natural Resource Data Series NPS/NCR/NCRN/NRDS—2010/105.

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Norris, M.E., J.M. Pieper, T.M. Watts, and A. Cattani. 2011. National Capital Region Network Inventory and Monitoring Program water chemistry and quantity monitoring protocol version 2.0: Water chemistry, nutrient dynamics, and surface water dynamics vital signs. Natural Resource Report NPS/NCRN/ NRR—2011/423. National Park Service, Fort Collins, CO.

Pieper, J., M. Norris, and T. Watts. 2012. National Capital Region Network FY 2010 water resources monitoring data report. Natural Resources Data Series NPS/NCRN/NRDS—2012/381. Natural Resources Program Center, Fort Collins, CO.

Southerland, M.T., G.M. Rogers, M.J. Kline, R.P. Morgan, D.M. Boward, P.F. Kazyak, R.J. Klauda, and S.A. Stranko. 2007. Improving biological indicators to better assess the condition of streams. Ecological Indicators 7: 751–767.

USGS (United States Geological Survey). 2013. Urbanization/water quality: Nitrogen. Accessed April 24, 2013. *http://ga.water.usgs.gov/edu/nitrogen.html*

Figure 4.30. Attainment of nitrate reference condition by site for CATO. Site medians were used for this analysis.

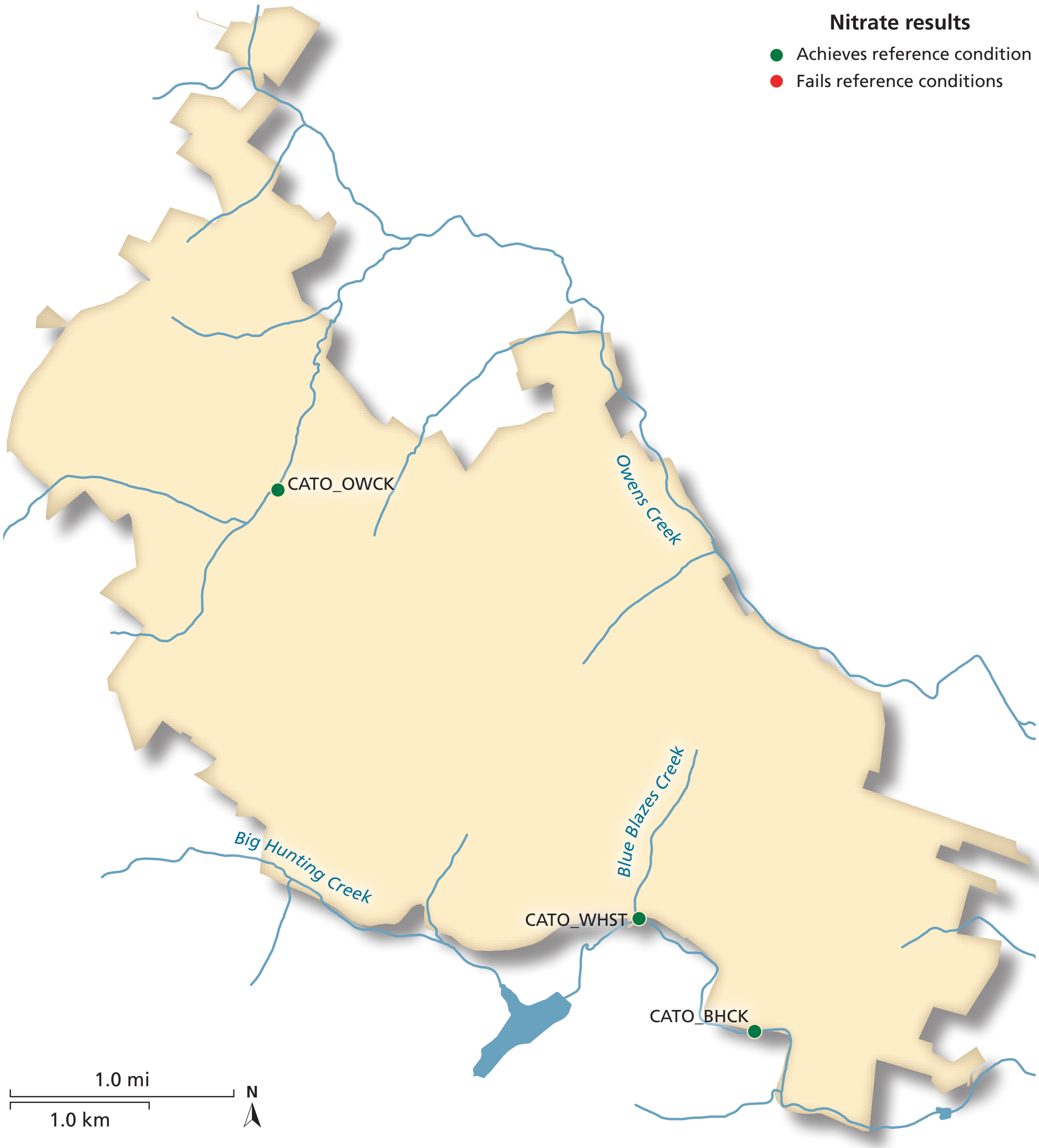
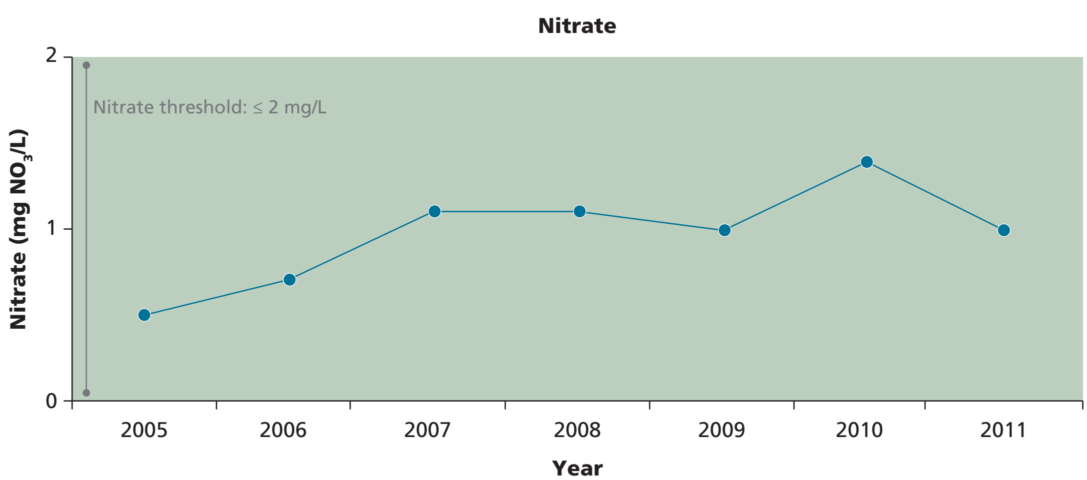


Figure 4.31. Annual median nitrate concentrations (mg NO_3/L) from 2005 to 2011 for three stream sampling locations in CATO. Reference condition (NO_3 ≤ 2.0 mg/L) is shown in gray.



4.2.8 Total phosphorus

Description

Phosphorus is an essential nutrient for plants to live and is frequently the limiting nutrient for plant growth in aquatic systems. Consequently, a minor increase in phosphorus concentration can significantly affect water quality by stimulating algal growth, leading to eutrophication (Allan 1995). The most common form of phosphorus pollution is in the form of phosphate (PO_4). Sources of phosphate pollution include sewage, septic tank leachate, fertilizer runoff, soil erosion, animal waste, and industrial discharge.

Data and methods

The data analyzed were collected monthly between 2000 and 2011 at three sites by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff (Pieper et al. 2012) (Figure 4.17, Table 4.10, Table A-2). NCRN followed the sampling protocol specified in Norris et al. 2011.

The total phosphorus threshold is based on the U.S. EPA Ecoregional Nutrient Criteria. These criteria were developed to prevent eutrophication nationwide and are not regulatory (U.S. EPA 2000). The criteria were developed as baselines for specific geographic regions known as Ecoregions, which are classified based on multiple geographic characteristics such as soils, climate, vegetation, geology, and land use—all of which affect the natural concentrations of nutrients found in streams. Reference sites in each Ecoregion were identified to calculate nutrient criteria. CATO is located in Ecoregion XI or the Central and Eastern Forested Uplands region (U.S. EPA 2000). The ecoregional reference condition value for total phosphorus is 0.010 mg P/L (10 ppb) (U.S. EPA 2000) (Table 4.11). Each data point was compared against the reference condition and assigned a pass or fail result. The percentage of passing results was used as the percent attainment and translated to a condition assessment (Table 4.12a).

Condition and trend

Condition of total phosphorus in CATO between 2007 and 2011 was very poor, with a median total phosphorus concentration of 0.08 mg/L and 0% of data points attaining the reference condition of 0.01 mg/L (Figures 4.32, 4.33, Tables 4.13, 4.21). Over the data range available, no significant trend was present (*p*-value > 0.01) (Figure 4.33).

Table 4.21. Median results for total phosphorus at each site. Locations of monitoring sites are shown in Figure 4.17.

Site	Median
CATO_BHCK	0.06
CATO_OWCK	0.10
CATO_WHST	0.06

Sources of expertise

James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

Literature cited

Allan, J. D. 1995. Stream ecology: structure and function of running waters. Chapman and Hall, New York, NY.

Norris, M.E., J.M. Pieper, T.M. Watts, and A. Cattani. 2011. National Capital Region Network Inventory and Monitoring Program water chemistry and quantity monitoring protocol version 2.0: Water chemistry, nutrient dynamics, and surface water dynamics vital signs. Natural Resource Report NPS/NCRN/ NRR—2011/423. National Park Service, Fort Collins, CO.

Pieper, J., M. Norris, and T. Watts. 2012. National Capital Region Network FY 2010 water resources monitoring data report. Natural Resources Data Series NPS/NCRN/ NRDS—2012/381. Natural Resources Program Center, Fort Collins, CO.

U.S. EPA. 2000. Ambient water quality criteria recommendations—rivers and streams in Nutrient Ecoregion XI. EPA 822-B-00-020. United States Environmental Protection Agency, Washington DC.

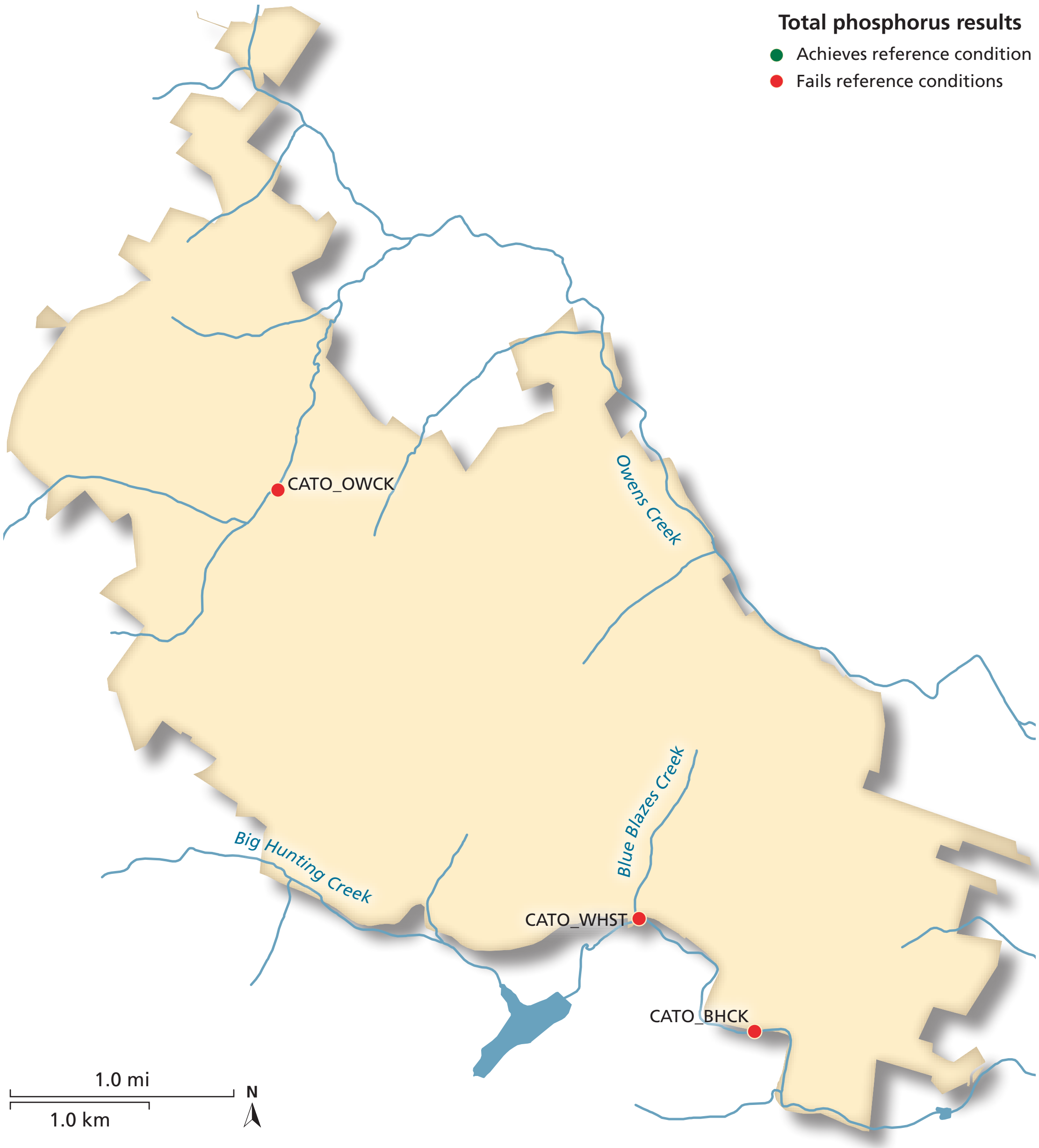


Figure 4.32. Attainment of total phosphorus reference condition by site for CATO. Site medians were used for this analysis.

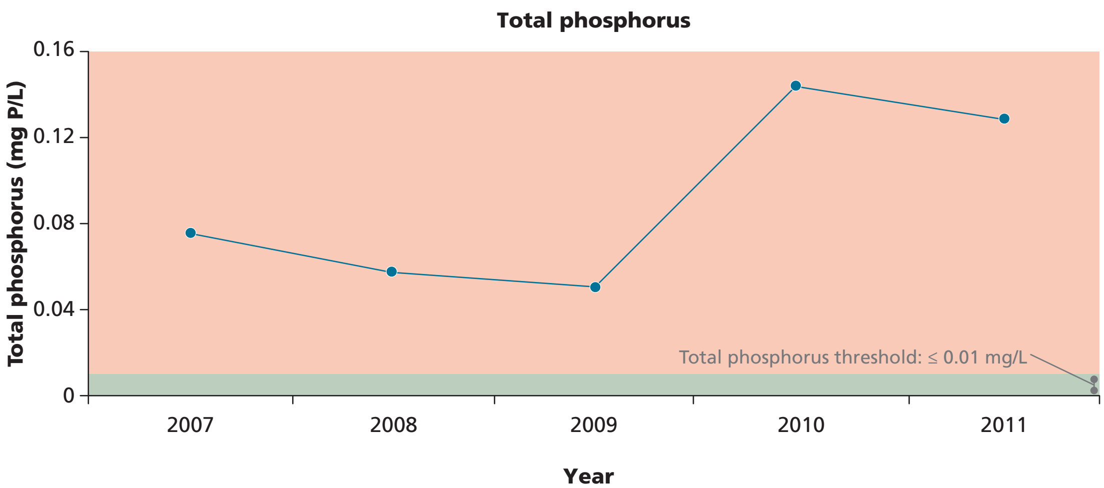


Figure 4.33. Annual median total phosphorus concentrations (mg P/L) from 2007 to 2011 for three stream sampling locations in CATO. Reference condition (TP ≤ 0.01 mg/L) is shown in gray.

4.2.9 Stream macroinvertebrates

Description

The State of Maryland uses biological indicators of stream condition to assess status and trends in biological integrity for all 9,400 non-tidal stream miles in Maryland (Southerland et al. 2007). The Benthic Index of Biotic Integrity (BIBI) is one multi-metric index monitored by the Maryland Department of Natural Resources' Maryland Biological Stream Survey (MBSS). BIBI is an indicator of the health of the benthic macroinvertebrate communities in a stream.

Data and methods

Data were collected at four sites between 2006 and 2010 (Figure 4.18, Table 4.10). These sites were sampled as part of the effort to develop the National Capital Region Biological Stream Survey protocol (Norris and Sanders 2009). The protocol is based on the MBSS. Twenty-three standard operating procedures (SOPs) document the methods used to collected the relevant data. Reported data are for one BIBI assessment per site.

The reference conditions are based on the MBSS interpretation of the BIBI. The BIBI scores range from 1 to 5 and are calculated by comparing the site's benthic assemblage to the assemblage found at minimally impacted sites (Norris and Sanders 2009). A score of 3 indicates that a site is considered to be comparable to (i.e., not significantly different from) reference sites. A score greater than 3 indicates that a site is in better condition than the reference sites. Any sites with BIBIs less than 3 are in worse condition than reference sites (Southerland et al. 2007, Norris and Sanders 2009). BIBI values were ranked as follows: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good), and these were the scale and categories used in this assessment (Southerland et al. 2007).

The range of BIBI scores from 1 to 5 were scaled linearly from 0 to 100% attainment (Figure 4.34, Table 4.22). The median of all the data points was compared to these reference conditions and given a percent attainment and converted to a condition assessment (Tables 4.11, 4.12b).

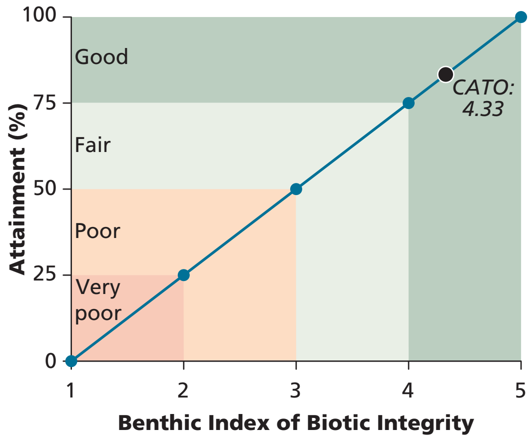


Figure 4.34. Application of the percent attainment categories to the Benthic Index of Biotic Integrity (BIBI) categories. BIBI at CATO was 4.33 which equated to 83% attainment of the reference condition.

Table 4.22. Benthic Index of Biotic Integrity (BIBI) categories, percent attainment, and condition assessment.

BIBI range	% attainment	Condition
4.0–5.0	100%	Good
3.0–3.9	↑ scaled	Fair
2.0–2.9	linearly ↓	Poor
1.0–1.9	0%	Very poor

Table 4.23. Benthic Index of Biotic Integrity (BIBI) results for CATO. Monitoring sites are shown in Figure 4.18.

Year	Site	Location	BIBI
2006	CATO-201-N-2006	Hunting Creek	4.00
2010	MONO-133-N-2010	Owens Creek	4.33
2010	MONO-134-N-2010	Blue Blazes Creek	4.67
2010	MONO-230-N-2010	Big Hunting Creek	4.33

Condition and trend

Current condition of benthic macroinvertebrates in CATO was good, with a median BIBI of 4.33 and 83% attainment of reference condition (Figure 4.35, Tables 4.13, 4.23).

No trend analysis was possible with the current data set.

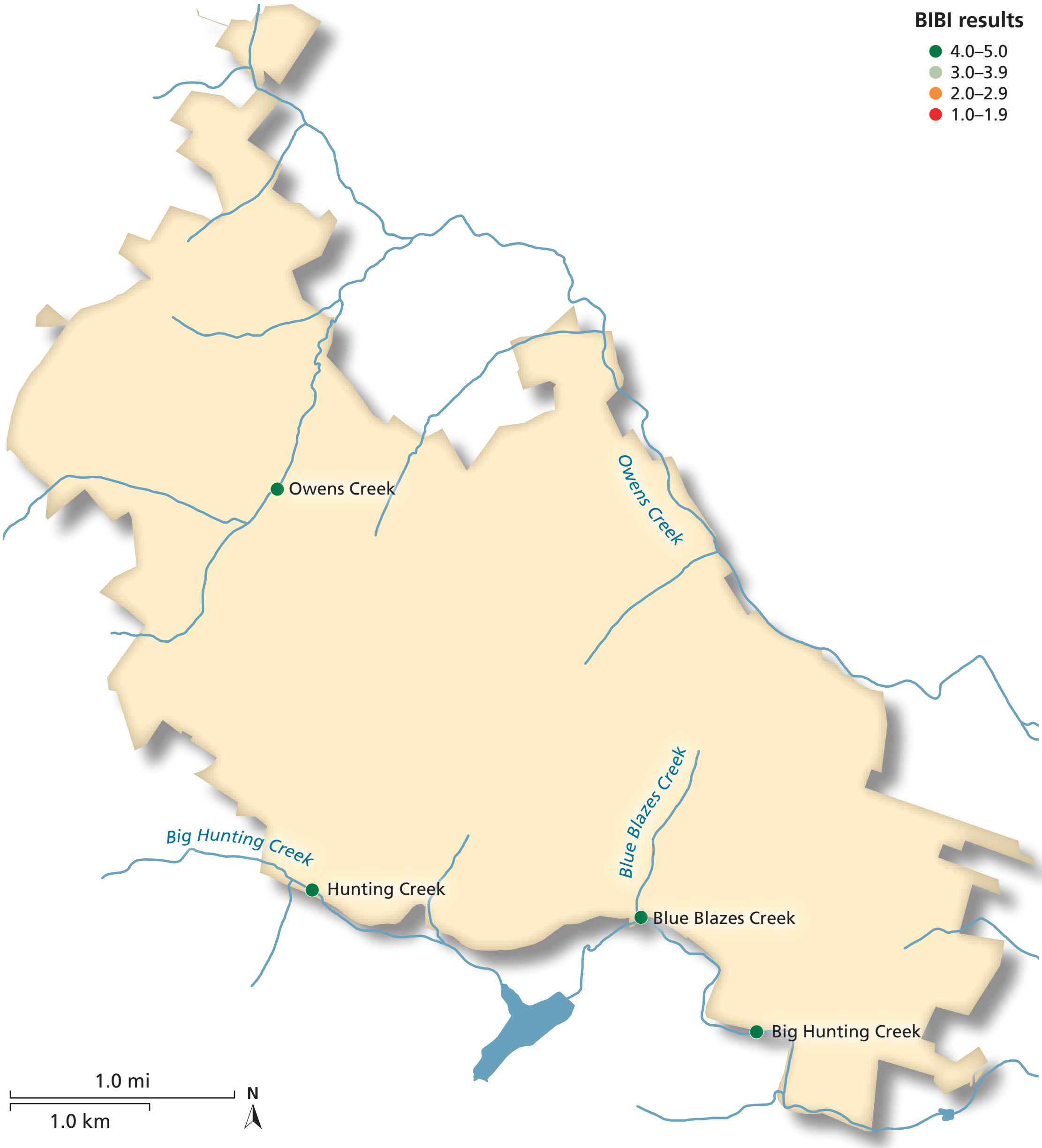
Sources of expertise

James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

Literature cited

Norris, M.E. & G. Sanders. 2009. National Capital Region Network biological stream survey protocol: physical habitat, fish, and aquatic macroinvertebrate vital signs. Natural Resource Report. NPS/NCRN/NRR—

Figure 4.35. Benthic Index of Biotic Integrity (BIBI) results by site for CATO.



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Southerland, M.T., G.M. Rogers, M.J. Kline, R.P. Morgan, D.M. Boward, P.F. Kazyak, R.J. Klauda, and S.A. Stranko. 2007. Improving biological indicators to better assess the condition of streams. Ecological Indicators 7: 751–767.

4.2.10 Physical habitat

Description

Physical habitat is an integral part of overall stream condition. Components of physical habitat include the diversity of flow conditions, the diversity and stability of substrates, the degree and extent of erosion, the amount of woody debris, and many other factors. These physical factors affect the biological potential of streams by providing the physical template upon which stream biological community structure is built (Paul et al. 2002).

Data and methods

Data for the Physical Habitat Index (PHI) were collected at four sites between 2006 and 2010 (Figure 4.18, Table 4.10). NCRN followed the National Capital Region Biological Stream Survey protocol (Norris and Sanders 2009). Habitat assessments are determined based on data from numerous metrics such as riffle quality, stream bank stability, woody debris, quality of streambed substrates, shading, and many more. Sites are given scores for each of the applicable categories and then those scores are adjusted to a percentile scale (Norris and Sanders 2009). Reported data are for one PHI assessment per site.

The PHI threshold was developed by the Maryland Biological Stream Survey (MBSS) program after initial sampling as described for the ANC threshold. The MBSS determined the scale for PHI values to be 0–50 (severely degraded), 51–65 (degraded), 66–80 (partially degraded), and 81–100 (minimally degraded), and these were the scale and categories used in this assessment (Paul et al. 2002, Southerland et al. 2005). Each of the four PHI value categories were assigned a percent attainment range (Figure 4.36, Table 4.24).

The median of all the data points was compared to these reference conditions and given a percent attainment and converted to a condition assessment (Tables 4.11, 4.12b).

Condition and trend

Current condition of PHI in CATO was partially degraded, with a median PHI of 66 which equated to 50% attainment of reference condition (Figure 4.37, Tables 4.13, 4.25).

No trend analysis was possible with the current data set.

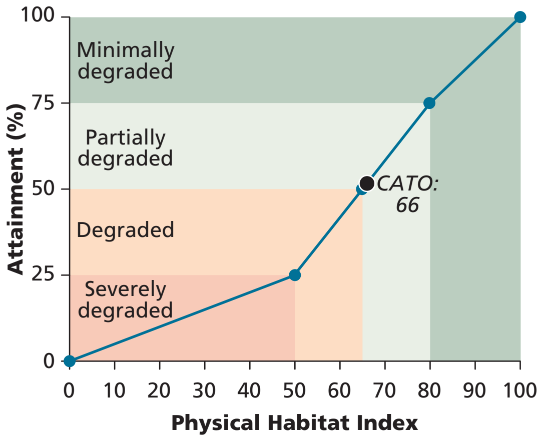


Figure 4.36. Application of the percent attainment categories to the Physical Habitat Index (PHI) value categories. PHI at CATO was 66 which equated to 50% attainment of the reference condition.

Table 4.24. Physical Habitat Index (PHI) categories, percent attainment, and condition assessment.

PHI range	% attainment	Condition
81–100	75–100%	Minimally degraded
66–80	50–75%	Partially degraded
51–65	25–50%	Degraded
0–50	0–25%	Severely degraded

Table 4.25. Physical Habitat Index (PHI) in CATO. Monitoring sites are shown in Figure 4.18.

Year	Site	Location	PHI
2006	CATO-201-N-2006	Hunting Creek	67.00
2010	MONO-133-N-2010	Owens Creek	71.94
2010	MONO-134-N-2010	Blue Blazes Creek	48.07
2010	MONO-230-N-2010	Big Hunting Creek	64.84

Sources of expertise

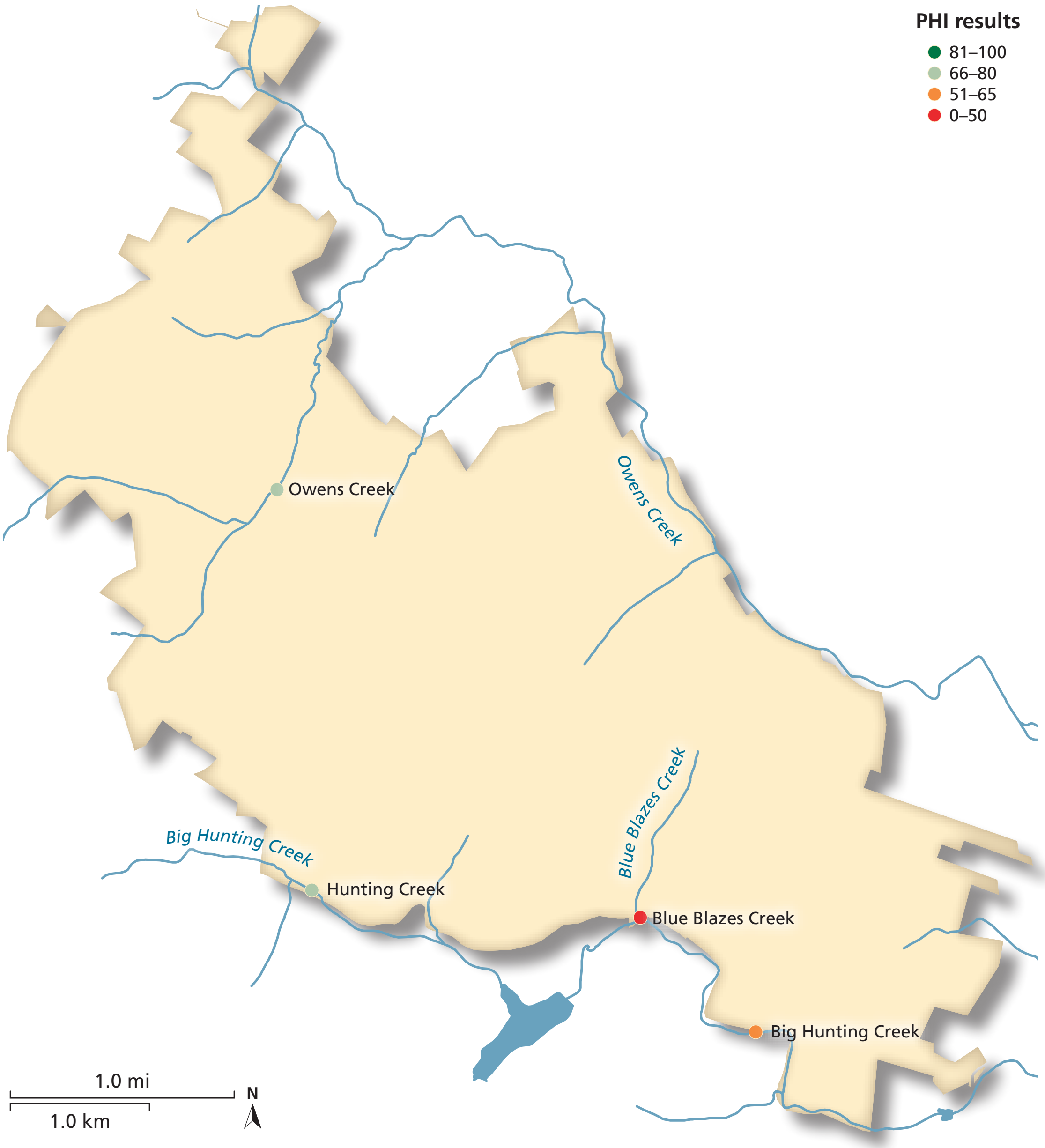
James Pieper, Hydrologic Technician, National Capital Region Network Inventory & Monitoring Program, National Park Service.

Literature cited

Norris, M.E. & G. Sanders. 2009. National Capital Region Network biological stream survey protocol: physical habitat, fish, and aquatic macroinvertebrate vital signs. Natural Resource Report. NPS/NCRN/NRR—2009/116. National Park Service, Fort Collins, CO.

Paul, M.J., J.B. Stribling, R. Klauda, P. Kazyak, M. Southerland, and N. Roth. 2003. A Physical Habitat Index for freshwater wadeable

Figure 4.37. Physical Habitat Index (PHI) results by site for CATO.



streams in Maryland. Report to the Maryland Department of Natural Resources, Annapolis, MD.

Southerland, M.T., L.A Erb, G.M. Rogers and P.F. Kazyak. 2005. Maryland Biological Stream Survey 2000–2004. Volume 7: Statewide and tributary basin results. Prepared for Maryland Department of Natural Resources.

4.3 BIOLOGICAL INTEGRITY

4.3.1 Biological integrity summary

Seven metrics were used to assess biological integrity in CATO—exotic herbaceous species, exotic trees and saplings, forest pest species, native tree seedling regeneration, Fish Index of Biotic Integrity (FIBI), Bird Community Index (BCI), and deer density (Table 4.26). All data were collected by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff except deer density which was collected by park staff. FIBI monitoring sites are shown in Figure 4.18, forest monitoring sites are shown in Figure 4.38, and bird monitoring sites are shown in Figure 4.39.

Reference conditions were established for each metric (Table 4.27) and the data were compared to these reference conditions to obtain the percent attainment and converted to the condition assessment for that metric (Table 4.28). Single reference conditions were used for exotic plants, forest pests, native tree seedling regeneration, and deer density, while multiple reference conditions were used for FIBI and BCI (Tables 4.27, 4.28).

CATO had variable results for biological integrity. The park scored as very good condition for area of exotic trees and saplings (100% attainment), medium integrity for the BCI (56% attainment), moderate or fair condition for forest pests and FIBI (49% and 71% attainment, respectively), degraded condition for absence of exotic herbaceous species (35% attainment), and very degraded condition for the seedling stocking index and deer density (both 0% attainment) (Table 4.29). This resulted in an overall biological integrity condition attainment of 44%, or moderate condition.

Literature cited

Bates, S.E. 2009. National Capital Region Network 2008 deer monitoring report. Natural Resource Technical Report NPS/NCRN/ NRTR—2009/275.

Table 4.26. Ecological monitoring framework data for Biological Integrity provided by agencies and specific sources included in the assessment of CATO.

Metric	Agency	Reference/Source
Cover of exotic herbaceous species	NCRN I&M	Schmit et al. 2009, 2010
Area of exotic trees & saplings	NCRN I&M	Schmit et al. 2009, 2010
Presence of forest pest species	NCRN I&M	Schmit et al. 2009, 2010
Seedling stocking index	NCRN I&M	Schmit et al. 2009, 2010
Fish Index of Biotic Integrity	NCRN I&M, MBSS	Norris and Sanders 2009, MBSS
Bird Community Index	NCRN I&M	O'Connell et al. 1998
Deer density	CATO	Bates 2009, 2012

Table 4.27. Biological Integrity reference conditions for CATO.

Metric	Reference condition/s	Sites	Samples	Period
Presence of exotic herbaceous species (% of plots with exotic species)	0% (absence)	48	48	2006–2010
Area of exotic trees & saplings (% of basal area)	< 5%	49	85	2006–2010
Presence of forest pest species (% of trees infested)	< 1%	49	49	2006–2010
Seedling stocking index	> 115	49	49	2007–2010
Fish Index of Biotic Integrity	1.0–1.9; 2.0–2.9; 3.0–3.9; 4.0–5.0	4	4	2006–2010
Bird Community Index	20–40; 40.1–52; 52.1–60; 60.1–100	45	45	2007–2011
Deer density (deer/km^2)	< 8	Park	11	2001–2011

Table 4.28a. Categorical ranking of reference condition attainment categories for exotic plants, forest pests, native tree seedling regeneration, and deer density.

Attainment of reference condition	Natural resource condition
80–100%	Very good
60–<80%	Good
40–<60%	Moderate
20–<40%	Degraded
0–<20%	Very degraded

National Park Service, Fort Collins, CO.

Bates, S.E. 2012. National Capital Region 2011 deer monitoring report.

Norris, M.E. & G. Sanders. 2009. National Capital Region Network biological stream survey protocol: physical habitat, fish, and aquatic macroinvertebrate vital signs. Natural Resource Report. NPS/NCRN/NRR—2009/116. National Park Service, Fort Collins, CO.

O'Connell, T.J., L.E. Jackson, and R.P. Brooks. 1998. A Bird Community Index of Biotic Integrity for the Mid-Atlantic Highlands. Environmental Monitoring and Assessment 51: 145–156.

Schmit, J.P., G. Sanders, M. Lehman, and T. Paradis. 2009. National Capital Region Network long-term forest monitoring protocol. Version 2.0. Natural Resource Report NPS/NCRN/ NRR—2009/113. National Park Service, Fort Collins, CO.

Schmit, J.P., P. Campbell, and J. Parrish. 2010. National Capital Region Network 2009 forest vegetation monitoring report. Natural Resource Data Series NPS/NCRN/NRDS—2010/043. National Park Service, Fort Collins, CO.

Table 4.28b. Categorical ranking of the reference condition attainment categories for the Fish Index of Biotic Integrity and the Bird Community Index.

Reference conditions	Attainment of reference condition	Natural resource condition
Fish Index of Biotic Integrity (FIBI)		
4.0–5.0	100%	Good
3.0–3.9	↑ scaled	Fair
2.0–2.9	linearly ↓	Poor
1.0–1.9	0%	Very poor

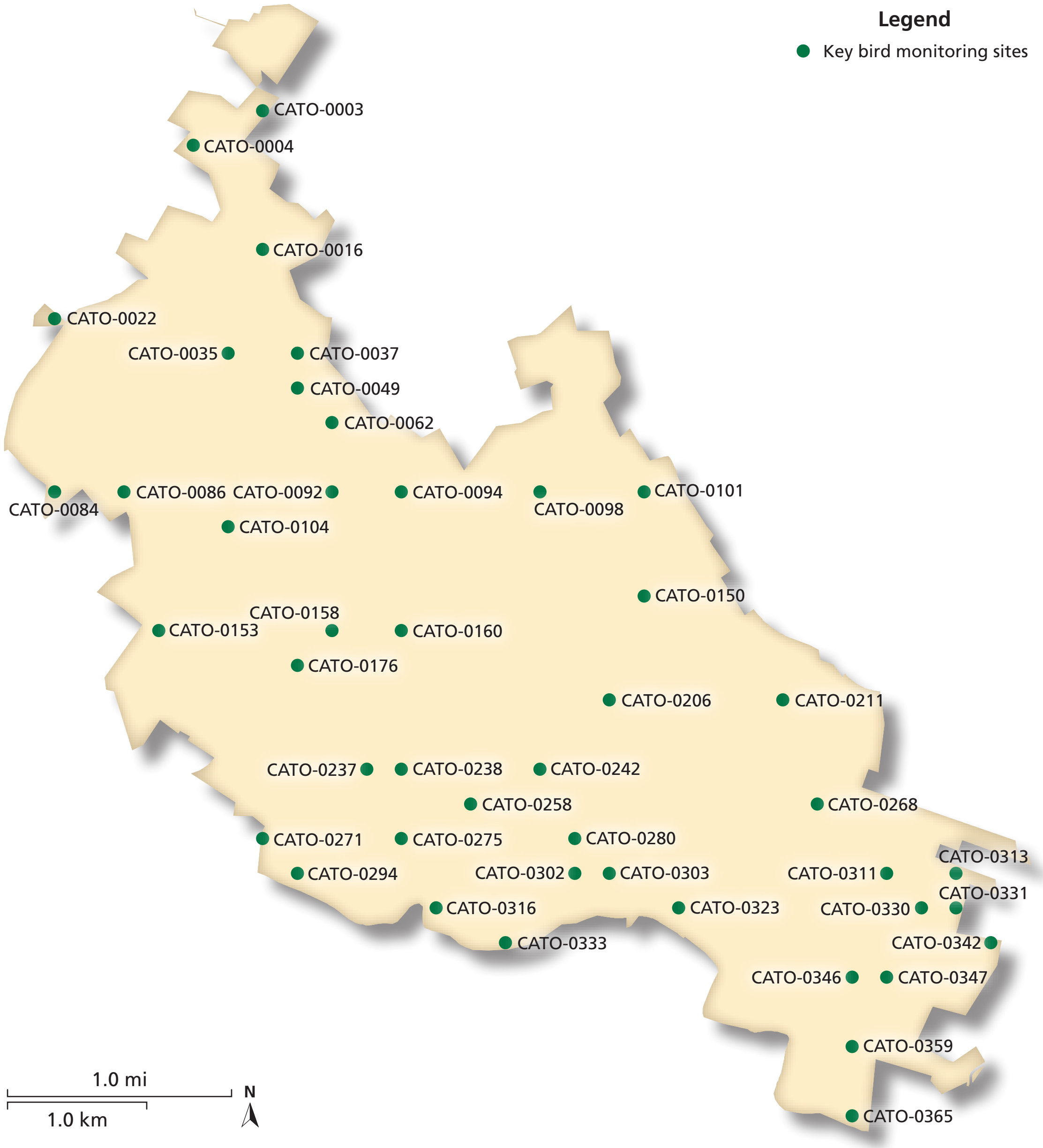
Reference conditions	Attainment of reference condition	Natural resource condition
Bird Community Index (BCI)		
60.1–77	75–100% (scaled)	Highest integrity
52.1–60	50–75% (scaled)	High integrity
40.1–52	25–50% (scaled)	Medium integrity
20.0–40	0–25% (scaled)	Low integrity

Table 4.29. Summary of resource condition assessment of Biological Integrity in CATO.

Metric	Result	Reference condition	% attainment	Condition	Biological integrity condition
Presence of exotic herbaceous species (% of plots with exotic species)	65%	0% (absence)	35	Degraded	**44%** **Moderate**
Area of exotic trees & saplings (% of basal area)	0%	< 5%	100	Very good	
Presence of forest pest species (% of trees infested)	5.3%	< 1%	49	Moderate	
Seedling stocking index	1.0	> 115	0	Very degraded	
Fish Index of Biotic Integrity	3.8	1.0–1.9; 2.0–2.9; 3.0–3.9; 4.0–5.0	71	Fair	
Bird Community Index	52.0	< 40; 40.1–52; 52.1–60; > 60	50	Medium integrity	
Deer density (deer/km^2)	40	< 8	0	Very degraded	

Figure 4.38. Forest monitoring sites and deer counting routes in CATO.

Figure 4.39. Bird monitoring sites in CATO.



4.3.2 Exotic herbaceous species

Description

Invasive exotic plants are non-native species that can reduce abundance and diversity of native plant communities (Vila et al. 2011). This can cause loss of forage and habitat for wildlife, reduced biodiversity, loss of forest productivity, changed groundwater levels, soil degradation, diminished recreational enjoyment, and economic harm (Mack et al. 2000). Although certain plant species were introduced in the United States for agriculture, erosion control (kudzu), or ornamental purposes (Japanese barberry, English ivy), many are now considered invasive threats. Exotic plant species, especially those that are invasive, are a widespread and growing threat in the National Capital Region.

Exotic herbaceous plants make up the majority of exotic plant species found in the forests of the National Capital Region, including CATO, and so pose a serious problem to park management (Schmit et al. 2010). The most common exotic herbaceous species in CATO forests are garlic mustard (*Alliaria petiolata*), Japanese barberry (*Berberis thunbergii*), and Japanese stiltgrass (*Microstegium vimineum*) (Schmit and Campbell 2007, 2008, Schmit et al. 2009a, 2010). Other exotic herbaceous species found in CATO include Japanese honeysuckle (*Lonicera japonica*), Oriental ladysthumb (*Polygonum caespitosum*), mile-a-minute (*Polygonum perfoliatum*), and wineberry (*Rubus phoenicolasius*).

Data and methods

Forest monitoring took place annually but not all plots were measured every year (Schmit et al. 2009b) (Figure 4.38, Table 4.26). To minimize soil compaction and trampling of the understory, plots were sampled on a rotating panel design, with four panels. Each year one panel was sampled. Sampling took place from May through October, when foliage was fully developed.

Each plot was assigned as having exotic herbaceous plants either present or absent. Each plot was then given a rating of either pass (no exotic herbaceous plants present) or fail (any exotic herbaceous plants present). The percentage of passing results was used as the percent attainment.

The Organic Act that established the National Park Service in 1916 and the U.S.

Table 4.30. Presence of exotic herbaceous plants. Site locations are shown in Figure 4.38.

Site	Year	Exotic plants	Site	Year	Exotic plants	Site	Year	Exotic plants
CATO-0003	2007	Present*	CATO-0106	2009	Present*	CATO-0271	2008	Present*
CATO-0004	2007	Present*	CATO-0113	2009	Present*	CATO-0275	2007	Present*
CATO-0016	2008	Present*	CATO-0127	2009	Present*	CATO-0280	2008	Present*
CATO-0035	2007	Absent	CATO-0131	2009	Present*	CATO-0294	2010	Present*
CATO-0037	2007	Present*	CATO-0150	2008	Present*	CATO-0302	2008	Present*
CATO-0043	2009	Present*	CATO-0156	2009	Present*	CATO-0303	2010	Present*
CATO-0049	2007	Present*	CATO-0158	2007	Present*	CATO-0311	2007	Absent
CATO-0062	2008	Present*	CATO-0160	2008	Absent	CATO-0313	2007	Absent
CATO-0084	2007	Absent	CATO-0176	2007	Present*	CATO-0316	2007	Absent
CATO-0086	2008	Present*	CATO-0206	2007	Absent	CATO-0330	2010	Absent
CATO-0092	2008	Present*	CATO-0211	2007	Absent	CATO-0331	2010	Absent
CATO-0094	2007	Present*	CATO-0217	2009	Present*	CATO-0333	2008	Present*
CATO-0098	2008	Present*	CATO-0237	2007	Absent	CATO-0346	2010	Absent
CATO-0100	2009	Present*	CATO-0238	2008	Absent	CATO-0347	2007	Absent
CATO-0101	2008	Present*	CATO-0258	2008	Present*	CATO-0359	2010	Absent
CATO-0104	2008	Present*	CATO-0268	2008	Absent	CATO-0365	2010	Absent

* Values outside of reference condition of having no exotic herbaceous plants present.

Department of Interior NPS Management Policies (U.S. Dept of Interior 2006) mandates the conservation of natural resources (see Section *2.1.1—Enabling legislation*). Because of the threat to the park posed by many exotic herbaceous plants, the threshold used for this assessment was that exotic herbaceous plants should be completely absent (Table 4.27). Each plot was compared against the reference condition to determine the percent attainment and condition (Table 4.28a).

Condition and trend

Current condition for cover of exotic herbaceous species in CATO was degraded, with 65% of plots containing at least one exotic herbaceous plant. Therefore, only 35% of plots attained the reference condition of having no exotic herbaceous plants (Figure 4.40, Tables 4.29, 4.30).

No trend analysis was possible with the current data set.

Sources of expertise

John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

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Figure 4.40. Exotic herbaceous species results by site for CATO.

Applications 10: 689–710.
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4.3.3 Exotic trees & saplings

Description

Invasive exotic plants are non-native species that can reduce abundance and diversity of native plant communities (Vila et al. 2011). This can cause loss of forage and habitat for wildlife, reduced biodiversity, loss of forest productivity, changed groundwater levels, soil degradation, diminished recreational enjoyment, and economic harm (Mack et al. 2000). Exotic plant species, especially those that are invasive, are a widespread and growing threat in the National Capital Region. The most common exotic tree and shrub species in forests of CATO are tree of heaven (*Ailanthus altissima*) and sweet cherry (*Prunus avium*), as well as the shrub Japanese barberry (*Berberis thunbergii*) (Schmit and Campbell 2007, 2008, Schmit et al. 2009a, 2010).

Data and methods

Forest monitoring took place annually but not all plots were measured every year (Schmit et al. 2009b) (Figure 4.38, Table 4.26). To minimize soil compaction and trampling of the understory, plots were sampled on a rotating panel design, with four panels. Each year one panel was sampled. Sampling took place from May through October, when foliage was fully developed.

The basal area of exotic trees and saplings in a plot was calculated as a percentage of total tree basal area. Results from each plot were assessed against the threshold and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

Table 4.31. Percent basal area of exotic trees and saplings. Site locations are shown in Figure 4.38.

Site	Year	Exotic trees	Exotic saplings
CATO-0003	2007	0	0
CATO-0004	2007	0	
CATO-0015	2009	0	0
CATO-0016	2008	1.7	0
CATO-0035	2007	0	
CATO-0037	2007	0	
CATO-0043	2009	0	0
CATO-0049	2007	2.3	0
CATO-0062	2008	0	0
CATO-0084	2007	0	0
CATO-0086	2008	0	0
CATO-0092	2008	0	0
CATO-0094	2007	0	0
CATO-0098	2008	0.5	0
CATO-0100	2009	0	
CATO-0101	2008	0	0
CATO-0104	2008	0	0
CATO-0106	2009	0	0
CATO-0113	2009	0	0
CATO-0127	2009	0	
CATO-0131	2009	0	
CATO-0150	2008	0	0
CATO-0156	2009	0	
CATO-0158	2007	0	0
CATO-0160	2008	0	0
CATO-0176	2007	0	0
CATO-0206	2007	0	0
CATO-0211	2007	0	0
CATO-0217	2009	0	0
CATO-0237	2007	0	0
CATO-0238	2008	0	0
CATO-0258	2008	0	
CATO-0268	2008	0	0
CATO-0271	2008	0	
CATO-0275	2007	0	0
CATO-0280	2008	1.6	0
CATO-0294	2010	0	
CATO-0302	2008	0	0
CATO-0303	2010	0	0
CATO-0311	2007	0	
CATO-0313	2007	0	0
CATO-0316	2007	0	0
CATO-0330	2010	0	0
CATO-0331	2010	0	
CATO-0333	2008	0	0
CATO-0346	2010	0	
CATO-0347	2007	0	0
CATO-0359	2010	0	0
CATO-0365	2010	0	0

* Values outside of reference condition of ≤ 5% cover. Blank cells indicate that there were no saplings present in the plot.

The threshold used for this assessment was that the abundance of these invasive exotic plants should not exceed 5% of total basal area of trees and saplings (Table 4.27). Because 100% eradication is not a realistic goal, the threshold is intended to suggest more than just simple presence of these exotic species but that the observed abundance has the potential to establish and spread, i.e., 5% basal area may be considered as the point where the exotic plants are becoming established rather than just present. The Organic Act that established the National Park Service in 1916 and the U.S. Department of Interior NPS Management Policies (U.S. Dept of Interior 2006) mandates the conservation of natural resources (see Section *2.1.1—Enabling legislation*). This threshold is a guide to consider active management of an area by removal of these species. Each data point was compared against the reference condition to determine the percent attainment and condition (Table 4.28a).

Condition and trend

Condition for basal cover of exotic trees and saplings in CATO was very good, with a median of 0% of total basal area and 100% of plots attaining the reference condition of ≤ 5% of total basal area (Figure 4.41, Tables 4.29, 4.31).

No trend analysis was possible with the current data set.

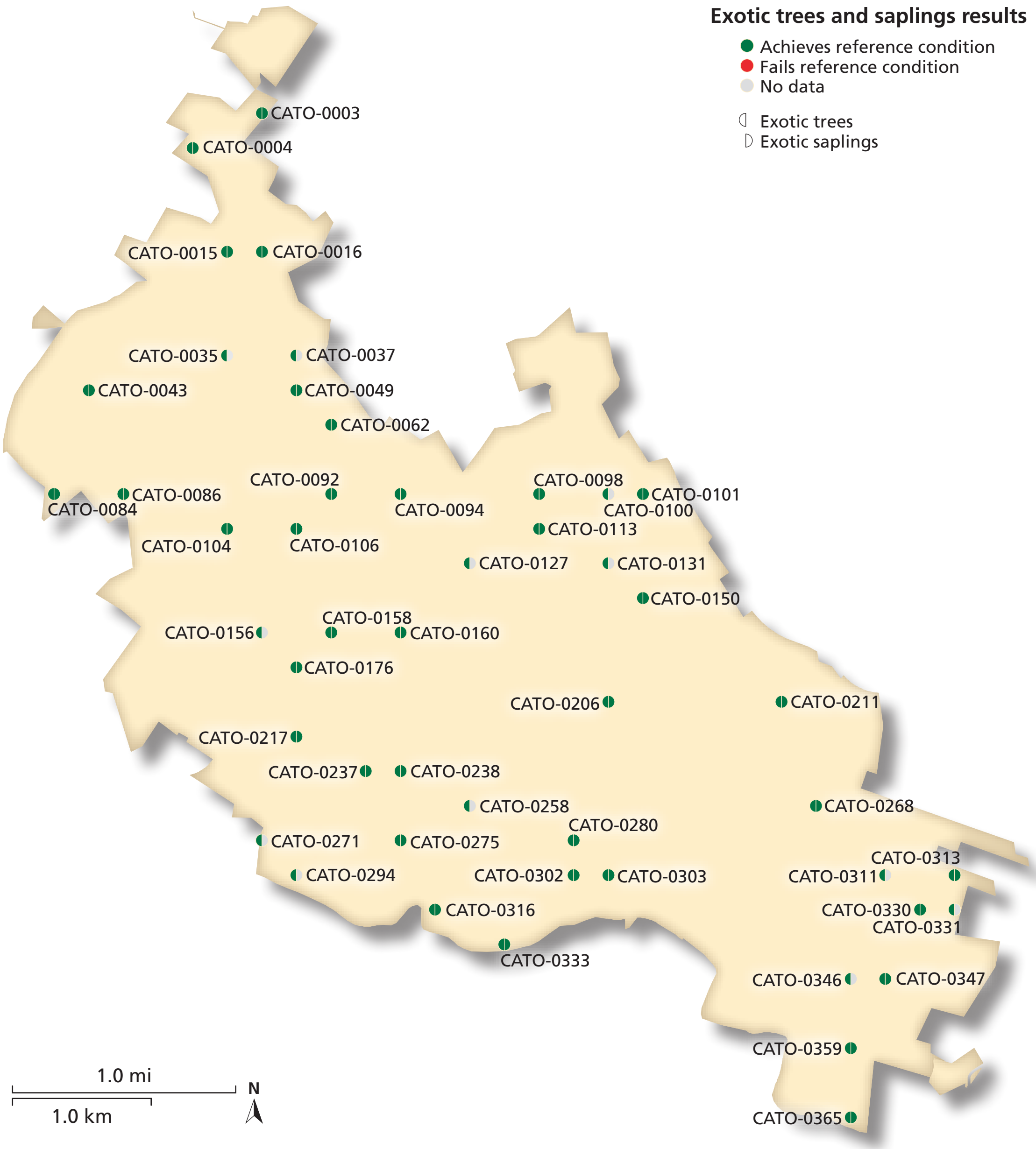

Figure 4.41. Exotic tree and sapling results by site for CATO.

Sources of expertise

John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

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4.3.4 Forest pests

Description

Forests in CATO have historically been impacted by pests such as the gypsy moth (*Lymantria dispar*) and hemlock woolly adelgid (*Adelges tsugae*), and diseases such as the chestnut blight and dogwood anthracnose.

The gypsy moth was accidentally introduced to North America in the late 1860s and has spread widely, resulting in an estimated 160,000 km^2 (62,500 mi^2) of forest defoliation during the 1980s alone (Liebhold et al. 1994, Montgomery 1990). The gypsy moth larvae feed on the foliage of hundreds of species of plants in North America, but its most common hosts are oak (*Quercus* spp.) and aspen (*Populus* spp.) trees (USDA Forest Service 2009a). Gypsy moth is one of the most serious threats to the forests of CATO (CATO 2009). Defoliation caused by gypsy moth caterpillars stresses and weakens trees leaving them more susceptible to secondary infections and infestations and other cumulative impacts. These impacts, both directly and indirectly caused by the gypsy moth infestation, weaken and eventually kill some forest trees. This in turn has adverse effects on water quality, wildlife and habitat, rare plants, visitor use and experience, safety, the cultural landscape and the wildland fire fuel load at CATO. To suppress gypsy moth populations and provide foliage protection, suppression activities have been carried out in CATO, including application of microbial insecticide and gypsy moth virus products (CATO 2009).

Hemlock woolly adelgid (HWA) is another insect pest first reported in the eastern United States in 1951 near Richmond, Virginia (USDA Forest Service 2009b). This aphid-like insect is originally from Asia and feeds on Eastern hemlock trees (*Tsuga canadensis*), which are often damaged and killed within a few years of becoming infested. HWA is responsible for the death of many hemlock trees at CATO. To suppress HWA populations, suppression activities have been carried out in CATO, including application of imidacloprid insecticides (L. Donaldson, pers.comm.).

Data and methods

Forest monitoring took place annually but not all plots were measured every year

Table 4.32. Percent of trees with evidence of forest pests. Site locations are shown in Figure 4.38.

Site	Year	% trees with pests	Site	Year	% trees with pests	Site	Year	% trees with pests
CATO-0003	2007	4.76*	CATO-0106	2009	0.00	CATO-0271	2008	4.35*
CATO-0004	2007	0.00	CATO-0113	2009	16.67*	CATO-0275	2007	14.29*
CATO-0015	2009	0.00	CATO-0127	2009	0.00	CATO-0280	2008	15.00*
CATO-0016	2008	0.00	CATO-0131	2009	0.00	CATO-0294	2010	14.29*
CATO-0035	2007	5.26*	CATO-0150	2008	9.09*	CATO-0302	2008	50.00*
CATO-0037	2007	0.00	CATO-0156	2009	0.00	CATO-0303	2010	0.00
CATO-0043	2009	0.00	CATO-0158	2007	10.34*	CATO-0311	2007	58.82*
CATO-0049	2007	0.00	CATO-0160	2008	11.43*	CATO-0313	2007	62.50*
CATO-0062	2008	0.00	CATO-0176	2007	0.00	CATO-0316	2007	69.57*
CATO-0084	2007	0.00	CATO-0206	2007	30.43*	CATO-0330	2010	56.00*
CATO-0086	2008	16.00*	CATO-0211	2007	16.13*	CATO-0331	2010	66.67*
CATO-0092	2008	10.00*	CATO-0217	2009	0.00	CATO-0333	2008	83.33*
CATO-0094	2007	0.00	CATO-0237	2007	40.91*	CATO-0346	2010	0.00
CATO-0098	2008	4.00*	CATO-0238	2008	67.74*	CATO-0347	2007	25.00*
CATO-0100	2009	0.00	CATO-0258	2008	21.05*	CATO-0359	2010	0.00
CATO-0101	2008	0.00	CATO-0268	2008	56.52*	CATO-0365	2010	25.00*
CATO-0104	2008	0.00						

* Values outside of reference condition of having no evidence of forest pests.

(Schmit et al. 2009a) (Figure 4.38, Table 4.26). To minimize soil compaction and trampling of the understory, plots were sampled on a rotating panel design, with four panels. Each year one panel was sampled. Sampling took place from May through October, when foliage was fully developed.

The percentage of trees infested was calculated by dividing the number of trees afflicted by pests in each plot by the total number of trees in each plot. Results from each plot were assessed against the threshold and assigned a pass or fail result. The percentage of plots passing was used as the percent attainment.

Due to the destructive nature and potential for forest damage from these pests, the threshold used was established as any observation of these pests (i.e., > 0% of trees infested) being considered degraded (Table 4.27). Each data point was compared against the reference condition to determine the percent attainment and condition (Table 4.28a).

Condition and trend

Current condition for forest pests in CATO was moderate, with a median of 5.3% of trees infested and 49% of data points attaining the reference condition of having no signs of forest pest species (Figure 4.42, Tables 4.29, 4.32).

Figure 4.42. Forest pest results by site for CATO.

Gypsy moth was found on various species of trees in all years, although the extent of infestation varied from year to year (Schmit and Campbell 2007, 2008, Schmit et al. 2009b, 2010).

In 2006, plot CATO-294 had 13 hemlock trees, two with HWA recorded and no hemlock saplings. The next time this plot was monitored, in 2010, it had nine dead hemlock trees and the remaining four had HWA. In 2006, plot CATO-365 had 10 hemlock trees—one with HWA—and 11 saplings. When next monitored in 2010, this plot had six dead hemlock trees, four infested with HWA, and three of the 11 hemlock saplings died (J.P. Schmit, pers. comm.).

It is noted that neither the emerald ash borer (*Agrilus planipennis*) nor Asian long-horned beetle (*Anoplophora glabripennis*)—both of which have the potential to be serious pests in CATO—are present in CATO as of the writing of this assessment.

No trend analysis was possible with the current data set.

Sources of expertise

John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

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4.3.5 Seedlings and forest regeneration

Description
Forests are the dominant natural vegetation in the parks of the National Capital Region Network. Many factors including dense white-tailed deer populations and fire suppression in forested regions can alter forest stand development and reduce wildlife habitat by reducing or eliminating young tree seedlings, shrubs, and herbaceous plants (Tierson et al. 1966, Jordan 1967, Marquis 1981, Tilghman 1989, Horsely et al. 2003, Côté et al. 2004, Nowacki and Abrams 2008). In response to regeneration concerns, scientists at the U.S. Forest Service developed a measure, called the 'stocking index,' to determine if regeneration is sufficient (Marquis and Bjorkbom 1982). The index takes into account three different aspects of forest regeneration: the number of seedlings recorded, the size of the seedlings, and the geographic distribution of the seedlings.

Data and methods
Forest monitoring took place annually but not all plots were measured every year (Schmit et al. 2009) (Figure 4.38, Table 4.26). To minimize soil compaction and trampling of the understory, plots were sampled on a rotating panel design, with four panels. Each year one panel was sampled. Sampling took place from May through October, when foliage was fully developed. At each plot, seedlings were counted and the height of each seedling was determined. Based on these measurements, each plot is given a score, with older/larger seedlings and saplings receiving a higher score than smaller plants. Seedlings were defined as trees less than 1 cm diameter at breast height and ≥ 15 cm height.

The seedling stocking index reference condition used in this assessment was 115, above which a plot is considered to be adequately stocked at high densities of white-tailed deer (Table 4.27). Each measurement was assessed against the reference condition and assigned a pass or fail result and the percentage of passing results was used as the percent attainment (Table 4.28a).

Condition and trend
Current condition for native tree seedling regeneration in CATO was very degraded, with a median index value of 1.0 and 0% of data points attaining the reference condition of > 115 (Figure 4.43, Tables 4.29, 4.33).

No trend analysis was possible with the current data set.

Table 4.33. Seedling stocking index values. Site locations are shown in Figure 4.38.

Site	Year	Index	Site	Year	Index	Site	Year	Index
CATO-0003	2007	0*	CATO-0106	2009	5.25*	CATO-0271	2008	39*
CATO-0004	2007	0*	CATO-0113	2009	0*	CATO-0275	2007	9*
CATO-0015	2009	0*	CATO-0127	2009	0*	CATO-0280	2008	8.5*
CATO-0016	2008	0*	CATO-0131	2009	0*	CATO-0294	2010	1*
CATO-0035	2007	3*	CATO-0150	2008	4.25*	CATO-0302	2008	0*
CATO-0037	2007	3*	CATO-0156	2009	0*	CATO-0303	2010	4.25*
CATO-0043	2009	1*	CATO-0158	2007	0*	CATO-0311	2007	5*
CATO-0049	2007	2*	CATO-0160	2008	0*	CATO-0313	2007	0*
CATO-0062	2008	0*	CATO-0176	2007	7.25*	CATO-0316	2007	5*
CATO-0084	2007	2*	CATO-0206	2007	2*	CATO-0330	2010	1*
CATO-0086	2008	0*	CATO-0211	2007	7*	CATO-0331	2010	0*
CATO-0092	2008	6*	CATO-0217	2009	0*	CATO-0333	2008	0*
CATO-0094	2007	1*	CATO-0237	2007	1*	CATO-0346	2010	0*
CATO-0098	2008	0*	CATO-0238	2008	0*	CATO-0347	2007	7*
CATO-0100	2009	1*	CATO-0258	2008	0*	CATO-0359	2010	0*
CATO-0101	2008	0*	CATO-0268	2008	0*	CATO-0365	2010	14.5*
CATO-0104	2008	12.5*						

* Values outside of reference condition of > 115.

Figure 4.43. Seedling regeneration results by site for CATO.

Sources of expertise

John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

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4.3.6 Stream fishes

Description

The Fish Index of Biotic Integrity (FIBI) was proposed as a way of providing a more informative measure of anthropogenic influence on fish communities and ecological integrity than measurements of physiochemical metrics alone (Karr 1981). The metric was then adapted and validated for streams of Maryland using a reference condition approach, based on 1994–1997 data from a total of 1,098 sites.

Data and methods

Data were collected at four sites between 2006 and 2010 (Figure 4.18, Table 4.26). NCRN followed the National Capital Region Biological Stream Survey protocol (Norris and Sanders 2009).Sites were classified based on physical and chemical data and fish assemblages were compared to identified reference sites. Reported data are for one FIBI assessment per site.

FIBI values were ranked as follows: 1.0–1.9 (very poor), 2.0–2.9 (poor), 3.0–3.9 (fair), 4.0–5.0 (good), and these were the scale and categories used in this assessment (Southerland et al. 2007). The range of FIBI scores from 1 to 5 were scaled linearly from 0 to 100% attainment (Figure 4.44, Table 4.34). The median of all the data points was compared to these reference conditions and given a percent attainment and converted to a condition assessment (Tables 4.27, 4.28b).

Condition and trend

Current condition of FIBI in CATO was fair, with a median FIBI of 3.8 and 71% attainment of reference condition (Figure 4.45, Tables 4.29, 4.35).

No trend analysis was possible with the current data set.

Sources of expertise

Marian Norris, Water Resources Specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service.

Literature cited

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6 :21–27.

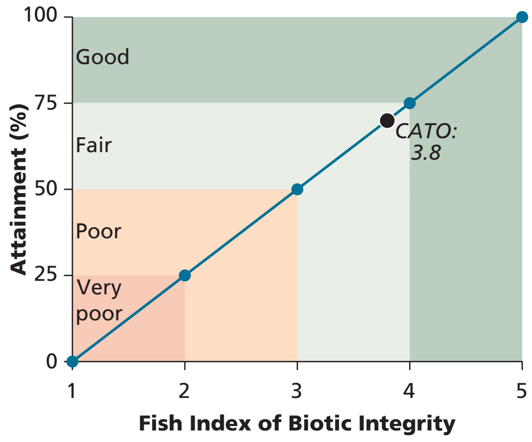


Figure 4.44. Application of the percent attainment categories to the Fish Index of Biotic Integrity (FIBI) value categories. FIBI at CATO was 3.88 which equated to 71% attainment of the reference condition.

Table 4.34. Fish Index of Biotic Integrity (FIBI) categories, percent attainment, and condition assessment.

FIBI range	% attainment	Condition
4.0–5.0	100%	Good
3.0–3.9	↑ scaled	Fair
2.0–2.9	linearly ↓	Poor
1.0–1.9	0%	Very poor

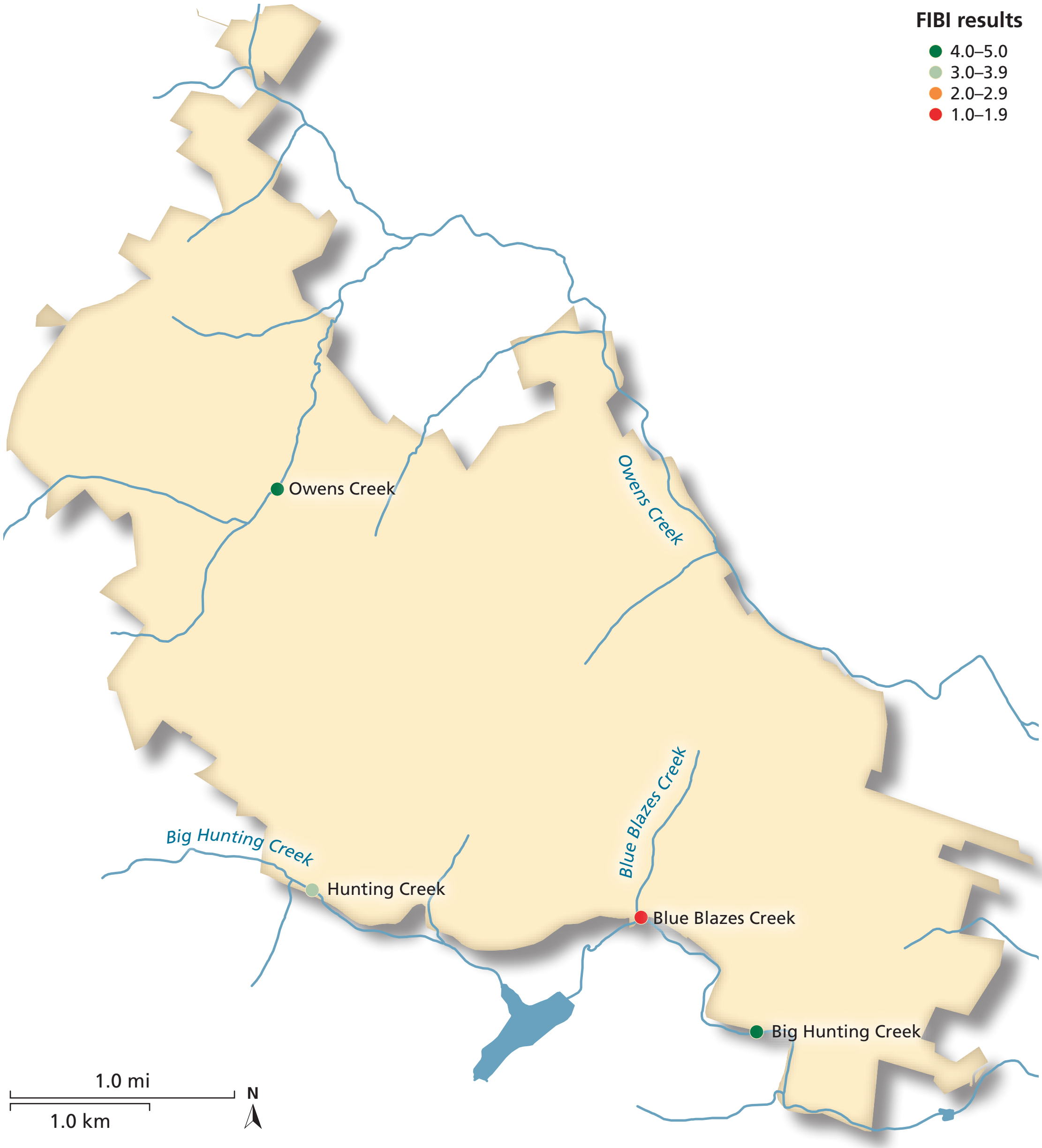
Table 4.35. Fish Index of Biotic Integrity (FIBI) in CATO. Monitoring sites are shown in Figure 4.18.

Year	Site	Location	FIBI
2006	CATO-201-N-2006	Hunting Creek	3.67
2010	MONO-133-N-2010	Owens Creek	4.00
2010	MONO-134-N-2010	Blue Blazes Creek	1.00
2010	MONO-230-N-2010	Big Hunting Creek	4.00

Norris, M.E. & G. Sanders. 2009. National Capital Region Network biological stream survey protocol: physical habitat, fish, and aquatic macroinvertebrate vital signs. Natural Resource Report. NPS/NCRN/NRR—2009/116. National Park Service, Fort Collins, CO.

Southerland, M.T., G.M. Rogers, M.J. Kline, R.P. Morgan, D.M. Boward, P.F. Kazyak, R.J. Klauda, and S.A. Stranko. 2007. Improving biological indicators to better assess the condition of streams. Ecological Indicators 7: 751–767.

Figure 4.45. Fish Index of Biotic Integrity (FIBI) results by site for CATO.



4.3.7 Birds

Description

Birds exhibit numerous characteristics that make them appropriate as ecological indicators. They are conspicuous components of terrestrial ecosystems in the National Capital Region, they can integrate conditions across major habitat types, and many require specific habitat conditions (O'Connell et al. 1998).

Modeled after previously developed Indices of Biotic Integrity (IBIs), the Bird Community Index (BCI) was developed as a multi-resource indicator of biotic integrity in the central Appalachians (O'Connell et al. 1998).

Data and methods

Data were collected at 45 forest sites between 2007 and 2011 (Figure 4.39, Table 4.26). Point count data from each plot were used to assess the BCI using the O'Connell et al. (1998) scoring and guild assignments for the Appalachian bird conservation region (BCR) (Ladin and Shriver 2013). BCI scores were ranked as follows: highest integrity (60.1– 77.0), high integrity (52.1–60.0), medium integrity (40.1–52.0), and low integrity (20.0–40.0), and these were the scale and categories used in this assessment (O'Connell et al. 1998).

Each of the four BCI value categories were assigned a percent attainment range (Figure 4.46, Table 4.36). The median of all the data points was compared to these reference conditions and given a percent attainment and converted to a condition assessment (Tables 4.27, 4.28b).

Condition and trend

The 2011 BCI of forest sites in CATO showed medium integrity, with a median of 52.0 and 50% attainment of reference condition (Figure 4.47, Tables 4.29, 4.37).

Sources of expertise

John Paul Schmit, Quantitative Ecologist, Center for Urban Ecology, National Park Service.

Literature cited

Ladin Z.S. and W.G. Shriver. 2013. Avian monitoring in the National Capital Region Network: Summary report 2007–2011. Natural Resource Technical Report. NPS/NCRN/NRTR—2013/698. National Park Service. Fort Collins, CO. Published Report-2193341.

O'Connell, T.J., L.E. Jackson, and R.P. Brooks. 1998. A Bird Community Index of Biotic Integrity for the Mid-Atlantic Highlands. Environmental Monitoring and Assessment 51: 145–156.

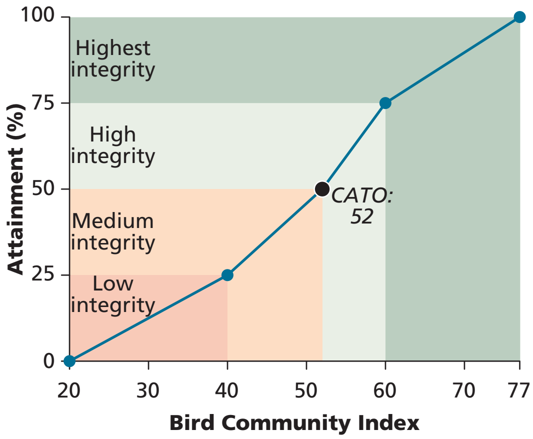


Figure 4.46. Application of the percent attainment categories to the Bird Community Index (BCI) value categories. BCI at CATO was 52 which equated to 50% attainment of the reference condition.

Table 4.36. Bird Community Index (BCI) categories, percent attainment, and condition assessment.

BCI range	% attainment	Condition
60.1–77	75–100%	Highest integrity
52.1–60	50–75%	High integrity
40.1–52	25–50%	Medium integrity
20.0–40	0–25%	Low integrity

Table 4.37. Median Bird Community Index (BCI) scores in CATO. Monitoring sites are shown in Figure 4.38.

Site	Median	Site	Median	Site	Median
CATO-0003	50.0	CATO-0150	54.5	CATO-0294	55.0
CATO-0004	51.0	CATO-0153	51.5	CATO-0302	56.0
CATO-0016	47.0	CATO-0158	51.0	CATO-0303	52.5
CATO-0022	43.0	CATO-0160	50.0	CATO-0311	52.0
CATO-0035	49.5	CATO-0176	50.5	CATO-0313	48.0
CATO-0037	44.5	CATO-0206	50.5	CATO-0316	47.5
CATO-0049	48.0	CATO-0211	59.5	CATO-0323	52.5
CATO-0062	54.0	CATO-0237	53.5	CATO-0330	49.0
CATO-0084	51.0	CATO-0238	48.5	CATO-0331	48.0
CATO-0086	60.5	CATO-0242	50.5	CATO-0333	51.5
CATO-0092	53.5	CATO-0258	53.5	CATO-0342	49.0
CATO-0094	53.0	CATO-0268	52.5	CATO-0346	52.5
CATO-0098	45.0	CATO-0271	52.5	CATO-0347	52.0
CATO-0101	59.5	CATO-0275	52.0	CATO-0359	49.0
CATO-0104	57.0	CATO-0280	57.5	CATO-0365	51.5

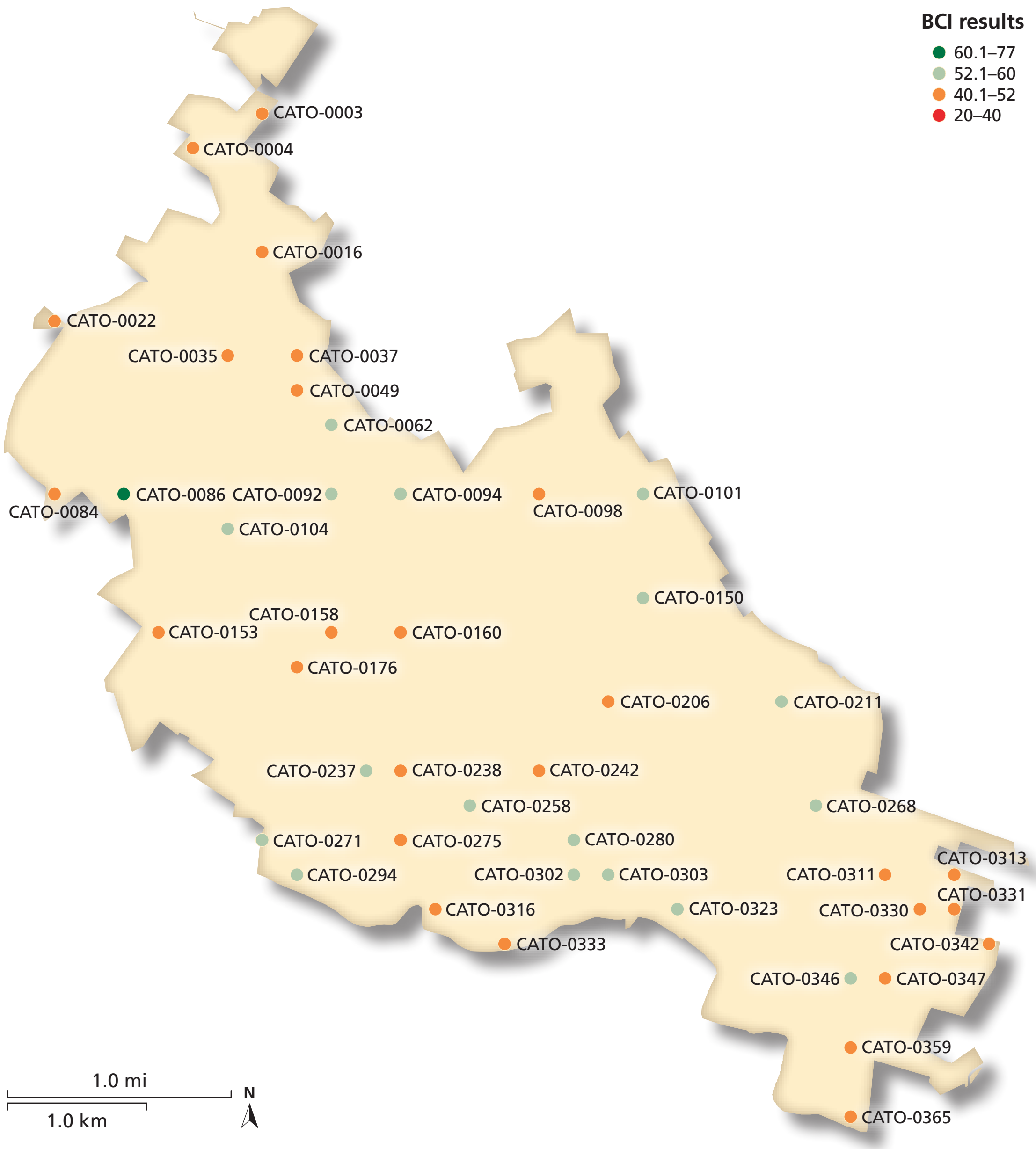


Figure 4.47. Bird Community Index (BCI) condition by site from 2007 to 2011 in 45 monitoring locations in CATO. Site medians were used for this analysis.

4.3.8 Deer density

Description

White-tailed deer (*Odocoileus virginianus*) are considered a significant stressor on forests of the National Capital Region. White-tailed deer densities throughout the eastern deciduous forest zone increased rapidly during the latter half of the 20th century and may now be at historically high levels. McCabe and McCabe (1997) estimate that pre-European deer densities in the eastern United States ranged between 3.1 and 4.2 deer/km^2 (8.0 and 10.9 deer/mi^2) in optimal habitats. Today, examples of deer populations exceeding 20 deer/km^2 (52 deer/mi^2) are commonplace (e.g., Knox 1997, Russell et al. 2001, Augustine and deCalesta 2003, Rossel Jr. et al. 2005, Griggs et al. 2006, McDonald Jr. et al. 2007).

The currently high population numbers for white-tailed deer regionally have been recognized since the 1980s as being of concern due to potentially large impacts upon regeneration of woody tree species as well as the occurrence and abundance of herbaceous species and consequent alterations to trophic interactions (Decalesta 1997, Waller and Alverson 1997, Côté et al. 2004). Besides directly impacting vegetative communities, deer overbrowsing can contribute to declines in breeding bird abundances by decreasing the structural diversity and density in the forest understory (McShea and Rappole 1997).

Data and methods

Deer population density was estimated annually between 2001 and 2011 using Program Distance counts (Bates 2006, 2009, 2012) (Figure 4.38, Table 4.26). Annual population densities were assessed against the reference condition and assigned a pass or fail result and the percentage of passing results was used as the percent attainment.

The forest threshold for white-tailed deer density (8.0 deer/km^2 [21 deer/mi^2]) is a well-established ecological threshold (Horsley et al. 2003) (Table 4.27). Species richness and abundance of herbs and shrubs are consistently reduced as deer densities approach 8.0/km^2 (21 deer/mi^2), although shown in some studies to change at densities as low as 3.7 deer/km^2 (9.6 deer/mi^2) (Decalesta 1997). One large manipulation study in central Massachusetts found deer densities of 10–17/km^2 (26–44 deer/mi^2) inhibited the regeneration of understory species, while densities of 3–6 deer/km^2 (8–16 deer/mi^2) supported a diverse and abundant forest understory (Healy 1997). There are multiple sensitive species of songbirds that cannot be found in areas where deer grazing has removed the understory vegetation needed for nesting, foraging and protection. Even though songbird species vary in how sensitive they are to increases in deer populations, these changes generally occur at deer densities greater than 8 deer/km^2 (21 deer/mi^2) (Decalesta 1997). Annual densities were compared against the reference condition to determine the percent attainment and condition (Table 4.28a).

Condition and trend

Current condition of deer population density in CATO was very degraded,

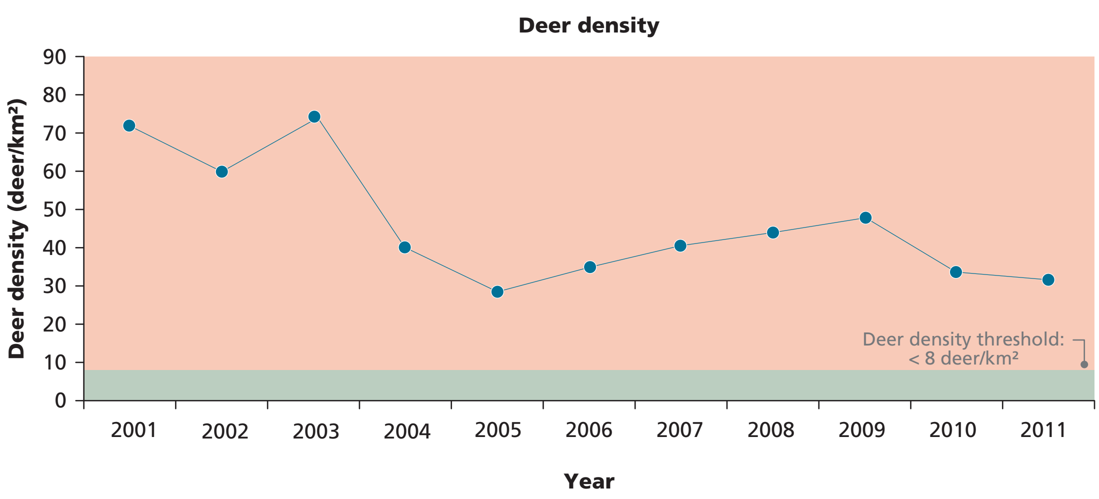


Figure 4.48. Annual mean deer density (deer/km^2) from 2001 to 2011 in CATO. Reference condition (< 8 deer/km^2) is shown in gray.

with 0% of years attaining the reference condition of < 8.0 deer/km^2 (Figure 4.48, Tables 4.29, A-3). Population estimates for deer population for 2001–2011 all exceeded the reference condition of < 8 deer/km^2, with a median deer population of 40 deer/km^2 for all years (Figure 4.48, Table A-3).

The deer population decreased significantly in 2004 but has been relatively stable since then (Figure 4.48, Table A-3). However, CATO has begun actively managing their deer population, with the first organized deer cull occurring in 2010, in line with the preferred management alternative outlined in the Deer Management Plan (NPS 2008, L. Donaldson, pers. comm.). A 2002 white-tailed deer herd health analysis indicated that the herd was near nutritional carrying capacity due to malnutrition/parasitism syndrome and that reduction of the population was appropriate to address the density dependent health problem (Davidson 2002).

Sources of expertise

Scott Bates, Wildlife Biologist, Center for Urban Ecology, National Park Service.

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Côté, S.D., T.P. Rooney, J.P. Tremblay, C. Dussault, and D.M. Waller. 2004. Ecological impacts of deer overabundance. Annual Review of Ecology, Evolution, and Systematics 35: 113–147.

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Horsley, S.B., S.L. Stout, and D.S. deCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 31: 98–118.

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McCabe, T.R., and R.E. McCabe. 1997. Recounting whitetails past. In: McShea, W.J., H.B. Underwood, and J.H. Rappole (eds). The science of overabundance: Deer ecology and population management. Springer, Netherlands.

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Russell, L.F., D.B. Zippin, and N.L. Fowler. 2001. Effects of whitetailed deer (*Odocoileus virginianus*) on plants, plant populations, and communities: a review. American Midland Naturalist 146: 1–26.

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4.4 LANDSCAPE DYNAMICS

4.4.1 Landscape dynamics summary

Four metrics were used to assess landscape dynamics in CATO—forest interior area, forest cover, impervious surface, and road density (measured at two different scales) (Table 4.38). Data from the 2006 National Land Cover Database and the 2010 ESRI Streets layer were analyzed by National Capital Region Network (NCRN) Inventory & Monitoring (I&M) staff (ESRI 2010, Fry et al. 2011, NPS 2010a, b).

The two spatial scales used for the analyses were: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary. The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park.

Reference conditions were established for each metric (Table 4.39) and the data were compared to these reference conditions to obtain the percent attainment and converted to the condition assessment for that metric (Table 4.40).

CATO scored as very good (81–100% attainment) for all landscape dynamics metrics except forest interior area at the 5x park area scale (69% attainment or good condition) and road density at the 5x park area scale (0% attainment or very degraded condition) (Table 4.41). This resulted in an overall landscape dynamics condition attainment of 81%, or very good condition.

Literature cited

ESRI 2010. ESRI Data and Maps – U.S. and Canada Detailed Streets, TeleAtlas 2005.

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77: 858–864.

Table 4.38. Ecological monitoring framework data for Landscape Dynamics provided by agencies and specific sources included in the assessment of CATO.

Metric	Agency	Reference/Source
Forest interior area (within park)	NPS NPScape	NPS 2010a
Forest interior area (within park + 5x buffer)	NPS NPScape	NPS 2010a
Forest cover (within park)	NPS NPScape	NPS 2010a
Forest cover (within park + 5x buffer)	NPS NPScape	NPS 2010a
Impervious surface (within park)	NPS NPScape	NPS 2010a
Impervious surface (within park + 5x buffer)	NPS NPScape	NPS 2010a
Road density (within park)	NPS NPScape	NPS 2010b
Road density (within park + 5x buffer)	NPS NPScape	NPS 2010b

Table 4.39. Landscape Dynamics reference conditions for CATO.

Metric	Reference condition	Sites	Samples	Period
Forest interior area (within park)	% of total potential forest area translates to % attainment	Park	1	2006
Forest interior area (within park + 5x buffer)	% of total potential forest area translates to % attainment	Park	1	2006
Forest cover (within park)	> 59%	Park	1	2006
Forest cover (within park + 5x buffer)	> 59%	Park	1	2006
Impervious surface (within park)	< 10%	Park	1	2006
Impervious surface (within park + 5x buffer)	< 10%	Park	1	2006
Road density (within park + 5x buffer)	< 1.5 km/km^2	Park	1	2006
Road density (within park + 5x buffer)	< 1.5 km/km^2	Park	1	2006

NPS 2010a. NPScape landcover measure – Phase 1 metrics processing SOP: Landcover area per category, natural vs. converted landcover, landcover change, and impervious surface metrics. Natural Resource Report. NPS/ NRPC/IMD/NRR—2010/252. Published Report-2165449. National Park Service, Natural Resource Program Center. Fort Collins, CO.

NPS 2010b. NPScape roads measure – Phase 2 road metrics processing SOP: Road density and distance from roads. National Park Service, Natural Resource Program Center. Fort Collins, CO.

Table 4.40. Categorical ranking of reference condition attainment categories for Landscape Dynamics metrics.

Attainment of reference condition	Natural resource condition
80–100%	Very good
60–<80%	Good
40–<60%	Moderate
20–<40%	Degraded
0–<20%	Very degraded

Table 4.41. Summary of resource condition assessment of Landscape Dynamics in CATO.

Metric	Result	Reference condition	% attainment	Condition	Landscape dynamics condition
Forest interior area (within park)	81%	% of total potential forest area translates to % attainment	81%	Very good	81% Very good
Forest interior area (within park + 5x buffer)	69%	% of total potential forest area translates to % attainment	69%	Good	
Forest cover (within park)	95%	> 59%	100%	Very good	
Forest cover (within park + 5x buffer)	75%	> 59%	100%	Very good	
Impervious surface (within park)	0.2%	< 10%	100%	Very good	
Impervious surface (within park + 5x buffer)	2.9%	< 10%	100%	Very good	
Road density (within park)	1.1 km/km^2	< 1.5 km/km^2	100%	Very good	
Road density (within park + 5x buffer)	2.1 km/km^2	< 1.5 km/km^2	0%	Very degraded	

4.4.2 Forest interior area

Description

Forest interior habitat functions as the highest quality breeding habitat for forest interior dwelling species (FIDS) of birds. When a forest becomes fragmented, areas that once functioned as interior breeding habitat are converted to edge habitat and are often associated with a significant reduction in the number of young birds that are fledged in a year (Jones et al. 2000).

Higher rates of nest predation occur in forest edges. In addition, forest edges provide access to the interior for avian predators such as blue jays, crows, grackles and mammalian predators that include foxes, raccoons, squirrels, dogs, and cats. These predators eat eggs and young birds still in the nest. They tend to be abundant near areas of human habitation and can be detrimental to nesting success (Jones et al. 2000).

Data and methods

Forest interior area as a percent of the park area (or buffered area) was calculated using the NPScape Phase 1 Landcover methods and script tools (NPS 2010) (Table 4.38) for forest morphology. The source data for this analysis was the 2006 National Land Cover Database (NLCD) (Fry et al. 2011) from which a Morphological Spatial Pattern Analysis (MSPA) dataset was generated using the GUIDOS software package (*http://forest.jrc.ec.europa.eu/download/software/guidos*) with the edge distance defined as 90 m (3 pixels). The number of acres of forest interior or 'core' area was extracted from the MSPA dataset for the park and the buffered areas.

The threshold attainment was expressed as the number of acres of interior forest in the park as a percentage of the total potential acres of interior forest within the park (if the total forest area was one large circular patch). The data used in this assessment represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary (Figure 4.49, Table 4.39). The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The percentage of potential forest interior area translated directly to the percent attainment and condition assessment (Table 4.40).

Table 4.42. Forest interior area (%) in CATO.

Area	Interior area (%)
Park	81
Park + 5x area	69
Park + 30 km	46

Interior forest was defined as mature forested land cover ≥ 100 m (330 ft) from non-forest land cover or from primary, secondary, or county roads (i.e., roads considered large enough to break the canopy) (Temple 1986).

Condition and trend

Forest interior area in CATO at the scale of the park and at the scale of the park plus the 5x buffer was 81% and 69%, respectively (Figure 4.49, Tables 4.41, 4.42). This indicated very good condition at the scale of the park, and good condition at the 5x area scale. Note: forest interior area at an additional scale (park boundary plus a 30 km buffer is also shown for reference in Table 4.42 but was not included in the current assessment.

No trend analysis was possible with the current data set.

Sources of expertise

Mark Lehman, GIS specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service.

Literature cited

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77: 858–864.

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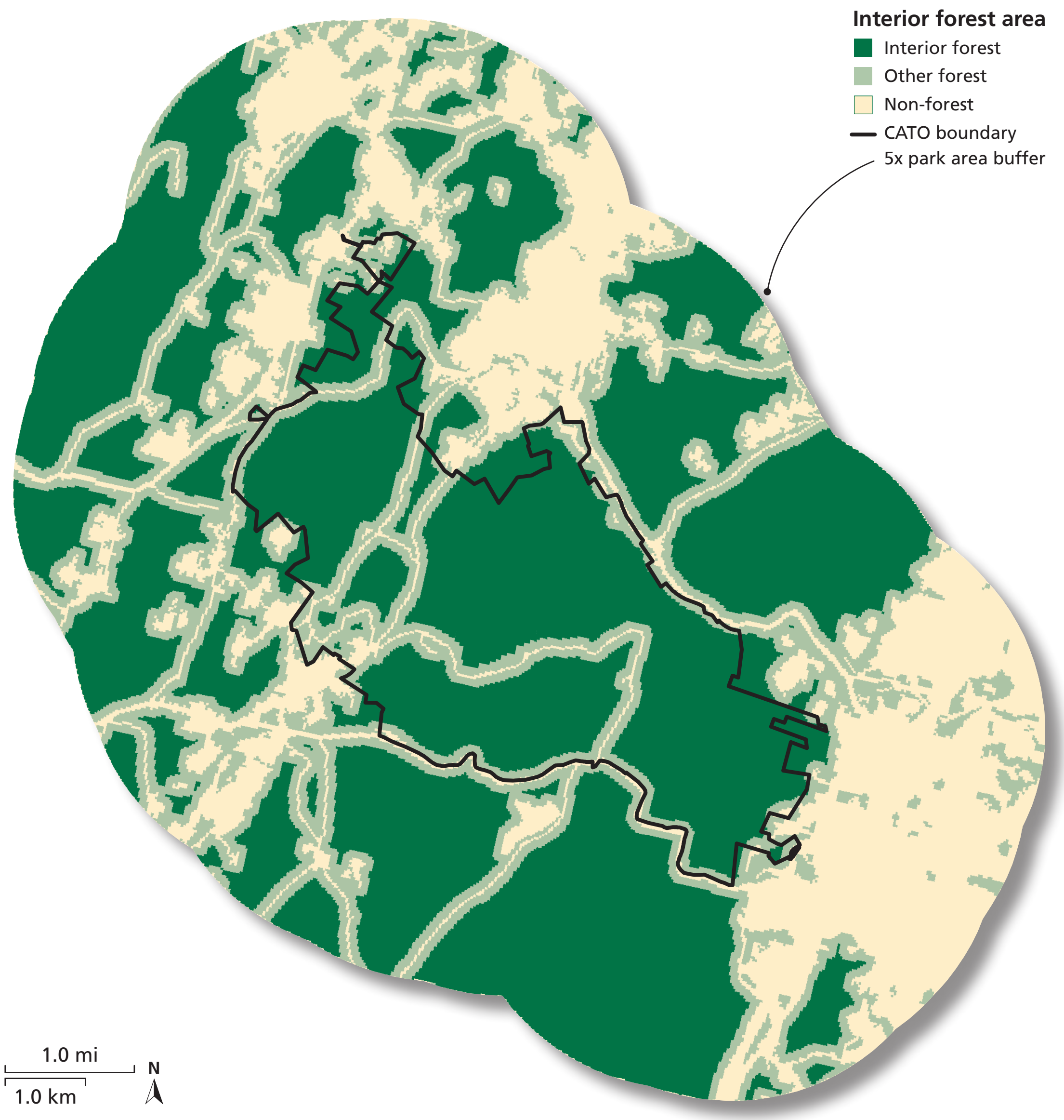

Figure 4.49. Extent of forest interior area in and around CATO in 2006. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

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4.4.3 Forest cover

Description

Forest is the dominant historical land use in the region surrounding CATO and is still the dominant land use within the park itself (Figure 2.3) (NPS 2008, NPS 2011). As intact and connected forest provides habitat, wildlife corridors, and ecosystem services, forest cover was chosen as a Landscape Dynamics metric.

Data and methods

Forest cover as a percent of the park area (or buffered area) was calculated using the NPScape Phase 1 Landcover methods and script tools (NPS 2010) (Table 4.38). The source data for this analysis was the 2006 National Land Cover Database (NLCD) (Fry et al. 2011). Three of the NLCD classifications were considered to be forested areas for this analysis: Deciduous Forest, Evergreen Forest, and Mixed Forest.

Modeling studies have found that in ecological systems, there is a 'tipping point' of forest cover below which a system becomes so fragmented that it no longer functions as a single system (Hargis et al. 1998). USGS digital land use data were used for forest cover in areas of North Carolina, West Virginia, and Alabama to determine the critical value of 59.28% (Gardner et al. 1987). Forest was chosen as it is a dominant vegetation type within the region, providing major structure to faunal and floral communities.

A forest cover threshold of > 59% was used in this assessment and the data used represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary (Figure 4.50, Table 4.39). The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

Condition and trend

Forest cover in CATO at the scale of the park and at the scale of the park plus the 5x buffer was 95% and 75%, respectively. These both exceeded the reference condition of 59% forest cover, resulting in 100% attainment and very good condition at both scales (Figure 4.50, Tables 4.41, 4.43). Note: forest cover at an additional scale (park boundary plus a 30 km buffer is also shown in Table 4.43 for reference but was not included in the current assessment.

Table 4.43. Forest cover (%) in CATO.

Area	Forest cover (%)
Park	95
Park + 5x area	75
Park + 30 km	31*

* Values outside of reference condition of > 59%.

No trend analysis was possible with the current data set.

Sources of expertise

Mark Lehman, GIS specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service.

Literature cited

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77: 858–864.

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NPS 2010. NPScape landcover measure – Phase 1 metrics processing SOP: Landcover area per category, natural vs. converted landcover, landcover change, and impervious surface metrics. Natural Resource Report. NPS/NRPC/IMD/NRR—2010/252. Published Report-2165449. National Park Service, Natural Resource Program Center. Fort Collins, CO.

NPS. 2011. NPScape: monitoring landscape dynamics of US National Parks. Natural Resource Program Center, Inventory and Monitoring Division. Fort Collins, CO. Accessed April 9, 2013. *http://science.nature.nps.gov/im/monitor/npscape*

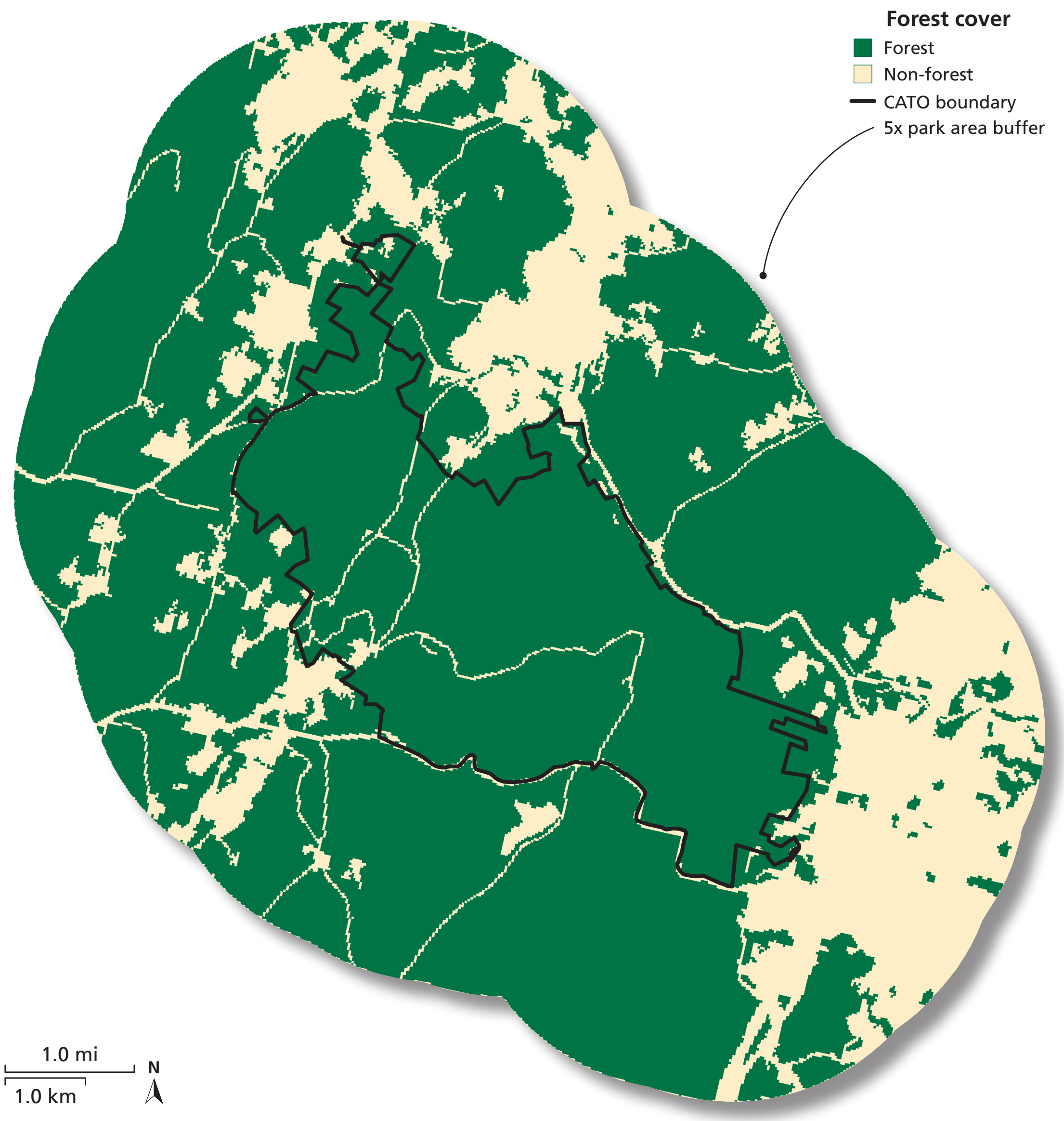

Figure 4.50. Extent of forest and non-forest landcover within and around CATO in 2006. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

4.4.4 Impervious surface

Description

Impervious surface is a human impact on the landscape and directly correlates to land development (Conway 2007). It includes roads, parking lots, rooftops, and transport systems that decrease infiltration, water quality, and habitat while increasing runoff.

Data and methods

A single mean impervious surface percentage was calculated for the park (and buffered areas) using ESRI zonal statistics on the 2006 National Land Cover Database impervious surface layer (NPS 2010a, b, Fry et al. 2011) (Table 4.38).

Many ecosystem components such as wetlands, floral and faunal communities, and streambank structure show signs of impact and loss of biodiversity when impervious surface covers more than 10% of the land area (Arnold and Gibbons 1996, Lussier et al. 2008). A study of nine metropolitan areas in the United States demonstrated measurable effects of impervious surface on stream invertebrate assemblages at impervious surface cover of 5% (Cuffney et al. 2010). Percent urban land is correlated to impervious surface and can provide a good approximation of watershed degradation due to increases of impervious surface.

An impervious surface threshold of < 10% was used in this assessment and the data used represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary (Figure 4.51, Table 4.39). The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

Condition and trend

Impervious surface in CATO at the scale of the park and at the scale of the park plus the 5x buffer was 0.2% and 2.9%, respectively. These were both below the reference condition of 10% impervious surface, resulting in 100% attainment and very good condition at both scales (Figure 4.51, Tables 4.41, 4.44). Note: impervious surface at an additional scale (park boundary plus a 30 km buffer) is also shown in Table 4.44 for reference but was not included in the current assessment.

Table 4.44. Impervious surface (%) in CATO.

Area	Impervious surface (%)
Park	0.2
Park + 5x area	2.9
Park + 30 km	3.8

* Values outside of reference condition of < 10%.

Areas adjacent to the park with the highest cover of impervious surface include the towns of Thurmont and Highfield–Cascade, MD, near the park's southeastern and northwestern boundaries, respectively.

No trend analysis was possible with the current data set.

Sources of expertise

Mark Lehman, GIS specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service.

Literature cited

Arnold Jr, C.L. and C.J. Gibbons. 1996. Impervious surface coverage. Journal of the American Planning Association 62: 243–269.

Conway, T.M. 2007. Impervious surface as an indicator of pH and specific conductance in the urbanizing coastal zone of New Jersey, USA. Journal of Environmental Management 85: 308–316.

Cuffney, T.F., R.A. Brightbill, J.T. May, and I.R. Waite. 2010. Responses of benthic macroinvertebraes to environmental changes associated with urbanization in nine metropolitan areas. Ecological Applications 20: 1384–1401.

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77: 858–864.

Lussier, S.M., S.N. da Silva, M. Charpentier, J.F. Heltshe, S.M. Cormier, D.J. Klemm, M. Chintala, and S. Jayaraman. 2008. The influence of suburban land use on habitat and biotic integrity of coastal Rhode Island streams. Environmental Monitoring and Assessment 139: 119–136.

NPS 2010a. NPScape landcover measure – Phase 1 metrics processing SOP: Landcover area per

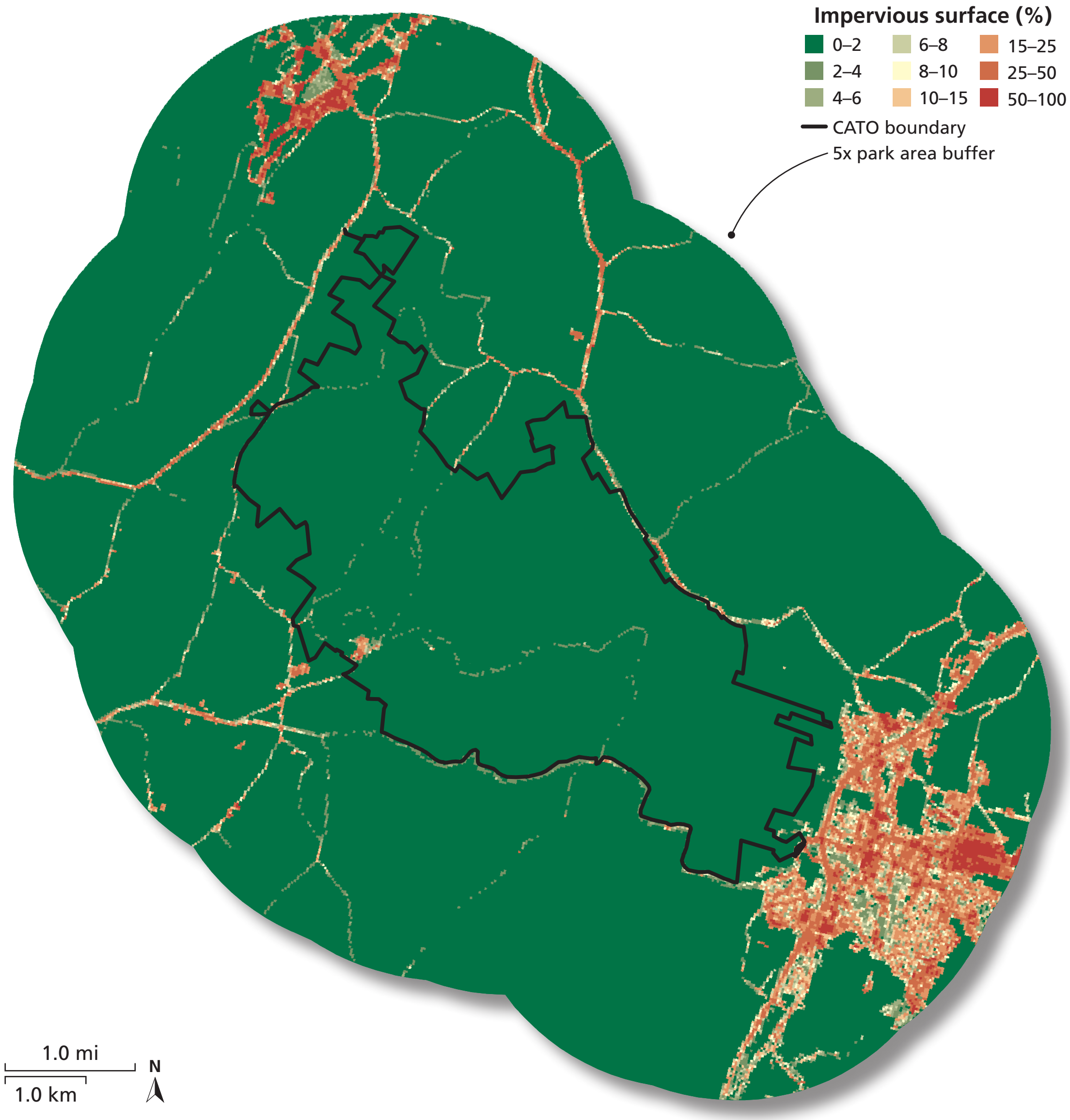

Figure 4.51. Percent impervious surface within and around CATO in 2006. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

category, natural vs. converted landcover, landcover change, and impervious surface metrics. Natural Resource Report. NPS/NRPC/IMD/NRR—2010/252. Published Report-2165449. National Park Service, Natural Resource Program Center. Fort Collins, CO.

NPS 2010b. NPScape landcover measure – Phase 2 North American Landcover metrics processing SOP: Landcover area per category and natural vs. converted landcover metrics. National Park Service, Natural Resource Program Center. Fort Collins, CO.

4.4.5 Road density

Description

Roads and other forest-dividing cuts such as utility corridors can act as barriers to wildlife movement and increase habitat fragmentation. High road density or the presence of a large roadway can decrease the quality of wildlife habitat by fragmenting it, and increases the risk of wildlife mortality by vehicle strike (Forman et al. 1995).

Data and methods

Road density (km of road per square km) and distance from roads were calculated using the NPScape Phase 2 Road Metrics Processing SOP (NPS 2010) for the park and buffered areas (Table 4.38). The 2010 ESRI Streets layer (ESRI 2010) was used as the source data. All of the features in this layer were included in this analysis with the exception of ferry routes.

Road densities higher than 1.5 km/km^2 have been shown to impact turtle populations, while densities higher than 0.6 km/km^2 can impact natural populations of large vertebrates (Forman et al. 1995, Gibbs and Shriver 2002, Steen and Gibbs 2004). A road density threshold of < 1.5 km/km^2 was used in this assessment and data used in this assessment represent a one-off calculation at two scales: 1) within the park boundary and 2) within the park boundary plus an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary (Figure 4.52, Table 4.39). The purpose of this analysis was to assess the influence on ecosystem processes of land use immediately surrounding the park. The park was given a rating of either 100% or 0% attainment based on the results of the one-off calculation.

Condition and trend

At the scale of the park, road density in CATO was 1.1 km/km^2, which is less than the reference condition of 1.5 km/km^2. This resulted in 100% attainment and very good condition (Figure 4.52, Tables 4.41, 4.45).

However, when a buffer of five times the park area was added, road density increased to 2.1 km/km^2. This did not meet the reference condition, resulting in 0% attainment of reference condition and indicating very degraded condition (Tables 4.41, 4.45). Note: road density at an additional scale (park boundary plus a 30 km buffer is also shown in Table 4.45 for reference but was not included in the current assessment.

Table 4.45. Road density (km/km^2) in CATO.

Area	Road density (km/km^2)
Park	1.1
Park + 5x area	2.1*
Park + 30 km	2.5*

* Values outside of reference condition of < 1.5 km/km^2.

No trend analysis was possible with the current data set.

Sources of expertise

Mark Lehman, GIS specialist, Inventory and Monitoring Program, National Capital Region Network, National Park Service.

Literature cited

ESRI 2010. ESRI Data and Maps – U.S. and Canada Detailed Streets, TeleAtlas 2005.

Forman, R.T.T., D.S. Friedman, D. Fitzhenry, J.D. Martin, A.S. Chen, and L.E. Alexander. 1995. Ecological effects of roads: Toward three summary indices and an overview for North America. In: Canters, K (ed). Habitat fragmentation and infrastructure. Ministry of Transport, Public Works and Water Management: Maastricht and The Hague, Netherlands.

Gibbs, J.P. and W.G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16: 1647–1652.

NPS 2010. NPScape roads measure – Phase 2 road metrics processing SOP: Road density and distance from roads. National Park Service, Natural Resource Program Center. Fort Collins, CO.

Steen, D.A. and J.P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18: 1143–1148.

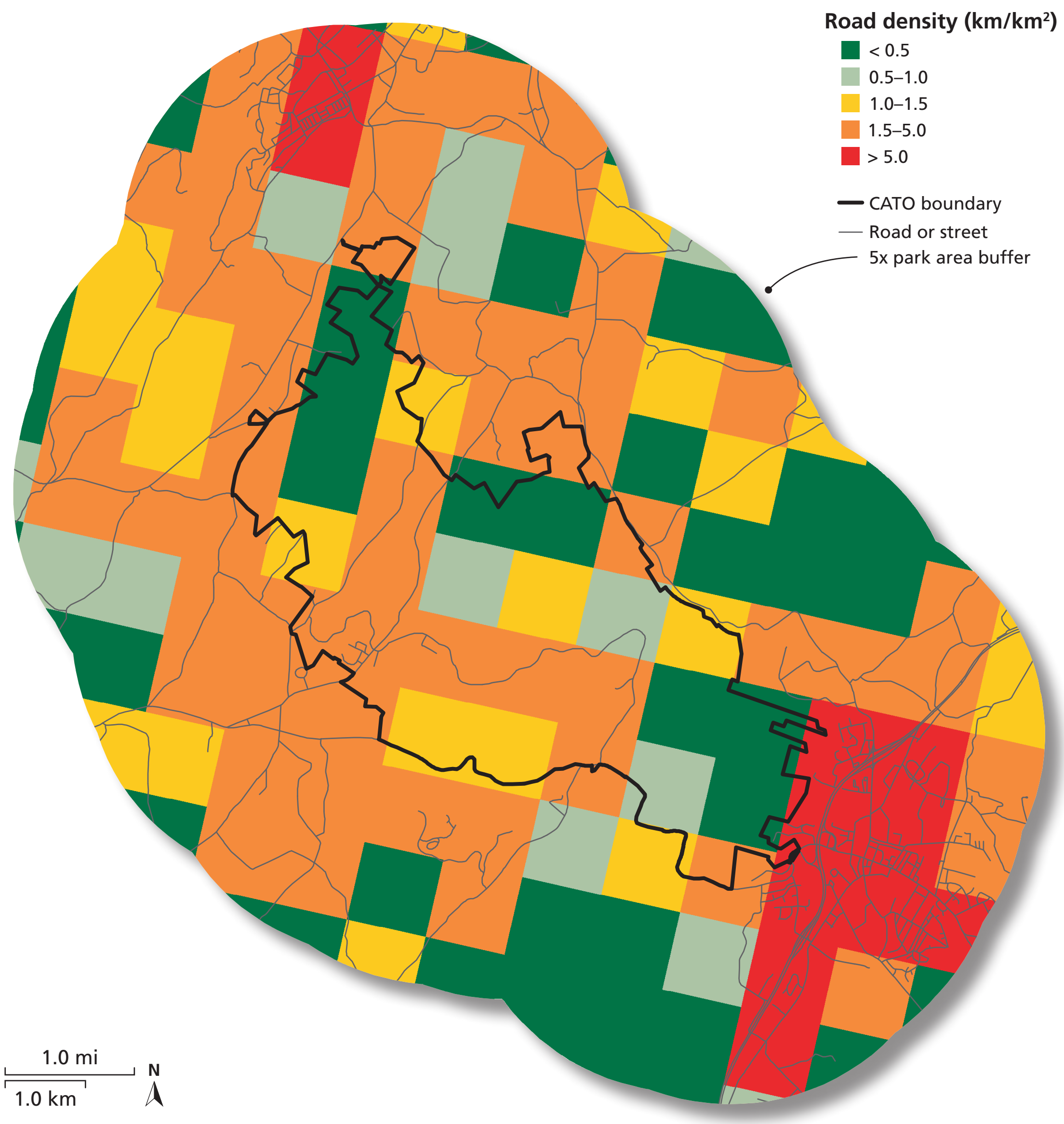

Figure 4.52. Road density within and around CATO in 2010. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

Chapter 5: Discussion

5.1 PARK NATURAL RESOURCE CONDITION

Overall, natural resources in Catoctin Mountain Park were in a moderate condition, with 55% achievement of the reference conditions (Table 5.1).

Table 5.1. Natural resource condition assessment of CATO.

Vital Sign	Reference condition attainment	Current condition
Air Quality	13%	Very degraded
Water Resources	80%	Very good
Biological Integrity	44%	Moderate
Landscape Dynamics	81%	Very good
Catoctin Mountain Park	**55%**	**Moderate**

5.1.1 Air quality

Air quality was in a very degraded condition, with 13% attainment of reference conditions (Tables 5.1, 5.2). Degraded air quality is a problem throughout the eastern United States, the causes of which are out of the park's control. Specific implications to the habitats and species in the park are less well known (Tables 5.3, 5.4). Gaining a better understanding of how reduced air quality is impacting sensitive habitats and species within the park would help prioritize management efforts.

Table 5.2. Summary of resource condition assessment of Air Quality in CATO.

Metric	Condition
Wet sulfur deposition	Significant concern
Wet nitrogen deposition	Significant concern
Ozone (ppb)	Significant concern
Ozone (W126)	Moderate
Visibility	Significant concern
Particulate matter	Moderate
Air Quality	**Very degraded**

Despite mercury wet deposition data being available, there is no published reference condition for wet deposition. The only available reference condition for mercury is for fish tissue concentration—a human health threshold. As fish tissue concentrations are not regularly monitored, establishment of a wet deposition reference condition would give a better picture of the effect of mercury in the ecosystem.

Table 5.3. Key findings, management implications, and recommended next steps for air quality in CATO.

Key findings	Management implications	Recommended next steps
• Air quality is very degraded	• Habitats and species in the park may be affected	• Monitor for local effects by maintaining the air quality monitoring station within the park and identifying sensitive species and habitats • Identify top sources of air pollution
• Air quality is a regional problem	• Habitats and species in the park may be affected	• Support regional air quality initiatives such as Climate Friendly Parks (*www.nps.gov/climatefriendlyparks*) • Stay engaged with the wider community in terms of air quality education and activities

Table 5.4. Data gaps, justification, and research needs for air quality in CATO.

Data gaps	Justification	Research needs
• Ecological thresholds for mercury wet deposition	• Wet deposition is monitored but the only available guideline is for fish tissue concentration	• Relate fish tissue concentrations to wet deposition
• Park-scale air quality data	• Need to implement park-specific management actions	• Use transport and deposition models • Calibrate with roadside data within the park
• Effects of poor air quality on park habitats and species	• Need to implement park-specific management actions	• Investigate effects of poor air quality on sensitive habitats and species within the park

Air quality is measured and interpolated on regional and national scales. Implementation of park-scale air quality monitoring would give better insights into park-level air quality condition and possible effects on park habitats and species.

Air quality is identified as an important resource/value for the park in its draft Foundation Document (NPS 2012).

Climate change

The close connection between climate and air quality is reflected in the impacts of climate change on air pollution levels. In particular, the U.S. EPA has concluded that climate change could have the following impacts on national air quality levels (U.S. EPA 2009):

- produce 2–8 ppb increases in the summertime average ground-level ozone concentrations in many regions of the country;
- further exacerbate ozone concentrations on days when weather is already conducive to high ozone concentrations;
- lengthen the ozone season; and
- produce both increases and decreases in particle pollution over different regions of the U.S.

Literature cited

NPS. 2012. Foundation Document—Catoctin Mountain Park, Maryland (draft). U.S. Department of the Interior, National Park Service.

U.S. EPA. 2009. Assessment of the impacts of global change on regional U.S. air quality: a synthesis of climate change impacts on ground-level ozone. An Interim Report of the U.S. EPA Global Change Research Program. National Center for Environmental Assessment, Washington, DC; EPA/600/R-07/094F. Available from the National Technical Information Service, Springfield, VA, and online at *http://www.epa.gov/ncea*

5.1.2 Water resources

Water resources were in a very good condition overall, with 80% attainment of reference conditions (Tables 5.1, 5.5). The very good water quality is likely explained by the location of the water sources within the park boundaries.

Total phosphorus was in a very degraded condition, which is similar to results found in parks throughout the region (Carruthers et al. 2009, Norris and Pieper 2010, Thomas et al. 2011a, b, c). Specific conductance is currently in very good condition but is showing a general degrading trend, also in keeping with trends throughout the region (Table 5.6). The Physical Habitat Index is on the borderline of being classified as being in degraded condition, so more data about sensitive locations and which parts of the index are failing would be informative. Data gaps and research recommendations revolve around maintaining good water quality by identification of nutrient sources and sensitive organisms (Table 5.7).

Table 5.5. Summary of resource condition assessment of Water Resources in CATO.

Metric	Condition
pH	Very good
Dissolved oxygen	Very good
Water temperature	Very good
Acid neutralizing capacity	Very good
Specific conductance	Very good
Nitrate	Very good
Total phosphorus	Very degraded
Benthic Index of Biotic Integrity	Good
Physical Habitat Index	Partially degraded
Water Resources	**Very good**

Climate change

The cold temperatures of streams in Catoctin Mountain Park support several species of trout. Water temperature increase is one of the most immediate threats from climate change, and this would result in the loss of trout from Catoctin's streams (Frederickson 2011).

Literature cited

Carruthers, T., S. Carter, L.N. Florkowski, J. Runde, and W.C. Dennison. 2009. Rock Creek Park natural resource condition assessment. Natural Resource Report NPS/NCRN/NRR—2009/109. National Park Service, Natural Resource Program Center. Fort Collins, CO.

Frederickson, S. 2011. Stream temperatures in Catoctin Mountain Park: Current and future suitability for brook trout (*Salvelinus*

Table 5.6. Key findings, management implications, and recommended next steps for water resources in CATO.

Key findings	Management implications	Recommended next steps
• Very degraded condition for phosphorus	• Affects stream flora and fauna • Reduces quality of visitor experience	• Continue riparian buffer establishment and minimize soil disturbance • Upgrade sewer and water systems in the park
• Physical Habitat Index (PHI) is borderline degraded	• Affects stream flora and fauna • Reduces quality of visitor experience	• Identify sensitive locations and unpack the Index to identify which measurements are showing degraded condition
• Specific conductance is showing a degrading trend	• Affects stream flora and fauna	• Implement intensive monitoring to identify sources and patterns and then develop management alternatives

Table 5.7. Data gaps, justification, and research needs for water resources in CATO.

Data gaps	Justification	Research needs
• Origins of nitrogen and phosphorus pollution are uncertain	• Affects stream flora and fauna • Reduces quality of visitor experience	• Identify sources of phosphorus
• Specific conductance is showing a degrading trend	• Affects stream flora and fauna	• Identify conductance-sensitive organisms and locations for management initiatives

fontinalis). Unpublished report by Shepherd University to NPS.

Norris, M. and J. Pieper. 2010. National Capital Region Network 2009 water resources monitoring report. Natural Resources Data Series. Natural Resources Program Center, Fort Collins, CO.

Thomas, J.E., T. Carruthers, W.C. Dennison, M. Lehman, M. Nortrup, P. Campbell, E. Wenschhof, J. Calzarette, D. Cohen, L. Donaldson, and A. Landsman. 2011a. Antietam National Battlefield natural resource condition assessment. Natural Resource Report NPS/NCRN/NRR—2011/413. National Park Service, Natural Resource Stewardship and Science. Fort Collins, CO.

Thomas, J.E., T. Carruthers, W.C. Dennison, M. Lehman, M. Nortrup, P. Campbell, and B. Gorsira. 2011b. Manassas National Battlefield Park natural resource condition assessment. Natural Resource Report NPS/NCRN/NRR—2011/414. National Park Service, Natural Resource Stewardship and Science. Fort Collins, CO.

Thomas, J.E., T. Carruthers, W.C. Dennison, M. Lehman, M. Nortrup, P. Campbell, and A. Banasik. 2011c. Monocacy National Battlefield natural resource condition assessment. Natural Resource Report NPS/NCRN/NRR—2011/415. National Park Service, Natural Resource Stewardship and Science. Fort Collins, CO.

5.1.3 Biological integrity

Biological integrity was in a moderate condition overall, with 44% attainment of reference conditions (Tables 5.1, 5.8). Deer density and the seedling stocking index were both in very degraded condition. Studies show a relationship between high deer density and poor forest regeneration (Horsley et al. 2003, Côté et al. 2004) and as such, deer management should continue to be a top priority (Table 5.9). Other monitoring recommendations include exotic species monitoring and education, and continuing to monitor pests and diseases (Table 5.9). Data gaps and research needs include developing a bird index for non-forest species and modeling the effects of climate change and other stressors on the region's forests (Table 5.10).

Table 5.8. Summary of resource condition assessment of Biological Integrity in CATO.

Metric	Condition
Cover of exotic herbaceous species	Degraded
Area of exotic trees & saplings	Very good
Presence of forest pest species	Moderate
Seedling stocking index	Very degraded
Fish Index of Biotic Integrity	Fair
Bird Community Index	Medium integrity
Deer density	Very degraded
Biological Integrity	**Moderate**

Climate change

How climate change may affect the park's resources and habitats should be an ongoing research focus, in particular how it might affect the introduction and spread of exotic species and forest pests and diseases.

Literature cited

Côté, S.D., T.P. Rooney, J.P. Tremblay, C. Dussault, and D.M. Waller. 2004. Ecological impacts of deer overabundance. Annual Review of Ecology, Evolution, and Systematics 35: 113–147.

Horsley, S.B., S.L. Stout, and D.S. deCalesta. 2003. White-tailed deer impact on the vegetation dynamics of a northern hardwood forest. Ecological Applications 31: 98–118.

Table 5.9. Key findings, management implications, and recommended next steps for biological integrity in CATO.

Key findings	Management implications	Recommended next steps
• Deer overpopulation may be impacting forest regeneration and agriculture	• Increased herbivory reducing desired plant and bird species, and lowering yields in agricultural areas • More road collisions • Potential for spread of chronic wasting disease	• Continue implementing the deer management plan and deer population control measures
• Presence of exotic plants	• Displacement of native species, reducing biodiversity	• Prioritize species and locations/habitats for implementing control measures • Restore and maintain native species and communities
• Other exotic species ('rock snot,' *Didymosphenia geminata*)	• Can result in dense algal blooms that block sunlight and disrupt ecological processes, causing a decline in native plant and animal life	• Educate visitors on how to stop the spread of this species
• Forest pests were in moderate condition	• Hemlock woolly adelgid and gypsy moth are both present in the park • Emerald ash borer has not been observed but are expected to be found in the park in the future • Dead trees become fire and maintenance hazards and can pose a threat to the cultural resources and historic structures in the park	• Continue to monitor all forest pest species in the park and implement management actions • Plan for the future forest with the absence of hemlock and ash trees • Establish a seed bank of hemlock and ash seeds

Table 5.10. Data gaps, justification, and research needs for biological integrity in CATO.

Data gaps	Justification	Research needs
• Bird data is limited to forest species only	• Knowledge about usage of other habitats by birds is needed	• Development of indices related to bird use of other habitats (e.g., wetlands)
• Limited knowledge on how forests might change in light of new and future stressors (climate change, pests, and diseases)	• These stressors are already present or will be present in the near future	• Research and modeling into the effects of these stressors on the region's forests

5.1.4 Landscape dynamics

Landscape dynamics were in a very good condition overall, with 81% attainment of reference conditions (Tables 5.1, 5.11). Forest interior area, forest cover, and impervious surface (at both spatial scales) were all in good or very good condition, as was road density within the park (Table 5.12). This is due at least in part to the proximity of several protected areas—Cunningham Falls State Park immediately to the south of Catoctin Mountain Park, South Mountain Park to the north-east, and Seymour B. Cooper Memorial Wildlife Sanctuary to the east of the park. However, road density adjacent to the park was in very degraded condition, mostly due to the proximity of the towns of Thurmont to the south-east of the park and Cascade to the north of the park.

Table 5.11. Summary of resource condition assessment of Landscape Dynamics in CATO.

Metric	Condition
Forest interior area (within park)	Very good
Forest interior area (within park + 5x buffer)	Good
Forest cover (within park)	Very good
Forest cover (within park + 5x buffer)	Very good
Impervious surface (within park)	Very good
Impervious surface (within park + 5x buffer)	Very good
Road density (within park)	Very good
Road density (within park + 5x buffer)	Very degraded
Landscape Dynamics	**Very good**

Climate change

Research needs for the park mostly relate to its function as a habitat corridor in the region (Table 5.13). Catoctin Mountain Park has conducted workshops to plan for different climate change scenarios (North Wind, Inc 2013). Even under a plausible climate future with the least change from existing climate conditions, impacts and implications to the park are substantial and include a dryer landscape, increased storms and wildfire, decrease in brook trout habitat, increase in floods and erosion, and less annual snowfall. How climate change may affect the park's resources and habitats should be an ongoing research focus.

Literature cited

North Wind, Inc. 2013. Catoctin Mountain Park Climate Change Scenario Planning Summary Report. Prepared for National Park Service, U.S. Department of the Interior, Natural Resource Stewardship and Science.

Table 5.12. Key findings, management implications, and recommended next steps for landscape dynamics in CATO.

Key findings	Management implications	Recommended next steps
• Forest interior area, forest cover, and impervious surface are in good to very good condition	• Supports wildlife and slows the flow of stormwater entering park streams	• Maintain quality of existing forest habitat by managing for exotic species and forest pests
• Road density is very good inside the park but very degraded adjacent to the park	• Road density outside the park may increase surface runoff/stormwater entering the park, and may increase wildlife mortality	• Continue to maintain pervious surfaces within the park and consider installing stormwater retention basins in areas of high stormwater input

Table 5.13. Data gaps, justification, and research needs for landscape dynamics in CATO.

Data gaps	Justification	Research needs
• Implications of external land use changes on park resources	• Connectivity of ecological processes from park to watershed	• Landscape analysis at multiple scales
• Impacts of climate change on habitat connectivity	• The park acts as a habitat corridor through the region	• Modeling of the potential effects of climate change on habitats within the park and surrounding region

Appendix A: Raw data

Table A-1. Particulate matter (µg PM2.5/m³). Site locations are shown in Figure 4.1 and reference conditions are shown in Table 4.3.

Site	Years	3-year mean
240430009	2000–2002	14.8
	2001–2003	14.0
	2002–2004	14.1
	2003–2005	14.1
	2004–2006	13.8
	2005–2007	13.2
	2006–2008	12.2
	2007–2009	11.5
	2008–2010	11.0
	2009–2011	10.9
420010001	2000–2002	13.3
	2001–2003	13.5
	2002–2004	13.4
	2003–2005	13.6
	2004–2006	13.0
	2005–2007	12.6
	2006–2008	11.9
	2007–2009	11.6
	2008–2010	11.4
	2009–2011	11.7
Overall median		**13.1**

Table A-2. Water quality data. Site locations are shown in Figure 4.17 and reference conditions are shown in Table 4.11.

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
I&M data								
CATO_BHCK	6/20/05	7.53	10.11	14.22	366	115.80	0.7	
CATO_BHCK	10/6/05	7.53	8.05	17.32	380	145.10	1.1	
CATO_BHCK	11/8/05	7.10	7.27	10.40	540	140.65	0.4	
CATO_BHCK	12/12/05	7.09	5.70	2.85		1313.00	0.4	
CATO_BHCK	1/23/06	6.71	12.37	4.40	376	100.63	0.6	
CATO_BHCK	2/23/06	6.98	10.97	4.20	280	86.00	0.7	
CATO_BHCK	3/21/06	7.76	8.59	4.60	290	108.90	0.6	
CATO_BHCK	4/10/06	7.33	2.69	7.50	418	117.70	0.4	
CATO_BHCK	5/16/06	7.69	3.32	14.30	426	116.50	0.9	
CATO_BHCK	6/26/06	7.67	7.80	21.70	468	122.80	0.6	
CATO_BHCK	7/24/06	7.55	7.11	16.80	518	114.20	1.1	
CATO_BHCK	8/15/06	6.97	7.06	18.80	524	107.60	1.0	
CATO_BHCK	9/13/06	7.38	7.77	16.70	802	107.00	0.9	
CATO_BHCK	10/16/06	7.72	9.72	9.00	560	130.30	0.7	
CATO_BHCK	11/30/06	7.81	9.41	9.35	394	117.70	0.9	
CATO_BHCK	1/4/07	7.46	11.10	5.80	366	109.97	0.5	0.1794
CATO_BHCK	1/31/07		12.61	0.20	342	107.86	1.7	0.1892
CATO_BHCK	3/6/07	7.36	11.67	2.65	376	123.13	1.4	0.0653
CATO_BHCK	4/3/07	7.16	9.66	8.40	302	132.45	0.8	0.0228
CATO_BHCK	5/23/07	7.39	7.68	12.87	464	119.23	1.2	0.0587
CATO_BHCK	6/28/07	6.79	8.26	17.40	518	123.80	0.5	0.0750
CATO_BHCK	7/26/07	7.27	8.66	18.00	564	133.80	0.5	0.0457
CATO_BHCK	8/27/07	7.48	7.47	18.60	710	140.30	0.6	0.0685
CATO_BHCK	9/27/07	7.03	6.94	18.80	718	128.50	1.4	0.0620
CATO_BHCK	10/22/07	6.79	7.42	14.10	522	150.90	1.3	0.0750
CATO_BHCK	11/20/07	7.53	8.40	6.50	696	158.00	1.4	0.0783
CATO_BHCK	12/18/07	7.66	11.02	0.80	538	117.43	1.5	0.0750
CATO_BHCK	1/28/08	7.00	9.70	2.57	548	171.15	1.7	0.0881
CATO_BHCK	2/25/08	7.00	12.17	3.72	440	188.28	1.4	0.0848
CATO_BHCK	3/24/08	7.61	12.14	6.55	420	153.25	1.4	0.0881
CATO_BHCK	4/24/08	7.54	10.93	12.10	418	126.48	1.3	0.0489
CATO_BHCK	5/14/08	7.48	9.84	12.02	420	111.58	1.5	0.0392
CATO_BHCK	6/24/08	7.64	8.68	14.93	420	129.25	0.8	0.0457
CATO_BHCK	7/29/08	7.63	7.50	16.78	550	134.30	1.0	0.0392
CATO_BHCK	8/25/08	7.63	6.12	17.92	570	138.25	1.0	0.0359
CATO_BHCK	9/22/08	7.43	7.67	17.70	614	148.47	0.7	0.0392
CATO_BHCK	10/21/08	7.75	9.21	12.47	586	151.05	0.7	0.0424
CATO_BHCK	11/18/08	7.62	10.22	4.70	604	154.50	0.6	
CATO_BHCK	2/3/09	7.94	17.61	2.95	438	156.10	1.5	0.0196
CATO_BHCK	3/31/09	7.57	10.68	6.93	456	169.60	1.2	0.0392
CATO_BHCK	5/14/09	7.64	10.27	12.80	472	126.27	1.1	0.0489
CATO_BHCK	6/10/09	7.65	8.47	18.10	516	135.03	1.4	0.0457
CATO_BHCK	7/7/09	7.79	9.75	17.15	570	124.75	0.8	0.0620

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
CATO_BHCK	7/21/09	7.84	9.90	16.60	564	134.47	0.7	0.0522
CATO_BHCK	8/17/09	7.79	8.50	18.87	632	141.37	1.3	0.0489
CATO_BHCK	9/15/09	7.88	8.65	17.45	560	147.15	0.9	0.0620
CATO_BHCK	10/13/09	7.84	10.03	11.50	690	153.50	0.9	
CATO_BHCK	11/10/09	7.79	10.30	11.10	696	151.05	0.9	0.0392
CATO_BHCK	12/8/09	7.79	12.30	6.10	524	138.67	0.6	0.0489
CATO_BHCK	1/12/10	7.78	13.63	2.40	358	120.57	0.9	0.0326
CATO_BHCK	3/9/10	7.67	13.17	4.13	410	179.50	0.7	0.1207
CATO_BHCK	4/6/10	7.73	10.97	10.83	430	132.40	1.6	0.1762
CATO_BHCK	5/4/10	7.78	9.10	16.13	500	145.40	1.2	0.1566
CATO_BHCK	6/8/10	7.59	9.80	13.83	588	138.53	1.6	0.0979
CATO_BHCK	7/13/10	7.77	8.10	17.97	428	144.63	1.5	0.0489
CATO_BHCK	8/9/10	7.84	8.15	18.85	656	146.40	1.4	0.0555
CATO_BHCK	9/15/10	7.85	9.03	15.80	712	157.00	1.9	0.2055
CATO_BHCK	10/13/10	7.89	8.07	14.22	756	138.93	1.8	0.1664
CATO_BHCK	11/8/10	7.70	10.87	7.30	648	158.10	0.7	0.1240
CATO_BHCK	12/6/10	7.66	12.43	3.77	444	136.40	1.6	0.2610
CATO_BHCK	1/5/11	8.26	13.00	9.90	558	137.40	1.5	0.1697
CATO_BHCK	2/7/11	7.78	13.95	2.70	480	248.30	0.5	0.1403
CATO_BHCK	3/9/11	7.37	12.45	4.90	324	167.55	1.0	0.0979
CATO_BHCK	4/4/11	7.57	11.37	7.30	376	140.00	0.8	0.1175
CATO_BHCK	5/2/11	7.68	9.90	13.30	420	120.50	1.0	0.1468
CATO_BHCK	6/6/11	7.56	9.70	14.00	446	124.35	0.9	0.0359
CATO_BHCK	7/11/11	7.79	8.07	18.73	604	115.23	1.0	0.0392
CATO_BHCK	8/8/11	7.76	7.85	20.30	658	146.50	1.3	0.0555
CATO_BHCK	9/13/11	7.72	8.40	17.90	738	162.70	0.8	0.1566
CATO_BHCK	10/11/11	7.54	8.95	14.80	668	156.90	1.0	0.0424
CATO_BHCK	11/8/11	7.51	10.75	9.30	578	156.40	0.8	0.1272
CATO_BHCK	12/6/11	7.48	10.30	8.80	490	122.65	1.3	0.1794
CATO_OWCK	6/20/05	7.57	9.65	14.65	604	133.87	0.9	
CATO_OWCK	10/6/05	7.22	5.89	15.40	548	170.60	1.2	
CATO_OWCK	11/8/05	7.73	7.25	10.30	720	169.00	0.1	
CATO_OWCK	12/12/05	7.54	11.37	2.35		153.90	0.8	
CATO_OWCK	1/23/06	6.83	11.79	4.40	338	129.67	0.9	
CATO_OWCK	2/23/06	7.17	8.97	4.00	336	122.40	1.3	
CATO_OWCK	3/21/06	7.48	8.44	3.02	490	122.87	1.0	
CATO_OWCK	4/10/06	7.52	2.94	7.13	574	128.50	0.8	
CATO_OWCK	5/16/06	7.55	4.18	11.00	514	122.60	1.1	
CATO_OWCK	6/26/06	7.40	8.10	17.50	508	102.70	0.5	
CATO_OWCK	7/24/06	7.57	7.59	17.50	640	139.10	1.2	
CATO_OWCK	8/15/06	6.97	5.20	18.90	840	144.90	1.2	
CATO_OWCK	9/13/06	7.45	7.56	14.60	658	154.60	0.9	
CATO_OWCK	10/16/06	7.45	9.08	7.65	960	154.57	0.8	
CATO_OWCK	11/30/06	8.12	9.02	11.23	438	135.23	1.0	
CATO_OWCK	1/4/07	7.69	11.21	6.50	398	137.60	0.7	0.1599

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
CATO_OWCK	1/31/07		12.43	0.30	434	133.40	2.5	0.0620
CATO_OWCK	4/3/07	7.65	9.30	11.10	434	131.13	1.1	0.1142
CATO_OWCK	5/23/07	7.56	8.05	13.57	640	130.15	1.3	0.1142
CATO_OWCK	6/28/07	7.31	6.39	18.20	858	142.30	0.8	0.0816
CATO_OWCK	7/26/07	7.31	5.96	17.90	892	150.10	0.9	0.1338
CATO_OWCK	8/27/07	7.46	5.86	17.60	906	156.90	0.7	0.1175
CATO_OWCK	9/27/07	7.31	6.04	17.40	856	154.20	1.5	0.0881
CATO_OWCK	10/22/07	6.99	5.79	12.30	1040	153.10	1.6	0.0914
CATO_OWCK	11/20/07	7.44	9.02	6.60	732	164.80	1.5	0.1011
CATO_OWCK	12/18/07	7.20	11.89	1.48	558	98.45	2.0	0.1011
CATO_OWCK	1/28/08	7.16	14.50	1.08	590	165.62	1.7	0.0946
CATO_OWCK	2/25/08	7.37	13.49	3.02	502	182.17	1.8	0.1207
CATO_OWCK	3/24/08	7.53	13.46	5.63	500	144.92	1.8	0.1077
CATO_OWCK	4/24/08	7.62	10.57	12.08	538	131.23	1.5	0.0555
CATO_OWCK	5/14/08	7.51	9.08	11.47	524	112.27	1.4	0.0653
CATO_OWCK	6/24/08	7.55	9.15	15.43	486	140.55	0.9	0.0848
CATO_OWCK	7/29/08	7.46	7.28	18.12	802	148.32	1.3	0.0750
CATO_OWCK	8/25/08	7.32	7.35	17.75	846	149.00	1.4	0.0718
CATO_OWCK	9/22/08	7.32	8.26	14.38	800	149.17	1.1	0.0587
CATO_OWCK	10/21/08	7.29	8.42	9.42	888	159.80	1.4	0.0718
CATO_OWCK	11/18/08		10.98	4.67	632	157.10	1.1	
CATO_OWCK	3/31/09	7.43	11.54	6.95	574	152.73	1.8	0.0457
CATO_OWCK	5/14/09	7.60	9.90	13.03	564	137.23	1.5	0.0946
CATO_OWCK	6/10/09	7.52	9.07	15.63	700	146.80	1.0	0.0783
CATO_OWCK	7/7/09	7.62	8.87	16.37	740	112.27	1.2	0.0979
CATO_OWCK	7/21/09	7.60	9.03	16.07	744	144.13	1.0	0.1142
CATO_OWCK	8/17/09	7.56	8.15	18.80	716	155.40	1.0	0.0914
CATO_OWCK	9/15/09	7.62	8.85	15.65	546	150.45	1.0	0.1338
CATO_OWCK	10/13/09	7.44	9.80	10.40	856	157.40	1.1	0.0587
CATO_OWCK	11/10/09	7.61	10.70	10.65	726	173.75	1.2	0.0522
CATO_OWCK	12/8/09	7.64	13.03	4.73	530	152.90	1.0	0.0555
CATO_OWCK	3/9/10	7.82	13.05	4.70	524	139.85	0.7	0.1272
CATO_OWCK	4/6/10	7.85	10.50	14.50	526	136.20	1.7	0.1762
CATO_OWCK	5/4/10	7.67	9.70	14.10	568	139.70	1.2	0.1827
CATO_OWCK	6/8/10	7.58	9.90	13.90	642	145.35	1.7	0.1011
CATO_OWCK	7/13/10	7.58	8.00	18.80	540	161.15	1.3	0.1240
CATO_OWCK	8/9/10	7.56	7.70	19.60	804	119.80	1.7	0.0914
CATO_OWCK	9/15/10	7.57	8.50	14.20	780	151.60	2.5	0.2251
CATO_OWCK	10/13/10	7.58	8.70	11.60	750	151.20	2.9	0.2251
CATO_OWCK	11/8/10	7.54	10.70	6.70	672	163.45	1.0	0.1370
CATO_OWCK	12/6/10	8.27	11.40	9.10	456	687.40	7.9	0.2121
CATO_OWCK	2/7/11	7.62	14.30	1.50	474	194.80	1.5	0.1142
CATO_OWCK	3/9/11	7.42	12.60	3.90	402	148.00	1.0	0.1468
CATO_OWCK	4/4/11	7.66	11.55	7.50	466	144.25	1.2	0.1958
CATO_OWCK	5/2/11	7.46	9.85	12.15	476	122.50	1.2	0.1468

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
CATO_OWCK	6/6/11	7.40	9.15	15.30	584	136.90	1.4	0.0783
CATO_OWCK	7/11/11	7.51	7.10	20.10	704	148.70	1.4	0.0914
CATO_OWCK	8/8/11	7.52	7.00	21.00	836	181.20	1.8	0.0848
CATO_OWCK	9/13/11	7.54	8.60	17.00	744	155.75	0.8	0.1697
CATO_OWCK	10/11/11	7.34	8.70	13.20	676	152.75	1.7	0.0718
CATO_OWCK	11/8/11	7.44	11.20	8.50	564	154.35	0.7	0.1501
CATO_OWCK	12/6/11	7.18	10.10	9.60	506	127.75	1.7	0.1533
CATO_WHST	6/20/05		8.60	15.60	478	84.60	0.1	
CATO_WHST	10/6/05	7.74	7.22	16.65	410	147.80	0.5	
CATO_WHST	11/8/05	7.50	6.03	10.55	880	146.00		
CATO_WHST	12/12/05	7.27	6.67	2.15	602	118.30	0.1	
CATO_WHST	1/23/06	6.84	11.82	4.90	384	103.90	0.2	
CATO_WHST	2/23/06	7.29	10.43	4.50	378	76.50	0.2	
CATO_WHST	3/21/06	7.68	8.66	3.75	410	91.60		
CATO_WHST	4/10/06	7.47	3.46	7.45	642	110.60		
CATO_WHST	5/16/06	7.70	4.07	11.60	556	73.75	0.6	
CATO_WHST	6/26/06	7.50	7.35	17.90	552	87.90	0.5	
CATO_WHST	7/24/06	7.93	8.08	19.00	734	104.30	0.5	
CATO_WHST	8/15/06	7.48	5.42	20.60	876	113.10	0.6	
CATO_WHST	9/12/06	7.51	8.74	15.20	598	132.90	0.5	
CATO_WHST	10/16/06	7.66	8.75	8.10	800	116.20	0.4	
CATO_WHST	11/30/06	8.03	9.03	11.30	582	111.10	0.5	
CATO_WHST	1/4/07	7.58	10.58	7.10	414	94.10	0.5	0.2316
CATO_WHST	1/31/07		13.24	0.30	382	78.00	1.2	0.0294
CATO_WHST	3/6/07	7.59	12.55	0.60	382	93.55	1.1	0.0359
CATO_WHST	4/3/07	7.51	8.95	11.40	432	80.80	0.3	0.0587
CATO_WHST	5/23/07	7.70	8.24	13.80	610	82.30	0.8	0.0392
CATO_WHST	6/28/07	7.65	6.74	20.10	796	109.90	0.2	0.0359
CATO_WHST	7/26/07	8.18	7.20	19.70	974	120.50	0.4	0.0653
CATO_WHST	8/27/07	7.81	5.20	19.00	1046	173.50	0.3	0.0555
CATO_WHST	11/20/07	7.58	9.60	6.20	848	143.30	1.1	0.0783
CATO_WHST	12/18/07	7.68	11.95	2.00	676	172.00	1.4	0.0424
CATO_WHST	2/25/08	7.44	11.26	3.40	606	158.90	1.0	0.0718
CATO_WHST	3/24/08	7.65	14.06	5.25	536	92.55	1.3	0.0424
CATO_WHST	4/24/08	7.64	10.65	12.60	530	85.25	1.0	0.0848
CATO_WHST	5/14/08	7.49	9.78	11.95	498	77.05	2.9	0.0424
CATO_WHST	6/24/08	7.84	9.14	16.20	648	90.20	0.6	0.0424
CATO_WHST	7/29/08	7.91	7.94	19.60	930	120.95	0.8	
CATO_WHST	8/25/08				712			0.0326
CATO_WHST	9/22/08	7.81	7.36	15.80	1058	175.75	0.9	0.0522
CATO_WHST	10/21/08	7.72	7.33	9.90	832	116.00	0.9	0.0457
CATO_WHST	11/18/08	7.64	11.83	5.30	908	150.15	0.6	
CATO_WHST	3/31/09	7.57	11.68	6.60	676	128.75	1.1	0.0326
CATO_WHST	5/14/09	7.59	10.50	12.50	492	68.90	0.8	0.0718
CATO_WHST	6/10/09	7.69	9.50	15.80	780	115.50	0.8	0.0424

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
CATO_WHST	7/7/09	7.72	9.60	16.80	600	80.30	0.6	0.0424
CATO_WHST	7/21/09	7.63	8.90	17.10	560	76.80	0.2	0.0489
CATO_WHST	8/17/09	7.68	7.60	20.00	736	103.20	1.0	0.0489
CATO_WHST	9/15/09	7.77	8.00	17.20	626	104.30	0.6	0.0979
CATO_WHST	10/13/09	7.66	9.70	10.50	730	106.70	1.6	0.0587
CATO_WHST	11/10/09	7.67	9.30	11.20	880	129.70	1.2	0.0424
CATO_WHST	12/8/09	7.72	12.70	5.50	658	109.00	0.7	0.0392
CATO_WHST	3/9/10	7.64	12.70	5.20	468	97.00	0.6	0.1207
CATO_WHST	4/6/10	7.60	9.90	14.60	484	72.50	1.4	0.1762
CATO_WHST	5/4/10	7.70	9.50	14.50	568	96.80	1.0	0.1892
CATO_WHST	6/8/10	7.63	9.60	14.40	640	82.20	1.2	0.0457
CATO_WHST	7/13/10	7.63	6.90	19.90	422	84.60	1.3	0.0653
CATO_WHST	8/9/10	7.77	6.80	20.70	782	97.80	1.2	0.0555
CATO_WHST	9/15/10	7.74	8.70	14.90	786	104.80	1.5	0.2186
CATO_WHST	10/13/10	7.89	9.01	12.20	682	120.10	1.9	0.2284
CATO_WHST	11/8/10	7.68	11.20	7.60	880	135.70	0.9	0.1436
CATO_WHST	12/6/10	7.68	13.00	2.60	472	104.30	1.2	0.2447
CATO_WHST	2/7/11	7.62	13.90	2.30	542	174.10	0.5	0.1305
CATO_WHST	3/9/11	7.47	12.20	4.60	378	88.90	0.7	0.1272
CATO_WHST	4/4/11	7.67	11.10	7.80	432	81.40	0.9	0.1468
CATO_WHST	5/2/11	7.60	9.70	11.90	446	78.10	0.8	0.1631
CATO_WHST	6/6/11	7.51	8.70	16.00	526	78.20	0.6	0.0359
CATO_WHST	7/11/11	7.56	7.10	21.00	650	86.90	0.9	0.0326
CATO_WHST	8/8/11	7.58	5.60	22.10	930	111.60	0.8	0.0620
CATO_WHST	9/13/11	7.75	6.90	17.90	900	135.10	1.1	0.1990
CATO_WHST	10/11/11	7.52	8.20	13.70	916	131.00	1.0	0.0326
CATO_WHST	11/8/11	7.61	10.60	9.20	640	117.30	1.4	0.1338
CATO_WHST	12/6/11	7.38	9.90	10.00	508	123.10	1.1	0.2316
				CATO data				
CROW	8/26/09	7.32	9.88	19.28		180.00		
CROW	9/28/09	7.13	10.50	15.60		160.00		
CROW	12/14/09	7.39	14.71	5.75		160.00		
CROW	4/26/10	7.75	10.54	11.10		140.00		
CROW	6/28/10	7.81	8.86	20.20		0.12		
CROW	7/20/10	7.76	8.35	21.10		0.12		
CROW	9/15/10	7.89	10.24	15.90		0.14		
CROW	10/28/10	7.87	10.95	13.90		0.12		
CROW	11/18/10	7.77	12.30	8.00		149.90		
CROW	12/2/10	7.30	12.80	7.40		99.50		
CROW	1/5/11	7.53	15.70	1.10		151.00		
CROW	2/24/11	7.17	14.88	2.20		171.10		
CROW	3/29/11	7.39	13.89	5.70		128.30		
CROW	4/15/11	7.37	11.57	10.60		128.00		
CROW	5/23/11	7.66	10.11	17.10		121.70		
CROW	6/23/11	7.81	8.30	19.60		128.60		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
CROW	7/26/11	7.80	9.38	19.00		123.90		
CROW	8/29/11	7.81	9.68	18.20		138.30		
CROW	9/19/11	7.85	9.25	15.30		149.30		
CROW	10/24/11	7.72	10.56	12.20		135.00		
CROW	11/28/11	7.42	10.86	10.90		113.30		
CROW	12/13/11	7.36	12.91	5.10		107.70		
FOXV	2/10/00	7.32	12.80	3.00		180.00		
FOXV	3/10/00	7.36	9.60	9.00		139.00		
FOXV	4/24/00	7.55	9.40	11.00		161.00		
FOXV	6/2/00	7.40	8.30	16.00		147.00		
FOXV	6/29/00	7.46	7.50	17.00		212.00		
FOXV	7/21/00	7.30	9.60	17.00		240.00		
FOXV	8/30/00	7.47	7.80	19.00		260.00		
FOXV	9/28/00	7.66	9.00	12.00		294.00		
FOXV	10/1/00			0.00				
FOXV	11/8/00	7.59	9.60	9.00		185.00		
FOXV	12/4/00	7.56	14.00	0.00		149.00		
FOXV	1/4/01	7.58		13.00		127.00		
FOXV	2/14/01	7.43	11.90	6.00		200.00		
FOXV	3/9/01	7.37	12.40	4.00		215.00		
FOXV	4/27/01	7.69	10.70	11.00		223.00		
FOXV	5/23/01	7.39	8.40	13.00		161.00		
FOXV	6/28/01	7.69	8.00	19.00		335.00		
FOXV	7/18/01	7.72	8.80	19.00		388.00		
FOXV	9/26/01	7.75	8.40	12.00		222.00		
FOXV	10/24/01	7.57	5.20	15.00		370.00		
FOXV	11/16/01	7.51	7.50	10.00		391.00		
FOXV	12/13/01	7.71	9.20	8.00		327.00		
FOXV	1/30/02	7.82	8.80	10.00		401.00		
FOXV	2/22/02	7.99	11.20	5.00		281.00		
FOXV	3/19/02	7.95	10.90	8.00		349.00		
FOXV	4/24/02	7.64	10.80	9.00		270.00		
FOXV	5/24/02	7.48	9.20	12.00		250.00		
FOXV	6/26/02	7.90	6.80	19.00		398.00		
FOXV	7/24/02	8.05	7.00	19.00		482.00		
FOXV	8/23/02	8.18	6.30	21.00		600.00		
FOXV	9/28/02	7.78	8.60	16.00		320.00		
FOXV	10/15/02			0.00				
FOXV	11/20/02	7.46	8.80	7.00		200.00		
FOXV	12/29/02	7.55	11.70	4.00		170.00		
FOXV	1/28/03	7.37	13.40	0.00		125.00		
FOXV	2/27/03	7.62		2.00		258.00		
FOXV	3/25/03	7.62	11.80	9.00		210.00		
FOXV	4/25/03	7.54	11.20	10.00		150.00		
FOXV	5/23/03	7.38	9.80	11.00		163.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
FOXV	6/27/03	7.52	8.40	17.00		189.00		
FOXV	7/30/03	7.80	8.00	17.00		300.00		
FOXV	8/27/03	7.51	8.40	19.00		165.00		
FOXV	9/29/03	7.38	9.10	13.00		175.00		
FOXV	10/21/03	7.43	9.40	13.00		159.00		
FOXV	11/4/03	7.49	8.30	13.00		162.00		
FOXV	12/11/03	6.93	12.10	4.00		62.00		
FOXV	1/14/04	7.56	13.40	2.00		142.00		
FOXV	2/1/04			0.00				
FOXV	3/26/04	7.82	10.35	12.00		289.00		
FOXV	4/21/04	8.04	10.75	17.00		245.00		
FOXV	5/1/04			0.00				
FOXV	6/23/04	7.51		16.00		199.00		
FOXV	7/16/04	7.80	7.70	19.00		349.00		
FOXV	8/27/04	7.87	7.55	20.00		263.00		
FOXV	9/1/04			0.00				
FOXV	10/15/04	7.51	8.78	13.00		180.00		
FOXV	11/1/04			0.00				
FOXV	1/12/05	7.44	10.40	5.00		109.00		
FOXV	2/5/05	7.36	14.10	1.00		96.00		
FOXV	3/18/05	7.55		6.00		118.00		
FOXV	4/23/05	7.28		10.00		108.00		
FOXV	5/12/05	7.47		14.00		131.00		
FOXV	6/28/05			0.00				
FOXV	7/22/05	7.73	7.59	19.00		414.00		
FOXV	8/25/05	7.77	9.02	15.00		201.00		
FOXV	9/16/05	8.05	7.63	20.00		540.00		
FOXV	10/26/05	7.60	9.77	10.00		190.00		
FOXV	11/18/05	7.54	10.67	4.00		145.00		
FOXV	1/11/06	7.42	12.14	5.00		140.00		
FOXV	2/10/06	7.40	14.39	1.00		118.00		
FOXV	3/31/06	7.74	10.25	13.00		218.00		
FOXV	4/14/06			0.00				
FOXV	5/31/06	7.78	8.40	17.00		298.00		
FOXV	6/29/06	7.30	7.93	17.00		121.00		
FOXV	7/21/06	7.72	7.02	20.00		270.00		
FOXV	8/30/06	7.84	7.26	20.00		420.00		
FOXV	9/28/06	7.58	7.30	15.00		345.00		
FOXV	10/27/06	7.67	9.50	8.00		262.00		
FOXV	11/20/06	7.53	11.21	7.00		149.00		
FOXV	12/11/06	7.56	12.77	4.00		148.00		
FOXV	4/13/07	7.39	13.28	5.00		79.00		
FOXV	5/31/07	7.70	8.87	16.00		237.00		
FOXV	6/20/07	7.62	8.39	18.00		168.00		
FOXV	8/31/07			0.00				

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
FOXV	9/10/07	7.81	6.28	20.40		500.00		
FOXV	10/22/07			0.00				
FOXV	11/19/07	7.61	9.92	5.20		310.00		
FOXV	12/12/07			0.00				
FOXV	4/14/08	7.56	10.50	8.50		123.00		
FOXV	5/20/08	7.32	9.57	10.10		112.00		
FOXV	6/3/08	7.56	9.22	14.50		272.00		
FOXV	7/3/08	7.60	8.13	16.80		364.00		
FOXV	8/25/08	7.88		13.00				
FOXV	9/24/08	7.95		13.00		419.00		
FOXV	10/22/08	7.49	9.72	9.09		348.00		
FOXV	11/20/08	7.48	13.38	4.96				
FOXV	12/17/08			0.00				
FOXV	1/29/09			0.00				
FOXV	2/9/09			0.00				
FOXV	7/23/09	7.60	7.80	18.60		181.10		
FOXV	8/26/09	7.38	8.64	19.10		440.00		
FOXV	4/26/10	7.28	10.31	10.00		150.00		
FOXV	6/28/10	7.75	8.18	20.40		0.27		
FOXV	10/28/10	7.16	6.61	13.80		0.22		
FOXV	11/18/10	7.15	9.60	7.90		300.60		
FOXV	12/2/10	7.33	11.09	5.90		230.10		
FOXV	1/5/11	7.56	14.27	0.30		452.10		
FOXV	3/29/11	7.11	13.95	3.00		239.20		
FOXV	4/15/11	7.23	12.02	9.80		202.20		
FOXV	5/23/11	7.27	9.53	14.40		243.30		
FOXV	6/23/11	7.43	7.94	18.00		223.80		
FOXV	7/26/11	7.53	7.03	20.70		344.60		
FOXV	9/19/11	7.67	8.89	15.00		431.30		
FOXV	11/28/11	7.40	9.64	12.30		315.80		
FOXV	12/13/11	7.05	12.83	3.70		315.20		
HEML	2/10/00	7.09	14.00	1.00		60.00		
HEML	3/10/00	7.49	10.80	9.00		86.00		
HEML	4/24/00	7.73	10.30	10.00		79.00		
HEML	6/2/00	7.44	9.10	15.00		99.00		
HEML	6/29/00	7.64	8.60	17.00		101.00		
HEML	7/21/00	7.30	9.50	16.00		110.00		
HEML	8/30/00	7.50	8.90	18.00		122.00		
HEML	9/28/00	7.75	9.80	12.00		97.00		
HEML	10/1/00			0.00				
HEML	11/8/00	7.60	11.00	8.00		95.00		
HEML	12/4/00	7.74	14.40	1.00		71.00		
HEML	1/4/01	7.30		12.00		60.00		
HEML	2/14/01	7.42	12.80	4.00		85.00		
HEML	3/9/01	7.35	14.20	2.00		102.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
HEML	4/27/01	7.77	11.40	9.00		89.00		
HEML	5/23/01	7.47	9.60	12.00		100.00		
HEML	6/28/01	7.49	8.40	18.00		133.00		
HEML	7/18/01	7.68	9.20	17.50		131.00		
HEML	8/7/01	7.61	10.20	21.50		158.00		
HEML	9/26/01	7.42	9.60	12.00		142.00		
HEML	10/24/01	7.64	8.10	14.00		140.00		
HEML	11/16/01	7.43	10.90	7.00		108.00		
HEML	12/13/01	7.59	11.60	6.00		110.00		
HEML	1/30/02	7.64	11.50	7.00		113.00		
HEML	2/22/02	7.63	12.50	4.00		99.00		
HEML	3/19/02	7.97	12.30	7.00		99.00		
HEML	4/24/02	7.81	11.40	10.00		99.00		
HEML	5/24/02	7.51	10.30	12.00		100.00		
HEML	6/26/02	7.78	8.20	19.00		127.00		
HEML	7/24/02	7.84	8.00	19.00		132.00		
HEML	8/23/02	7.88	7.40	21.00		148.00		
HEML	9/28/02	7.61	9.50	16.00		120.00		
HEML	10/15/02			0.00				
HEML	11/20/02	7.40	12.00	5.00		80.00		
HEML	12/29/02	7.67	13.60	2.00		77.00		
HEML	1/28/03	7.19	14.80	0.00		70.00		
HEML	3/25/03	7.52	13.60	8.00		92.00		
HEML	4/25/03	7.58	11.20	9.00		100.00		
HEML	5/23/03	7.51	10.60	10.00		98.00		
HEML	6/27/03	7.60	9.10	17.00		120.00		
HEML	7/30/03	7.83	8.80	17.00		138.00		
HEML	8/27/03	7.69	9.20	19.00		136.00		
HEML	9/29/03	7.53	9.80	13.00		99.00		
HEML	10/21/03	7.51	10.90	12.00		102.00		
HEML	11/4/03	7.69	10.00	13.00		104.00		
HEML	12/11/03	7.15	12.40	4.00		69.00		
HEML	1/14/04	7.61	14.40	0.00		72.00		
HEML	2/1/04			0.00				
HEML	3/26/04	7.78	10.18	10.00		104.00		
HEML	4/21/04	7.89	9.25	16.00		110.00		
HEML	5/1/04			0.00				
HEML	6/23/04			0.00				
HEML	7/16/04	7.87	8.00	19.00		140.00		
HEML	8/27/04	7.77	8.40	19.00		147.00		
HEML	9/1/04			0.00				
HEML	10/15/04	7.68	9.59	12.00		110.00		
HEML	11/1/04			0.00				
HEML	12/4/04	7.77	12.65	3.00		72.00		
HEML	1/12/05	7.49	12.02	5.00		73.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
HEML	2/5/05	7.37	14.60	1.00		80.00		
HEML	3/18/05	7.66		5.00		90.00		
HEML	4/23/05	7.53		9.00		105.00		
HEML	5/12/05	7.49		15.00		114.00		
HEML	6/28/05	7.72	8.02	20.00		142.00		
HEML	7/22/05	7.70	7.83	21.00		158.00		
HEML	8/25/05	7.93	8.76	16.00		123.00		
HEML	9/16/05	7.91	8.07	19.00		149.00		
HEML	10/26/05	7.80	11.08	9.00		97.00		
HEML	11/18/05	7.69	11.51	3.00		95.00		
HEML	12/30/05	7.59	12.73	3.00		99.00		
HEML	1/11/06	7.55	12.31	5.00		88.00		
HEML	2/10/06	7.58	13.50	1.00		71.00		
HEML	3/31/06	8.11	10.35	12.00		110.00		
HEML	4/14/06	7.62	9.85	12.00		117.00		
HEML	5/31/06	7.66	8.50	17.00		119.00		
HEML	6/29/06	7.51	8.89	17.00		105.00		
HEML	7/21/06	7.72	7.88	20.00		140.00		
HEML	8/30/06	7.86	7.98	20.00		155.00		
HEML	9/28/06	7.46	9.13	15.00		137.00		
HEML	10/27/06	7.76	11.76	7.00		110.00		
HEML	11/20/06	7.71	11.70	6.00		87.00		
HEML	12/11/06	7.73	13.12	3.00		79.00		
HEML	1/22/07	7.49	13.73	1.00		59.00		
HEML	2/9/07	7.46		0.00				
HEML	3/9/07	7.34	13.16	2.00		94.00		
HEML	4/13/07	7.53	12.47	5.00		99.00		
HEML	5/31/07	7.69	8.68	17.00		139.00		
HEML	6/20/07	7.75	8.34	18.00		131.00		
HEML	8/31/07	7.77	7.96	19.70		172.00		
HEML	9/10/07	7.78	7.84	20.70		170.00		
HEML	10/22/07	7.78	9.61	12.70		150.00		
HEML	11/19/07	7.57	11.93	4.70		112.00		
HEML	12/12/07	7.52	11.07	7.10		122.00		
HEML	1/7/08	7.48	12.24	4.70		119.00		
HEML	2/19/08	7.59	12.96	3.10		128.00		
HEML	3/10/08	7.44	14.34	1.80		103.00		
HEML	4/14/08	7.74	11.28	8.60		112.00		
HEML	5/20/08	7.48	14.73	9.90		101.00		
HEML	6/3/08	7.67	9.32	14.70		119.00		
HEML	7/3/08	7.67	8.39	17.30		144.00		
HEML	8/25/08	7.93		13.00				
HEML	9/24/08	7.99		13.00		96.00		
HEML	10/22/08	7.58	11.63	8.56		178.00		
HEML	11/20/08	7.37	16.21	3.36				

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
HEML	12/17/08	7.12	14.91	3.87				
HEML	1/29/09			0.00				
HEML	2/9/09	7.27	16.69	1.18				
HEML	7/23/09	7.64	8.04	18.80		156.40		
HEML	8/26/09	7.57	9.09	19.17		240.00		
HEML	9/28/09	7.23	10.02	14.74		200.00		
HEML	12/14/09	7.14	14.26	4.92		160.00		
HEML	4/26/10	7.59	10.35	10.20		170.00		
HEML	6/28/10	7.70	6.72	21.30		0.17		
HEML	7/20/10	7.69	7.65	21.40		0.16		
HEML	9/15/10	7.71	8.62	15.60		0.17		
HEML	10/28/10	7.61	9.95	13.80		0.15		
HEML	11/18/10	7.56	12.20	7.10		153.30		
HEML	12/2/10	7.56	13.81	4.50		138.70		
HEML	1/5/11	7.14	14.80	0.00		194.40		
HEML	2/24/11	7.19	15.19	0.70		213.70		
HEML	3/29/11	7.38	14.62	2.80		159.80		
HEML	4/15/11	7.38	11.63	9.50		155.40		
HEML	5/23/11	7.41	9.70	15.50		152.60		
HEML	6/23/11	8.12	7.63	19.50		182.70		
HEML	8/29/11	7.69	8.52	17.30		224.60		
HEML	9/19/11	7.72	8.88	14.40		196.20		
HEML	10/24/11	7.50	10.40	10.20		156.30		
HEML	11/28/11	7.68	10.67	10.90		139.40		
HEML	12/13/11	7.35	13.23	3.00		139.90		
IKES	2/10/00	7.42	13.00	3.00		90.00		
IKES	3/10/00	7.41	11.20	8.00		100.00		
IKES	4/24/00	7.63	11.00	9.00		90.00		
IKES	6/2/00	7.51	9.30	14.00		116.00		
IKES	6/29/00	7.78	9.20	15.00		138.00		
IKES	7/21/00	7.53	9.70	15.00		140.00		
IKES	8/30/00	7.83	8.40	17.00		164.00		
IKES	9/28/00	7.87	9.80	12.00		130.00		
IKES	10/1/00			0.00				
IKES	11/8/00	7.64	11.00	8.00		130.00		
IKES	12/4/00	7.58	14.20	1.00		89.00		
IKES	1/4/01	7.65		12.00		83.00		
IKES	3/9/01	7.49	12.40	4.00		89.00		
IKES	4/27/01	7.71	11.30	9.00		99.00		
IKES	5/23/01	7.62	9.50	12.00		122.00		
IKES	6/28/01	7.79	8.50	16.50		150.00		
IKES	7/18/01	7.72	9.40	16.00		150.00		
IKES	8/7/01	7.80	9.02	19.00		172.00		
IKES	9/26/01	8.02	8.80	11.00		142.00		
IKES	10/24/01	7.75	6.60	13.00		149.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
IKES	11/16/01	7.89	8.80	8.00		130.00		
IKES	12/13/01	7.76	9.80	7.00		128.00		
IKES	1/30/02	7.32	8.80	7.00		129.00		
IKES	2/22/02	7.63	9.20	4.50		110.00		
IKES	3/19/02	7.77	10.80	6.00		120.00		
IKES	4/24/02	7.66	11.20	8.00		118.00		
IKES	5/24/02	7.55	10.20	10.50		122.00		
IKES	6/26/02	7.67	8.00	17.00		170.00		
IKES	7/24/02	7.82	7.60	18.00		175.00		
IKES	8/23/02	7.72	6.80	20.00		193.00		
IKES	9/28/02	7.91	9.20	15.00		160.00		
IKES	10/15/02			0.00				
IKES	11/20/02	7.55	10.80	7.00		90.00		
IKES	12/29/02	7.63	12.40	4.00		90.00		
IKES	1/28/03	7.56	14.20	0.00		77.00		
IKES	2/27/03	7.56		1.00		80.00		
IKES	3/25/03	7.54	12.20	7.00		93.00		
IKES	4/25/03	7.53	11.10	9.00		103.00		
IKES	5/23/03	7.59	10.90	10.00		110.00		
IKES	6/27/03	7.80		15.00		132.00		
IKES	7/30/03	7.86		15.00		150.00		
IKES	9/29/03	7.58	10.40	12.00		123.00		
IKES	10/21/03	7.73	10.60	11.00		130.00		
IKES	11/4/03	7.77	9.60	12.00		130.00		
IKES	12/11/03	7.36	13.40	4.00		65.00		
IKES	1/14/04	7.70	12.80	2.00		84.00		
IKES	2/1/04			0.00				
IKES	3/26/04	7.68	11.72	9.00		107.00		
IKES	4/21/04	7.91	9.78	14.00		120.00		
IKES	5/1/04			0.00				
IKES	6/23/04	7.64		14.00		141.00		
IKES	7/16/04	7.74	7.80	17.00		170.00		
IKES	8/27/04	7.74	8.25	17.00		189.00		
IKES	9/1/04			0.00				
IKES	10/15/04	7.74	9.05	12.00		150.00		
IKES	11/1/04			0.00				
IKES	1/12/05	7.60	10.25	6.00		97.00		
IKES	2/5/05	7.65	13.00	3.00		91.00		
IKES	3/18/05	7.61		5.00		92.00		
IKES	4/23/05	7.70		9.00		115.00		
IKES	5/12/05	7.55		13.00		123.00		
IKES	6/28/05	7.66	7.90	16.00		153.00		
IKES	7/22/05	7.64	7.37	18.00		167.00		
IKES	8/25/05	7.79	8.20	15.00		162.00		
IKES	9/16/05	7.68	7.35	17.00		176.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
IKES	10/26/05	7.76	10.62	9.00		138.00		
IKES	11/18/05	7.51	8.55	6.00		137.00		
IKES	12/30/05	7.64	12.62	5.00		104.00		
IKES	1/11/06	7.56	11.71	6.00		92.00		
IKES	2/10/06	7.47	13.44	3.00		81.00		
IKES	3/31/06	7.52	9.22	10.00		120.00		
IKES	4/14/06	7.41	8.74	12.00		131.00		
IKES	5/31/06	7.59	8.90	14.00		180.00		
IKES	6/29/06	7.56	9.22	15.00		109.00		
IKES	7/21/06	7.85	8.70	18.00		165.00		
IKES	8/30/06	7.77	7.06	18.00		180.00		
IKES	9/28/06	7.64	8.14	14.00		153.00		
IKES	10/27/06	7.91	10.27	8.00		134.00		
IKES	11/20/06	7.78	11.75	7.00		110.00		
IKES	12/11/06	7.64	12.67	5.00		112.00		
IKES	1/22/07	7.48	14.08	3.00		100.00		
IKES	2/9/07	7.55	13.34	0.00				
IKES	3/9/07	7.50	14.61	4.00		92.00		
IKES	4/13/07	7.64	13.20	5.00		104.00		
IKES	5/31/07	7.71	9.38	14.00		145.00		
IKES	6/20/07	7.78	8.77	16.00		163.00		
IKES	8/31/07	7.75	7.41	17.70		181.00		
IKES	9/10/07	7.66	6.79	18.30		185.00		
IKES	10/22/07	7.73	7.03	12.90		145.00		
IKES	11/19/07	7.54	9.97	6.30		135.00		
IKES	12/12/07	7.48	8.88	7.50		150.00		
IKES	1/7/08	7.49	10.14	5.70		118.00		
IKES	2/19/08	7.68	12.01	3.90		103.00		
IKES	3/10/08	7.56	12.54	3.60		92.00		
IKES	4/14/08	7.61	11.03	7.60		112.00		
IKES	5/20/08	7.53	10.52	9.80		118.00		
IKES	6/3/08	7.67	9.58	12.90		139.00		
IKES	7/3/08	7.67	8.28	15.30		158.00		
IKES	8/25/08	7.75		10.00				
IKES	9/24/08	7.80		13.00		151.00		
IKES	10/22/08	7.42	10.07	8.86		132.00		
IKES	11/20/08	7.38	13.01	5.15				
IKES	12/17/08	7.12	14.29	4.73				
IKES	1/29/09	7.22	15.55	1.43				
IKES	2/9/09	6.95	14.90	2.94				
IKES	7/23/09	7.62	8.56	16.00		165.90		
IKES	8/26/09	6.86	9.17	17.05		250.00		
IKES	9/8/09	4.00	7.00					
IKES	9/28/09	6.80	9.64	13.88		230.00		
IKES	12/14/09	7.09	1.80	6.00		200.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
IKES	4/26/10	7.66	9.70	9.80		160.00		
IKES	6/28/10	7.61	7.50	17.70		0.17		
IKES	7/20/10	7.52	7.80	18.40		0.16		
IKES	9/15/10	7.54	7.99	14.30		0.18		
IKES	10/28/10	7.44	7.05	12.80		0.17		
IKES	11/18/10	7.31	9.77	8.10		209.00		
IKES	12/2/10	7.71	12.53	6.00		162.60		
IKES	1/5/11	7.22	10.76	2.10		207.60		
IKES	2/24/11	7.26	12.55	3.30		147.50		
IKES	3/29/11	7.22	12.93	4.90		118.20		
IKES	4/15/11	7.13	11.36	9.00		130.80		
IKES	5/23/11	7.63	10.67	13.00		190.20		
IKES	6/23/11	7.78	9.10	16.50		220.50		
IKES	7/26/11	7.49	7.68	18.90		218.40		
IKES	8/29/11	7.42	8.49	16.30		230.20		
IKES	9/19/11	7.43	8.43	13.30		227.60		
IKES	10/24/11	7.37	10.36	10.70		213.90		
IKES	11/28/11	7.50	10.79	11.10		187.50		
IKES	12/13/11	7.15	12.73	5.10		177.00		
JOEB	2/10/00	7.18	14.20	2.00		65.00		
JOEB	3/10/00	7.52	11.20	9.00		82.00		
JOEB	4/24/00	7.68	10.30	12.00		76.00		
JOEB	6/2/00	7.45	8.80	17.00		93.00		
JOEB	6/29/00	7.37	8.90	15.00		97.00		
JOEB	7/21/00	7.30	9.40	17.00		100.00		
JOEB	8/30/00	7.52	8.10	19.00		108.00		
JOEB	9/28/00	7.70	8.90	5.00		100.00		
JOEB	10/1/00			0.00				
JOEB	11/8/00	7.58	10.00	11.00		89.00		
JOEB	12/4/00	7.74		4.00		73.00		
JOEB	1/4/01	7.61		15.00		65.00		
JOEB	2/14/01	7.48	13.20	4.00		75.00		
JOEB	3/9/01	7.39	13.40	4.00		89.00		
JOEB	4/27/01	7.66	10.30	12.00		86.00		
JOEB	5/23/01	7.59	8.60	15.00		100.00		
JOEB	6/28/01	7.41	8.90	17.00		109.00		
JOEB	7/18/01	7.40	9.20	18.00		105.00		
JOEB	8/7/01	7.39	9.20	15.00		100.00		
JOEB	9/26/01	7.55	8.20	14.00		96.00		
JOEB	10/24/01	7.53	8.60	13.00		105.00		
JOEB	11/16/01	7.62	9.40	9.00		92.00		
JOEB	12/13/01	7.60	10.00	8.00		90.00		
JOEB	1/30/02	7.53	10.60	7.00		102.00		
JOEB	2/22/02	7.67	10.80	5.00		96.00		
JOEB	3/19/02	7.68	10.80	8.00		109.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
JOEB	4/24/02	7.69	9.80	12.00		100.00		
JOEB	5/24/02	7.50	9.40	16.00		102.00		
JOEB	6/26/02	7.46	8.20	17.00		119.00		
JOEB	7/24/02	7.45	7.80	16.00		112.00		
JOEB	8/23/02	7.65	8.50	15.00		108.00		
JOEB	9/28/02	7.61	8.20	16.00		127.00		
JOEB	10/15/02			0.00				
JOEB	11/20/02	7.56	10.60	8.00		81.00		
JOEB	12/29/02	7.62	13.00	3.00		73.00		
JOEB	1/28/03	7.44	15.00	1.00		70.00		
JOEB	2/27/03	7.66	14.30	0.00		90.00		
JOEB	3/25/03	6.92	11.60	8.00		77.00		
JOEB	4/25/03	7.63	11.40	12.00		98.00		
JOEB	5/23/03	7.42	10.40	11.00		80.00		
JOEB	6/27/03	7.61	9.60	17.00		94.00		
JOEB	7/30/03	7.62	10.00	13.00		110.00		
JOEB	8/27/03	7.78	9.30	17.00		114.00		
JOEB	9/29/03	7.49	8.90	16.00		87.00		
JOEB	10/21/03	7.60	10.00	13.00		89.00		
JOEB	11/4/03	7.77	10.20	13.00		91.00		
JOEB	12/11/03		12.70	4.00		68.00		
JOEB	1/14/04	7.58	13.20	2.00		70.00		
JOEB	2/1/04			0.00				
JOEB	3/26/04	7.67	10.15	11.00		102.00		
JOEB	4/21/04	7.62	9.03	17.00		101.00		
JOEB	5/1/04			0.00				
JOEB	6/23/04	7.64		17.00		91.00		
JOEB	7/16/04	7.71	8.30	20.00		110.00		
JOEB	8/27/04	7.61	9.18	17.00		113.00		
JOEB	9/1/04			0.00				
JOEB	10/15/04	7.61	8.95	15.00		101.00		
JOEB	11/1/04			0.00				
JOEB	12/4/04	7.79	11.50	6.00		76.00		
JOEB	1/12/05	7.45	12.23	5.00		67.00		
JOEB	2/5/05	7.38	12.90	3.00		62.00		
JOEB	3/18/05	7.57		6.00		85.00		
JOEB	4/23/05	7.58		13.00		95.00		
JOEB	5/12/05	7.52		13.00		93.00		
JOEB	6/28/05	7.54	9.62	14.00		99.00		
JOEB	7/22/05	7.53	9.48	15.00		110.00		
JOEB	8/25/05	7.69	8.74	16.00		116.00		
JOEB	9/16/05	7.55	8.08	19.00		125.00		
JOEB	10/26/05	7.74	10.25	12.00		110.00		
JOEB	11/18/05	7.68	9.90	7.00		98.00		
JOEB	12/30/05	7.64	12.47	4.00		92.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
JOEB	1/11/06	7.55	12.67	5.00		82.00		
JOEB	2/10/06	7.60	13.02	3.00		71.00		
JOEB	3/31/06	7.89	10.55	11.00		90.00		
JOEB	4/14/06	7.58	10.18	11.00		96.00		
JOEB	5/31/06	7.60	8.30	17.00		103.00		
JOEB	6/29/06	7.60	9.37	18.00		89.00		
JOEB	7/21/06	7.53	8.88	17.00		100.00		
JOEB	8/30/06	7.56	8.34	17.00		92.00		
JOEB	9/28/06	7.47	8.24	16.00		109.00		
JOEB	10/27/06	7.46	9.69	10.00		98.00		
JOEB	11/20/06	7.75	10.90	9.00		85.00		
JOEB	12/11/06	7.79	12.15	5.00		72.00		
JOEB	1/22/07	7.60	12.85	4.00		65.00		
JOEB	2/9/07	7.57	12.26	2.00				
JOEB	3/9/07	7.41	15.85	4.00		83.00		
JOEB	4/13/07	7.56	12.57	7.00		90.00		
JOEB	5/31/07	7.47	9.74	12.00		99.00		
JOEB	6/20/07	7.66	8.89	15.00		113.00		
JOEB	8/31/07	7.62	8.39	18.50		129.00		
JOEB	9/10/07	7.41	7.49	19.30		135.00		
JOEB	10/22/07	7.65	7.53	15.80		120.00		
JOEB	11/19/07	7.45	11.86	7.10		103.00		
JOEB	12/12/07	7.55	10.31	6.90		140.00		
JOEB	1/7/08	7.51	11.71	5.60		109.00		
JOEB	2/19/08	7.62	12.49	4.00		111.00		
JOEB	3/10/08	7.46	12.14	4.10		112.00		
JOEB	4/14/08	7.75	10.52	10.40		111.00		
JOEB	5/20/08	7.35	10.25	12.40		89.00		
JOEB	6/3/08	7.62	9.32	15.20		96.00		
JOEB	7/3/08	7.41	9.02	15.30		110.00		
JOEB	8/25/08	7.61		10.00				
JOEB	9/24/08	7.71		16.00		127.00		
JOEB	10/22/08	7.44	9.62	14.09		133.00		
JOEB	11/20/08	7.50	14.13	6.50				
JOEB	12/17/08	7.25	14.73	4.42				
JOEB	1/29/09			0.00				
JOEB	2/9/09	7.35	15.23	3.81				
JOEB	7/23/09	7.54	8.86	16.70		113.80		
JOEB	8/26/09	7.40	8.90	18.82		180.00		
JOEB	9/28/09	7.36	8.82	16.67		160.00		
JOEB	12/14/09	7.33	12.84	5.88		550.00		
JOEB	4/26/10	7.58	9.66	11.50		150.00		
JOEB	6/28/10	7.55	9.36	16.70		0.14		
JOEB	7/20/10	7.48	9.28	16.90		0.13		
JOEB	9/15/10	7.52	8.24	17.30		0.14		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
JOEB	10/28/10	7.61	9.14	14.10		0.12		
JOEB	11/18/10	7.49	11.26	8.90		153.30		
JOEB	12/2/10	7.67	13.15	6.50		93.20		
JOEB	1/5/11	7.37	13.94	2.60		159.40		
JOEB	2/24/11	7.17	14.27	2.80		174.50		
JOEB	3/29/11	7.33	13.16	6.30		135.30		
JOEB	4/15/11	7.29	11.47	10.30		135.10		
JOEB	5/23/11	7.51	9.19	18.00		130.00		
JOEB	6/23/11	7.49	8.26	17.90		135.80		
JOEB	7/26/11	7.46	9.70	15.50		128.80		
JOEB	8/29/11	7.47	7.99	17.80		146.50		
JOEB	9/19/11	7.54	8.16	17.30		157.50		
JOEB	10/24/11	7.61	9.56	13.20		138.70		
JOEB	11/28/11	7.52	11.36	9.60		119.30		
JOEB	12/13/11	7.31	12.54	5.50		114.60		
OCCM	2/10/00	7.37	12.00	3.00		78.00		
OCCM	3/10/00	7.36	11.20	8.00		84.00		
OCCM	4/24/00	7.57	10.90	10.00		78.00		
OCCM	6/2/00	7.36	9.30	15.00		98.00		
OCCM	6/29/00	7.63	8.70	16.00		112.00		
OCCM	7/21/00	7.44	9.70	15.00		110.00		
OCCM	8/30/00	7.57	8.20	18.00		128.00		
OCCM	9/28/00	7.73	9.40	12.00		102.00		
OCCM	10/1/00			0.00				
OCCM	11/8/00	7.41	10.60	9.00		98.00		
OCCM	12/4/00	7.58	14.00	1.00		74.00		
OCCM	1/4/01	7.61		12.00		75.00		
OCCM	3/9/01	7.63	14.00	4.00		85.00		
OCCM	4/27/01	7.75	10.70	9.00		89.00		
OCCM	5/23/01	7.70	9.20	12.00		104.00		
OCCM	6/28/01	7.59	8.80	17.50		129.00		
OCCM	7/18/01	7.59	9.20	18.00		132.00		
OCCM	8/7/01	7.62	9.00	19.00		136.00		
OCCM	9/26/01	7.73	9.40	11.00		105.00		
OCCM	10/24/01	7.33	7.00	13.00		139.00		
OCCM	11/16/01	7.45	8.80	8.00		123.00		
OCCM	12/13/01	7.65	10.10	7.00		113.00		
OCCM	1/30/02	7.59	8.80	8.00		117.00		
OCCM	2/22/02	7.58	11.20	5.00		100.00		
OCCM	3/19/02	7.65	11.20	7.00		101.00		
OCCM	4/24/02	7.50	12.00	9.00		107.00		
OCCM	5/24/02	7.49	9.30	11.00		112.00		
OCCM	6/26/02	7.48	7.60	16.00		146.00		
OCCM	7/24/02	7.43	7.50	17.00		162.00		
OCCM	8/23/02	7.11	5.40	16.00		118.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
OCCM	9/28/02	7.62	8.60	15.00		112.00		
OCCM	10/15/02			0.00				
OCCM	11/20/02	7.55	10.80	6.00		79.00		
OCCM	12/29/02	7.68	13.20	3.00		80.00		
OCCM	1/28/03	7.25	14.60	0.00		71.00		
OCCM	2/27/03	7.44	14.00	0.00		82.00		
OCCM	3/25/03	7.46	12.20	8.00		81.00		
OCCM	4/25/03	7.33	11.30	9.00		93.00		
OCCM	5/23/03	7.33	10.30	11.00		83.00		
OCCM	6/27/03	7.53	8.60	16.00		105.00		
OCCM	7/30/03	7.66	8.80	16.00		120.00		
OCCM	8/27/03	7.60	8.50	18.00		125.00		
OCCM	9/29/03	7.58	9.40	13.00		101.00		
OCCM	10/21/03	7.61	10.60	12.00		101.00		
OCCM	11/4/03	7.61	9.80	12.00		103.00		
OCCM	12/11/03	7.27	13.00	5.00		65.00		
OCCM	1/14/04	7.50	13.80	1.00		70.00		
OCCM	2/1/04			0.00				
OCCM	3/26/04	7.60	11.89	9.00		95.00		
OCCM	4/21/04	7.94	9.52	16.00		100.00		
OCCM	5/1/04			0.00				
OCCM	6/23/04	7.40		15.00		108.00		
OCCM	7/16/04	7.63	8.80	18.00		110.00		
OCCM	8/27/04	7.65	9.15	18.00		142.00		
OCCM	9/1/04			0.00				
OCCM	10/15/04	7.74	9.49	12.00		115.00		
OCCM	11/1/04			0.00				
OCCM	12/4/04	7.57	13.30	4.00		79.00		
OCCM	1/12/05	7.50	11.90	5.00		77.00		
OCCM	2/5/05	7.37	14.50	1.00		60.00		
OCCM	3/18/05	7.55		5.00		80.00		
OCCM	4/23/05	7.51		10.00		97.00		
OCCM	5/12/05	7.27		13.00		105.00		
OCCM	6/28/05	7.49	8.05	17.00		133.00		
OCCM	7/22/05	7.54	7.99	19.00		143.00		
OCCM	8/25/05	7.68	9.02	15.00		129.00		
OCCM	9/16/05	7.48	7.07	18.00		149.00		
OCCM	10/26/05	7.59	11.16	9.00		93.00		
OCCM	11/18/05	7.29	9.77	4.00		102.00		
OCCM	12/30/05	7.52	13.28	4.00		98.00		
OCCM	1/11/06	7.37	12.91	5.00		90.00		
OCCM	2/10/06	7.32	13.49	3.00		83.00		
OCCM	3/31/06	7.46	9.80	12.00		104.00		
OCCM	4/14/06	7.33	10.02	11.00		109.00		
OCCM	5/31/06	7.53	8.42	15.00		123.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
OCCM	6/29/06	7.35	8.93	16.00		91.00		
OCCM	7/21/06	7.71	8.29	19.00		130.00		
OCCM	8/30/06	7.69	7.30	19.00		140.00		
OCCM	9/28/06	7.39	8.84	14.00		120.00		
OCCM	10/27/06	7.57	10.63	7.00		101.00		
OCCM	11/20/06	7.54	11.74	7.00		88.00		
OCCM	12/11/06	7.57	14.16	4.00		82.00		
OCCM	1/22/07	7.32	14.95	2.00		84.00		
OCCM	2/9/07	7.28	14.37	0.00		76.00		
OCCM	3/9/07	7.26	14.70	3.00		62.00		
OCCM	4/13/07	7.45	13.48	5.00		87.00		
OCCM	5/31/07	7.61	9.03	15.00		116.00		
OCCM	6/20/07	7.64	8.63	17.00		130.00		
OCCM	8/31/07	7.48	7.37	18.10		145.00		
OCCM	9/10/07	7.44	6.62	18.40		150.00		
OCCM	10/22/07	7.37	8.37	12.70		120.00		
OCCM	11/19/07	7.40	11.42	5.50		100.00		
OCCM	12/12/07	7.31	10.41	7.50		132.00		
OCCM	1/7/08	7.35	12.23	5.20		108.00		
OCCM	2/19/08	7.57	12.57	3.80		110.00		
OCCM	3/10/08	7.40	12.62	3.10		88.00		
OCCM	4/14/08	7.50	11.29	8.00		98.00		
OCCM	5/20/08	7.26	10.38	10.00		98.00		
OCCM	6/3/08	7.45	9.25	13.90		109.00		
OCCM	7/3/08	7.52	8.72	15.80		128.00		
OCCM	8/25/08	7.40		11.00				
OCCM	9/24/08	7.44		12.00		139.00		
OCCM	10/22/08	7.03	10.44	8.75		110.00		
OCCM	11/20/08	7.32	15.10	4.55				
OCCM	12/17/08	6.97	14.51	4.42				
OCCM	1/29/09	7.18	15.82	0.96				
OCCM	2/9/09	6.66	15.50	1.94				
OCCM	7/23/09	7.40	8.08	17.10		127.90		
OCCM	8/26/09	6.47	8.46	17.53		210.00		
OCCM	9/28/09	6.05	9.50	14.05		180.00		
OCCM	12/14/09	6.94	14.36	5.58		160.00		
OCCM	4/26/10	7.58	10.44	9.90		150.00		
OCCM	6/28/10	7.52	7.52	19.30		0.14		
OCCM	7/20/10	7.20	7.70	19.30		0.12		
OCCM	9/15/10	7.13	7.41	13.90		0.14		
OCCM	10/28/10	7.32	9.03	13.20		0.14		
OCCM	11/18/10	7.26	11.93	7.40		156.80		
OCCM	12/2/10	8.01	13.41	5.40		127.20		
OCCM	1/5/11	7.25	14.61	0.30		179.20		
OCCM	2/24/11	7.52	14.90	1.60		161.10		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
OCCM	3/29/11	7.53	14.23	3.50		136.10		
OCCM	4/15/11	6.97	11.80	9.00		130.80		
OCCM	5/23/11	7.39	10.03	13.50		151.10		
OCCM	6/23/11	7.76	8.47	17.40		159.10		
OCCM	7/26/11	7.23	8.55	19.70		166.60		
OCCM	8/29/11	6.97	8.09	16.10		176.50		
OCCM	9/19/11	7.00	8.87	13.90		166.40		
OCCM	10/24/11	7.37	10.23	10.70		182.30		
OCCM	11/28/11	6.95	10.72	11.10		154.50		
OCCM	12/13/11	7.04	13.26	4.20		147.80		
OCPC	2/10/00	7.15	12.00	1.00		80.00		
OCPC	3/10/00	7.38	11.00	8.00		94.00		
OCPC	4/24/00	7.65	10.80	10.00		90.00		
OCPC	6/2/00	7.43	8.80	16.00		120.00		
OCPC	6/29/00	7.66	8.00	17.00		127.00		
OCPC	7/21/00	7.35	9.80	16.00		125.00		
OCPC	8/30/00	7.58	8.10	18.00		131.00		
OCPC	9/28/00	7.69	9.80	12.00		105.00		
OCPC	10/1/00			0.00				
OCPC	11/8/00	7.54	10.60	8.00		122.00		
OCPC	12/4/00	7.42	15.00	0.00		88.00		
OCPC	1/4/01	7.26		12.00		82.00		
OCPC	2/14/01	7.42	13.00	4.00		101.00		
OCPC	3/9/01	7.31	13.20	3.00		100.00		
OCPC	4/27/01	7.68	11.40	9.00		99.00		
OCPC	5/23/01	7.51	9.30	12.00		108.00		
OCPC	6/28/01	7.61	8.60	18.00		148.00		
OCPC	7/18/01	7.55	9.00	18.00		210.00		
OCPC	8/7/01	7.60	8.50	21.00		201.00		
OCPC	9/26/01	7.67	9.00	12.00		164.00		
OCPC	10/24/01	7.51	7.20	13.00		255.00		
OCPC	11/16/01	7.53	8.80	7.00		237.00		
OCPC	12/13/01	7.65	10.80	6.00		171.00		
OCPC	1/30/02	7.47	11.00	7.00		192.00		
OCPC	2/22/02	7.59	11.20	4.00		162.00		
OCPC	3/19/02	7.64	11.10	6.00		121.00		
OCPC	4/24/02	7.58	11.20	9.00		128.00		
OCPC	5/24/02	7.35	8.60	11.00		170.00		
OCPC	6/26/02	7.58	7.30	18.00		220.00		
OCPC	7/24/02	7.80	7.40	19.00		288.00		
OCPC	8/23/02	7.88	6.80	20.00		450.00		
OCPC	9/28/02	7.64	8.80	16.00		130.00		
OCPC	10/15/02			0.00				
OCPC	11/20/02	7.32	11.40	5.00		90.00		
OCPC	12/29/02	7.62	13.00	2.00		91.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
OCPC	1/28/03	7.15	14.10	0.00		190.00		
OCPC	2/27/03	7.47	14.00	0.00		114.00		
OCPC	3/25/03	7.39	12.20	8.00		101.00		
OCPC	4/25/03	7.55	11.00	9.00		110.00		
OCPC	5/23/03	7.55	10.70	10.00		105.00		
OCPC	6/27/03	7.64	9.10	17.00		123.00		
OCPC	7/30/03	7.73	8.80	17.00		140.00		
OCPC	9/29/03	7.48	9.60	13.00		112.00		
OCPC	10/21/03	7.50	10.50	12.00		112.00		
OCPC	11/4/03	7.61	9.40	13.00		118.00		
OCPC	12/11/03	7.17	13.20	4.00		63.00		
OCPC	1/14/04	7.52	13.60	1.00		70.00		
OCPC	2/1/04			0.00				
OCPC	3/26/04	7.62	11.40	10.00		116.00		
OCPC	4/21/04	7.75	9.20	16.00		118.00		
OCPC	5/1/04			0.00				
OCPC	6/23/04			0.00				
OCPC	7/16/04	7.71	8.40	18.00		130.00		
OCPC	8/27/04	7.81	8.49	19.00		193.00		
OCPC	9/1/04			0.00				
OCPC	10/15/04	7.67	9.64	12.00		130.00		
OCPC	11/1/04			0.00				
OCPC	12/4/04	7.66	14.15	2.00		84.00		
OCPC	1/12/05	7.48	11.43	5.00		82.00		
OCPC	2/5/05	7.54	14.60	1.00		80.00		
OCPC	3/18/05	7.59		6.00		91.00		
OCPC	4/23/05	7.56		10.00		101.00		
OCPC	5/12/05	7.58		14.00		116.00		
OCPC	6/28/05	7.68	8.25	18.00		170.00		
OCPC	7/22/05	7.65	7.91	22.00		207.00		
OCPC	8/25/05	7.77	8.71	16.00		201.00		
OCPC	9/16/05	7.59	7.95	19.00		257.00		
OCPC	10/26/05	7.67	11.46	9.00		102.00		
OCPC	11/18/05	7.45	11.25	3.00		102.00		
OCPC	12/30/05	7.55	13.74	4.00		110.00		
OCPC	1/11/06	7.44	13.28	5.00		99.00		
OCPC	2/10/06	7.47	14.93	1.00		79.00		
OCPC	3/31/06	7.49	10.05	12.00		109.00		
OCPC	4/14/06	7.40	9.40	11.00		123.00		
OCPC	5/31/06	7.53	8.63	16.00		150.00		
OCPC	6/29/06	7.45	8.66	17.00		110.00		
OCPC	7/21/06	7.66	8.38	19.50		145.00		
OCPC	8/30/06	7.73	7.90	20.00		177.00		
OCPC	9/28/06	7.67	9.19	14.00		149.00		
OCPC	10/27/06	7.91	11.25	7.00		120.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
OCPC	11/20/06	7.66	12.41	6.00		93.00		
OCPC	12/11/06	7.62	14.51	3.00		85.00		
OCPC	1/22/07	7.35	15.47	1.00		82.00		
OCPC	3/9/07	7.34	16.18	1.00		91.00		
OCPC	4/13/07	7.51	13.73	5.00		85.00		
OCPC	5/31/07	7.65	9.26	16.00		130.00		
OCPC	6/20/07	7.68	8.75	18.00		133.00		
OCPC	8/31/07	7.72	8.06	19.10		215.00		
OCPC	9/10/07	7.54	8.00	19.70		245.00		
OCPC	10/22/07	7.63	9.29	12.50		245.00		
OCPC	11/19/07	7.46	11.87	4.80		135.00		
OCPC	12/12/07	7.40	10.61	7.30		172.00		
OCPC	1/7/08	7.43	10.87	6.30		130.00		
OCPC	2/19/08	7.57	12.77	3.10		125.00		
OCPC	3/10/08	7.46	13.21	2.00		92.00		
OCPC	4/14/08	7.62	11.57	7.90		103.00		
OCPC	5/20/08	7.39	10.13	10.00		97.00		
OCPC	6/3/08	7.56	9.28	14.20		112.00		
OCPC	7/3/08	7.56	8.54	16.40		137.00		
OCPC	8/25/08	7.66		11.00				
OCPC	9/24/08	7.80		12.00		182.00		
OCPC	10/22/08	7.26	10.96	8.41		172.00		
OCPC	11/20/08	7.38	15.47	3.60				
OCPC	12/17/08	7.09	14.81	3.91				
OCPC	1/29/09	7.09	16.80	0.27				
OCPC	2/9/09	6.90	16.12	1.21				
OCPC	7/23/09	7.51	8.57	17.90		140.30		
OCPC	8/26/09	7.27	9.26	18.54		240.00		
OCPC	9/28/09	7.09	9.67	14.26		190.00		
OCPC	12/14/09	7.08	14.59	5.22		160.00		
OCPC	4/26/10	7.54	10.61	10.00		150.00		
OCPC	6/28/10	7.59	8.35	20.40		0.17		
OCPC	7/20/10	7.57	8.18	20.60		0.17		
OCPC	9/15/10	7.48	7.88	14.60		0.23		
OCPC	10/28/10	7.39	9.00	13.30		0.16		
OCPC	11/18/10	7.30	11.78	7.10		157.00		
OCPC	12/2/10	7.56	13.75	4.70		134.00		
OCPC	1/5/11	7.08	14.74	0.00		212.30		
OCPC	2/24/11	7.14	14.94	0.70		176.10		
OCPC	3/29/11	7.15	14.73	2.70		150.40		
OCPC	4/15/11	7.18	11.96	9.10		147.40		
OCPC	5/23/11	7.33	10.17	14.30		149.40		
OCPC	6/23/11	7.51	8.81	18.30		168.80		
OCPC	7/26/11	7.49	8.47	20.70		210.10		
OCPC	8/29/11	7.37	8.47	16.60		222.70		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
OCPC	9/19/11	7.49	9.33	13.90		187.30		
OCPC	10/24/11	7.46	10.18	10.40		175.70		
OCPC	11/28/11	7.43	10.66	11.30		140.20		
OCPC	12/13/11	7.13	13.45	2.90		149.10		
PENL	2/10/00	7.24	12.40	2.00		69.00		
PENL	3/10/00	7.60	11.30	9.00		82.00		
PENL	4/24/00	7.69	10.20	12.00		75.00		
PENL	6/2/00	7.51	9.00	17.00		92.00		
PENL	6/29/00	7.69	9.80	16.00		98.00		
PENL	7/21/00	7.27	9.10	18.00		100.00		
PENL	8/30/00	7.71	8.80	19.00		108.00		
PENL	9/28/00	7.78	9.70	14.00		98.00		
PENL	10/1/00			0.00				
PENL	11/8/00	7.68	9.80	10.00		85.00		
PENL	12/4/00	7.75		3.00		70.00		
PENL	1/4/01	7.62		15.00		63.00		
PENL	2/14/01	7.48	12.80	4.00		80.00		
PENL	3/9/01	7.43	13.90	4.00		91.00		
PENL	4/27/01	7.69	10.40	12.00		83.00		
PENL	5/23/01	7.67	9.40	15.00		100.00		
PENL	6/28/01	7.47	8.40	19.00		109.00		
PENL	7/18/01	7.55	9.60	19.00		103.00		
PENL	8/7/01	7.53	9.00	19.00		110.00		
PENL	9/26/01	7.63	9.70	12.00		105.00		
PENL	10/24/01	7.60	8.80	13.00		100.00		
PENL	11/16/01	7.82	9.70	9.00		85.00		
PENL	12/13/01		7.70	10.20		91.00		
PENL	1/30/02	7.64	10.40	8.00		105.00		
PENL	2/22/02	7.78	11.20	5.50		97.00		
PENL	3/19/02	7.76	11.70	7.00		111.00		
PENL	4/24/02	7.70	10.00	11.00		99.00		
PENL	5/24/02	7.49	8.50	16.00		100.00		
PENL	6/26/02	7.62	7.80	19.00		112.00		
PENL	7/24/02	7.71	7.80	19.00		106.00		
PENL	8/23/02	7.80	7.90	18.00		117.00		
PENL	9/28/02	7.81	9.20	16.00		123.00		
PENL	10/15/02			0.00				
PENL	11/20/02	7.54	11.20	7.00		80.00		
PENL	12/29/02	7.61	13.70	3.00		73.00		
PENL	1/28/03	7.45	15.00	0.00		69.00		
PENL	2/27/03	7.64	14.00	1.00		92.00		
PENL	3/25/03	7.32	11.60	8.00		81.00		
PENL	4/25/03	7.67	11.30	12.00		98.00		
PENL	5/23/03	7.52	11.00	11.00		80.00		
PENL	6/27/03	7.69	9.80	17.00		96.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
PENL	7/30/03	7.78	10.40	14.00		110.00		
PENL	9/29/03	7.60	9.60	15.00		84.00		
PENL	10/21/03	7.68	10.50	13.00		87.00		
PENL	11/4/03	7.72	10.20	13.00		88.00		
PENL	12/11/03			4.00		68.00		
PENL	1/14/04	7.65	13.30	2.00		68.00		
PENL	2/1/04			0.00				
PENL	3/26/04	7.76	10.33	11.00		101.00		
PENL	4/21/04	7.66	9.02	17.00		101.00		
PENL	5/1/04			0.00				
PENL	6/23/04	7.69		17.00		87.00		
PENL	7/16/04	7.88	8.50	20.00		110.00		
PENL	8/27/04	7.85	9.05	18.00		112.00		
PENL	9/1/04			0.00				
PENL	10/15/04	7.76	9.47	14.00		80.00		
PENL	11/1/04			0.00				
PENL	12/4/04	7.80	11.88	6.00		73.00		
PENL	1/12/05	7.51	12.30	5.00		65.00		
PENL	2/5/05	7.48	13.30	3.00		63.00		
PENL	3/18/05	7.62		6.00		83.00		
PENL	4/23/05	7.64		12.00		92.00		
PENL	5/12/05	7.58		13.00		93.00		
PENL	6/28/05	7.75	9.30	17.00		102.00		
PENL	7/22/05	7.78	9.56	19.00		115.00		
PENL	8/25/05	7.81	9.32	16.00		112.00		
PENL	9/16/05	7.73	8.77	18.00		122.00		
PENL	10/26/05	7.82	10.87	11.00		109.00		
PENL	11/18/05	7.79	11.62	5.00		90.00		
PENL	12/30/05	7.70	12.43	4.00		100.00		
PENL	1/11/06	7.54	12.54	5.00		82.00		
PENL	2/10/06	7.62	12.93	3.00		70.00		
PENL	3/31/06	7.96	10.55	12.00		90.00		
PENL	4/14/06	7.65	10.50	11.00		96.00		
PENL	5/31/06	7.64	8.80	17.00		101.00		
PENL	6/29/06	7.55	9.37	18.00		89.00		
PENL	7/21/06	7.65	9.41	18.00		102.00		
PENL	8/30/06	7.74	8.55	19.00		79.00		
PENL	9/28/06	7.87	9.71	16.00		102.00		
PENL	10/27/06	7.64	11.50	9.00		91.00		
PENL	11/20/06	7.79	11.06	9.00		82.00		
PENL	12/11/06	7.78	12.44	5.00		71.00		
PENL	1/22/07	7.56	13.09	3.00		62.00		
PENL	2/9/07	7.69	13.20	1.00		60.00		
PENL	3/9/07	7.46	15.87	5.00		85.00		
PENL	4/13/07	7.64	12.94	7.00		90.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
PENL	5/31/07	7.54	10.13	13.00		97.00		
PENL	6/20/07	7.75	9.21	17.00		117.00		
PENL	8/31/07	7.88	9.27	19.20		130.00		
PENL	9/10/07	7.61	8.61	20.10		132.00		
PENL	10/22/07	7.77	9.38	14.20		120.00		
PENL	11/19/07	7.59	11.75	6.00		100.00		
PENL	12/12/07	7.65	10.72	7.10		142.00		
PENL	1/7/08	7.60	11.81	5.80		90.00		
PENL	2/19/08	7.68	12.22	4.00		111.00		
PENL	3/10/08	7.50	12.04	4.00		105.00		
PENL	4/14/08	7.74	10.61	10.20		110.00		
PENL	5/20/08	7.55	10.54	12.30		90.00		
PENL	6/3/08	7.69	9.65	15.30		96.00		
PENL	7/3/08	7.53	9.46	16.50		110.00		
PENL	8/25/08	7.80		12.00				
PENL	9/24/08	7.82		14.00		119.00		
PENL	10/22/08	7.54	10.86	12.30		143.00		
PENL	11/20/08	7.31	15.74	4.69				
PENL	12/17/08	7.26	15.01	4.36				
PENL	1/29/09	7.16	15.36	2.15				
PENL	2/9/09	7.36	15.33	3.51				
PENL	7/23/09	7.84	9.30	17.70		103.30		
PENL	8/26/09	7.26	10.08	19.00		180.00		
PENL	9/28/09	7.34	10.07	15.92		160.00		
PENL	12/14/09	7.35	14.39	5.25		150.00		
PENL	2/22/10	7.56	13.85	3.70		160.00		
PENL	4/26/10	7.75	10.50	11.30		140.00		
PENL	6/28/10	8.02	9.76	19.10		0.13		
PENL	7/20/10	7.79	9.29	19.70		0.12		
PENL	9/15/10	7.89	10.07	16.30		0.14		
PENL	10/28/10	7.80	10.56	13.80		0.12		
PENL	11/18/10	7.70	12.02	8.00		153.70		
PENL	12/2/10	7.54	13.29	6.50		126.90		
PENL	1/5/11	7.52	14.79	1.50		157.20		
PENL	2/24/11	7.29	14.69	2.50		170.10		
PENL	3/29/11	7.39	13.47	6.20		134.10		
PENL	4/15/11	7.38	11.50	10.60		135.80		
PENL	5/23/11	7.64	9.82	17.40		129.00		
PENL	6/23/11	7.70	8.63	19.00		133.90		
PENL	7/26/11	7.73	9.92	17.50		124.80		
PENL	8/29/11	7.78	9.53	17.80		142.00		
PENL	9/19/11	7.86	9.44	15.80		153.80		
PENL	10/24/11	7.68	10.30	12.70		138.00		
PENL	11/28/11	7.52	11.45	10.00		120.00		
PENL	12/13/11	7.34	12.78	5.40		113.90		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WHST	2/10/00	7.23	12.80	2.00		50.00		
WHST	3/10/00	7.47	10.60	10.00		54.00		
WHST	4/24/00	7.74	10.40	11.00		57.00		
WHST	6/2/00	7.53	9.00	15.00		72.00		
WHST	6/29/00	7.73	7.80	18.00		85.00		
WHST	7/21/00	7.44	9.40	17.00		100.00		
WHST	8/30/00	7.75	7.90	19.00		100.00		
WHST	9/28/00	7.85	9.20	12.00		105.00		
WHST	10/1/00			0.00				
WHST	11/8/00	7.62	9.40	10.00		83.00		
WHST	12/4/00	7.80		1.00		60.00		
WHST	1/4/01	7.54		12.00		38.00		
WHST	2/14/01	7.52	12.60	5.00		61.00		
WHST	3/9/01	7.34	13.80	3.00		73.00		
WHST	4/27/01	7.64	10.70	10.00		52.00		
WHST	5/23/01	7.59	9.90	12.00		83.00		
WHST	6/28/01	7.56	7.10	19.00		90.00		
WHST	7/18/01	7.51	9.10	19.00		92.00		
WHST	8/7/01	7.80	6.12	22.50		115.00		
WHST	9/26/01	7.78	9.60	11.00		128.00		
WHST	10/24/01	7.61	7.50	14.00		105.00		
WHST	11/16/01	7.56	9.00	9.00		71.00		
WHST	12/13/01	7.77	10.70	7.00		58.00		
WHST	1/30/02	7.62	9.90	8.00		100.00		
WHST	2/22/02	7.65	10.20	5.00		86.00		
WHST	3/19/02	7.82	10.90	8.00		79.00		
WHST	4/24/02	7.80	10.70	10.00		85.00		
WHST	5/24/02	7.68	9.40	13.00		89.00		
WHST	6/26/02	7.57	6.60	20.00		139.00		
WHST	7/24/02	7.74	7.00	20.00		113.00		
WHST	9/28/02	7.83	8.90	16.00		109.00		
WHST	10/15/02			0.00				
WHST	11/20/02	7.60	11.60	7.00		70.00		
WHST	12/29/02	7.70	12.80	3.00		57.00		
WHST	1/28/03	7.36	15.00	0.00		32.00		
WHST	2/27/03	7.88	14.60	0.00		51.00		
WHST	3/25/03	7.52	11.20	9.00		50.00		
WHST	4/25/03	7.61	11.40	11.00		62.00		
WHST	5/23/03	7.47	10.60	11.00		50.00		
WHST	6/27/03	7.61	9.20	18.00		71.00		
WHST	7/30/03	7.88	8.60	17.00		68.00		
WHST	9/29/03	7.59	9.30	13.00		67.00		
WHST	10/21/03	7.61	10.30	12.00		70.00		
WHST	11/4/03	7.80	9.20	14.00		77.00		
WHST	12/11/03		12.20	6.00		51.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WHST	1/14/04	7.59	13.60	1.00		28.00		
WHST	2/1/04			0.00				
WHST	3/26/04	7.61	9.74	12.00		61.00		
WHST	4/21/04	7.65	8.65	17.00		63.00		
WHST	5/1/04			0.00				
WHST	6/23/04			0.00				
WHST	7/16/04	7.74	8.20	20.00		80.00		
WHST	8/27/04	7.90	8.05	20.00		100.00		
WHST	9/1/04			0.00				
WHST	10/15/04	7.83	9.58	13.00		80.00		
WHST	11/1/04			0.00				
WHST	12/4/04	7.79	11.65	5.00		59.00		
WHST	1/12/05	7.45	11.60	6.00		52.00		
WHST	2/5/05	7.35	13.20	3.00		41.00		
WHST	3/18/05	7.67		6.00		52.00		
WHST	4/23/05	7.63		11.00		60.00		
WHST	5/12/05	7.64		14.00		67.00		
WHST	6/28/05	7.74	7.62	19.00		79.00		
WHST	7/22/05	7.70	7.92	21.00		108.00		
WHST	8/25/05	7.95	8.70	16.00		99.00		
WHST	9/16/05	7.68	8.15	19.00		159.00		
WHST	10/26/05	7.88	10.85	10.00		90.00		
WHST	11/18/05	7.75	11.30	3.00		80.00		
WHST	12/30/05	7.78	12.19	5.00		80.00		
WHST	1/11/06	7.71	12.31	5.00		58.00		
WHST	2/10/06	7.65	13.29	2.00		43.00		
WHST	3/31/06	7.81	10.50	12.00		62.00		
WHST	4/14/06	7.50	8.03	11.00		78.00		
WHST	5/31/06	7.69	8.57	17.00		62.00		
WHST	6/29/06	7.75	9.74	17.00		81.00		
WHST	7/21/06	7.71	7.81	21.00		95.00		
WHST	8/30/06	7.91	7.58	21.00		101.00		
WHST	9/28/06	7.67	8.16	14.00		85.00		
WHST	10/27/06	7.62	10.94	7.00		80.00		
WHST	11/20/06	7.83	11.34	8.00		71.00		
WHST	12/11/06	7.82	12.37	5.00		62.00		
WHST	1/22/07	7.62	12.94	2.00		45.00		
WHST	2/9/07	7.56	12.95	0.00				
WHST	3/9/07	7.45	15.15	4.00		53.00		
WHST	4/13/07	7.57	12.34	6.00		60.00		
WHST	5/31/07	7.72	8.69	16.00		68.00		
WHST	6/20/07	7.83	8.25	18.00		102.00		
WHST	8/31/07	7.86	7.58	20.00		121.00		
WHST	9/10/07	7.64	6.67	20.60		125.00		
WHST	10/22/07	7.85	8.70	12.90		105.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WHST	11/19/07	7.59	11.19	5.50		80.00		
WHST	12/12/07	7.59	10.13	8.00		130.00		
WHST	1/7/08	7.44	11.06	6.20		81.00		
WHST	2/19/08	7.70	11.45	4.50		80.00		
WHST	3/10/08	7.62	12.59	3.00		55.00		
WHST	4/14/08	7.84	10.30	9.20		70.00		
WHST	5/20/08	7.51	10.95	10.40		56.00		
WHST	6/3/08	7.70	9.85	14.30		58.00		
WHST	7/3/08	7.66	8.59	17.10		76.00		
WHST	8/25/08	7.79		13.00				
WHST	9/24/08	7.89		13.00		115.00		
WHST	10/22/08	7.38	9.85	9.30		103.00		
WHST	11/20/08	7.49	15.14	4.48				
WHST	12/17/08	7.21	14.38	5.22				
WHST	1/29/09	7.34	16.72	0.37				
WHST	2/9/09	7.37	15.73	2.84				
WHST	7/23/09	7.63	7.56	18.30		71.30		
WHST	8/26/09	7.33	8.04	19.16		140.00		
WHST	9/28/09	7.42	9.21	14.91		150.00		
WHST	12/14/09	7.35	13.59	6.71		120.00		
WHST	2/22/10	7.63	13.57	3.50		90.00		
WHST	4/26/10	7.37	10.39	10.40		90.00		
WHST	6/28/10	7.66	5.73	21.00		0.07		
WHST	7/20/10	7.61	7.00	21.20		0.08		
WHST	9/15/10	7.78	7.68	15.20		0.10		
WHST	10/28/10	7.72	8.27	14.20		0.12		
WHST	11/18/10	7.68	11.86	8.50		125.00		
WHST	1/5/11	7.42	15.02	0.20		107.60		
WHST	2/24/11	7.36	14.84	1.80		115.60		
WHST	3/29/11	7.45	13.85	4.30		79.40		
WHST	4/15/11	7.46	11.61	9.90		86.80		
WHST	5/23/11	7.35	9.66	15.00		94.10		
WHST	6/23/11	7.42	7.90	19.10		85.60		
WHST	7/26/11	7.63	5.93	21.80		100.70		
WHST	8/29/11	7.64	6.18	17.70		121.40		
WHST	9/19/11	7.76	7.48	14.20		118.00		
WHST	10/24/11	7.65	9.36	11.00		110.20		
WHST	11/28/11	7.62	10.46	12.10		83.60		
WHST	12/13/11	7.45	12.62	4.90		79.20		
Overall median		**7.6**	**9.8**	**11.0**	**564**	**115**	**1.0**	**0.078**

Table A-3. Deer density (deer/km^2) in CATO. Deer monitoring sites are shown in Figure 4.38.

Year	Density
2001	71.75
2002	60.01
2003	74.54
2004	40.17
2005	28.39
2006	34.87
2007	40.39
2008	44.13
2009	47.66
2010	33.74
2011	31.40
Overall median	**40.39**

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National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov