National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Chesapeake and Ohio Canal National Historical Park Natural Resource Condition Assessment

National Capital Region

Natural Resource Report NPS/CHOH/NRR—2014/760

ON THE COVER

C&O Canal and towpath in Maryland, just west of Harpers Ferry, West Virginia.
Photo by Kevin Smith.

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Fort Collins, Colorado

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 in digital format 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*). To receive this report in a format optimized for screen readers, please email *irma@nps.gov.*

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BACKGROUND

The 297-km (184.5-mile) Chesapeake and Ohio Canal National Historical Park was established in 1971 to "preserve and interpret the historic and scenic features of the Chesapeake and Ohio Canal, and to develop the potential of the canal for public recreation." The long and linear shape of the park makes it particularly vulnerable to changes in adjacent land use and also more susceptible to the introduction of exotic plants and animals. Other threats to the park include deer overpopulation, adverse recreational use, sedimentation, flooding, and nutrient pollution and contamination.

Due to its location spanning four physiographic provinces, Chesapeake and Ohio Canal National Historical Park provides a wealth of natural resource values. The range of geology and soils, combined with the Potomac River, has resulted in diverse habitats including caves, wetlands, and forests which support a variety of rare, threatened, and endangered plants and animals.

NATURAL RESOURCE CONDITION ASSESSMENT

Assessment of natural resource condition within Chesapeake and Ohio Canal National Historical Park (CHOH) was carried out using the Inventory and Monitoring Program Vital Signs ecological monitoring framework. Twenty-six 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 Chesapeake and Ohio Canal National Historical 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 variable but generally good, biological integrity condition was variable but moderate overall, and landscape dynamics condition was generally moderate.

Air quality metrics were either in conditions of significant concern (wet nitrogen and sulfur deposition and visibility) or moderate condition (ozone and particulate matter). Water resources results were variable, with pH, water temperature, dissolved oxygen, and acid neutralizing capacity scoring as very good. The remaining metrics scored as moderate to very degraded and 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 and presence of forest pests, while area of exotic herbaceous species, seedling stocking index, and deer density scored as very degraded. Landscape dynamics metrics were also variable. CHOH scored as very good for forest cover within the park, for impervious surface at both scales, and for road density within the park. Forest interior area at both scales was degraded. Forest cover and road density at the 5x park area scale were very degraded.

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 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

Natural resoures in Chesapeake and Ohio Canal National Historical Park are in moderate condition overall but are under threat from surrounding land use, regionally poor air quality, overpopulation of deer, and the recent documentation of the presence of emerald ash borer and white-nose syndrome within the park. Climate change is predicted to negatively affect many of the natural resources of the park.

condition would give a better picture of the effect of mercury in the ecosystem.

Water resources were in a good condition overall. No water resources metrics (apart from Benthic Index of Biotic Integrity [BIBI] and Physical Habitat Index [PHI]) were measured inside the park boundary which necessitated the use of data collected upstream of the park. It is recommended to establish regular water quality monitoring within the park boundary. Nutrients, specific conductance, BIBI, and PHI were in moderate to very degraded condition while pH, dissolved oxygen, water temperature and acid neutralizing capacity were very good, similar to results found in parks throughout the region. Specific conductance also showed a significant degrading trend. Several data gaps and research recommendations revolve around water in the park, including wetland delineation, sources of stormwater, contaminants, and sediments, and the karst geology of the park.

Biological integrity was in a moderate condition overall. Deer density and the seedling stocking index were both very degraded. Studies show a relationship between high deer density and poor forest regeneration and as such, deer management should become a top priority. Monitoring recommendations include expanding amphibian monitoring, updating and repeating Fish Index of Biotic Integrity (FIBI) monitoring, and continuing to monitor pests and diseases. Forest pest species were in a very good condition; however, emerald ash borer has been detected in the park but has not yet shown up in the regularly monitored forest plots. It is expected that it is only a matter of time until emerald ash borer does appear in the monitoring plots. White-nose syndrome is absent from the tunnels in the park, which highlights their importance to bat populations. However, white-nose syndrome has been detected elsewhere in the park and due to the high mortality from this disease, management intervention is warranted. Emerald ash borer and white-nose syndrome are two of the biggest threats facing the park and it is worrisome that both have recently reached the park. 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 moderate condition overall, with 59% attainment of reference conditions (Tables 5.1, 5.11). Forest interior area was in a degraded condition both inside and adjacent to the park. This was mostly due to the linear shape of the park which limits the amount of potential forest interior area. Forest cover inside the park was in a very good condition but was in very degraded condition adjacent to the park. This relates to the proximity of the park to the Potomac River which is a non-forest land cover. Management opportunities for the park relating to these two results include maintaining and improving the quality of existing forest habitat within the park (Table 5.12).

Impervious surface and road density within the park were both in very good condition. Impervious surface adjacent to the park was also in very good condition; however, road density at the same scale was very degraded. High road density has implications for wildlife mortality and could also result in increased surface runoff and stormwater entering the park. With development increasing near the park, it can be expected that impervious surface and road density will increase in the areas surrounding the park in the future. Management options include maintaining or increasing pervious surfaces within the park and installing stormwater retention basins.

CONCLUSIONS

Natural resoures in Chesapeake and Ohio Canal National Historical Park are in moderate condition overall but are under threat from surrounding land use, regionally poor air quality, overpopulation of deer, and the recent documentation of the presence of emerald ash borer and white-nose syndrome within the park. 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 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. Kevin Brandt, Superintendent at Chesapeake and Ohio Canal National Historical 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://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm*

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

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

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

The Chesapeake and Ohio Canal National Historical Park (CHOH) was established in 1971 to "preserve and interpret the historic and scenic features of the Chesapeake and Ohio Canal, and to develop the potential of the canal for public recreation." The 297-km (184.5-mile) canal was built and operated as a commercial transportation artery between 1828 and 1924. It now sees more traffic from recreational hikers and bikers along its towpath and is home to valuable landscape and increasingly rare natural resources. The current park is comprised of 8,190 ha (20,239 acres).

Lock 7 at Glen Echo. Photo by Tom Paradis/ NPS.

George Washington is credited with the original vision for construction of a canal along the Potomac River from Washington, D.C., to Cumberland, Maryland, and from there over the mountains to the headwaters of the Ohio River in Western Pennsylvania. Washington died in 1799, but the idea of the canal did not. Work to build it began in 1828. Over the next 22 years, numerous obstacles were overcome to bring the canal as far as Cumberland. Plans to continue to the headwaters of the Ohio River in Pittsburgh were abandoned.

The 184-meter (605-foot) difference in elevation between Georgetown and Cumberland dictated most of the engineering feats along the canal's 184.5 miles, including 74 lift locks, 7 dams, 11 stone aqueducts over major Potomac tributaries, hundreds of culverts for lesser streams and road underpasses, and a great assortment of water control devices, river locks, and bridges. Its two most impressive engineering features are undoubtedly the Monocacy Aqueduct and the 950-meter (3,117-foot) Paw Paw Tunnel, dug through a mountain to shortcut two bends in the river (Mackintosh 1991).

In 1924, the canal closed because of flood damage and diminishing revenues. For the next five decades, the canal was made into a scenic park, restored by depression-era Civilian Conservation Corps, destroyed by floods, targeted for transformation into an automobile parkway, and saved by public outcry. President Eisenhower designated the entire length of the canal as a National Monument in 1961 and 10 years later, Congress established the park with the passage of the Chesapeake and Ohio Canal National Historical Park Act.

The southernmost part of CHOH begins in the soft sediments of the Coastal Plain in Georgetown, Washington D.C. It then winds its way north and west paralleling the Potomac River, travelling through 100 km (60 miles) of the Piedmont Plateau, a rolling hilly upland underlain by hard rocks. At Harpers Ferry water gap, the Blue Ridge begins, and the canal follows the sweeping bends of the Potomac through the Great Valley to Hancock, Maryland. Above Hancock, the canal cuts through the folded mountain ridges of the Ridge and Valley Province (NPS 1988).

Along the span of the park, numerous geologic formations are exposed that support diverse native plant communities. The park is home to several populations of state and nationally rare, threatened, or endangered species of plants and animals and outstanding examples of unusual and imperiled natural communities (Bartgis et al. 1993).

In addition to numerous historic buildings and canal structures, the park includes areas preserved in agriculture, mid-Appalachian shale barrens, limestone forests, floodplain forests, wetlands, and some of the very best examples of scoured bedrock terrace habitat in the eastern US.

Yet the park also contains natural areas that bear the mark of human activity. "Man's influence in the area has been pronounced but not disastrous. Gone are the original forest and the large mammals which once inhabited it" (NPS 1988). The floodplain is mostly second or third growth eastern bottomland forest. A great diversity of flowering plants and ferns are found in the park, both native and introduced, in part as a result of differences in topography and soil conditions (NPS 1988).

It is difficult to summarize the park and its 184.5-mile-long canal. However, a wide range of scenic vistas, rare biota, and a largely undeveloped canal and riverfront are some of its primary assets, along with important services provided by the riparian habitat and wildlife corridor that exist along the length of the park.

2.1.1 Enabling legislation

Several laws and documents guide natural resource management for the Chesapeake and Ohio Canal National Historical Park: the National Park Service Organic Act of 1916 ("Organic Act," Ch. 1, 39 Stat 535), the 1924 National Capital Park and Playground Act, the 1930 Capper-Cramton Act, the 1961 Proclamation establishing the Chesapeake and Ohio Canal National Monument, and the 1971 Chesapeake and Ohio Canal Historical Park Act.

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 the park's chief mandates is to preserve the scenery and 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 first federal legislation pertaining specifically to the canal was the Capper-Cramton Act of May 29, 1930, which authorized the George Washington Memorial Parkway along both sides of the Potomac River to just above Great Falls. This bill also included,

> *"the shores of the Potomac, and adjacent lands. . .from Fort Washington to a similar point above Great Falls on the Maryland side except within the District of Columbia, and including the protection and preservation of the natural scenery of the Gorge and the Great Falls of the Potomac and the acquisition of that portion of the Chesapeake and Ohio Canal."*

In its final form, the Capper–Cramton Act authorized acquisition of the canal as far upriver as Point of Rocks (NPS 1996a). It followed and was in accordance with Public Law 69-202 of June 6, 1924, known as the "National Capital Park and Playground Act." An important purpose of that act was to:

> *"prevent pollution of Rock Creek and the Potomac and Anacostia Rivers, to preserve forests and natural scenery in and about Washington, and to provide for the comprehensive, systematic, and continuous development of the park, parkway, and playground system of the National Capital."*

President Franklin D. Roosevelt purchased the entire canal from the Baltimore & Ohio

Railroad in 1938 under authority granted by the National Industrial Recovery Act of 1933. On January 18, 1961, President Dwight D. Eisenhower issued Proclamation 339 creating the Chesapeake and Ohio Canal National Monument. This monument included all canal property between Seneca and Cumberland, but had little practical effect as it contained no funding and did not authorize any expansion or development (NPS 1996a).

Finally, the Chesapeake and Ohio Canal Historical Park Act (Public Law 91-664) established CHOH in 1971:

> *"In order to preserve and interpret the historic and scenic features of the Chesapeake and Ohio Canal, and to develop the potential of the canal for public recreation, including such restoration as may be needed, there is hereby established the Chesapeake and Ohio Canal National Historical Park, in the states of Maryland and West Virginia and in the District of Columbia."*

All these pieces of legislation were considered when putting together the 2013 Foundation Document (NPS 2013a) which defines the purpose of the park as being:

> *"...to preserve and interpret the 19th century transportation canal from Washington, D.C., to Cumberland, Maryland, and its associated scenic, natural, and cultural resources; and to provide opportunities for education and appropriate outdoor recreation."*

2.1.2 Geographic setting

Park description

CHOH follows the northern side of the Potomac River for 297 km (184.5 mi) from Georgetown in Washington, D.C. to Cumberland, MD (Figures 2.1, 2.2). The park comprises 8,190 ha (20,239 acres). From east to west, the park starts in the Coastal Plain physiographic province at approximately sea level and then crosses over three subsequent provinces: Piedmont Plateau, Blue Ridge, and ends in the Valley and Ridge at 320 m elevation (Figure 2.3). The Atlantic Coastal Plain lies to the east of the Fall Line over generally flat terrain positioned slightly above sea level (Thornberry–Ehrlich 2005, Southworth et

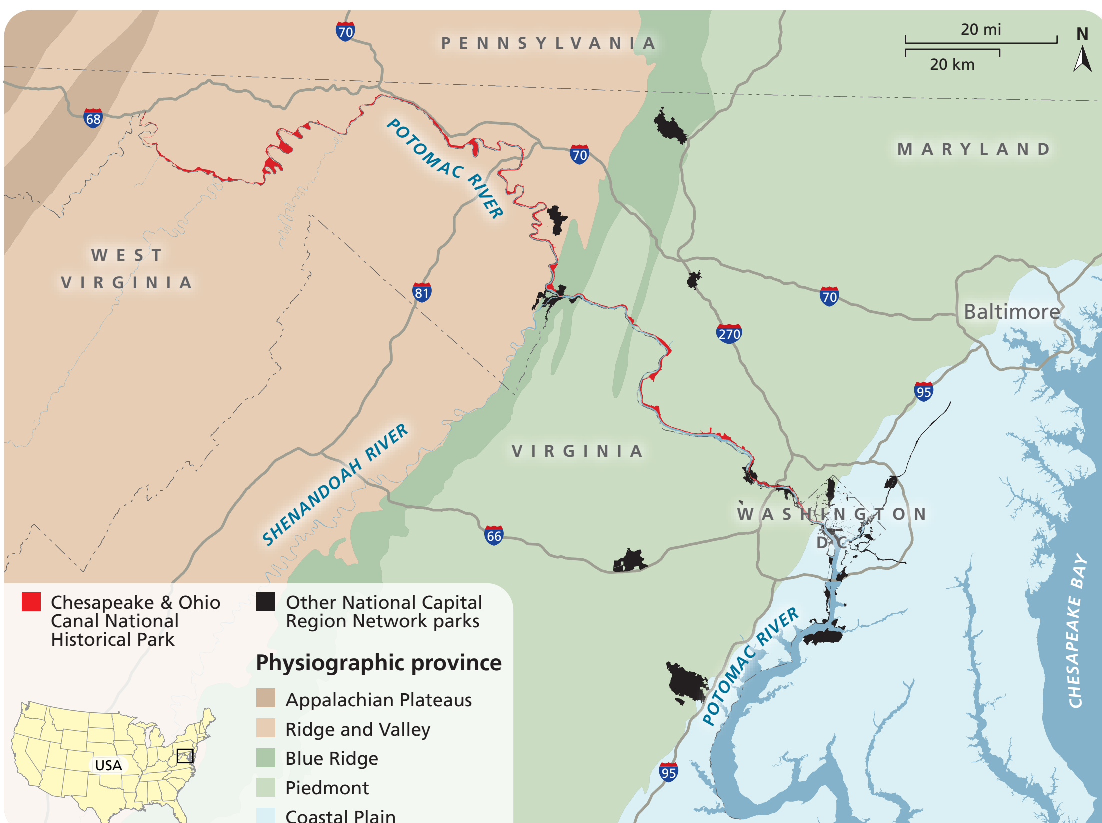


Figure 2.1. Location of the Chesapeake and Ohio Canal National Historical Park (CHOH) along the Potomac River (NPS).

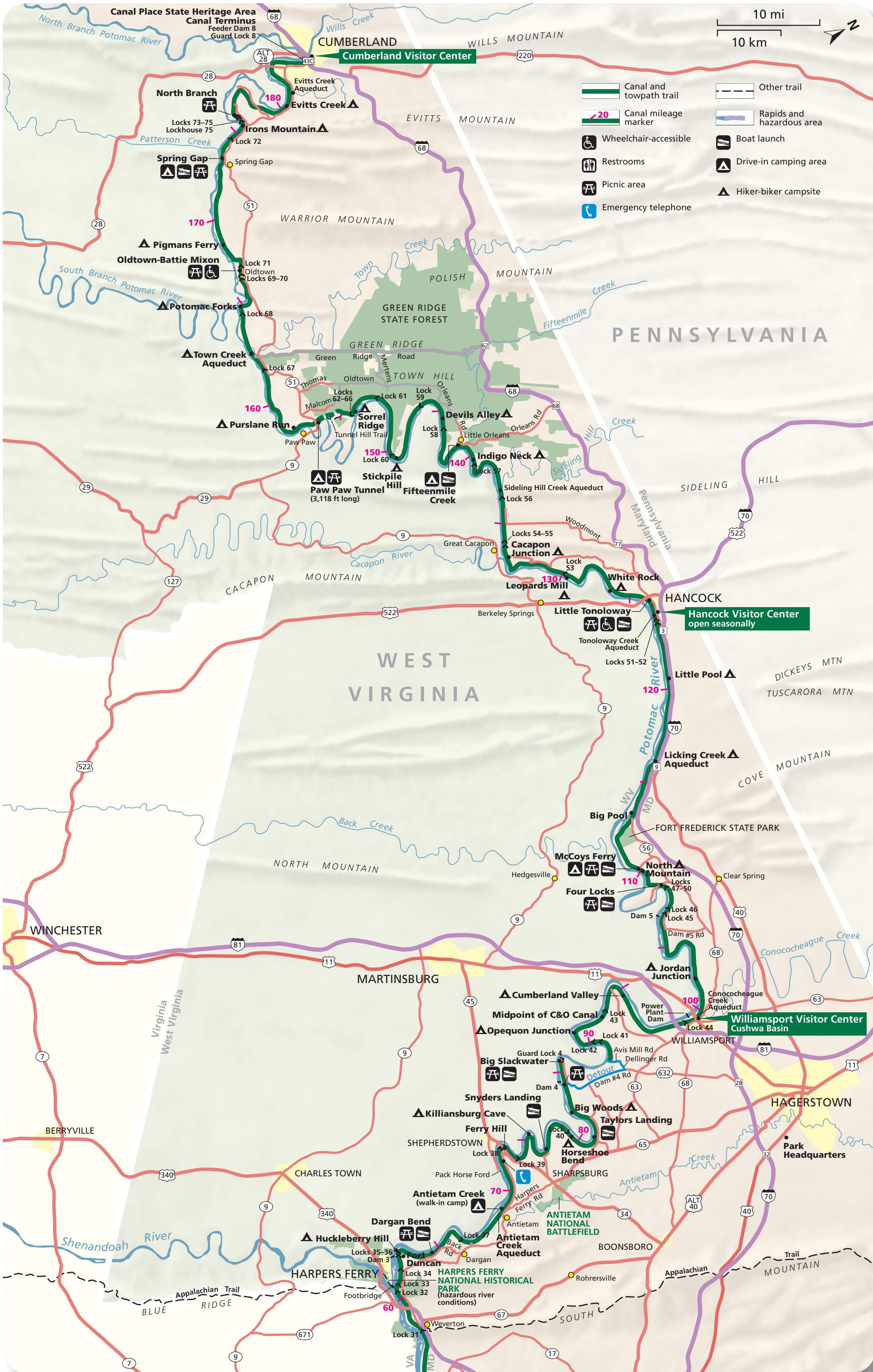
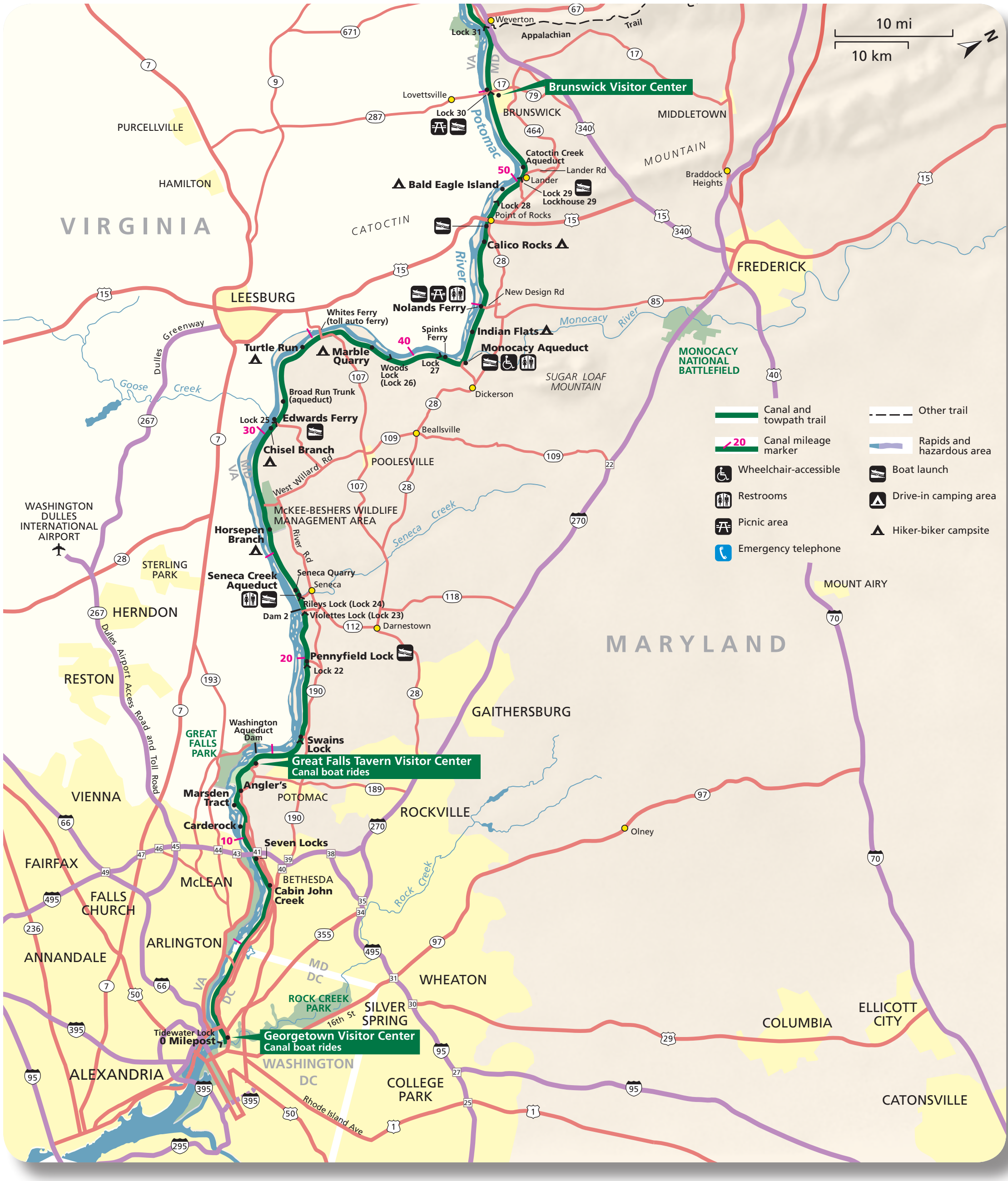


Figure 2.2. Detailed map of CHOH (continued on facing page) (NPS).


10 mi
10 km
N
VIRGINIA
MARYLAND
Brunswick Visitor Center
Great Falls Tavern Visitor Center
Canal boat rides
Georgetown Visitor Center
Canal boat rides
Weverton
Appalachian Trail
Lock 31
Lovettsville
Lock 30
BRUNSWICK
MIDDLETOWN
PURCELLVILLE
HAMILTON
Catoctin Creek Aqueduct
Lander Rd
Lander
Bald Eagle Island
Lock 29
Lockhouse 29
Lock 28
Point of Rocks
MOUNTAIN
CATOCTIN
Braddock Heights
Calico Rocks
Potomac River
FREDERICK
LEESBURG
New Design Rd
Nolands Ferry
Whites Ferry (toll auto ferry)
Indian Flats
Monocacy River
Greenway
Spinks Ferry
Monocacy Aqueduct
MONOCACY NATIONAL BATTLEFIELD
Turtle Run
Marble Quarry
Woods Lock (Lock 26)
Lock 27
Dulles
Goose Creek
Dickerson
SUGAR LOAF MOUNTAIN
Broad Run Trunk (aqueduct)
Lock 25
Edwards Ferry
Beallsville
Chisel Branch
POOLESVILLE
West Willard Rd
McKEE-BESHERS WILDLIFE MANAGEMENT AREA
WASHINGTON DULLES INTERNATIONAL AIRPORT
Horsepen Branch
River Rd
Seneca Creek
STERLING PARK
Seneca Creek Aqueduct
Seneca Quarry
Seneca
Rileys Lock (Lock 24)
Violettes Lock (Lock 23)
Dam 2
Darnestown
HERNDON
Pennyfield Lock
Lock 22
RESTON
Dulles Airport Access Road and Toll Road
GAITHERSBURG
Washington Aqueduct Dam
GREAT FALLS PARK
Swains Lock
VIENNA
Marsden Tract
Angler's
POTOMAC
ROCKVILLE
Carderock
Olney
Seven Locks
FAIRFAX
BETHESDA
Cabin John Creek
Rock Creek
FALLS CHURCH
McLEAN
ARLINGTON
ANNANDALE
WHEATON
ROCK CREEK PARK
SILVER SPRING
16th St
Tidewater Lock
0 Milepost
COLUMBIA
ELLICOTT CITY
WASHINGTON DC
COLLEGE PARK
ALEXANDRIA
Rhode Island Ave
CATONSVILLE
MOUNT AIRY
Canal and towpath trail
Canal mileage marker
Wheelchair-accessible
Restrooms
Picnic area
Emergency telephone
Other trail
Rapids and hazardous area
Boat launch
Drive-in camping area
Hiker-biker campsite

al. 2008). The Piedmont Plateau province, to the west of the Atlantic Coastal Plain, encompasses the Fall Line. This 27-km (17-mi) zone from Little Falls to Seneca, MD, divides the sedimentary rock of the east from the metamorphic rock of the west. This geological transition manifests within CHOH at the Potomac Gorge, where the numerous waterfalls and rapids presented one of the obstacles to transportation that prompted the construction of the Canal. The Piedmont province is characterized by rolling hills. Further west, the Blue Ridge province contains steep mountain and valley topography formed during several orogenic events. The Valley and Ridge province is underlain by parallel formations of sandstone ridges and carbonate, which eroded to form valleys. Carbonate formations found within this province are conducive to karst topography, which include the fissures, sinkholes, underground streams, and caverns found throughout the park.

Land use

Land cover in the Potomac River watershed is about 58% forest, 32% agriculture, 5%

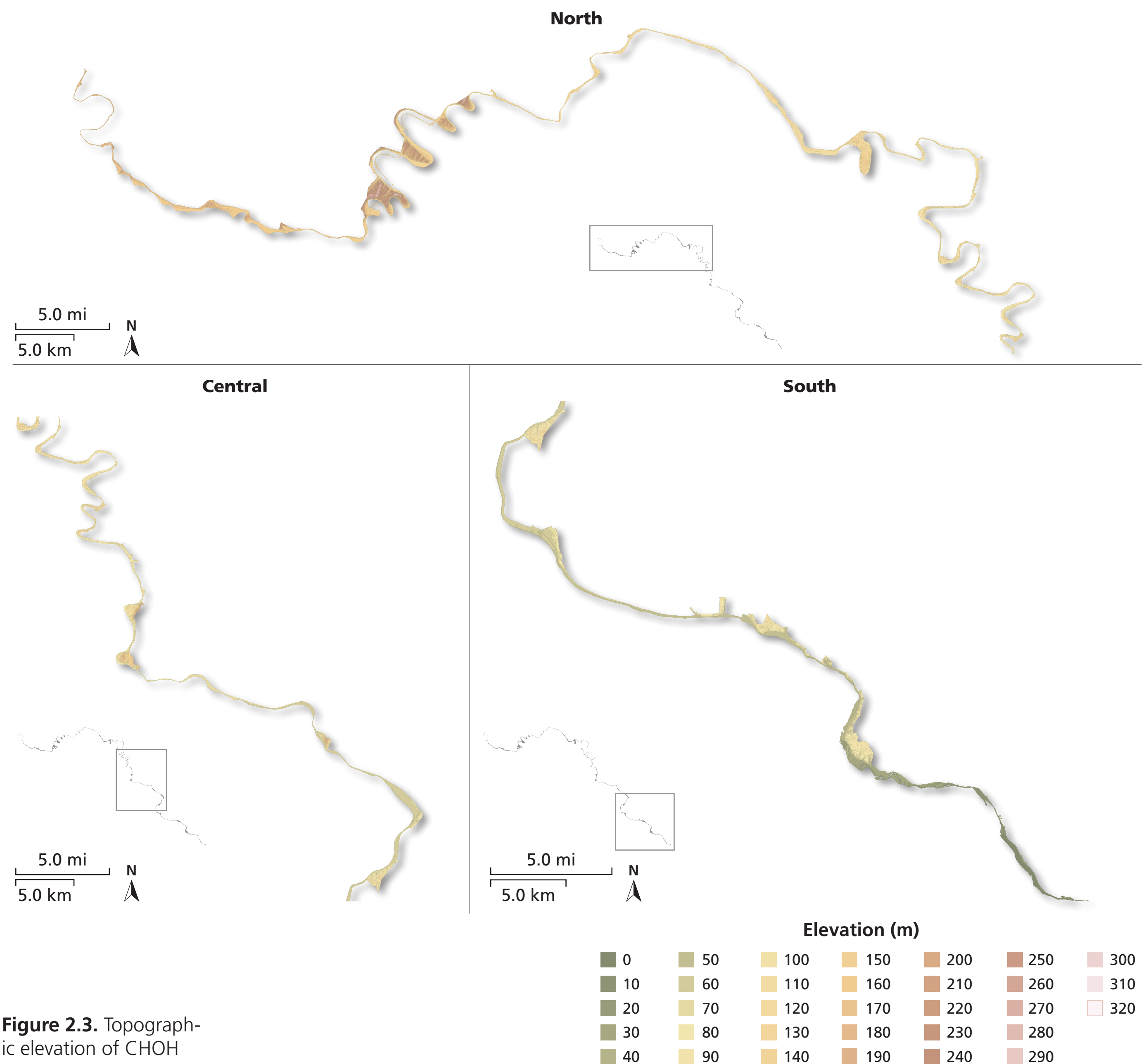


Figure 2.3. Topographic elevation of CHOH (Gesch 2007).

water and wetlands, and 5% developed (ICPRB 2012). Land use within a 30 km (19 mi) area surrounding park boundaries exhibits similar characteristics (Figures 2.4, 2.5). In the area around Washington, D.C. at the beginning of CHOH, developed land uses dominate the region, varying from high intensity near the center of the city to lower intensity further away from D.C. Open water cover is higher at the more southern, downstream extent of the Potomac River. Moving to the west, developed land becomes interspersed with other land uses, such as forest, cultivated cropland, and pastureland. Near the midpoint of the canal, pastureland is dominant, with notable bands of forestland and pockets of development around the cities of Frederick and Hagerstown. The western section is dominated by deciduous forest, with valleys of pastureland and medium intensity development at the western park terminus in Cumberland, Maryland.

Population

Approximately 6.11 million people live within the Potomac River watershed, 5.36 million of whom are located in the Washington, D.C. metropolitan area (ICPRB 2012). This metropolitan area has grown at a constant high pace for the past several decades. In the four Maryland counties through which the park passes—Montgomery, Frederick, Washington, and Allegany—population has also expanded rapidly. From 2000 to 2010, Montgomery County grew by 11.3% to nearly 1 million people; Frederick County grew by 19.5% to 233,000 people; Washington County by 11.8% to 147,000; and Allegany County by 0.2% to 75,000 people (U.S. Census Bureau 2012). Aside from Washington, D.C. and its surrounding metropolitan area, larger cities and towns along the canal include Brunswick, MD (population 6,000), Harpers Ferry, WV (300), Sharpsburg, MD (700), Williamsport, MD (2,000),

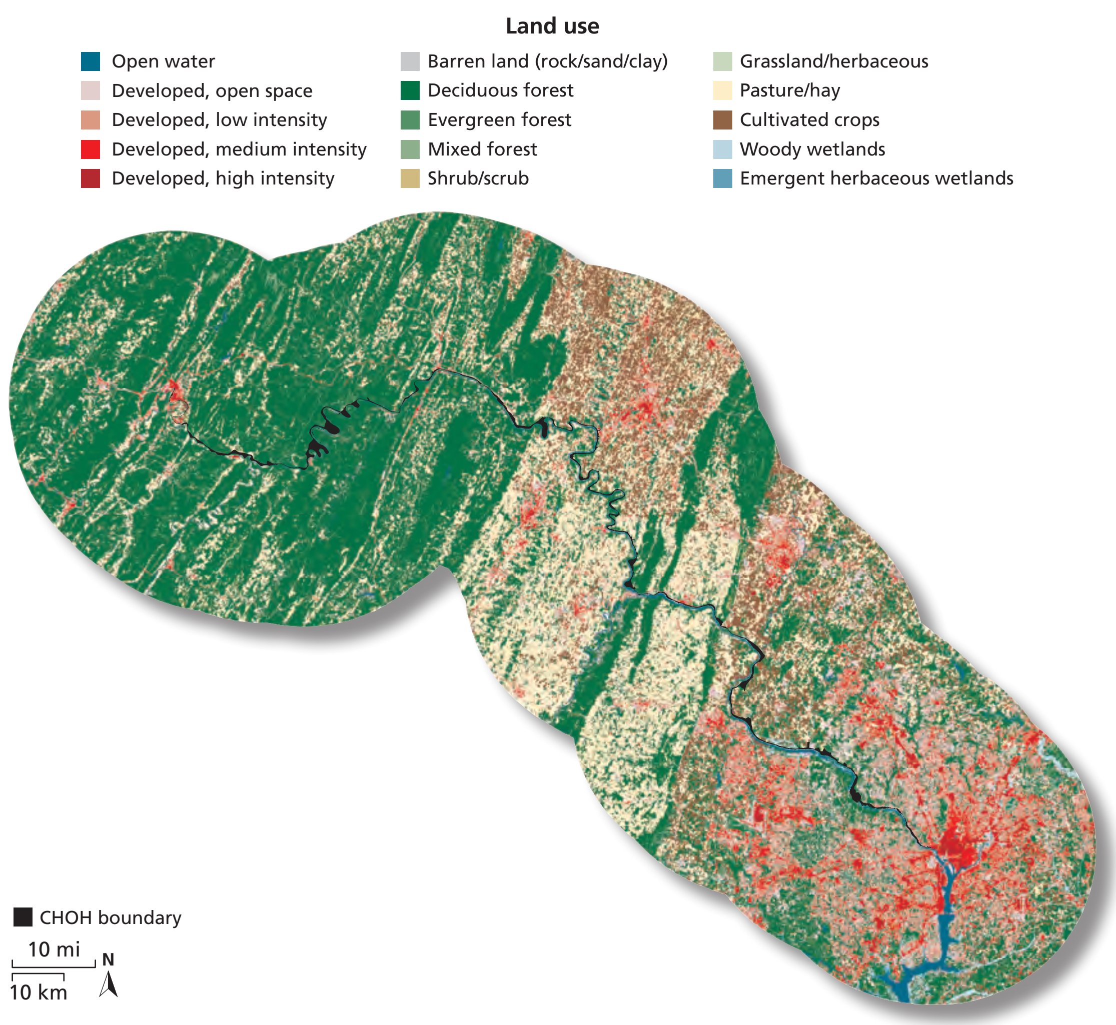


Figure 2.4. Land use within a 30-km area surrounding CHOH in 2006 (Fry et al. 2011, NPS 2011a).

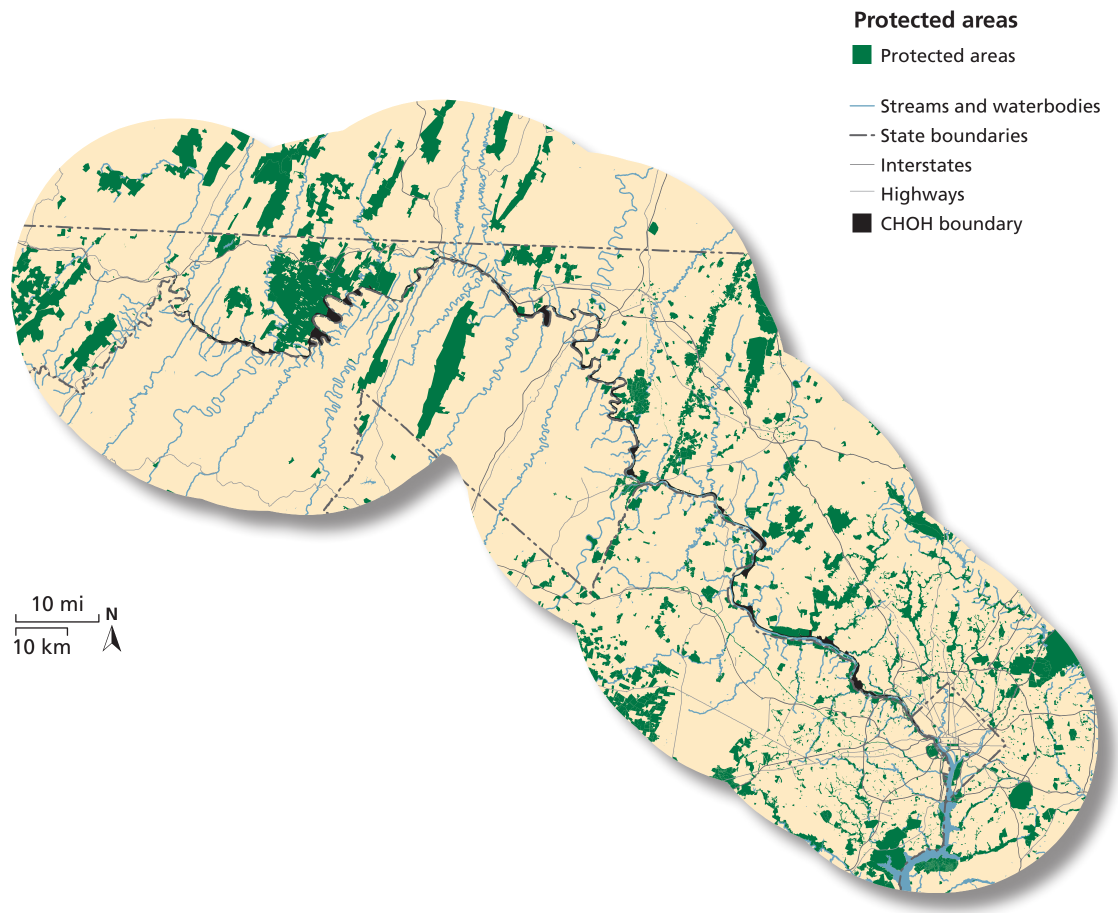


Figure 2.5. Protected areas within a 30-km area surrounding CHOH in 2011 (NPS 2010b, 2011a, USGS 2011).

Hancock, MD (1,500), and Cumberland, MD (21,000), with Leesburg, VA (43,000), Potomac, MD (45,000), Frederick, MD (65,000), and Hagerstown, MD (40,000) within close proximity (U.S. Census Bureau 2012) (Figures 2.6, 2.7).

Climate

Temperatures in the park range from wintertime lows around 0°C (32°F) to summertime highs of 27°C (80°F) (NPS 2009). Temperatures are higher in the eastern part of the park, where Washington, D.C. is affected by both the maritime climate (Weeks 2001) and urban heat island effects. Annual precipitation is moderate and varies along a gradient, with about 91 cm (36 in) falling on Cumberland on the western end to slightly more, about 98 cm (39 in), in Washington, D.C. on the eastern end (Weeks 2001). Average annual snowfall is 45 cm (18 in). Thunderstorms occur with some frequency during the late spring and summer, and cause heavy precipitation and wind gusts. Other weather events, such as tornadoes, hailstorms, tropical storms, floods, and blizzards occur within and near the park (Allen and Flack 2001). The average last freezing temperature in the spring is April 1 and average first freezing temperature in the fall is November 10 (Allen and Flack 2001).

2.1.3 Visitation statistics

Annual visitation to CHOH has fluctuated over the past 10 years, although has been increasing since 2007 (NPS 2010c) (Figure 2.8). Visitors in 2012 numbered over four million, making it one of the most visited National Park units in the country.

Surveys were conducted during the summer of 2003 to assess visitor use. Most visitors travelled to the park in family groups (46%), while groups of two were also common (38%), and some visited the park alone (20%) (Meldrum et al. 2004). The majority of visitors had visited the park more than once: 29% had visited only once, while 44% had visited nine or more times. Most visitors were 31–60 years old (53%),

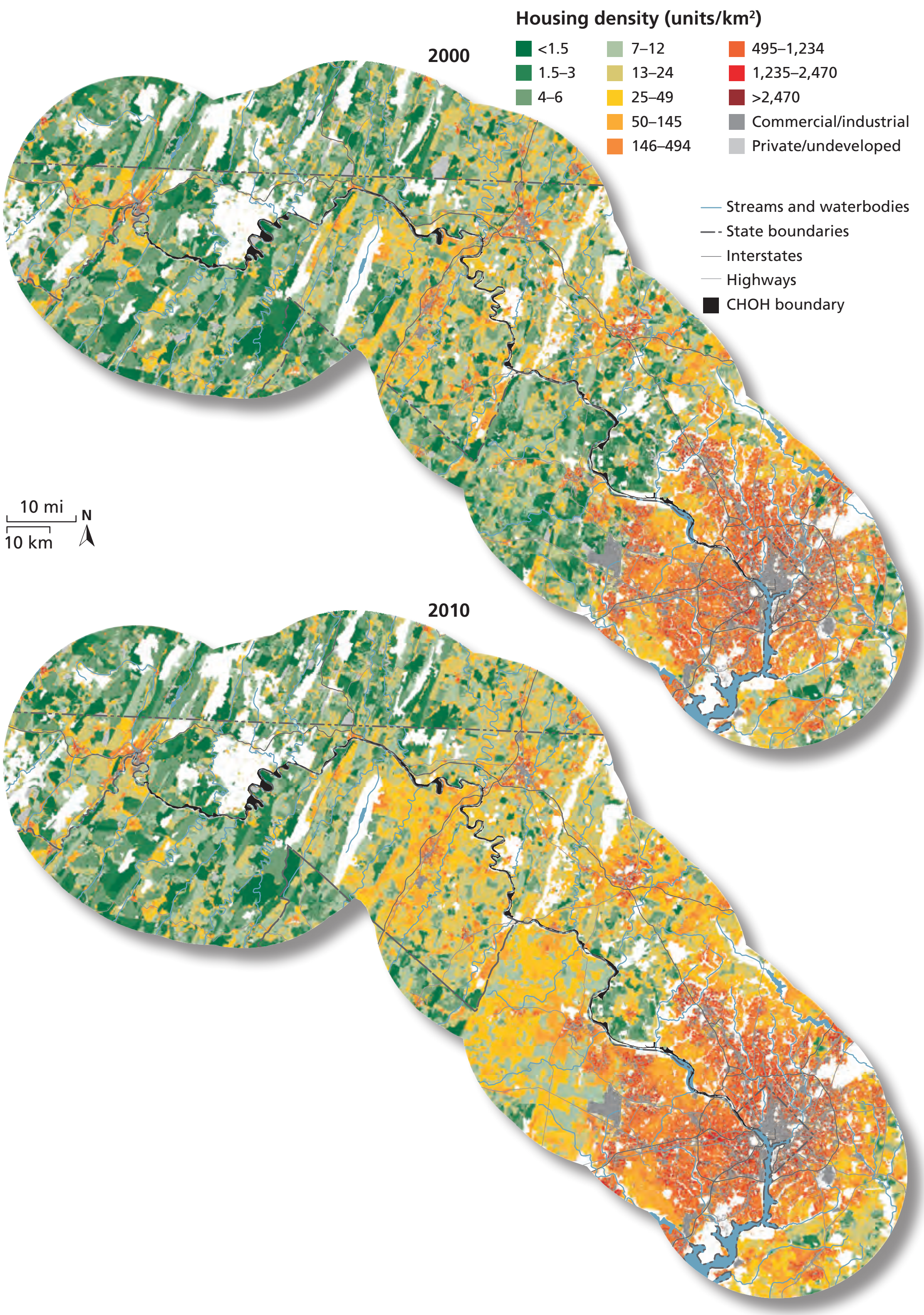
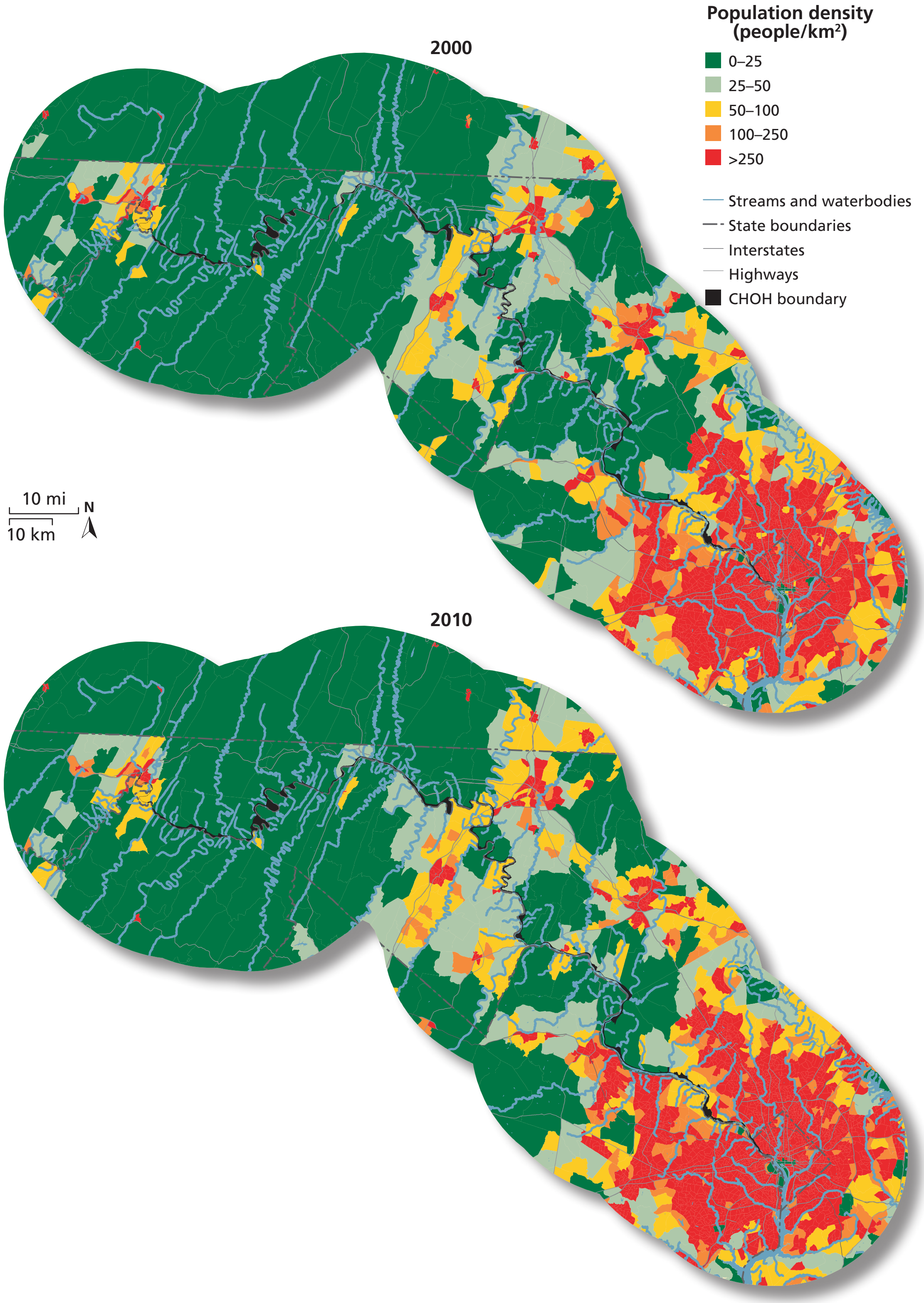


Figure 2.6. Housing density within a 30-km area surrounding CHOH in 2000 and 2010 (NPS 2010b, 2011a).

Figure 2.7. Population density within a 30-km area surrounding CHOH in 2000 and 2010 (NPS 2010b, 2011a).



with 18% of visitors younger than 15 years old. Marylanders were the primary visitors (45%), but residents of Virginia (17%), Washington, D.C. (11%), other states (22%), and international countries (5%) comprised the rest. Most visitors (75%) spent between 1–3 hours in the park. The most common activities within the park included jogging, walking, or hiking (64%), viewing Great Falls (28%), bicycling (22%), and visiting visitor centers (21%) (Meldrum et al. 2004).

Visitors to the park generally fall into one of four categories: tourists, short-term towpath users, long-term towpath users, and non-towpath users (Parsons 1976). Tourists generally visit for a short period of time and focus on the historic areas of the canal. Short-term towpath users recreate (e.g., walk, hike, bike, jog, canoe, horseback ride) for a portion of a day within the park. Long-term towpath users also recreate within the park, but for a longer period of time, generally at least one overnight. These users might travel the entire 297-km (184.5-mi) length of the park. Non-towpath users typically utilize adjacent areas of the park, particularly the Potomac River (Parsons 1976).

Based on the variety of visitor use patterns, the Park has been subdivided into five zones, ranging from high- to low-density visitor use (Parsons 1976). The goals for the zones differ, with higher density areas targeted for complete historic restoration, while low-density areas are intended for a remote natural experience. The zones are as follows: A) National Interpretive Center Zone; B) Cultural Interpretive Zone; C) Short-term Recreation Zone; D) Short-term Remote Zone; and E) Long-term Remote Zone.

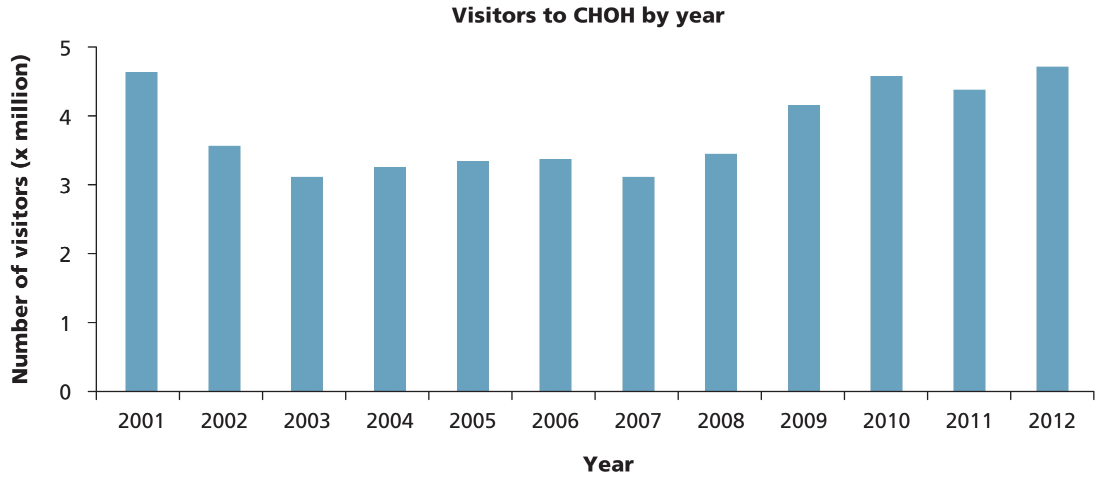


Figure 2.8. Visitors to CHOH over the past decade by year and by month (NPS 2010c).

2.2 NATURAL RESOURCES

2.2.1 Resource descriptions

Natural resources in the park, and threats to those resources, are depicted in Figure 2.9.

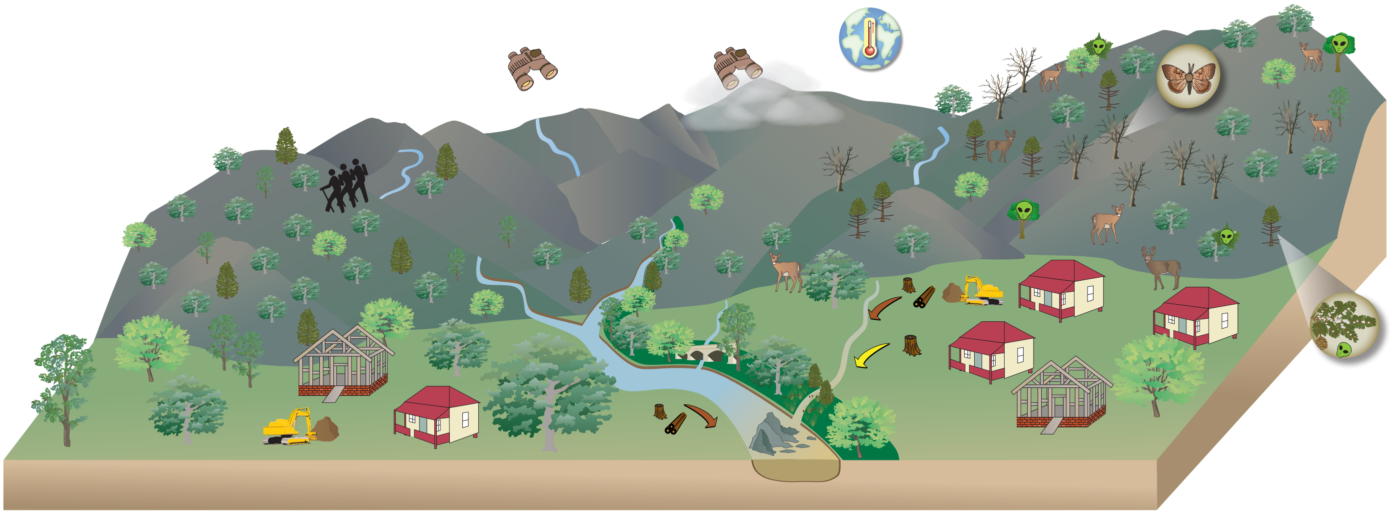
Geology

The Potomac River watershed crosses over five physiographic provinces from east to west: the Atlantic Coastal Plain, Piedmont Plateau, Blue Ridge, Valley and Ridge, and Appalachian Plateau, although CHOH itself does not extend into the Appalachian Plateau (Thornberry–Ehrlich 2005, Southworth et al. 2008) (Figures 2.1, 2.10). The provinces differ in their underlying bedrock, surficial deposits, and landscape. Precambrian rocks form the foundation on top of which other geological formations were deposited. The oldest rocks—granite gneisses—of the Catoctin and Swift Run Formations were deposited more than a billion years ago, and intruded by volcanic rocks over a period of 100 million years during the Proterozoic Eon. These rocks are exposed in the Blue Ridge province. Fluvial and shallow-marine sediments were subsequently deposited, as evidenced within the western Piedmont and Valley and Ridge provinces. Within the Great Valley section of the Valley and Ridge province, carbonate rocks from the Cambrian and Ordovician Periods (545–480 million years ago) were formed and then overlain by Ordovician shale (450 mya) during the Taconian orogeny. Sedimentary rocks within the Piedmont province were thrust westward, and deposition of sandstone, shale, siltstone, quartzite, and limestone occurred within the shallow-marine and deltaic Appalachian basin, now the Valley and Ridge province. This sedimentation continued from the Ordovician through the Permian Period (480–280 mya). During the Alleghanian orogeny, the North American and African continental plates collided to produce the Appalachian Mountain range, and rocks within the Blue Ridge and Piedmont provinces moved westward into the Valley and Ridge province. Over the ensuing 20 million years (220–200 mya) of the Mesozoic Era, the rocks rifted and fractured, and were deposited by alluvial fans from the Blue Ridge and Piedmont provinces to the western Piedmont. Igneous rocks subsequently intruded, creating diabase dikes and sills. Erosion of unconsolidated gravel, sand, and silt deposited onto the Atlantic Coastal Plain province, a process that continues today (Southworth et al. 2008).

Paleontology

Fossils are reported from geological formations of various ages along the canal (Clites and Santucci 2010). Exposures of fossiliferous formations within the park are limited, therefore, many fossil remains are known from exposures occurring in proximity to the park. The Poolesville Member of the Manassas Sandstone within the Culpepper Basin of the Piedmont province contains plant fossils; trace fossil burrows of crustacean Scoyenia in outcrops and stone quarries; fossil footprints of Cheirotherium (Triassic archosaur), Brachychirotherium (Triassic armadillo-like aetosaur), and Plesiornis pilulatus (primitive bird); and plant spores and pollen near Seneca and Comptons Corner (Clites and Santucci 2010). Within the Blue Ridge province, the Harpers Formation contains fossil burrows of the worm trace fossil Skolithos dating to the early Cambrian. The Antietam Formation above Harpers Ferry has abundant fossils; along with Skolithos, the trilobite Olenellus, hyolithids, ostracods, brachiopods, and trace fossils of Rusophycus and Planolites are found.

The Valley and Ridge province, and particularly the Great Valley section, is especially rich in fossil remains due to its younger geological age that coincides with the Cambrian Explosion (Clites and Santucci 2010). Within the Bolivar Heights and Fort Duncan Members of Tomstown Formation, Salterella (potentially a mollusc, but yet undetermined) and trilobite fragments have been found. The Dargan Member contains microbial mats and algal stromatolites, potentially also within the park area. The Elbrook Formation contains stromatolites and various trilobites (e.g., Amecephalina, Glyphaspis, Olenoides) along the canal. Within the Conococheague Formation are trilobites and conodonts; algal mounds with gastropods, brachiopods, and trilobites are also present in proximity



Natural resources

- Scenic views (good air quality)
- Native plant communities
- Historic places and events
- Sustainable visitor use

Threats to park natural resources

- Obstructed scenic views (poor air quality)
- Invasive exotic species (including gypsy moth, hemlock woolly adelgid, and plant species)
- Deer overpopulation
- Exotic diseases and tree death
- Adjacent land use/development
- Sediments and contaminants
- Global climate change (including increasing stream temperature)

Figure 2.9. Features of and threats to the natural resources of CHOH.

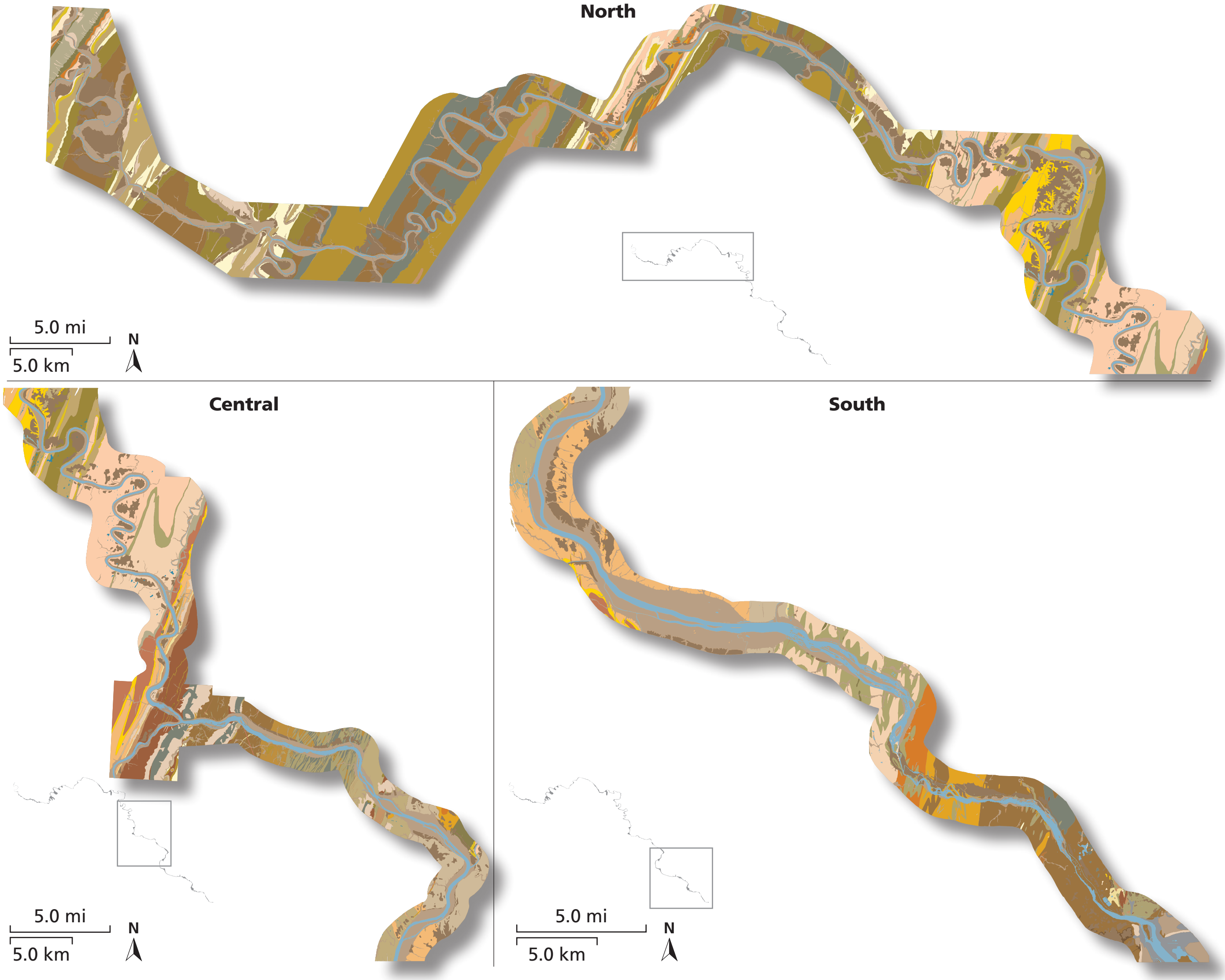


Figure 2.10. Geology of CHOH (Thorneberry–Ehrlich 2005).

Surficial units

- Colluvium
- Alluvium
- Terraces
- Potomac Formation
- Sinkholes
- Water
- Artificial fill

Bedrock units

- Diabase dike
- Metasediment
- Balls Bluff Silstone Formation, Leesburg Member
- Balls Bluff Silstone Formation, Lacustrine Member
- Manassas Sandstone Formation, Poolesville Member
- Manassas Sandstone Formation, Tuscarora Creek Member
- Manassas Sandstone Formation, Restone Member
- Purslane Formation
- Rockwell Formation
- Lamprophyre dike
- Hampshire Formation
- Foreknobs Formation
- Brallier and Scherr Formation
- Mahantango Formation
- Marcellus Shale and Needmore Formations
- Oriskany Formation
- Helderberg Formation and Keyser Limestone
- Tonoloway Limestone
- Wills Creek Formation
- Bloomsburg Formation
- McKenzie Formation
- Keefer Sandstone
- Rosehill Formation and Keefer Sandstone
- Rosehill Formation
- Tuscarora Quartzite
- Juniata Formation
- Martinsburg Formation, Upper Member
- Martinsburg Formation, Stickley Run Member
- Chambersburg Limestone
- New Market Limestone
- Pinesburg Station Dolomite
- Kensington Tonalite
- Georgetown Intrusive Suite, biotite–hornblende tonalite
- Georgetown Intrusive Suite, biotite tonalite
- Georgetown Intrusive Suite, quartz gabbro and quartz diorite
- Georgetown Intrusive Suite, serpentinite–schist
- Dalecarlia Intrusive Suite, biotite monzogranite and granodiorite
- Dalecarlia Intrusive Suite, muscovite trondjemite
- Rockdale Run Formation
- Bear Island Granodiorite
- Stonehenge Limestone
- Stonehenge Limestone, Stoufferstown Member
- Quartz veins
- Conococheague Limestone
- Conococheague Limestone, Big Spring Station Member
- Frederick Formation, Adamstown Member
- Frederick Formation, Rocky Springs Station Member
- Elbrook Limestone
- Araby Formation
- Waynesboro Formation, Chewsville Member
- Waynesboro Formation, Cavetown Member
- Waynesboro Formation, Red Run Member
- Tomstown Formation
- Tomstown Formation, Dargan Member
- Tomstown Formation, Bebevola Member
- Tomstown Formation, Fort Duncan Member
- Tomstown Formation, Bolivar Heights Member
- Carbonaceous phyllite
- Antietam Formation
- Harpers Formation
- Harpers Formation, quartzite
- Weverton Formation
- Sykesville Formation
- Laurel Formation
- Loudoun Formation, conglomerate
- Loudoun Formation, phyllite
- Ijamsville Phyllite Formation
- Ijamsville Phyllite Formation, greenstone
- Ijamsville Phyllite Formation, argillaceous metalimestone
- Mather Gorge Formation, metagraywacke
- Mather Gorge Formation, migmatite
- Mather Gorge Formation, phyllonite
- Mather Gorge Formation, schist
- Ultramafic rock
- Amphibolite and ultramafic rock
- Metagabbro and metapyroxenite
- Tuffaceous schist
- Catoctin Formation, metabasalt
- Catoctin Formation, metasandstone and phyllite
- Catoctin Formation, phyllite
- Catoctin Formation, marble
- Metarhyolite dike
- Metadiabase dike
- Swift Run Formation, marble
- Swift Run Formation, phyllite
- Swift Run Formation, metasandstone
- Biotite granite gneiss
- Leucocratic metagranite
- Garnetiferous leucocratic metagranite
- Quartz–plagioclase gneiss
- Hornblende monzonite gneiss
- Garnet–graphite paragneiss

to the park. The Stonehenge Limestone of the Beekmantown Group hosts stromatolites, brachiopods, gastropods, straight nautiloid cephalopods, and conodonts, likely within the park; the Rockdale Run Formation contains these fossils as well as sponges and corals. Rock Park and New Market Limestone within the park expose fossils of gastropods, brachiopods, colonial tabulate coral Tetradium, cephalopods, ostracods, and algal colonies. The late Silurian Willis Creek Formation has exposures along the park that yield ostracode Leperditia, bryozoans, brachiopods, trilobite Calymene, and gastropod Hormotoma. The Tonoloway Limestone also exposed leperditiid ostracodes. Brachiopods and fossil "coral heads" can be observed within the lock infrastructure of Locks 74 and 75, which were built from Keyser Limestone rocks. Gastropods, corals, crimoids, pelecypod bivalves, trilobites, and brachiopods characterize the Devonian formations of the Oriskany Sandstone within and near the park. Brachiopod molds are visible at the base of the Dam 6 abutments, as well as in culverts built within the canal. Exposures of Marcellus Shale within CHOH show brachiopod Leiorhynchus, pteropod mollusc Styliolina, pelecypods, gastropods, cephalopods, and conodonts. Fossil burrows have been found above the north portal of the Paw Paw Tunnel. The Foreknobs Formation is exposed in numerous places, including near Indigo Tunnel and Paw Paw Tunnel, and is one of the most fossiliferous formations within the park. It contains brachiopods, pelecypod bivalves, echinoderm (crinoid) plates, in addition to plant stems and debris (Clites and Santucci 2010).

Caves

Numerous cave features, including mines connected to or mistaken for caves, have been identified within the park or in the vicinity (Franz and Slifer 2001, Tudek and Vesper in press). These are located almost exclusively within the Valley and Ridge province of Washington County and include Antietam Quarry Cave, Artz Cave, Cave-in-the-Field, C&O Canal Cave, Dam No. 4 Cave, Dam No. 6 Mine, Dargan Quarry Caves, Dellingers Cave, Eby Cave, Howell and Little Howell Caves, McMahon's Mill Caves No. 1 and No. 2, Natural Well, Neck Cave, Pinesburg Cave, Round Top Mines No. 1–5 and 7 and Caves No. 6 and 8, Round Top Summit Cave, Round Top No. 2 Cave, Synders Landing Caves No. 1 and No. 2, and Two Locks Caves (Franz and Slifer 2001).

These cave formations are predominantly solutional caves, in which the carbonic acid in groundwater slowly dissolves soluble carbonate rocks (e.g., limestone, dolomite, marble). The act of groundwater dissolution also results in the formation of speleothems, such as stalactites, stalagmites, flowstone, and crystals. Some non-solutional, or fissure, caves also exist in Maryland, typically within bedrock joints and fractures. Tomstown Dolomite, Elkbrook Limestone, Conococheague Limestone, Beekmantown Limestone, Stones River Limestone, Tonoloway Limestone, Keyser Formation, and Oriskany Sandstone contain the caves near the park (Franz and Slifer 2001, Tudek and Vesper in press). Many cave complexes of karstic origin also include sinkholes. Over time, the Potomac River eroded and incised into the bedrock layers, exposing the caves known near the park in these geological formations. Several of these caves contain thick deposits of gravel, clay, and silt deposited from the Potomac River. Groundwater serves to hydrologically connect several of these cave systems, such as the streams running through Natural Well, Cave-in-the-Field, McMahons Mill Caves, and Howell Cave (Franz and Slifer 2001).

Many animals are found in the cave ecosystem, particularly within the naturally illuminated twilight zone (Franz and Slifer 2001). Trogloxenes, or animals that utilize the cave temporarily but cannot complete their life cycle within the cave, include cave crickets, cave moths, red-backed and slimy salamanders, wood rats, and bats. Six bat species found within CHOH are primarily cave-dwelling, including the endangered Indiana bat (*Myotis sodalis*). Troglophiles are capable of completing their life cycle within the cave, and include planarians, cave spiders, collembolans, and long-tailed salamanders. Obligate cave dwellers, or troglobites, live deep within the cave interior. Some spiders, millipedes, collembolans, and crustaceans exhibit adaptations necessary for this life style (Franz and Slifer 2001). Howell Cave in the cliffs along the Potomac River hosts several rare subterranean invertebrates: the only known population of the Blue Ridge spring snail (*Fontigens orolibas*) in the state (listed as endangered), an undescribed *Sphalloplana* planarian, the state watchlist Price's cave isopod (*Caecidotea pricei*), and the Allegheny cave amphipod (*Stygobromus allegheniensis*), a state species in need of conservation (Bartgis et al. 1993). The state-endangered Appalachian spring snail (*Fontigens bottimeri*), a rare planarian, and a rare amphipod are also found in Dellingers Spring and the caves of Roundtop Hill. The state-endangered amphipods (*Stygobromus biggersi* and *Stygobromus gracilipes*) have been documented in Dam No. 4 Cave (Bartgis et al. 1993).

Soils

The National Park Service, in conjunction with the United States Department of Agriculture and Natural Resource Conservation Service, is working to develop a soil survey map for the park (*https://irma.nps.gov/App/Reference/Profile/2171198*).

Soils vary in their parent material and drainage classes based on their physiographic region and geologic setting. Underlying the upland forests of the Piedmont and Blue Ridge provinces are well drained, moderately deep to deep soils, in addition to impermeable fragipans (Weeks 2001). Limestone is present in the soils of the Great Valley section of the Valley and Ridge province, allowing for productive agricultural use. Soils of the Coastal Plain province vary from very poorly to excessively drained, but tend to be sandier in structure. Floodplain soils tend to be silt loam or silty clay loam, deep, and somewhat poorly to poorly drained (Weeks 2001).

Groundwater

Within the Potomac River basin, carbonate rock contains the largest groundwater supplies, particularly in the Great Valley section of the Valley and Ridge province (Weeks 2001). Aquifers in the Blue Ridge and Piedmont provinces are small, with springs that are accordingly seasonal and low in flow. These springs serve as important habitat for groundwater invertebrates, some of them rare. Water is transmitted within these provinces through joints and bedding planes. The groundwater quality, however, is affected by elevated levels of iron, acidity, radon, pesticides, and nutrients (Weeks 2001). Groundwater that flows through carbonate bedrock of soluble materials (e.g., dolomite, limestone) slowly dissolves the material and forms karstic features. Karst aquifers are particularly susceptible to land use (e.g., agricultural use of pesticides) and flow alteration and withdrawals (Weeks 2001).

McMahon's Mill Cave #1. Photo by Eckee.

Waterways

The canal's entire 297 km (184.5 mi) length is built adjacent to the Potomac River (Figures 2.1, 2.2). The Potomac River watershed drains 37,995 km^2 (14,670 mi^2) across Maryland, Virginia, West Virginia, Pennsylvania, and the District of Columbia (ICPRB 2012). After the Susquehanna River, the Potomac is the largest tributary to Chesapeake Bay. The major tributaries to the Potomac River are the Shenandoah River, South Branch, North Branch, Cacapon River, Conococheague Creek, Monocacy River, and Anacostia River (Allen and Flack 2001; ICPRB 2012). Approximately 261 perennial and hundreds of intermittent streams flow through the park, primarily by entering the canal and then exiting into the Potomac River via waste weirs (NPS 1996b, Weeks 2001). Some larger streams flow under the canal and into the Potomac River.

While many springs have 'hard water' (enriched with calcite), some take this to the extreme. Some springs contain so much calcite that once they reach the surface, the change in atmosphere is enough to cause the spring to drop some of its mineral content. This frequently happens when the stream is aerated—frequently over rapids, rocky terrain or waterfalls. The released minerals accumulate on the surface in large mounds, called travertine. While travertine mounds are common in places like Yellowstone National Park, they are just as welcome (if less frequent) along the canal. Photo by John Tudek, West Virginia University.

The average water flow in the Potomac at Washington, D.C. is 26 billion liters (7 billion gallons) per day before water withdrawals—withdrawals account for 1,840 million liters (486 million gallons) per day for Washington area water supply, and 380 million liters (100 million gallons) per day for groundwater withdrawals in rural areas (ICPRB 2012). The Potomac River supplies 75% of the drinking water for the metropolitan Washington, D.C. area, and 100% of the drinking water for the District of Columbia itself (U.S. EPA 2004). Wastewater treatment plants in D.C. (Blue Plains Plant), Arlington VA, and Alexandria VA discharge water into the river (US EPA 2004).

Due to a combination of underlying geology and high precipitation, the Potomac River is subject to flashy hydrology with frequent flooding events (Allen and Flack 2001). The average low flow occurs in September, while the average high flow typically occurs in March, primarily in response to snowmelt and occasionally from tropical storms. Historic low flows at Great Falls was recorded as 693 cubic feet per second (cfs) (448 million gallons per day [mgd]) in 1914, and historic high flows were recorded at 475,976 cfs (307,677 mgd) in 1936 (Weeks 2001). Low flows are detrimental to water quality and aquatic life. Quantity of water for municipal and industrial uses may be reduced during low flows, and demand for water also tends to increase during dry periods (Weeks 2001). Although precipitation is highest in spring and summer, the greatest input to groundwater aquifers occurs in winter and spring. Temporal recharge asymmetry is due primarily to phototranspiration uptake by plants during the growing season. When plants are dormant, from November to April, groundwater infiltration is highest and spring emergence flow rates peak (Otten and Hilleary 1985).

Numerous dams were constructed along the Potomac River for the purposes of maintaining canal water levels (Feeder Dams), hydroelectric power production, and flood control (Weeks 2001). Moving up the canal from Washington, D.C. to Cumberland, these dams include Feeder Dam 1/ Little Falls Dam (mile 5.5), Washington Aqueduct Dam (mile 14), Feeder Dam 2 (mile

23), Feeder Dam 3 (mile 62), Feeder Dam 4 (mile 84), Potomac Edison/Allegany Energy Dam (mile 100), Feeder Dam 5 (mile 107), and a replacement dam for Feeder Dam 8 (mile 184.5). The Washington Aqueduct Dam is located directly upstream of Great Falls and is used for municipal water supply. Hydroelectric facilities exist on Dams 4 and 5. More than 97 km (60 mi) of the canal is watered, either naturally or through park maintenance (NPS 2009).

The canal passes under the Capital Beltway (Route I495). Photo by NPS.

Wetlands

Wetlands are defined by the presence of one or more of the following: hydrology that supports flooding and saturation, hydric soils, and hydrophytic plants (Cowardin et al. 1979). Wetlands are classified as five types: marine, estuarine, riverine, lacustrine, and palustrine (Cowardin et al. 1979)—the latter three of which are found within CHOH (Weeks 2001). Riverine systems are defined by wetlands and deepwater habitats contained within a channel, excluding those areas dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and those habitats with salinity greater than 0.5 parts per thousand (ppt). Riverine wetlands are subdivided by tidal, lower perennial, upper perennial, and intermittent. Lacustrine systems are situated in a topographic depression or dammed river channel; lack trees, shrubs, persistent emergents, emergent mosses, or lichens with greater than 30% cover; and maintain at least 8 ha (20 acres) in area. These wetlands are either limnetic or littoral, tidal or nontidal, but with less than 0.5 ppt salinity. Palustrine wetlands include nontidal areas with vegetation dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and tidal areas with less than 0.5 ppt salinity. It includes such wetland types as marsh, swamp, bog, fen, and prairie (Cowardin et al. 1979).

The majority—approximately 85%—of the park lies within the 50-year floodplain of the Potomac River (Parsons 1976; NPS 1996b) (Figure 2.4). This creates conditions conducive to the occurrence of wetlands (Weeks 2001). Forested palustrine wetlands comprise the majority of those wetland areas, but riverine and lacustrine types are also present. Such wetlands include the floodplain island of Bear Island (61 ha [150 acres]), Dickerson Floodplain (36 ha [90 acres]), Cabin John Island (20 ha [50 acres]), and the Olmstead Island Complex, including Olmstead Island, Falls Island, and land adjacent to Lock 17 (Weeks 2001).

The Potomac Gorge is also rich in wetland types, such as vernal pools, permanent ponds, springs and seeps, wet floodplain forests, and seasonal riverbank wetlands (Allen and Flack 2001). The National Wetland Inventory has mapped about 300 discrete wetland units within the Gorge area, 114 ha (281 acres) of which are palustrine, 65 ha (160 acres) are riverine, and 11 ha (27 acres) are lacustrine. Springs and seeps may serve as habitat for rare groundwater invertebrates, some of which are state-listed. Wetland types also contain numerous rare plants: two globally rare and 28 state-rare species, 21 of which are state-listed as endangered or threatened (Allen and Flack 2001).

Flora

According to NPFLORA, 1,258 native and 261 non-native plant species have been identified within the park (NPS 1996a). Over the course of the 2006–2009 forest vegetation monitoring surveys, 52 species of trees, nine species of shrubs, and 17 species of vines were documented within CHOH (Schmit et al. 2012). Box elder (*Acer negundo*), a short-lived tree common in early successional habitats prone to flooding, was the most prevalent tree species. Silver maple (*Acer saccharinum*) and American elm (*Ulmus americana*) are important bottomland tree species, while green ash (*Fraxinus pennsylvanica*) and common hackberry (*Celtis occidentalis*) are important bottomland seedling species (Schmit et al. 2012). Shade-tolerant upland tree species include chestnut oak (*Quercus prinus*), red maple (*Acer rubrum*), and American beech (*Fagus grandifolia*); early successional species range in shade intolerance and include tuliptree (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), black cherry (*Prunus serotina*), bitternut hickory (*Carya cordiformis*), and Eastern red cedar (*Juniperus virginiana*). Northern spicebush (*Lindera benzoin*) was the most common shrub.

A grass, sedge, and rush survey of the park yielded 181 species, 26 of which are non-native introduced species (Engelhardt et al. 2008). This survey found 10 species of state-endangered, highly rare, rare, and watchlist grasses and sedges not previously documented in the park (Engelhardt et al. 2008). The invasive graminoid, Japanese stiltgrass (*Microstegium vimineum*), presents the greatest management challenge due to its prevalence and propensity to outcompete native species.

Rare, threatened, and endangered plants

Three surveys have been conducted with specific attention paid to documenting rare, threatened, and endangered (RTE) plants: during 1994–1995 field surveys from Sandy Hook to Cumberland (Wiegand and Becker 1995), in 1998 for Potomac Gorge (Wiegand 1999), and during 1999–2000 from Sandy Hook to the District of Columbia (Wiegand 2001). When the species from the three surveys are combined, 219 rare, threatened, and endangered species were documented in at least one of the surveyed sections of the park. The conservation status of several of these species has changed since the surveys were conducted. When compared to the most recent Maryland Natural Heritage List , the species in the park results in 71 state-endangered, 26 state-threatened, 10 highly rare, 12 rare, six possibly rare, 52 watch list, and nine extirpated species (Maryland Natural Heritage Program 2010a). Two species—twin oats (*Diarrhena americana*) and Clingman's hedge-nettle (*Stachys clingmanii*)—were included in surveys, but are considered falsely reported in the state of Maryland. Thirty-one RTE species from the surveys did not have updated status information available. Changes in status from the vegetation surveys to the Maryland Natural Heritage list indicate that the status worsened for 10 species, while the status improved for 16 species, eight of which were listed as extirpated in one or more survey but were listed as threatened or endangered according to the current Natural Heritage list. One federally listed endangered species, harperella (*Ptilimnium nodosum*), was documented during the 1994–1995 surveys (Wiegand and Becker 1995). Efforts were made to reintroduce the species into the park in 2008. Annual surveys have been conducted to document survival of the plants. No surviving specimens were located at the introduction sites during the 2012 survey (M. Carter, pers. comm.).

Rare, threatened, and endangered species are concentrated in significant habitat types. Those types identified from Sandy Hook to Cumberland include: floodplain forest, floodplain scourbar, floodplain old-field, upland rich limestone forest, upland dry limestone forest, upland limestone woodland, upland limestone cliff (cool and shaded), upland limestone cliff (dry and open), upland rich shale forest, upland dry shale forest and woodland, upland shale barren and cliff, and upland sandstone (Wiegand and Becker 1995). Significant habitat types identified in the Sandy Hook to D.C. area—including Potomac Gorge—include scour bar, scour prairie, scour savanna, bedrock terrace woodland, bedrock terrace forest, exposed bedrock, depositional bar, various wetlands, rich floodplain forest, and upland forest (Wiegand 1999; Wiegand 2001).

More than 40 state and nationally significant natural areas exist within the park (NPS 2009). The Potomac Gorge near Great Falls, including the river islands and shoreline of Falls, Olmstead, Rocky, Bear Islands, and Chain Bridge Flats, represents unique river ecosystems (NPS 1996a), with six globally rare riparian communities that host 25 state-rare plant species and four globally rare terrace communities that host three globally rare and 32 state-rare plant species (Allen and Flack 2001). Many additional rare species are found with the Gorge but not within rare community assemblages: five globally rare and 30 state-rare riparian plants, and10 state-rare terrace plants (Allen and Flack 2001). Within the floodplain terrace of the Lander natural area, the state-threatened white trout lily (*Erythronium albidum*) occurs in the most significant concentration in Maryland (Bartgis et al. 1993). The floodplain forests of Nolands Ferry and Sycamore Landing – Hunting Quarter support state-threatened Shumard's oak (*Quercus shumardii*), state-endangered starry false Solomon's-seal (*Smilacina stellata*), and white trout lily; the lily is also found on the floodplain at Fort Duncan North (Bartgis et al. 1993). Rare ostrich fern (*Matteuccia struthiopteris*) is found along the floodplain forest at Little Pool and Roundtop Hill.

The Appalachian shale barren, a rare community type restricted to the Valley and Ridge province of the central Appalachians and found near the Paw Paw Tunnel and Bevan Bend also host globally rare and unique plants (Bartgis et al. 1993; NPS 1996a). Bevan Bend contains the endemic and state-threatened Kate's Mountain clover (*Trifolium virginicum*), the state-threatened bent milkvetch (*Astragalus distortus*), the state-rare northern harebell (*Campanula rotundifolia*), and possibly the state-endangered yellow nailwort (*Paronychia virginica*) (Bartgis et al. 1993). The shale barrens at Paw Paw Bends North (Carroll Road Barrens) support the endemic shale barren ragwort (*Senecio antennariifolius*), state-watchlist shale barren evening-primrose (*Oenothera argillicola*), and the state-threatened bent milkvetch, snowberry (*Symphoricarpos albus*) and three-flowered melic grass (*Melica nitens*). Paw Paw Bends South also contains the ragwort, evening-primrose, bent milkvetch, Kate's Mountain clover, and northern harebell, in addition

Ostrich fern. Photo by Miika Silfverberg.

to the state-rare side-oats gramma (*Bouteloua curtipendula*).

The highest quality limestone and calcareous shale habitats remaining in Maryland—at Ferry Hill bluffs and Chilton Woods—are preserved within the park. Additionally, the limestone forest present at Whites Ferry Woods documents the state-endangered small skullcap (*Scutellaria parvula*) (possibly now state-extirpated according to Maryland Natural Heritage Program 2010b); historical records of state-endangered smooth cliffbrake (*Pellaea glabella*) indicate that it might still exist in the area (Bartgis et al. 1993). The unique conditions created at Cedar Grove where dry west-facing limestone forest and cliffs meet mesic northwest-facing limestone cliffs and hardwood limestone forests support many rare species: state-threatened northern white cedar (*Thuja occidentalis*), black-fruited mountain rice (*Oryzopsis racemosa*), glade fern (*Athyrium pycnocarpon*), leatherwood (*Dirca palustris*), and state-endangered smooth cliffbrake (*Pellaea glabella*) and sweet Indian-plantain (*Cacalia suaveolans*). The mountain rice and leatherwood area also found within the limestone forest of Dargan Bend Woods and Ferry Hill. Ferry Hill additionally hosts northern white cedar, state-endangered black-stem spleenwort (*Asplenium resiliens*), state-endangered northern bedstraw (*Galium boreale*), and one population of the broad-glumed brome (*Bromus latiglumis*). Highly rare snow trillium (*Trillium nivale*) is state-endangered, found only at Dellingers Spring within Maryland. Northern white cedar, leatherwood, northern bedstraw, and state-threatened goldenseal (*Hydrastis canadensis*) are found at Snyders Landing.

Also protected on park lands is the largest extant area of upland forest in the Maryland Piedmont, at Goldmine tract (NPS 2009); other tracts of upland forest on park land include Riverbend, Great Falls, Turkey Run, and Scotts Run (Allen and Flack 2001). These upland forest tracts contain four globally rare and 15 state-rare plant species. The upland forest at Fort Duncan is a population of largeleaf waterleaf (*Hydrophyllum macrophyllum*), which is state-threatened (Bartgis et al. 1993).

Non-native plants

During surveys of rare vegetation communities, approximately 10% of the species identified in the survey area were non-native, although the actual number is likely higher (Wiegand 2001). Areas with disturbed soils, such as floodplain habitats, are particularly vulnerable to invasion; some of these areas now contain more non-native species than native ones. Non-native species of primary concern include: tree-of-heaven (*Ailanthus altissima*), mimosa tree (*Albizia julibrissin*), garlic mustard (*Alliaria petiolata*), wormwood (*Artemisia annua*), musk thistle (*Carduus thoermeri*), climbing bittersweet (*Celastrus orbiculatus*), Canada thistle (*Cirsium arvense*), bull thistle (*Cirsium vulgare*), ground ivy (*Glechoma hederacea*), English ivy (*Hedera helix*), day lily (*Hemerocallis fulva*), a bush clover (*Lespedeza cuneata*), Japanese honeysuckle (*Lonicera japonica*), Morrow's honeysuckle (*Lonicera morrowii*), bush honeysuckle (*Lonicera tartarica*), Japanese stiltgrass (*Microstegium vimineum*), princess-tree (*Paulownia tomentosa*), beefsteak plant (*Perilla frutescens*), Japense knotweed (*Polygonum cuspidatum*), mile-a-minute vine (*Polygonum perfoliatum*), kudzu (*Pueraria montana*), lesser celandine (*Ranunculus ficaria*), multiflora rose (*Rosa multiflora*), soapwort (*Saponaria officinalis*), a chickweed (*Stellaria media*), stinging nettle (*Urtica dioica*), and ivy-leaved speedwell (*Veronica hederifolia*) (NPS 1996a; Wiegand 2001).

Fauna

Mammals

In 1969, Paradiso identified 30 species of mammals (not including bats) that occur within CHOH, including six species that potentially occur in the park (Paradiso 1969). Small mammal surveys documented 18 of these species and an additional three that were not included on the Paradiso list (McShea and O'Brien 2003). Rare species include the state-watchlist eastern cottontail (*Sylvilagus floridanus*), species in need of conservation smoky shrew (*Sorex fumeus*), and state-watchlist southeastern shrew (*Sorex longirostris*) (Maryland Natural Heritage Program 2010b). A small population of the state-endangered Allegheny woodrat (*Neotoma floridana*) is known to exist in rocky ledges of Paw Paw Bends South (Bartgis et al. 1983), and woodrats were observed during bat surveys in Indigo Tunnel (Kennedy 2006).

Nine bat species have been documented in the caves, mines, and tunnels of CHOH: big brown bats (*Eptesicus fuscus*), silver-haired bats (*Lasionycteris noctivagans*), eastern red bats (*Lasiurus borealis*), hoary bats (*Lasiurus cinereus*), little brown bats (*Myotis lucifugus*), northern myotis (*Myotis septentrionalis*; recently proposed for federal listing), eastern pipistrelles/tricolor bats (*Pipistrellus subflavus*/*Perimyotis subflavus*), the globally rare and state-endangered eastern small-footed myotis (*Myotis leibii*), and the globally rare and state and federally endangered Indiana bat (*Myotis sodalis*) (Gates and Johnson 2005; Johnson and Gates 2006a; Johnson and Gates 2006b; Johnson and Gates 2007a; Johnson and Gates 2007b; Johnson and Gates 2007c; Johnson et al. 2008). Two additional bat species—Keen's bat (*Myotis keenii*) and evening bat (*Nycticeius humer-*

alis)—have been documented in the past, but not in recent surveys (Paradiso 1969; Gates et al. 1984).

In surveys, CHOH had the highest levels of bat activity in comparison with other National Capital Region parks, perhaps since bat activity tends to be greater in floodplain than upland forests (Gates and Johnson 2005). In the summer, caves, mines, and tunnels provide roosting sites for bats, while in the winter these sites are used for hibernacula. Surveys typically take place within periods of concentrated bat activity—during spring emergence from hibernation and during fall swarming to mate and begin hibernation. Caves occupied by bats include Dargan Quarry No. 3, Synders Landing Caves No. 1 and No. 2, Dam No. 4 Cave, Dellingers Cave, McMahons Mill Cave, and Two Locks No. 2, many of which have entrances visible to visitors from the tow path (Gates and Johnson 2005). The tunnels of the park generally have have the largest hibernating bat communities among CHOH hibernacula (Gates et al. 1984, Gates and Johnson 2005). Tunnels that contain bats include the three former Western Maryland Rail Road (WMRR) tunnels—Indigo, Stickpile, and Kessler Tunnels—as well as Paw Paw Tunnel which was constructed by the C&O Canal Company for use by the canal boats. All three former WMRR tunnels were slated to become part of the Western Maryland Rail Trail, but in an effort to conserve the bats and help prevent the spread of white-nose syndrome (WNS), the trail will instead be diverted around the tunnels. Bat gates have been installed at both ends of Indigo Tunnel to allow bat access but prevent human interference (NPS 2012a).

White-nose syndrome was confirmed within the park in March 2012 in the Roundtop Mine complex—an abandoned cement mine complex in Washington County (NPS 2012b). The disease, caused by the fungus *Pseudogymnoascus destructans*, was found in the state-owned mines belonging to the same complex, adjacent to the park in spring 2011. Six of the bat species found within the park are known to be susceptible to WNS: big brown bats, eastern small-footed bats, Indiana bats, northern myotis, little brown bats, and tricolored bats (USFWS 2012), the latter two of which were observed with the disease in the cement mine (NPS 2012b). It is not yet known whether WNS affects bats that use torpor (instead of hibernation) but do not regularly utilize caves and mines, such as silver-haired bats, hoary bats, and eastern red bats (USFWS 2011).

Birds

According to the NPSpecies database, 180 species of birds occur within CHOH (NPS 2003). During surveys from 2007–2010, 107 bird species were detected (NPS 2011b), 98 of which are included on the NPSpecies list. Of these detected birds, six species are on the Partners in Flight watchlist, and 12 species are on the Stewardship Species list (NPS 2011b) (Table 2.1). Within the upland forest tracts in the Potomac Gorge area, seven species of Forest Interior Dwelling (FID) and neotropical migratory birds have been found that are considered conservation priorities according to the Partners in Flight program (Allen and Flack 2001). The bald eagle, a formerly federally threatened species, is found at the park (NPS 2009). The American Bird Conservancy and National Audubon Society designated the park an Important Bird Area, which considers small sites that are either critical to rare species, or that support large concentrations of a species (NPS 2009).

Table 2.1. Bird species listed on Partners in Flight watchlist or stewardship species list.

Partners in Flight watchlist	Stewardship Species
Cerulean warbler	Acadian flycatcher
Kentucky warbler	Brown thrasher
Prairie warbler	Carolina wren
Prothonotary warbler	Eastern towhee
Wood thrush	Indigo bunting
Worm-eating warbler	Louisiana waterthrush
	Pine warbler
	Red-bellied woodpecker
	Red-shouldered hawk
	White-eyed vireo
	Yellow-throated vireo
	Yellow-throated warbler

Herpetofauna

Multiple surveys have been conducted for amphibians and reptiles within the park. Twenty-five species of amphibians—13 salamanders and 12 frogs—were observed in past surveys (Thompson 1998; Forester 2000; Thompson 2000; Pauley et al. 2005; Harris 2006; Campbell Grant et al. 2011). Historical records and species distribution maps exist for an additional three salamanders and six frogs (Brady 1937; Forester 2000; Pauley et al. 2005). The Jefferson salamander (*Ambystoma jeffersonianum*), encountered during multiple surveys in Washington County during the past two years, is considered a watchlist species in Maryland (Maryland Natural Heritage Program 2010b, Maryland Department of Natural Resources 2013). Pauley and others (2005) found that mixed deciduous forests and aquatic habitats yielded the highest number of species, while floodplains contained few species. Ephemeral pools are important breeding habitat for amphibians, and small streams contain numerous salamander species. Hydroperiod is one of the most significant factors determining amphibian colonization of wetland habitat—hydroperiod varies based on changes within the park (e.g., changes in canal water level), as well as changes outside the park (e.g., watershed modifications, water diversion, climate change) (Campbell Grant et al. 2011). Wetland size and flooding frequency, as well as the absence of fish, are also important habitat parameters for amphibians.

Twenty-eight reptile species—16 snakes, three lizards, and nine turtles—were documented during surveys of park habitats (Pauley et al. 2005; Harris 2006; Pfaffko 2008). Of these species, one (timber rattlesnake [*Crotalus horridus*]) is on the state watchlist, and five (wood turtle [*Glyptemys insculpta*], corn snake [*Elaphe guttata*], broad-headed skink [*Eumeces laticeps*], queen snake [*Regina septemvittata*], and Eastern ribbon snake [*Thamnophis sauritus sauritus*]) are currently under review for inclusion on the state rare, threatened, and endangered list (Maryland Natural Heritage Program 2010b). Potentially seven additional species exist within the park based on historical records and species distribution maps (Brady 1937; Pauley et al. 2005; Harris 2006). The invasive red-eared slider (*Trachemys scripta elegans*) was also found (Pfaffko 2008). The presence of red-eared sliders is likely due to release or escape from the domestic pet trade starting in the 1930s; these sliders are highly adaptable and compete with native turtles for foraging and basking sites (USGS 2009).

Fishes

The fish inventory of the National Capital Region yielded 61 fish species for CHOH (Raesly 2004), of the 74 species listed on the NPSpecies certified list for the park (NPS 2007). Six of these fish are considered species of concern (Raesly 2004; Maryland Natural Heritage Program 2010b). Three of these species are coldwater—state-rare checkered sculpin (*Cottus* sp. *cf. cognatus*), state-threatened pearl dace (*Margariscus margarita*), and state-watchlist brook trout (*Salvelinus fontinalis*)—and three are warmwater, including white catfish (*Ameiurus catus*), state-threatened comely shiner (*Notropis amoenus*), and state-watchlist shield darter (*Percina peltata*). An additional two rare species potentially occur in the park based on the NPSpecies database, but were not documented during the survey: state-watchlist mottled sculpin (*Cottus bairdii*) and state-endangered stripeback darter (*Percina notogramma*). Shortnose sturgeon (*Acipenser brevirostrum*), a federally and state-endangered species, have been tracked in the Potomac River, in addition to the state-rare and federal candidate Atlantic sturgeon (*Acipenser oxyrinchus*) near Little Falls Dam and Chain Bridge (Kynard et al. 2007; Kynard et al. 2009; Maryland Natural Heritage Program 2010b). Seventeen additional species were identified during surveys either within the Potomac River or its tributaries that potentially occur in CHOH (Roth et al. 1999; Kynard et al. 2007).

American eel (*Anguilla rostrata*), the only catadromous fish species in the area, migrates through the Potomac River. Dams on the Potomac provide an impediment to migration, particularly the hydroelectric plants on Dams 4 and 5. After conducting an Environmental Assessment, the National Park Service determined that eel ladders be built on both dams, with pumps run during American eel migratory season, approximately March through October (NPS 2010d).

Invertebrates

The rare shale barren habitat hosts several rare fauna: the northern metalmark (*Calephelis borealis*), a state-threatened butterfly species, at Fairplay and Paw Paw Bends South; the state-listed giant swallowtail (*Papilio cresphontes*), a species in need of conservation; and the state-rare Olympia butterfly (*Euchloe olympia*) in need of conservation (Bartgis et al. 1993). State-endangered six-banded longhorn beetle (*Dryobius sexnotatus*) and giant swallowtail have been documented in the floodplain forest of Sycamore Landing–Hunting Quarter natural area. A species in need of conservation, the cherrydrop snail (*Hendersonia occulta*), occurs on limestone cliff ledges of Dellingers Spring, Ferry Hill, and Snyders Landing (Bartgis et al. 1993).

Rare, threatened, and endangered animals

Due to the large geographic range of the park and the presence of many different kinds of habitats, many rare, threatened, and endangered species, including the federally listed Indiana bat and short-nose sturgeon, have been documented in the park (Table 2.2).

Table 2.2. Species found in CHOH with state-listed status (Maryland Natural Heritage Program 2010b). Species that are also federally endangered are connoted with LE (listed endangered).

	State-endangered	State-threatened	State-rare	State-watchlist	In need of conservation	State candidate
Mammals	Allegheny woodrat			Eastern cottontail	Smoky shrew	
	Indiana bat (LE)			Southeastern shrew		
	Eastern small-footed myotis					
Birds	Olive-sided flycatcher		Common raven	Bald eagle	American bittern	
			Dark-eyed junco	Black-throated blue warbler		
			Northern waterthrush	Cerulean warbler		
				Least flycatcher		
Amphibians				Jefferson salamander		
Reptiles				Timber rattlesnake		Wood turtle
						Corn snake
						Broad-headed skink
						Queen snake
						Eastern ribbon snake
Fish	Short-nose sturgeon (LE)	Pearl dace	Checkered sculpin	Brook trout		
		Comely shiner	Atlantic sturgeon	Shield darter		
Invertebrates	Six-banded longhorn beetle	Northern metalmark		Price's cave isopod	Giant swallowtail	
	Biggers' cave amphipod				Olympia butterfly	
	Shenandoah cave amphipod				Cherrydrop snail	
	Appalachian spring snail				Allegheny cave amphipod	
	Blue Ridge spring snail					

Non-native animals

Several non-native introduced species are present within CHOH, some of which have become invasive. Two species of mammals, five birds, two amphibians, one reptile, and 20 species of fish are non-native within the park, either documented in past surveys, or potentially occurring based on NPSpecies taxonomic group databases.

Viewshed

The National Park Service has purchased 254 scenic easements on land adjacent to the park with the purpose of preserving natural resources and surrounding viewshed from urban encroachment (NPS 1996a). In surveys of park visitors, 93% of visitors rated scenic views as very or extremely important to the park experience (Meldrum et al. 2004).

Soundscape

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); within CHOH, 88% of visitors ranked quiet/sounds of nature as very or extremely important to their park experience (Meldrum et al. 2004). In a historical park, culturally related sounds might also be heard.

Wildlife rely on sound for intraspecies communication, territory establishment, courtship and mating, nurture and protection of young, predation and predator avoidance, and effective habitat use (NPS 2012c). Alteration of the natural soundscape can adversely affect wildlife by displacing individuals or habituating them to sounds such that they eventually do not react to them (Barber et al. 2009). Wildlife behavior alteration (e.g., vocalization patterns) has also been observed in areas of anthropogenic noise (Barber et al. 2011). Human-made sounds originating from outside the park might include road traffic, construction, and aircraft noise. Numerous roads cross the canal or follow it for different lengths, contributing to road noise heard within park boundaries.

Lightscapes

The natural darkness associated with the night sky is an important natural, scientific, and cultural resource valued by the National Park Service (NPS 2012d). 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. Cultural and historical resource parks value the night sky for preserving the sense of place and time inherent to the site.

Light pollution is increasing globally, especially in areas of high growth, such as the east coast of the United States. Longcore and Rich (2004) recognize two types of light pollution: astronomical and ecological. Astronomical light pollution impedes the ability to see stars and other celestial bodies. Sky glow, or the night-time illumination of the sky resulting from the multitudes of human-caused light scattered into the atmosphere, contributes to astronomical light pollution. Ecological light pollution alters the natural patterns of light and dark in ecosystems and has adverse affects on wildlife (Longcore and Rich 2004). Ecological light pollution includes direct glare, sky glow, and temporary, unexpected fluctuations in lighting. Behavioral and population-level ecology is affected based on individual and species differences in orientation or disorientation to increased light availability, attraction or repulsion to light sources, lowered reproductive capacity, and hindered visual and audio intraspecies communication. These factors culminate in changes in community ecology, influencing competition, including resource partitioning, and predation, ultimately favoring species that are most light tolerant (Longcore and Rich 2004).

Within the park, lightscapes are more intact towards the western end of the park and more degraded towards the eastern end with proximity to Washington, D.C.

2.2.2 Resource issues overview

Internal park threats

Exotic species

Exotic plants, animals, and diseases are prevalent within CHOH. Several hundred exotic plants and several dozen exotic animals have been documented within the park (Table 2.3). Many of these species are also invasive and outcompete and displace native species. Many invasive plants thrive on disturbances created within the ecosystem, such as fragmentation and natural disasters such as wind events, derecho, flooding, or wildfires. When native species are displaced by these disturbances, invasive species can more rapidly colonize the area, further facilitating competition for resources. This changes the habitat structure and composition of vegetation communities, which can affect nutrient cycling, water resources, and habitat quality for wildlife. Invasive wildlife create similar community and ecosystem-level changes detrimental to native organisms.

Table 2.3. Non-native introduced species found or potentially found in CHOH. Those species that are also gamefish are marked with (g).

	Species
Mammals	Domestic/feral cat
	Norway rat
Birds	Common pheasant
	European starling
	House finch
	House sparrow
	Rock dove
Amphibians	Southern toad
	Bullfrog
Reptiles	Red-eared slider
Fish	Rock bass
	Goldfish
	Common carp
	Threadfin shad
	Greenside darter
	Channel catfish
	Green sunfish
	Warmouth
	Bluegill
	Longear sunfish
	Redear sunfish
	Smallmouth bass (g)
	Largemouth bass (g)
	Rainbow trout (g)
	Bluntnose minnow
	Fathead minnow
	White crappie
	Brown trout (g)
	Walleye
	Cutthroat trout (g)
	Snakehead

Several invasive pests and diseases, among them the gypsy moth, Dutch elm disease, hemlock woolly adelgid, and emerald ash borer, threaten forest resources. 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, including upland mixed oak, oak-tulip tree, and oak-pine forests. While oak assemblages cover less than 10% of park area, these areas occur primarily in the Great Falls area, which contains biologically important and diverse communities. Pesticide use associated with invasive species eradication, such as that to combat gypsy moths, has been implicated in the decline of several butterfly species in Maryland (NPS 1996a). Hemlock woolly adelgid, first discovered in the park in 1992, threatens Eastern hemlock trees. Eastern hemlock is rarely the dominant tree species in an assemblage, but groves exist in Potomac River gorge in proximity to Great Falls and Plummer's Island, primarily on steep, rocky slopes and ravines. Vaso Island and Hermit Island contain substantial groves of native hemlock trees, representing 90% of the Park's population. Dutch elm disease is an introduced fungus that destroys American elm trees and is transmitted by the elm bark beetle (native and European species).

An 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 not been documented in any of the Inventory & Monitoring plots within the park; however, it was documented at several locations inside the park in 2012 (M. Carter, pers. comm.).

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 (Bates 2009). High populations of native white-tailed deer heavily browse the vegetation in upland forest and river terrace communities in the park. Overbrowse alters the structure and composition of the vegetation by extirpating native plants, inhibiting regeneration of other native plants, and facilitating the spread of invasive species (Allen and Flack 2001). Deer populations affect other forest species that depend on vegetation structure. Opening or removing the forest understory potentially alters the soil moisture content that amphibians depend upon; deer can also trample ephemeral ponds used for amphibian breeding (Pauley et al. 2005). Alteration of the shrub layer affects forest nesting birds that depend on structural complexity. Declines in regeneration of oaks and other mast-producing trees affect small mammal populations that depend on mast as a food source (Bates 2009). Deer also carry disease, such as Lyme disease—which is spread through deer ticks—and are affected by chronic wasting disease.

Adverse recreational use

Heavy recreational use in areas such as Great Falls leads to trampling of native plants. Trampling also creates corridors conducive to the invasion of non-native species. In access areas to the towpath, trails, and campgrounds, soil erosion and compaction present widespread problems. These problems are accentuated by illegal mountain bike use, particularly on steep and poorly drained trail sections. Rock climbing, a popular recreational activity, especially at Carderock, can affect the surrounding area by destroying cliff vegetation, eroding trails, and adversely affecting trees used as top-rope anchors. During vegetation surveys, damage to the state-threatened Nantucket serviceberry (*Amelanchier nantucketensis*) was observed at several sites at the top of a rock climbing route, where top-rope gear was likely placed (Davis 2011). At other climbing sites, such as the 'Bird's Nest,' there are signs of shrub vegetation clipping (Davis 2011).

Visitor use in caves, particularly in the better known Dam 4 and Dellingers, has damaged many speleothems (i.e., cave formations). Human disturbance may be a contributing factor to declining bat populations within the cave system (NPS 1996a).

Sedimentation

The geologic setting of CHOH, with steeply sloped river valleys, combined with relatively high rainfall, contributes to soil erosion, seasonal runoff, and slumping within the Park (Thornberry–Ehrlich 2005). Excessive runoff has been shown to flood forests and drown large trees within the park (NPS 1996b). Increasing development and impervious surface cover within the watershed surrounding the park accelerates this issue. Agriculture, construction, forestry, and removal of riparian vegetation are major sources of sediment. The nutrients and other pollutants that bind with sediment are transported through the watershed.

Sedimentation is also an issue within the canal (NPS 1996b; Weeks 2001). Sediment is deposited by tributary streams that feed into the canal, and by floods from the Potomac River. Rewatering sections of the canal by diverting water from the Potomac River adds further sediment. Suspended sediments settle out of suspension and accumulate on the bottom of the canal bed, gradually filling in the canal from its historic 2 m (6 ft) depth. Removal of sediments is expensive and time consuming, and adversely impacts aquatic fauna, such as freshwater mussels (Weeks 2001).

Regional threats

Development/encroachment

Rapidly expanding development within the Potomac River watershed threatens numerous park resources and habitats. Increases in impervious surface cover contribute to increased stormwater runoff and lower groundwater infiltration. Water that runs off impervious surfaces is also of higher temperature, contributing to higher stream temperatures. This water also contributes to streambank erosion due to higher stream flows from flashier hydrology. Treatments for snow melting and de-icing wash into neighboring streams, where they alter stream chemistry and threaten stream fauna.

Roads and development fragment the habitat, restricting or impeding the movement and migration of terrestrial and aquatic organisms. Roads also affect the ambient soundscape, further altering wildlife behavior. The road network along the coastal United States is pervasive, particularly around the national capital region. Riitters and Wickham (2003) calculated the proportion of total area in a watershed within 382 m (1253 ft) of the nearest road for watersheds across the continental United States. For the Potomac River watershed, this proportion ranges from 0.8–1.0 in the area around D.C., to 0.6–0.8 in the middle region, to 0.4–0.6 in the upper reaches (Riitters and Wickham 2003). A similar phenomenon was seen when proportions were calculated for ecoregions. The ecoregion containing the national capital region had more than 20% of their total area within 85 m (279 ft) of the nearest road; the ecoregions overlapping the capital region and watershed had more than 90% of their total area within 1061 m (3481 ft) of the nearest road (Riitters and Wickham 2003).

Flooding

Flooding is a regular occurrence in the park, with some degree of flooding every year, and large events on the scale of every 10–15 years. More than 85% of the park area lies within the Potomac River 50-year floodplain, including the majority of the more than 1200 historic structures. Flood-induced damages occur to historic and modern park infrastructure, including aqueducts, culverts, wastewiers, stop locks, dams, bypass flumes, and revetments. The aqueducts face damages from debris carried by floods, and part of the Seneca Creek Aqueduct arch collapsed during high flooding in 1971. Two locations particularly prone to flood damage are Harpers Ferry, WV, at the confluence of the Potomac and Shenandoah Rivers, and at the Widewater section between Great Falls and Old Angler's Inn (Weeks 2001).

In addition to structural damage, large flood events can negatively affect the park's natural resources. High water flows can kill and displace salamanders that live within streams and their floodplains (Pauley et al. 2005). High water levels can also inundate ephemeral ponds used by amphibians as breeding sites, and floods can introduce invasive species. The timing, quantity, and frequency of flood events affects vegetation communities located within the floodplain; many rare vegetation communities are located within the scour line.

Dwarf wedge mussel. Photo by U.S. Fish and Wildlife Service.

Nutrient pollution and contamination

Water quality testing in the Potomac River shows high levels of nutrient pollution and chemical contamination from the watershed (Weeks 2001). Approximately 450 stream segments within CHOH, totalling about 200 km (125 mi), are considered impaired according to the Clean Water Act regulations for beneficial use (Weeks 2001). Historically, water quality in the Potomac River suffered from nonexistent or inadequate sewage treatment facilities that loaded the river with high fecal coliform and depressed dissolved oxygen levels (Allen and Flack 2001). Accidental raw sewage discharges into the watershed and ultimately the Potomac River still occur (Allen and Flack 2001).

Streams draining agricultural and urban areas of the watershed contribute the highest quantities of nutrients (i.e., nitrogen and phosphorus) to the River (Ator et al. 1998). Nearly 2.2 million kg (5 million lbs) of synthetic organic herbicides, insecticides, and fungicides are applied to cropland within the watershed every year (Ator et al. 1998). Additional pesticides are applied by landowners for landscaping and other non-agricultural uses. Surface water and groundwater samples frequently contain pesticides, although typically in low concentrations; the most commonly detected are atrazine, simazine, metolachlor, and prometon (Ator et al. 1998).

Three mines and multiple quarries are present within the park that pose an ecological and management issue. Gold was mined in the Great Falls region from 1867–1940, leaving abandoned mine shafts. Surface water and groundwater that flow through mines can become contaminated with heavy metals from mine tailings (Thornberry–Ehrlich 2005). Limestone for cement was mined at Round Top Hill near Hancock, MD. Coal mining occurs within the Upper (North Branch) Potomac River watershed; surface waters draining coal mines have have been monitored and indicate lower pH, higher dissolved solids (e.g., iron, manganese, aluminium), and exposed iron sulfides (Thornberry–Ehrlich 2005). Property was purchased by CHOH in Williamsport, MD that may have contamination problems based on historic use. The property includes 10 sedimentation ponds previously owned by the Garden State Tannery. These sedimentation ponds could represent hazardous sites that require time-sensitive mitigation, and so the ‘health’ of this property should be thoroughly assessed (Weeks 2001). Additionally, a rail yard owned by CSX Transportation in Brunswick, MD, and adjacent to the park is contaminated with liquid phase hydrocarbons (LPH) and dissolved phase hydrocarbons (DPH). Activities are currently underway to characterize the site and determine the extent of the contamination (CHOH letter to MDE, June 5, 2012).

Regional threats

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—with particulate matter and ozone being 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.

Climate change

Climate change, and the associated temperature shifts, will likely alter the phenology of plant species. The timing of flowering is tied to pollinator activity, a relationship that might become decoupled as temperature increases shift the first flowering date earlier in the season (Davis 2011). In the Washington, D.C. area, the timing of first flowering has shifted earlier by 0.2 to 46 days for early-flowering plants and later in the season by 0.3 to 10.4 days for late-flowering plants (Abu-Asab et al. 2001). Four of the 100 species studied—green and gold (*Chrysogonum virginianum*), eastern leatherwood (*Dirca palustris*), harbinger-of-spring (*Erigenia bulbosa*), and golden zizia (*Zizia aurea*)—are state watchlist or threatened species and exhibited a significant advance (15–31 days) in first flowering date over the 20–23 years on record (Abu-Asab et al. 2001). Additionally, species with narrow springtime flowering windows, such as state-threatened Nantucket serviceberry (*Amelanchier nantucketensis*), may be adversely affected by this phenological shift (Davis 2011).

2.3 RESOURCE STEWARDSHIP

According to the park's Foundation Document (NPS 2013a), the following significance statements have been identified for CHOH:

- The Chesapeake and Ohio Canal National Historical Park preserves and interprets 19th century canal transportation, civil engineering technology, and the evolution of a flat water transportation system in support of the industrial growth of the nation.
- The Chesapeake and Ohio Canal National Historical Park contains more than 1,300 historic structures, including one of the largest collections of 19th century canal features and buildings in the national park system.
- The Chesapeake and Ohio Canal National Historical Park preserves archeological evidence of 13,000 years of human habitation along the Potomac River.
- Through preservation efforts that began in the 1950s, the Chesapeake and Ohio Canal National Historical Park towpath was transformed into one of the most heavily used recreational trails in the nation and serves as the backbone for national and regional trail systems.
- The Chesapeake and Ohio Canal National Historical Park provides diverse recreational opportunities for millions of visitors annually, including numerous access points to the Potomac River, ranging from urban to rural settings.
- The 15-mile-long Potomac Gorge, managed in part by the Chesapeake and Ohio Canal National Historical Park, is one of the most biologically diverse natural areas in the national park system.
- Paralleling the Potomac River for 184.5 miles and travelling through four physiographic provinces, Chesapeake and Ohio Canal National Historical Park provides a natural buffer of forest, woodlands, prairies, and barrens and a wildlife corridor along the second-largest tributary to the Chesapeake Bay.
- Interpretive and educational opportunities engage a diverse cross-section of urban and rural communities along the length of the Chesapeake and Ohio Canal National Historical Park and were envisioned in the park's enabling legislation. Living history events, school programming, canal operations demonstrations, and a nationally renowned Canal Quarters program offer visitors the opportunity to experience different eras of the canal's existence.

Golden zizia. Photo by H. Zell.

Interpretative themes define the most important ideas of concepts communicated to visitors about a park. Themes are derived from—and should reflect—park purpose, significance, resources, and values. The following interpretive themes have been identified for Chesapeake and Ohio Canal National Historical Park (NPS 2013a):

- **Human Ingenuity:** The Chesapeake and Ohio Canal is a testament to human ingenuity and capacity to build an enduring transportation system that challenged natural obstacles, creating communities, connecting regions, and advancing European American expansion.
- **Transportation Heritage:** The Chesapeake and Ohio Canal plays a vital role in the nation's transportation heritage—a catalyst for westward expansion and economic development—shaping industry, culture, recreation, and tourism for generations.
- **Life on the Canal:** Life on the Chesapeake and Ohio Canal during its construction and operation was fraught with

challenges and life-threatening hazards in pursuit of uncertain rewards.
- **Change and Adaptation:** The prehistory and history of the Potomac Valley illustrates and reflects constant change and adaptation—the river's impact on land, nature, and cultures within the valley, and the interaction between the cultures and their impact on the river valley.
- **Geology and Geography:** The unique convergence of geology and geography in the Potomac River Valley inspires a sense of awe and humility.
- **Place of Refuge:** The Chesapeake and Ohio Canal is a place of refuge from the modern world—a setting where one can be spiritually renewed and reconnected to past generations and the natural world.

Fundamental resources and values are those features, systems, processes, experiences, stories, scenes, sounds, smells, or other attributes determined to merit primary consideration during planning and management processes because they are essential to achieving the purpose of the park and maintaining its significance. The following fundamental resources and values have been identified for Chesapeake and Ohio Canal National Historical Park:

- Historic Districts—Historic Structures—Archaeology
- Towpath
- Museum/Archival Collections
- Scenic Views Including Great Falls and the Potomac Gorge
- Recreational Opportunities
- Biodiversity within the Potomac Gorge
- Natural Communities
- Interpretation and Education

The resource management objectives derived from Park-specific legislation (NPS 1996a) direct CHOH to:

"Protect and preserve both natural and historic scenery.

Preserve and restore the historic features of the canal, including its associated structures.

Conduct historical research on the canal, in order to assist in preserving and restoring these resources and to interpret the story of the canal.

Provide for recreational use consistent with protection of Park natural and cultural resources."

The resource management objectives derived from NPS general legislation and other federal legislation (NPS 1996a) include provisions to:

"Protect and preserve cultural resources associated with the Potomac valley, not directly related to the history of the C&O Canal (prehistoric sites, Civil War sites, mines, etc).

Protect and preserve native organisms and biological diversity.

Protect and preserve geological and ecological processes which shape the Potomac Valley.

Protect and preserve floodplains and wetlands.

Protect and preserve cave resources."

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 2013b):

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).

CHOH is one of 11 parks served by the National Capital Region I&M Network (NCRN I&M). Numerous baseline inventories have been conducted at the park (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 viabil-

Table 2.4. Status of NCRN I&M inventories at Chesapeake and Ohio Canal National Historical 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 2011
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 2011
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 2010
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 2 010 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

ity 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 to fill gaps in knowledge and have a better understanding of conditions and trends of park resources. Just a few of the many collaborators have included various state and federal government agencies, The University of Maryland, Hood College, The University of Arkansas, West Virginia University, Frostburg State University, Virginia Tech, and non-government organisations. A partial bibliography of research that has been completed at CHOH can be seen in Table 2.5.

2.4 LEGISLATION

Presidential Proclamation 3391 by Dwight D. Eisenhower. "Establishing the Chesapeake and Ohio Canal National Monument, Maryland." January 23, 1961.

U.S. Congress. Public Law 69-202. 43 Stat 463. June 6, 1924. "National Capital Park and Playground Act."

U.S. Congress. Capper–Cramton Act. 46 Stat. 482. Chap 354. May 29, 1930. "An act for the acquisition, establishment, and development of the George Washington Memorial Parkway along the Potomac from Mount Vernon and Fort Washington to the Great Falls…"

U.S. Congress. Public Law 184 , Chapter 310 – 1st Session, H.R. 5804, August 1, 1953. "to authorize the Secretary of the Interior to grant easements for rights-of-way through, over, and under the parkway land along the line of the Chesapeake and Ohio Canal, and to authorize an exchange of lands with other Federal departments and agencies, and for other purposes."

U.S. Congress. Public Law 91-664, H.R. 19342, January 8, 1971. "to establish and develop the Chesapeake and Ohio Canal National Historical Park, and for other purposes."

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Table 2.5. A partial bibliography of research that has been completed at Chesapeake and Ohio Canal National Historical Park.

Study topic	Reference
Mammals	Manville 1968, Fisher and Fisher 1994, 1998, Jefferson 2000, McShea and O'Brien 2003, Gates and Johnson 2005, Kennedy 2006, Rattner and Ackerson 2006, Stewart et al. 2006, Johnson and Gates 2006a, 2006b, 2007a, 2007b, 2007c, Johnson et al. 2008, Bates 2009.
Birds	Manville 1968, Gates 1995, Gates and Walters 2000, Rattner and Ackerson 2006, Ladin and Shriver 2013*.
Herpetofauna	Manville 1968, Thompson 2000, Pauley et al. 2005, Harris 2006, Rattner and Ackerson 2006, Mattfeldt et al. 2008, Campbell Grant et al. 2011.
Fish	Manville 1968, Starnes 2002, Raesly et al. 2004, Kynard et al. 2007, 2009.
Insects	Feller 1997, Brown and Bahr 2005, Orr 2005.
Molluscs	NPS 2004.
Plants	Maxon et al. 1935, Brady 1937, Kilip and Blake 1953, Lawrey and Hale 1977, Everson and Boucher 1998, West Virginia Department of Natural Resources 2003, Shetler et al. 2006, Adams 2007, Engelhardt et al. 2008.
Geology & Soils	Weeks 2001, Thorneberry–Ehrlich 2005, Southworth et al. 2008, Tudek and Vesper in press.
Caves & Paleontology	Franz and Slifer 2001, Kenworthy and Santucci 2004, Clites and Santucci 2010.
Hydrology	NPS 1996b, Doheny 1997, Shaffer 1997.
Water Quality	NPS 1996b, Weeks 2001, Norris and Pieper 2010*.
Habitat	Bartgis et al. 1993, Schmit and Campbell 2007*, 2008*, Schmit et al. 2009*, 2010*.
Fungi	Hawkins and Brantley 2007, Stephenson 2008, Barron and Emery 2009.
Rare and Endangered Species	Wiegand 1999, 2001.

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Chapter 3: Study scoping and design

3.1 PRELIMINARY SCOPING

3.1.1 Park involvement

Scoping for the assessment of Chesapeake and Ohio Canal National Historical Park (CHOH) began in December 2010 with a meeting at Harpers Ferry National Historical Park to start the Natural Resource Condition Assessment (NRCA) process for Chesapeake and Ohio Canal National Historical Park, Catoctin Mountain Park, and Harpers Ferry 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). Park resources data from CHOH and NCRN I&M were organized into an electronic library comprised of management reports, data files, and geospatial data, which provided the primary sources for the assessment. Additional datasets were obtained from the NPS Air Resources Division (ARD), the Interagency Monitoring of Protected Visual Environments (IMPROVE), Antietam National Battlefield, Maryland Department of the Environment, National Park Service, and Pennsylvania Department of Environmental Protection.

Several follow-up meetings with staff from CHOH, 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 Chesapeake and Ohio Canal National Historical 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. Because no water quality data is collected within the park boundary, the U.S. EPA STORET database was mined for water quality data from sites located upstream of CHOH and within three miles of the park boundary.

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 policy-makers and non-scientists. Aggregated indices were developed and presented within the current natural resource assessment for Chesapeake and Ohio Canal National Historical Park.

3.2.3 General approach and methods

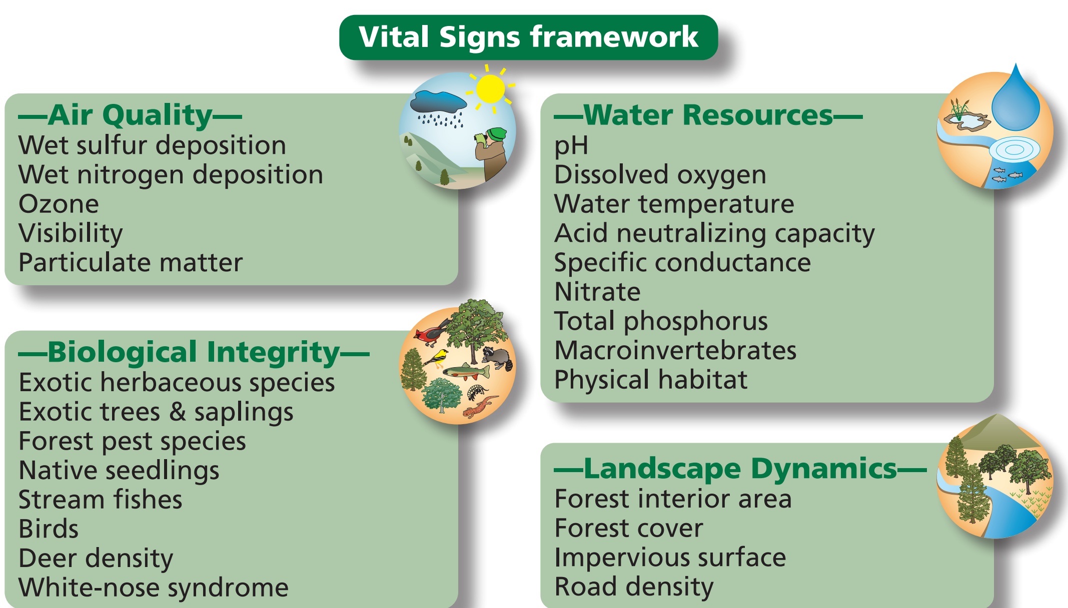
The general approach taken to assess natural resource condition was to determine indicators of current status within each habitat, establish a reference condition for each indicator, and then assess the percentage attainment of reference condition. Details

Table 3.1. Ecological monitoring framework data provided by agencies and specific sources included in the assessment of Chesapeake and Ohio Canal National Historical 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.
2/7/2011	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.	CHOH: Brian Carlstrom, Chris Stubbs, John Hitchcock, Michelle Carter, Bill Spinrad, Curt Gaul, Alyssa Baltrus. NCRN I&M: Mark Lehman, Megan Nortrup. UMCES-IAN: Heath Kelsey, Jane Thomas, Joanna Woerner, Melissa Andreychek.
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.
12/5/2012	In person	Draft conclusions and recommendations for Chapter 5.	CHOH: Brian Carlstrom, Chris Stubbs, John Hitchcock, Michelle Carter. NCRN I&M: Pat Campbell, Mark Lehman, Megan Nortrup. UMCES-IAN: Bill Dennison, Simon Costanzo, Jane Thomas.

CATO—Catoctin Mountain Park; CHOH—Chesapeake and 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.



of approach, background, and justification are provided on a metric-by-metric basis in Chapter 4. Once attainment was calculated for each indicator, the median 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 26 metrics were used to determine the natural resource condition of Chesapeake and Ohio Canal National Historical Park. The approach for assessing resource condition within CHOH 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, an unweighted mean 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

Budde P.J., B.J. Frakes, L. Nelson, and U. Glick. 2009. Technical guide for NPScape data and processing. Inventory & Monitoring Division, National Park Service, Fort Collins, CO.

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 Chesapeake and Ohio Canal National Historical Park (CHOH)—wet sulfur (S) deposition, wet nitrogen (N) deposition, ozone (ppb), 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

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

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 CHOH.

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; $\mu g/m^3$)	≤ 12; 12.1–15; > 15	4	5,650	2001–2010
Mercury deposition (ng/L)	N/A	3	1,052	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 ($\mu g/m^3$)		
< 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

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

Reference conditions were established for each of the six metrics (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 CHOH from the National Atmospheric Deposition Program (NADP) and Interagency Monitoring of Protected Visual Environments (IMPROVE) program (Figure 4.1).

CHOH scored 0% attainment (conditions of significant concern) for wet sulfur and nitrogen deposition and visibility. The remaining metrics had moderate conditions, with ozone (ppb) scoring 17% attainment and particulate matter scoring 44% attainment (Table 4.4). This resulted in an overall air quality condition attainment of 12%, or very degraded condition.

Literature cited

NPS ARD (National Park Service, Air Resources Division). 2010. Air quality in National Parks: 2009 annual performance and progress report.

Table 4.4. Summary of resource condition assessment of Air Quality in CHOH. The ozone W126 metric and mercury deposition were not included in the overall assessment of air quality condition.

Metric	Result	Reference conditions	% attainment	Condition	Air quality condition
Wet sulfur deposition (kg/ha/yr)	5.26	< 1; 1–3; > 3	0	Significant concern	12% Very degraded
Wet nitrogen deposition (kg/ha/yr)	4.51	< 1; 1–3; > 3	0	Significant concern	
Ozone (ppb)	72.5	≤ 60; 60.1–75; > 75	17	Moderate	
Ozone (W126; ppm-hrs)	10.7	< 7; 7–13; > 13	38	Moderate	
Visibility (dv)	12.0	< 2; 2–8; > 8	0	Significant concern	
Particulate matter (PM2.5; µg/m^3)	13.7	≤ 12; 12.1–15; > 15	44	Moderate	
Mercury deposition (ng/L)	8.6	N/A	N/A	N/A	

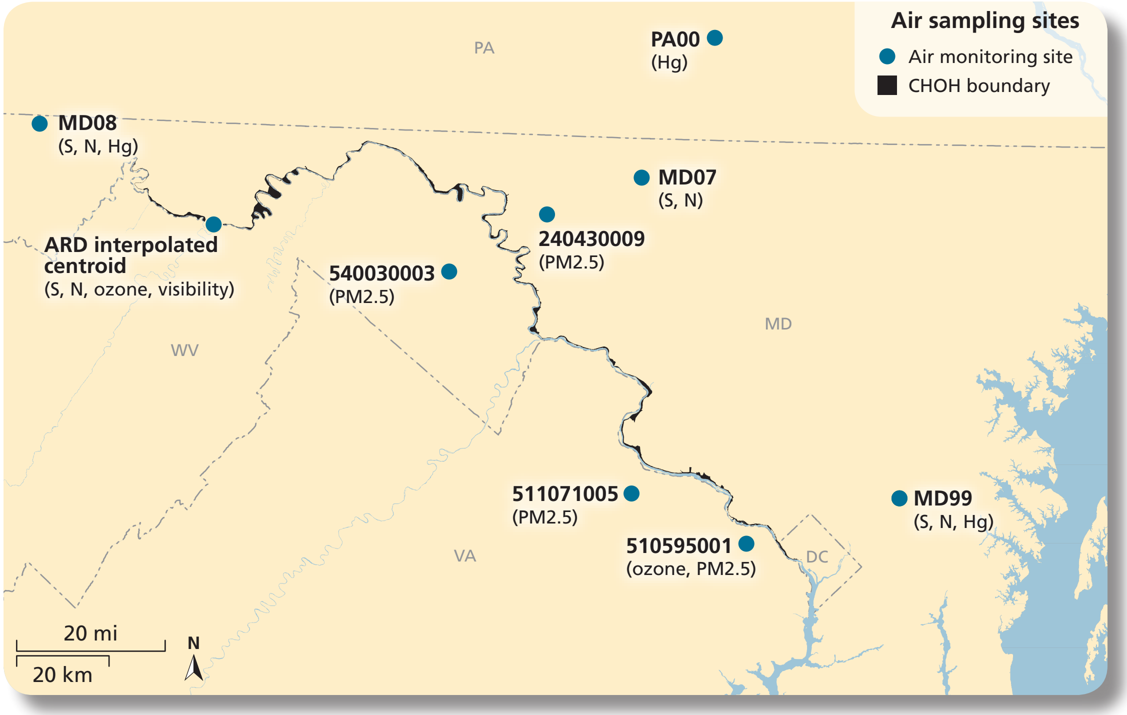


Figure 4.1. Regional air quality monitoring sites for wet deposition of sulfur and nitrogen, ozone, visibility, particulate matter, and mercury deposition. Wet deposition, ozone, and visibility condition data for 2005–2009 were interpolated by NPS ARD to estimate mean concentrations for CHOH.

Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, CO.

NPS ARD (National Park Service, Air Resources Division). 2011a. 2005–2009 5-year average 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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NPS ARD (National Park Service, Air Resources Division). 2011d. Rating air quality conditions. National Park Service, Denver, CO. Accessed April 9, 2013. *http://www.nature.nps.gov/air/planning/docs/20111122_Rating-AQ-Conditions.pdf*

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 CHOH was taken from the interpolation at the park centroid, which was located towards the western end 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 CHOH, so this value was assessed against the three reference condition ranges described above.

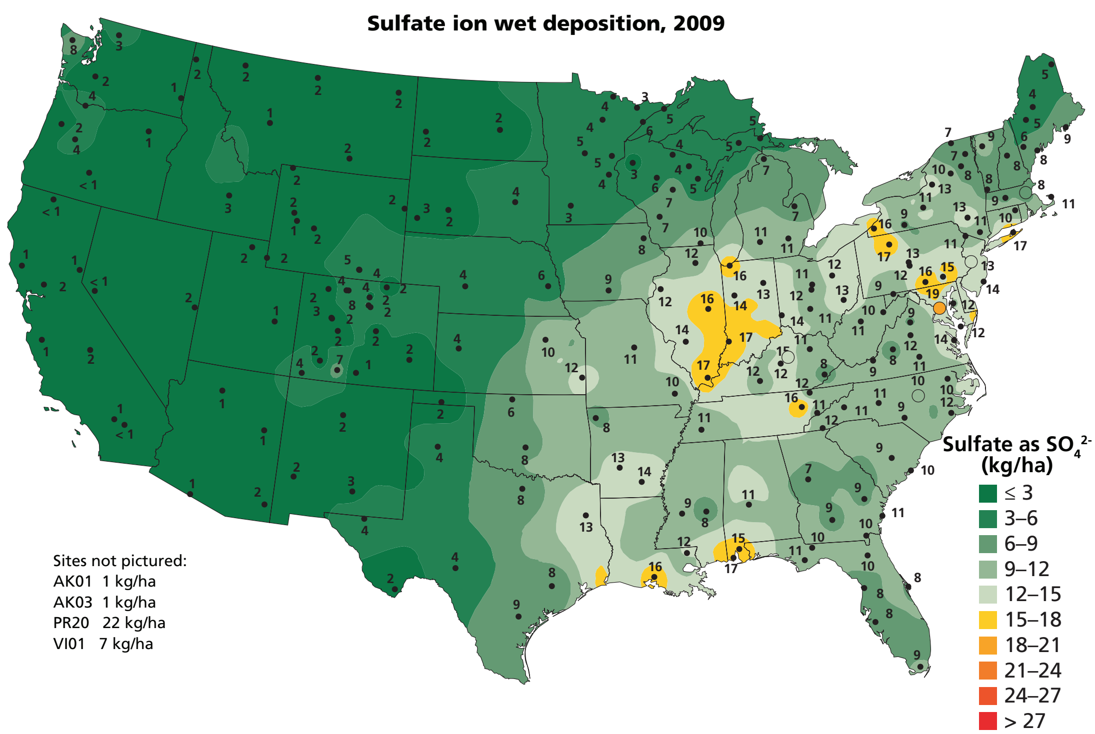

Figure 4.2. Total wet deposition of sulfate (SO_4^{3-}) for the continental United States in 2009 (NADP/NTN 2010).

Additionally, National Atmospheric Deposition Program (NADP) data from the three monitoring sites closest to CHOH were used—sites MD07, MD08, and MD99 (Table 4.1, Figure 4.1).

Condition and trend

Interpolated wet sulfur deposition between 2005 and 2009 for CHOH was 5.26 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, CHOH was ranked at very high risk (Sullivan et al. 2011a, b), suggesting that streams and soils in the park are very vulnerable to acidification.

CHOH 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 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 effects, and management strategies. Bioscience 51: 180–198.

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

NPS ARD (National Park Service, Air Resources Division). 2011a. 2005–2009 5-year average wet deposition estimates. NPS Air Quality Estimates. National Park Service. Denver, CO. Accessed April 9, 2013. *http://www.nature.*

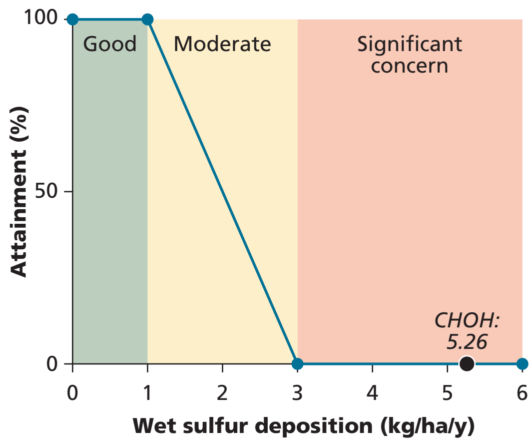

Figure 4.3. Application of the percent attainment categories to the wet sulfur deposition value categories. Wet sulfur deposition at CHOH was 5.26 kg/ha/y which equated to 0% attainment of the reference condition.

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

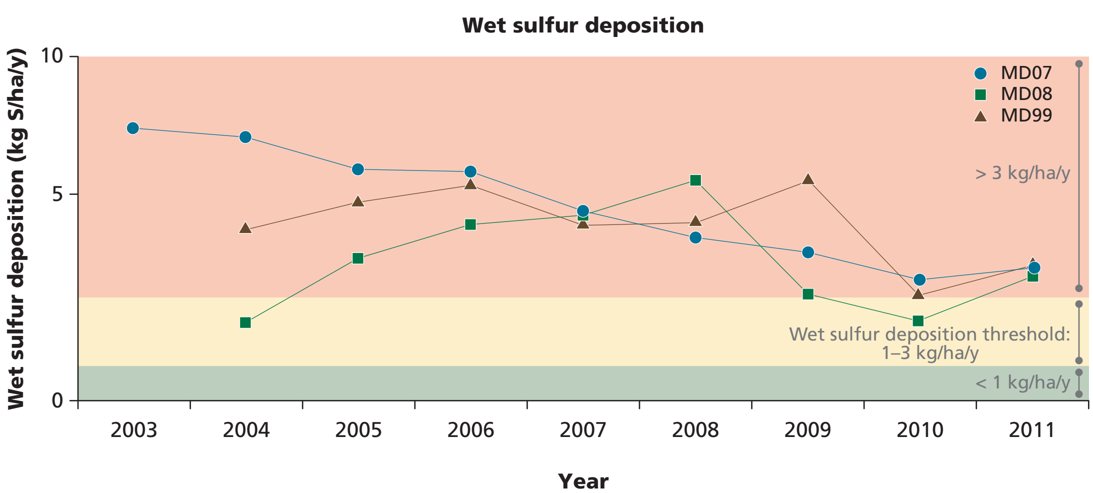

Figure 4.4. Annual wet deposition of sulfate (kg SO_4/ha/yr) at the three sites closest to CHOH. Data were reported as SO_4 deposition; these data were converted to total S deposition using atomic weights (multiplying by 0.333). Reference conditions are shown in gray.

nps.gov/air/ Maps/AirAtlas/IM_materials.cfm
NPS ARD (National Park Service, Air Resources Division). 2011b. Rating air quality conditions. National Park Service, Denver, CO. Accessed April 9, 2013. *http://www.nature.nps.gov/air/planning/docs/20111122_Rating-AQ-Conditions.pdf*
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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 CHOH was taken from the interpolation at the park centroid, which was located towards the western end 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

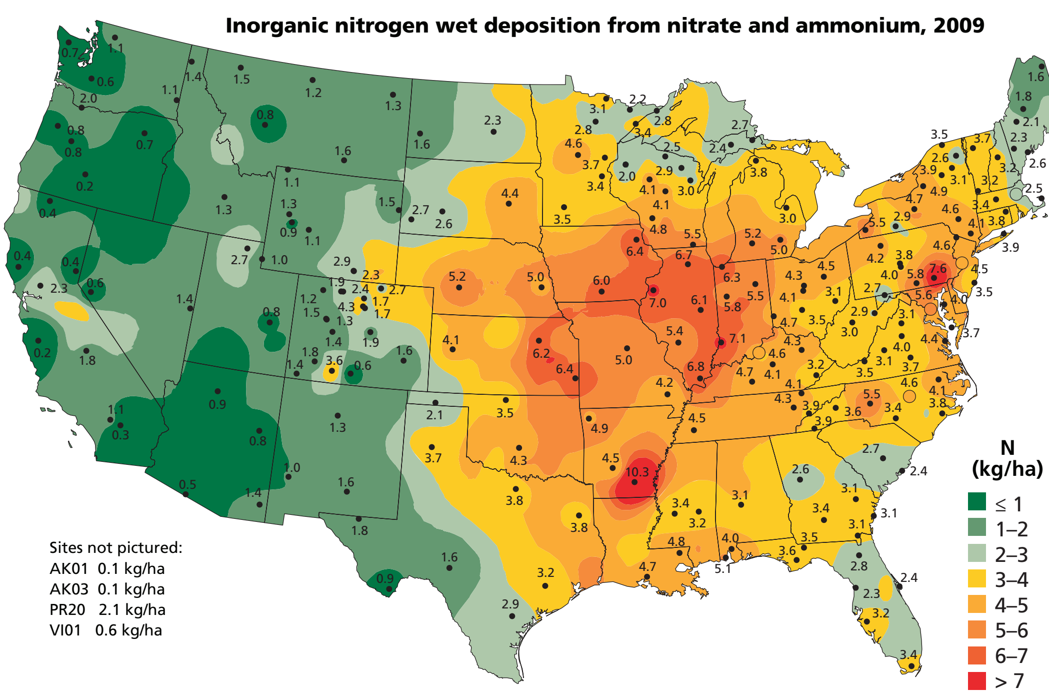

Figure 4.5. Total wet deposition of nitrate (NO_3^-) and ammonium (NH_4^+) (kg/ha) for the continental United States in 2009 (NADP/NTN 2010).

to 100% between these two reference points (Figure 4.6, Table 4.6). 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 nitrogen deposition for the park, 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 CHOH were used—sites MD07, MD08, and MD99 (Table 4.1, Figure 4.1).

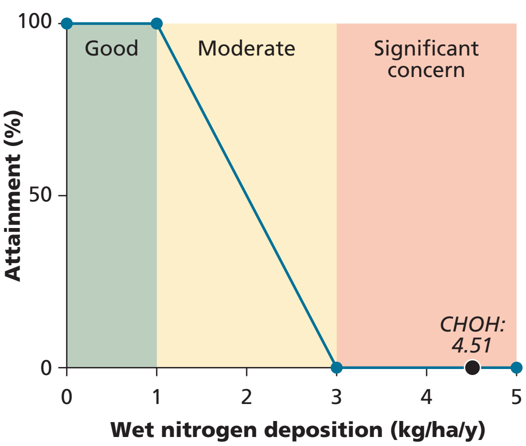

Figure 4.6. Application of the percent attainment categories to the wet nitrogen deposition value categories. Wet nitrogen deposition at CHOH was 4.51 kg/ha/y which equated to 0% attainment of the reference condition.

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 CHOH was 4.51 kg/ha/yr which resulted in 0% attainment of reference condition, or a condition of significant concern (Table 4.4) (NPS ARD 2011b). In a national assessment that ranked parks according to relative risk from nutrient nitrogen effects, CHOH was ranked at moderate risk (Sullivan et al. 2011a, b).

CHOH 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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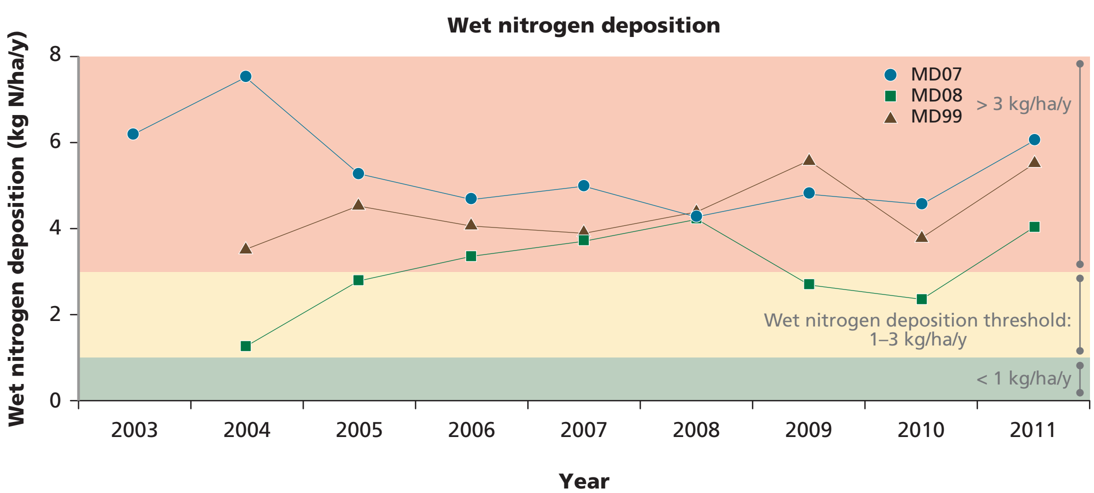

Figure 4.7. Annual wet deposition of total nitrogen (kg N/ha/yr) at the three sites closest to CHOH. Reference conditions are shown in gray.

United States: sources and inputs, ecosystem effects, and management strategies. Bioscience 51: 180–198.

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NPS ARD (National Park Service, Air Resources Division). 2011b. 2005–2009 5-year average wet deposition estimates. NPS Air Quality Estimates. National Park Service. Denver, CO. Accessed April 9, 2013. *http://www.nature.nps.gov/air/ Maps/AirAtlas/IM_materials.cfm*

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Sullivan, T.J., T.C. McDonnell, G.T. McPherson, S.D. Mackey, and D. Moore. 2011b. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: National Capital Region Network (NCRN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/317. National Park Service, Denver, CO.

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 CHOH was taken from the interpolation at the park centroid, which was located towards the western end 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 CHOH, 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 CHOH was 72.5 ppb which resulted in 17% attainment of reference condition, or moderate condition (NPS ARD 2011a) (Table 4.4). In addition, EPA has announced its intention to designate Montgomery and Frederick Counties,

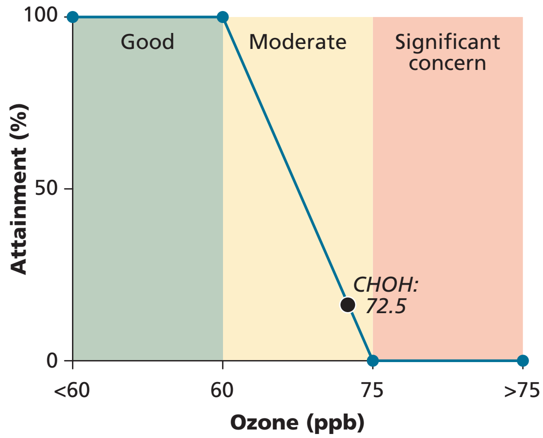

Figure 4.8. Application of the percent attainment categories to the ozone (ppb) value categories. Ozone concentration at CHOH was 72.5 ppb which equated to 17% attainment of the reference condition.

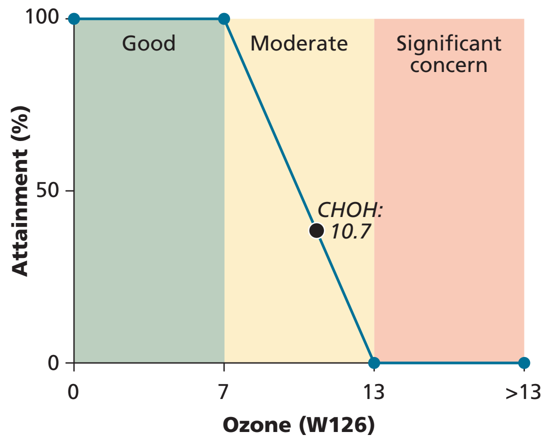

Figure 4.9. Application of the percent attainment categories to the ozone (W126) value categories. W126 at CHOH was 10.7 which equated to 38% attainment of the reference condition.

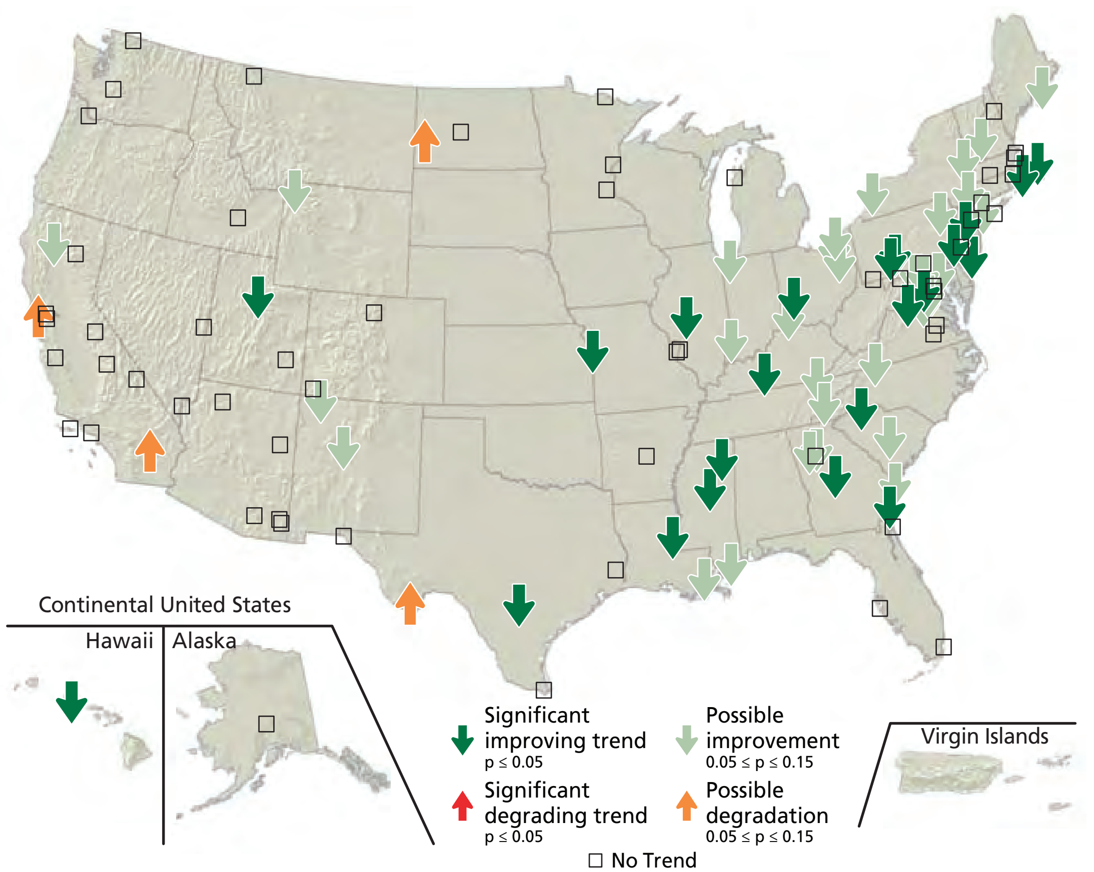

Figure 4.10. Trends in annual fourth-highest eight-hour ozone concentration (ppb), 1999–2008 (NPS ARD 2010b).

MD, and the District of Columbia, in which CHOH is partially located, as nonattainment for ozone (U.S. EPA 2011) because of violations of the 75 ppb standard at nearby monitors, recognizing that air quality is unhealthy at times in the area.

Interpolated W126 value between 2005 and 2009 for CHOH was 10.7 ppm-hrs which resulted in 38% attainment of reference condition, or moderate conditions (NPS ARD 2011a) (Table 4.4). A national assessment concluded that vegetation at CHOH 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 CHOH 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 CHOH 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 partially located in Montgomery and Frederick Counties, MD, and the District of Columbia, which are all 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 CHOH 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 CHOH was taken from the interpolation at the park centroid, which was located towards the western end 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).

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

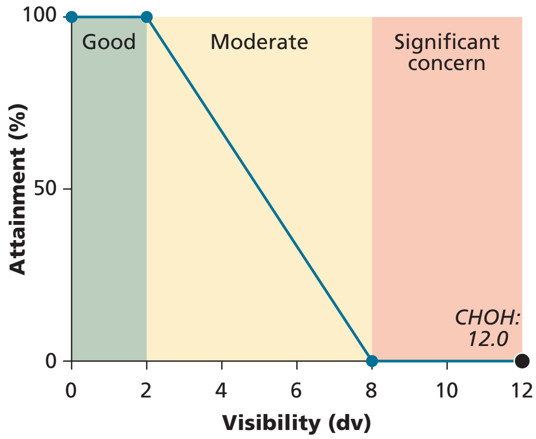

Figure 4.11. Application of the percent attainment categories to the visibility value categories. Visibility at CHOH was 12.0 dv which equated to 0% attainment of the reference condition.

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

Condition and trend

Interpolated haze index between 2005 and 2009 for CHOH was 12.0 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 there was no significant trend in visibility at CHOH, although general trends in the region seem to be improving (NPS ARD 2010) (Figure 4.12).

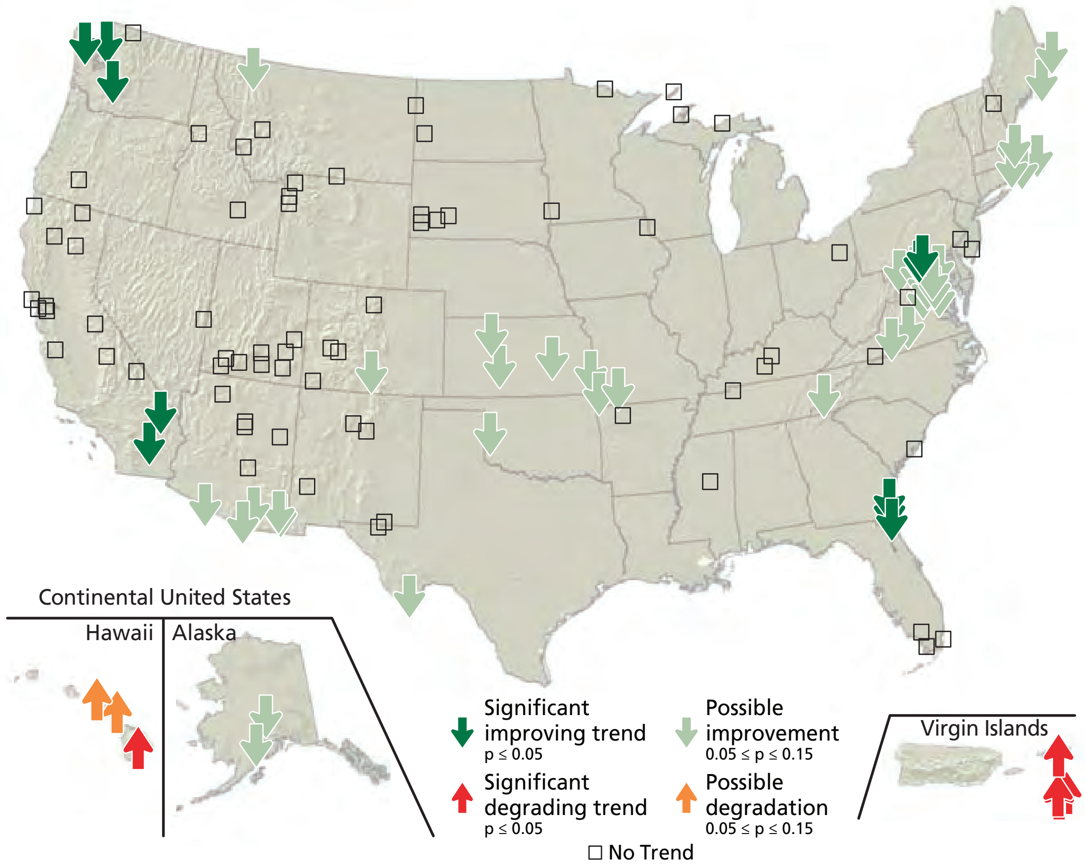

Figure 4.12. Visibility trends measured by the haze index (deciview) on haziest days, 1999–2008 (NPS ARD 2010b).

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 four sampling locations closest to CHOH: sites 240430009 near St. James in Washington County, MD, 510595001 near McLean in Fairfax County, VA, 511071005 in Loudoun County, VA, and 540030003 near Martinsburg in Berkeley County, WV (Figure 4.1, Table A-1).

The current National Ambient Air Quality Standards (NAAQS) particulate matter regulatory threshold is a concentration of 35 µg/m^3 (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/m^3, and the 24-hour or 'daily' standard is met when the three-year average of the annual 98th percentile is ≤ 65.0 µg/m^3 (NAAQS 2008). The annual standard (≤ 15.0 µg/m^3) 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

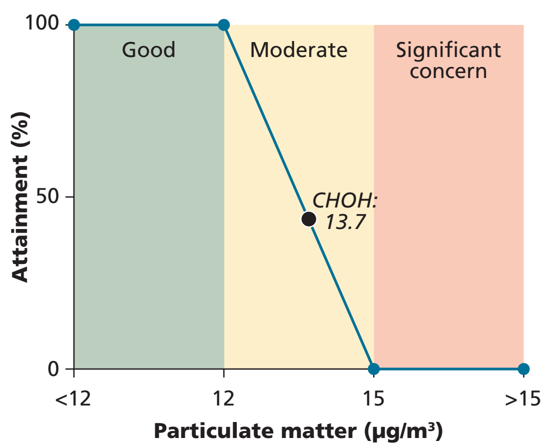

Figure 4.13. Application of the percent attainment categories to the particulate matter value categories. Particulate matter at CHOH was 13.7 µg/m^3 which equated to 44% attainment of the reference condition.

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

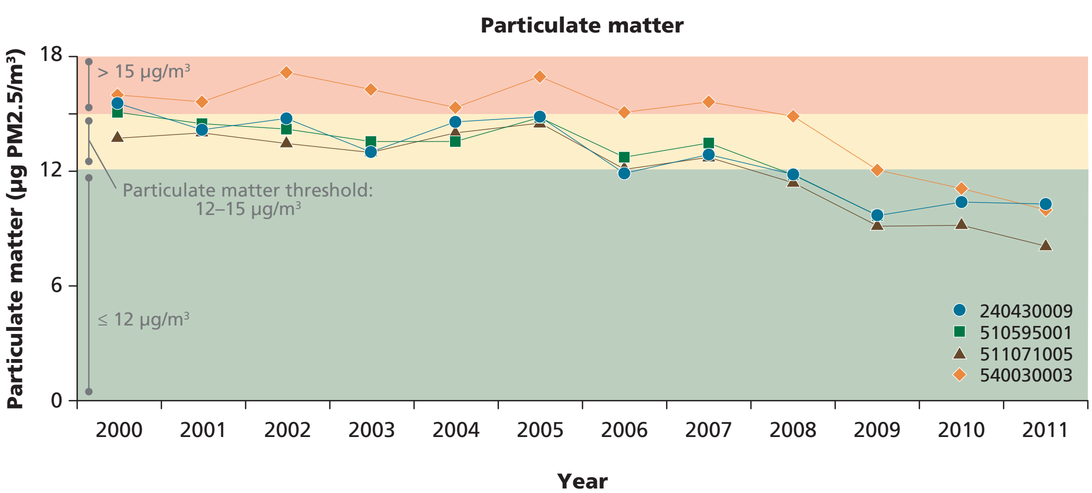

Figure 4.14. Particulate matter (µg PM2.5/m^3) at the four sites closest to CHOH. Reference conditions are shown in gray. Data show the annual mean concentrations.

ARD 2011), good condition (or 100% attainment) for particulate matter represents 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 four sites closest to CHOH had a median of 13.7 μg/m^3 between 2001 and 2010, with 44% attainment of the reference condition, or moderate condition (Figure 4.14, Table 4.4). All four 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 three sites: Piney Reservoir (MD08) in Garrett County, MD, Beltsville (MD99) in Prince Georges County, MD, and Arendtsville (PA00) in Adams County, PA (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 CHOH, but was included for informational purposes only.

Condition and trend

Annual median mercury concentrations in precipitation from two sites in the region of CHOH over the past decade range from ~6–13 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

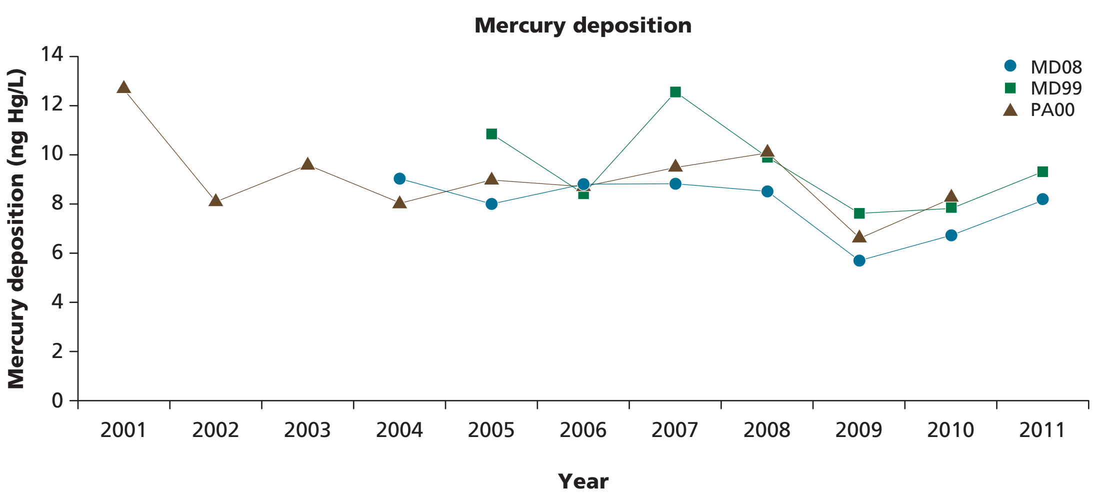

Figure 4.15. Median annual mercury concentrations (ng Hg/L) in precipitation from three sites in the region of CHOH.

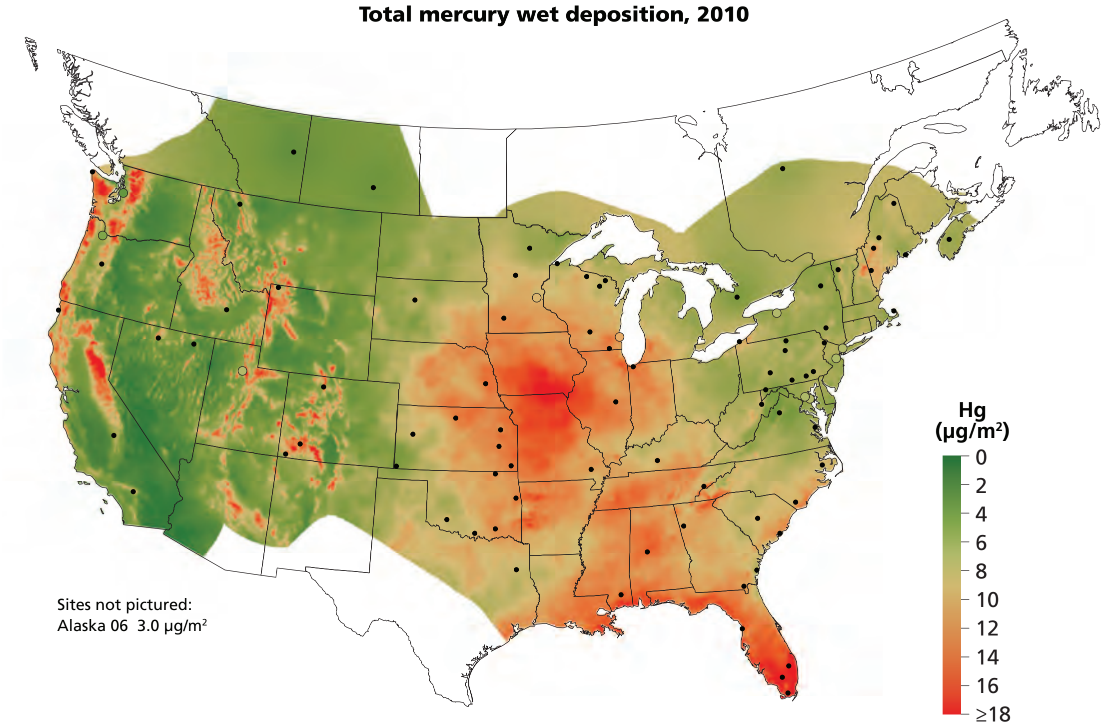

Figure 4.16. Total mercury wet deposition across the United States in 2010 (NADP/MDN 2012).

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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U.S. EPA. 2012. National recommended water quality criteria | Current water quality criteria. Accessed April 9, 2013. *http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm#hh*

4.2 WATER RESOURCES

4.2.1 Water resources summary

Nine metrics were used to assess water resources in CHOH—pH, dissolved oxygen (DO), water temperature, acid neutralizing capacity (ANC), specific conductance, nitrate, total phosphorus, Benthic Index of Biotic Integrity (BIBI), and Physical Habitat Index (PHI) (Table 4.10). A tenth metric (*E. coli*) was included for informational purposes but not included in the overall assessment. Data were collected by various agencies. Water quality monitoring sites are shown in Figures 4.17 and 4.18 and BIBI and PHI monitoring sites are shown in Figure 4.19.

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

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

Metric	Agency	Reference/source
pH	Antietam National Battlefield, MD Dept of the Environment, National Park Service, PA Dept of Environmental Protection	*http://www.epa.gov/storet/*
Dissolved oxygen	As above	As above
Water temperature	As above	As above
Acid neutralizing capacity	NCRN I&M	Norris and Pieper 2010, Norris et al. 2011
Specific conductance	Antietam National Battlefield, MD Dept of the Environment, National Park Service, PA Dept of Environmental Protection	*http://www.epa.gov/storet/*
Nitrate	As above	As above
Total phosphorus	As above	As above
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
E. coli	MD Dept of Environment	*http://www.epa.gov/storet/*

Table 4.11. Water Resources reference conditions for CHOH.

Metric	Reference condition/s	Sites	Samples	Period
pH	6.5–8.5 (MD); 6.0–8.5 (DC)	53	2,714	2000–2011
Dissolved oxygen (mg/L)	≥ 5.0 (MD); ≥ 5.0 (Feb 1–May 31) (DC); ≥ 3.2 (Jun 1–Jan 31) (DC)	50	2,679	2000–2011
Water temperature (°C)	≤ 32.2 (DC); ≤ 32.0 (MD Use I-P); ≤ 23.9 (MD Use IV-P); ≤ 20.0 (MD Use III-P)	50	2,721	2000–2011
Acid neutralizing capacity (µeq/L)	≥ 200	14	619	2005–2011
Specific conductance (µS/cm)	≤ 500	50	2,377	2000–2011
Nitrate (mg/L)	≤ 2	49	2,423	2000–2011
Total phosphorus (mg/L)	≤ 0.03656 (Ecoregion IX); ≤ 0.010 (Ecoregion XI)	50	1,706	2000–2011
Benthic Index of Biotic Integrity	1.0–1.9; 2.0–2.9; 3.0–3.9; 4.0–5.0	38	38	2003–2004
Physical Habitat Index	0–50; 51–65; 66–80; 81–100	34	34	2003–2004
E. coli (MPN)	N/A	9	250	2002–2004

converted to the condition assessment for that metric (Table 4.12). Single reference conditions were used for pH, DO, water temperature, ANC, specific conductance, nitrate, and total phosphorus, while multiple reference conditions were used for BIBI and PHI (Tables 4.11, 4.12a, 4.12b).

CHOH scored as very good condition for pH (92% attainment), DO (96% attainment), water temperature (98% attainment), and ANC (100% attainment). Specific conductance was moderate, with 49% attainment. BIBI and PHI scored as poor or degraded, with 38%, and 48% attainment, respectively (Table 4.13). Both nitrate and total phosphorus scored as very degraded, with 0% and 19% attainment, respectively. This resulted in an overall water resources condition attainment of 60%, or good condition.

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

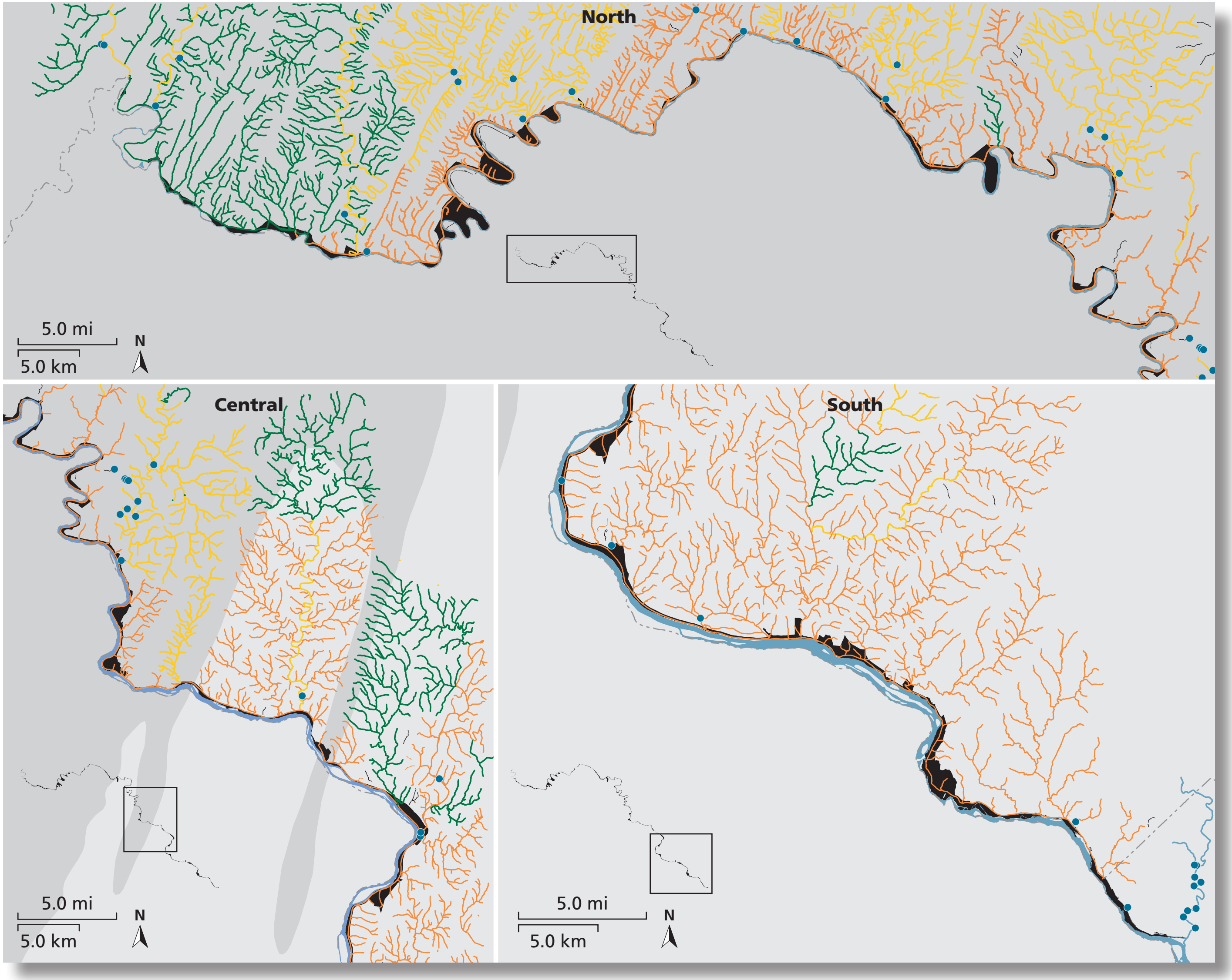
Table 4.12b. Categorical ranking of the reference condition attainment categories for the Benthic Index of Biotic Integrity and the Physical Habitat Index.

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 linearly ↓	Fair
2.0–2.9		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 CHOH.

Metric	Result	Reference condition	% attainment	Condition	Water resources condition
pH	7.8	6.5–8.5 (MD); 6.0–8.5 (DC)	92	Very good	**60%** **Good**
Dissolved oxygen (mg/L)	9.3	≥ 5.0 (MD); ≥ 5.0 (Feb 1–May 31) (DC); ≥ 3.2 (Jun 1–Jan 31) (DC)	96	Very good	
Water temperature (°C)	13.0	≤ 32.2 (DC); ≤ 32.0 (MD Use I-P); ≤ 23.9 (MD Use IV-P); ≤ 20.0 (MD Use III-P)	98	Very good	
Acid neutralizing capacity (μeq/L)	1,848	≥ 200	100	Very good	
Specific conductance (μS/cm)	504	≤ 500	49	Moderate	
Nitrate (mg/L)	3.3	≤ 2	0	Very degraded	
Total phosphorus (mg/L)	0.065	≤ 0.03656 (Ecoregion IX); ≤ 0.010 (Ecoregion XI)	19	Very degraded	
Benthic Index of Biotic Integrity	2.5	1.0–1.9; 2.0–2.9; 3.0–3.9; 4.0–5.0	38	Poor	
Physical Habitat Index	64	0–50; 51–65; 66–80; 81–100	48	Degraded	
E. coli (MPN)	201	N/A	N/A	N/A	



Legend

Maryland stream designated uses

- Use I (Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life)
- Use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply)
- Use III (Nontidal Cold Water)
- Use III-P (Nontidal Cold Water and Public Water Supply)
- Use IV (Recreational Trout Waters)
- Use IV-P (Recreational Trout Waters and Public Water Supply)
- Not yet determined
- Streams outside Maryland (District of Columbia)

Ecoregions

- Ecoregion IX (Southeastern Temperate Forested Plains and Hills)
- Ecoregion XI (Central and Eastern Forested Uplands)

- Site locations
- CHOH boundary
- State boundaries

Figure 4.17. Stream locations monitored for water quality within three miles of and upstream from CHOH. Sites were monitored for pH, dissolved oxygen, water temperature, acid neutralizing capacity, specific conductance, nitrate, total phosphorus, and *E. coli*, although not all parameters were measured at all sites.

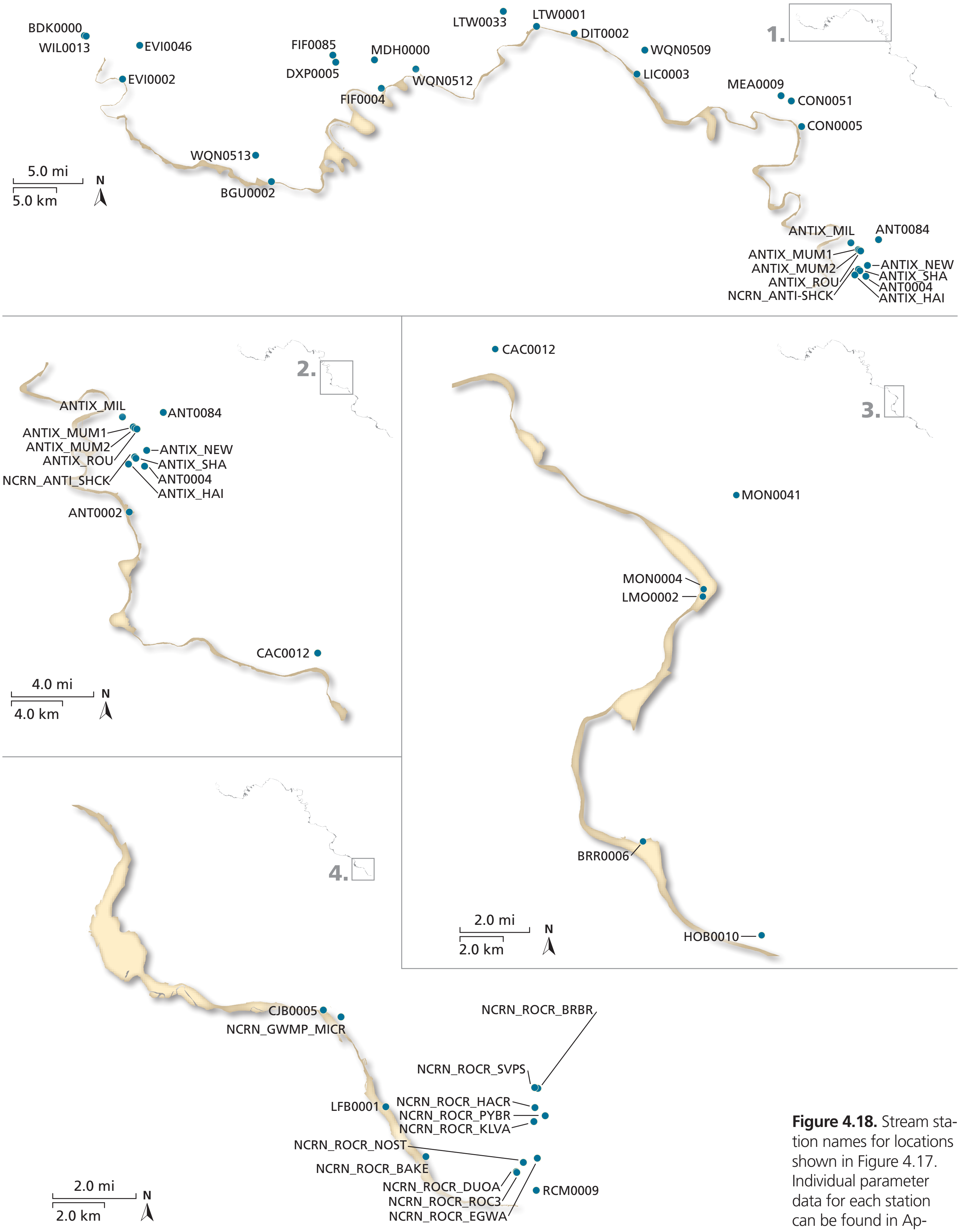


Figure 4.18. Stream station names for locations shown in Figure 4.17. Individual parameter data for each station can be found in Appendix A.

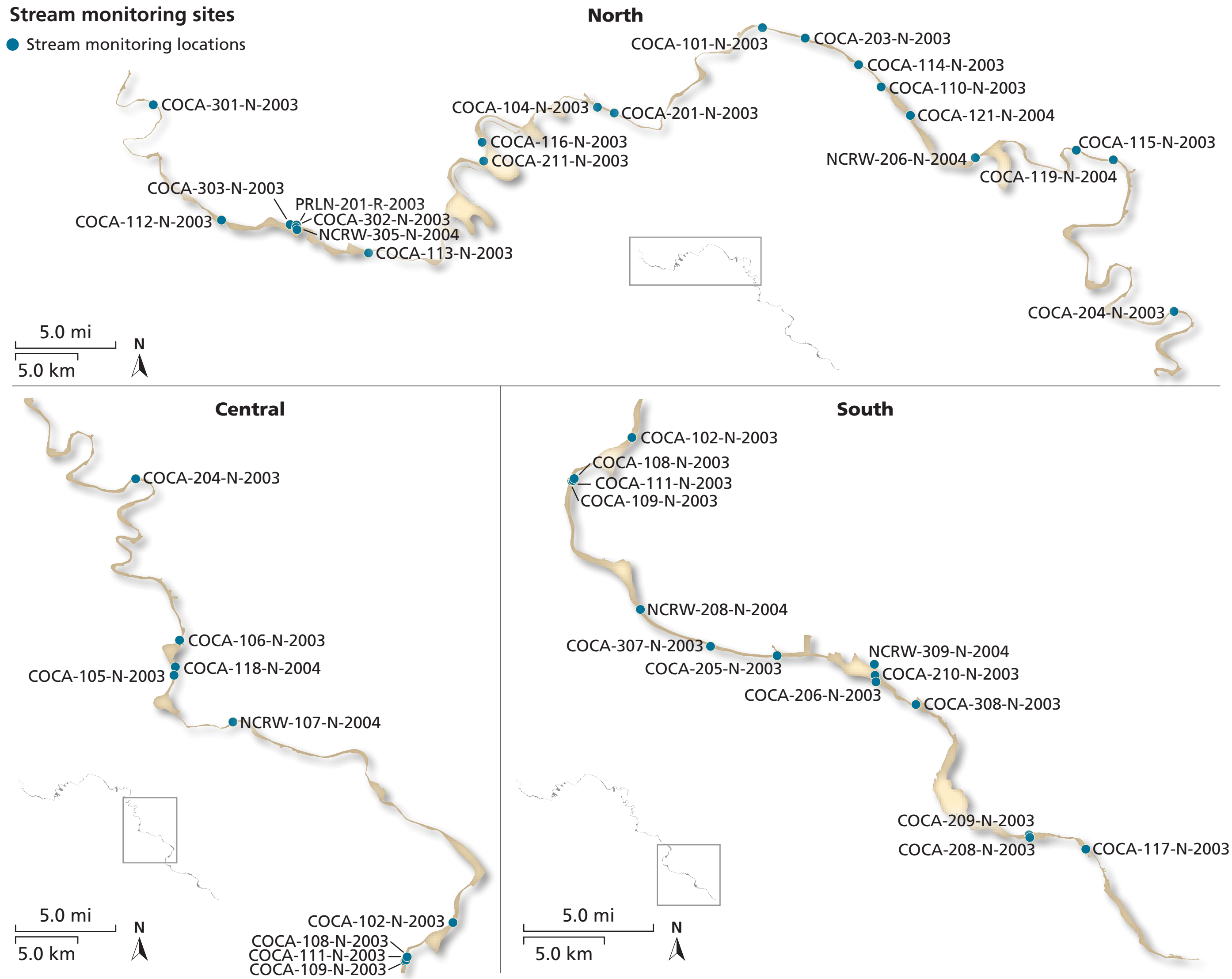


Figure 4.19. Stream sampling locations near CHOH monitored for stream macroinvertebrates, physical habitat, and stream fishes.

Literature cited

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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.

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.

4.2.2 Water pH

Description

The streams in and adjacent to CHOH 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 (Sadinski and Dunson 1992, NPS ARD 2010). Salamanders and fish are susceptible to extreme pH values (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

As pH was not measured in streams within the park boundary, data from sites upstream of the park were used. Data were downloaded from the U.S. EPA's STORET database (*http://www.epa.gov/storet*). Locations were chosen from waterways upstream of CHOH and within three miles of the park boundary (Figures 4.17, 4.18, Tables 4.10, 4.14). The data analyzed were collected between 2000 and 2011 at 50 sites by Antietam National Battlefield, Maryland Department of the Environment, the National Park Service, and the Pennsylvania Department of Environmental Protection.

Two reference conditions were used for this assessment. A reference condition pH range of 6.5–8.5 was used for stream locations in Maryland, consistent with the State's criteria for this metric (COMAR 2007a, 2007b, 2007c) (Table 4.11). A reference condition pH range of 6.0–8.5 was used for stream locations in the District of Columbia (Rock Creek), consistent with the District's criteria for this metric (District of Columbia Municipal Regulations 2010) (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 streams that flow into CHOH was very good, with a median pH of 7.8 and 92% of data points attaining the reference condition between 2000 and 2011 (Figures 4.20, 4.21, Tables 4.13, 4.14). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.21).

Sources of expertise

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

Literature cited

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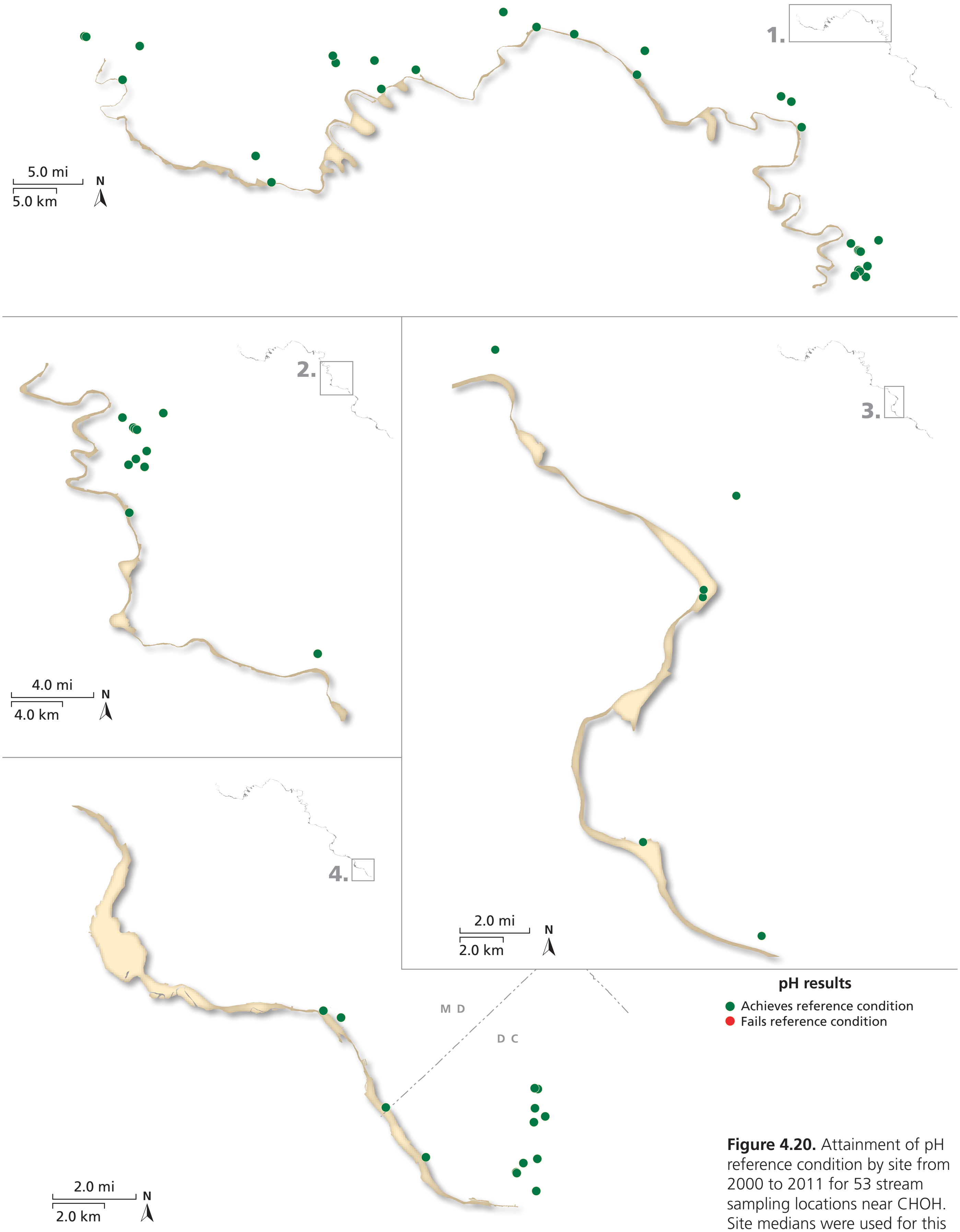

Figure 4.20. Attainment of pH reference condition by site from 2000 to 2011 for 53 stream sampling locations near CHOH. Site medians were used for this analysis.

Table 4.14. Median results for pH at each site. Locations of monitoring sites are shown in Figure 4.18.

Site	Location (MD/DC)	Median	Site	Location (MD/DC)	Median
ANT0002	MD	8.10	LIC0003	MD	7.80
ANT0044	MD	8.10	LMO0002	MD	7.90
ANT0084	MD	8.00	LTW0001	MD	7.70
ANTIX_HAI	MD	7.21	LTW0033	MD	7.50
ANTIX_MIL	MD	7.19	MDH0000	MD	6.95
ANTIX_MUM1	MD	7.19	MEA0009	MD	8.00
ANTIX_MUM2	MD	7.96	MON0004	MD	7.80
ANTIX_NEW	MD	7.99	MON0041	MD	7.95
ANTIX_ROU	MD	8.03	NCRN_ANTI_SHCK	MD	8.21
ANTIX_SHA	MD	8.00	NCRN_GWMP_MICR	MD	7.93
BDK0000	MD	8.00	NCRN_ROCR_BAKE	DC	7.55
BGU0002	MD	7.60	NCRN_ROCR_BRBR	DC	8.00
BRR0006	MD	7.70	NCRN_ROCR_DUOA	DC	7.95
CAC0012	MD	7.80	NCRN_ROCR_EGWA	DC	7.98
CJB0005	MD	7.90	NCRN_ROCR_HACR	DC	7.91
CON0005	MD	8.00	NCRN_ROCR_KLVA	DC	7.57
CON0051	MD	8.10	NCRN_ROCR_NOST	DC	7.59
DIT0002	MD	6.60	NCRN_ROCR_PYBR	DC	7.84
DXP0005	MD	7.10	NCRN_ROCR_ROC3	DC	7.83
EVI0002	MD	8.00	NCRN_ROCR_SVPS	DC	8.00
EVI0046	MD	7.90	RCM0009	DC	7.70
FIF0004	MD	7.20	WIL0013	MD	7.80
FIF0085	MD	7.20	WQN0509	MD	7.88
HOB0010	MD	7.55	WQN0512	MD	7.30
LFB0001	MD	8.20	WQN0513	MD	7.78

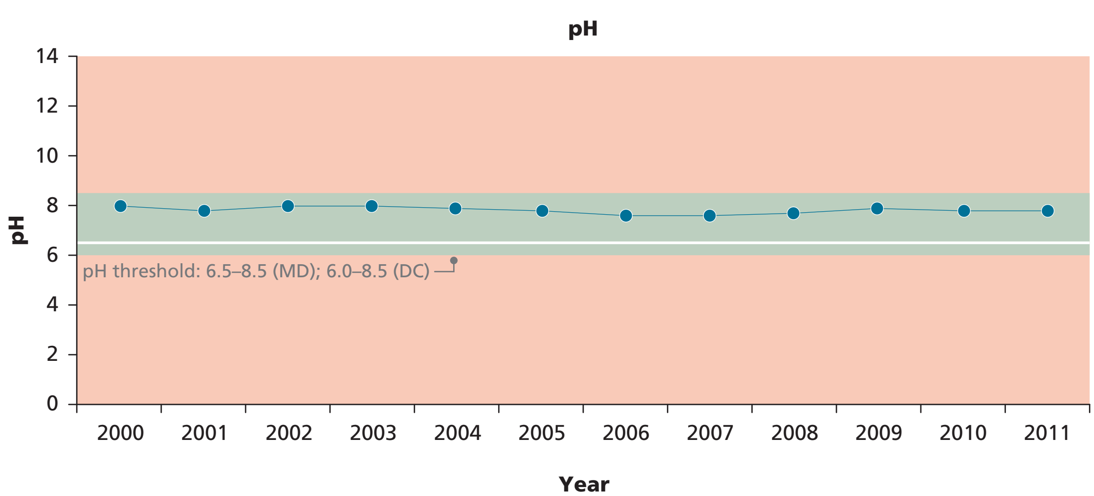

Figure 4.21. Annual median pH values from 2000 to 2011 for 50 stream sampling locations near CHOH. Reference conditions for various geographic locations are shown in gray.

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. For example, American shad (*Alosa sapidissima*) requires at least 5 mg/L of oxygen, while spot (*Leiostomus xanthurus*) can tolerate dissolved oxygen concentrations as low as 2 mg/L.

Data and methods

As DO was not measured in streams within the park boundary, data from sites upstream of the park were used. Data were downloaded from the U.S. EPA's STORET database (*http://www.epa.gov/storet*). Locations were chosen from waterways upstream of CHOH and within three miles of the park boundary (Figures 4.17, 4.18, Tables 4.10, 4.15). The data analyzed were collected between 2000 and 2011 at 50 sites by Antietam National Battlefield, Maryland Department of the Environment, the National Park Service, and the Pennsylvania Department of Environmental Protection.

Two reference conditions were used for this assessment. A reference condition of ≥ 5.0 mg DO/L was used for stream locations in Maryland, consistent with the State's criteria for this metric (COMAR 2007a, 2007b, 2007c) (Table 4.11). For stream locations in the District of Columbia (Rock Creek), a reference condition of ≥ 5.0 mg DO/L was used for sampling dates Feb 1–May 31 and ≥ 3.2 mg DO/L was used for sampling dates Jun 1–Jan 31, consistent with the District's criteria for this metric (District of Columbia Municipal Regulations 2010) (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 dissolved oxygen in streams that flow into CHOH was very good, with a median DO of 9.3 mg/L and 96% of data points attaining the reference condition between 2000 and 2011 (Figures 4.22, 4.23, Tables 4.13, 4.15). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.23).

Sources of expertise

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

Literature cited

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.

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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*

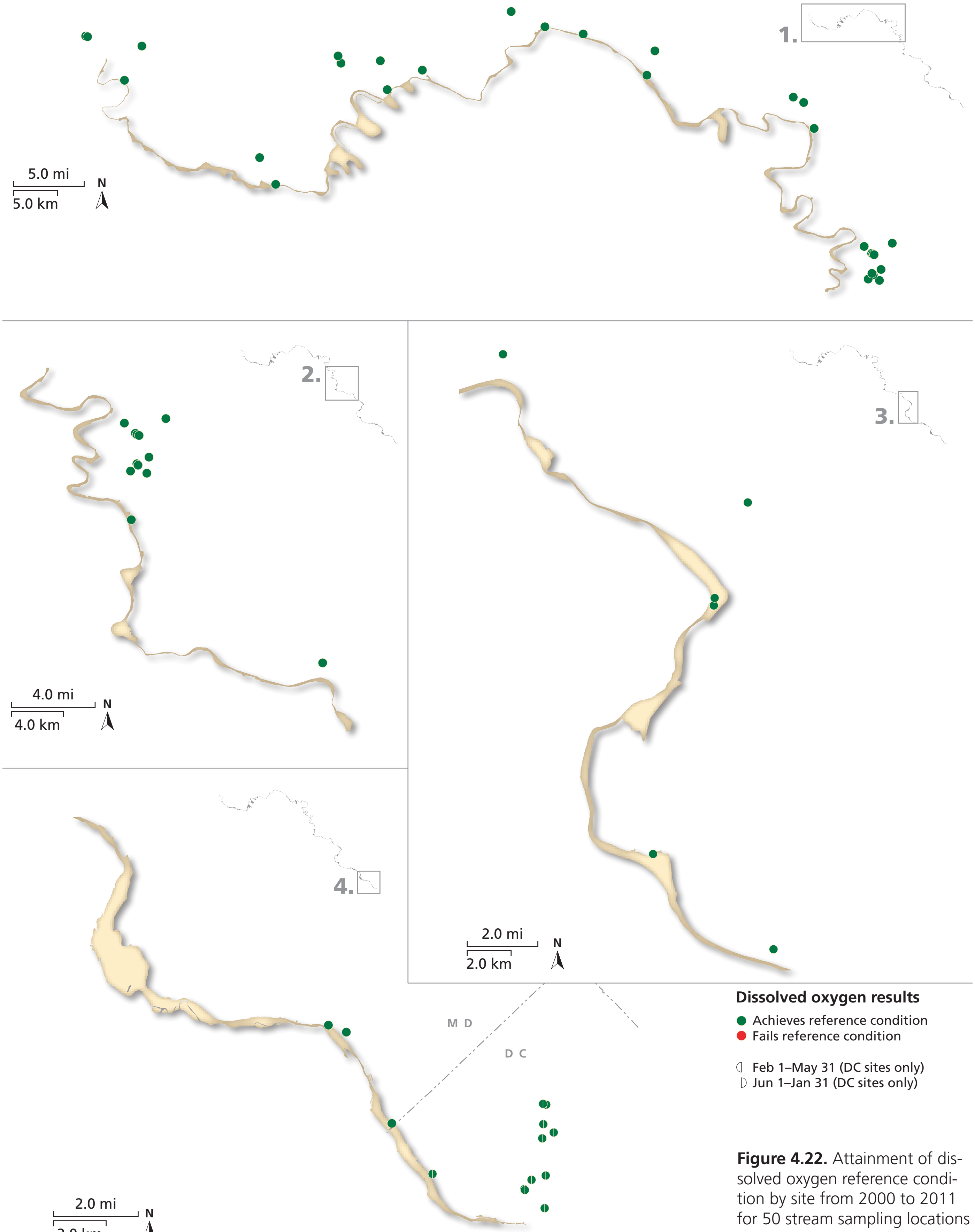

Figure 4.22. Attainment of dissolved oxygen reference condition by site from 2000 to 2011 for 50 stream sampling locations near CHOH. Site medians were used for this analysis.

Table 4.15. Median results for dissolved oxygen at each site. Locations of monitoring sites are shown in Figure 4.18. For sites in DC, the first number is the median for Feb 1–May 31 and the second number is the median for Jun 1–Jan 31.

Site	Location (MD/DC)	Median
ANT0002	MD	9.35
ANT0044	MD	9.80
ANT0084	MD	8.60
ANTIX_HAI	MD	5.80
ANTIX_MIL	MD	8.82
ANTIX_MUM1	MD	7.10
ANTIX_MUM2	MD	9.99
ANTIX_NEW	MD	9.97
ANTIX_ROU	MD	9.76
ANTIX_SHA	MD	10.60
BDK0000	MD	10.55
BGU0002	MD	11.20
BRR0006	MD	9.35
CAC0012	MD	9.80
CJB0005	MD	10.40
CON0005	MD	9.30
CON0051	MD	9.10
DIT0002	MD	11.70
DXP0005	MD	10.40
EVI0002	MD	10.20
EVI0046	MD	9.90
FIF0004	MD	10.10
FIF0085	MD	10.30
HOB0010	MD	11.05
LFB0001	MD	10.10
LIC0003	MD	9.50
LMO0002	MD	10.40
LTW0001	MD	10.90
LTW0033	MD	10.65
MDH0000	MD	10.80
MEA0009	MD	9.80
MON0004	MD	8.60
MON0041	MD	8.30
NCRN_ANTI_SHCK	MD	9.70
NCRN_GWMP_MICR	MD	9.10
NCRN_ROCR_BAKE	DC	10.27/8.22
NCRN_ROCR_BRBR	DC	11.46/8.17
NCRN_ROCR_DUOA	DC	10.19/8.73
NCRN_ROCR_EGWA	DC	6.89/7.50
NCRN_ROCR_HACR	DC	10.50/8.30
NCRN_ROCR_KLVA	DC	9.70/8.00
NCRN_ROCR_NOST	DC	9.48/6.66
NCRN_ROCR_PYBR	DC	11.63/8.73
NCRN_ROCR_ROC3	DC	10.78/8.58
NCRN_ROCR_SVPS	DC	11.55/8.00
RCM0009	DC	10.90/8.50
WIL0013	MD	10.60
WQN0509	MD	10.54
WQN0512	MD	10.02
WQN0513	MD	9.86

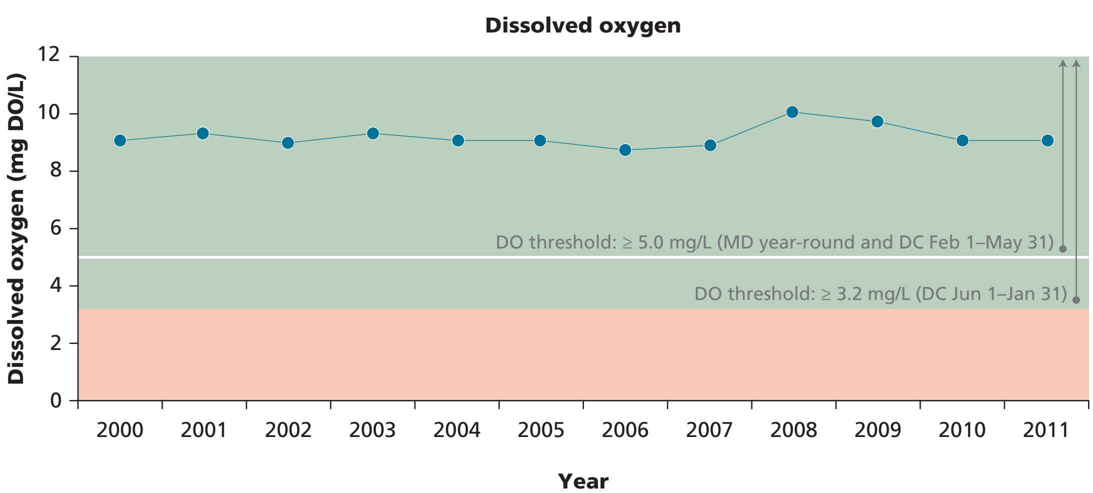

Figure 4.23. Annual median dissolved oxygen concentrations (mg/L) from 2000 to 2011 for 50 stream sampling locations near CHOH. Reference conditions for time of year and geographic location are shown in gray.

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.

Data and methods

As water temperature was not measured in streams within the park boundary, data from sites upstream of the park were used. Data were downloaded from the U.S. EPA's STORET database (*http://www.epa.gov/storet*). Locations were chosen from waterways upstream of CHOH and within three miles of the park boundary (Figures 4.17, 4.18, Tables 4.10, 4.16). The data analyzed were collected between 2000 and 2011 at 50 sites by various agencies, including Antietam National Battlefield, Maryland Department of the Environment, the National Park Service, and the Pennsylvania Department of Environmental Protection.

Four reference conditions were used for this assessment. A reference condition of ≤ 32.2°C was used for stream locations in the District of Columbia (Rock Creek), consistent with the District's criteria for this metric (District of Columbia Municipal Regulations 2010) (Table 4.11). For streams in Maryland, three different reference conditions were applied based on the stream designated uses (COMAR 2007a, 2007b, 2007c) (Figure 4.17). For sites in streams with designated use I-P (Water Contact Recreation, Protection of Aquatic Life, and Public Water Supply), the reference condition was water temperature ≤ 32.0°C. For sites in streams with designated use III-P (Nontidal Cold Water and Public Water Supply), the reference condition was water temperature ≤ 20.0°C. For sites in streams with designated use IV-P (Recreational Trout Waters and Public Water Supply), the reference condition was water temperature ≤ 23.9°C (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 streams that flow into CHOH was very good, with a median temperature of 13°C and 98% of data points attaining the reference condition between 2000 and 2011 (Figures 4.24, 4.25, Tables 4.13, 4.16). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.25).

Sources of expertise

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

Literature cited

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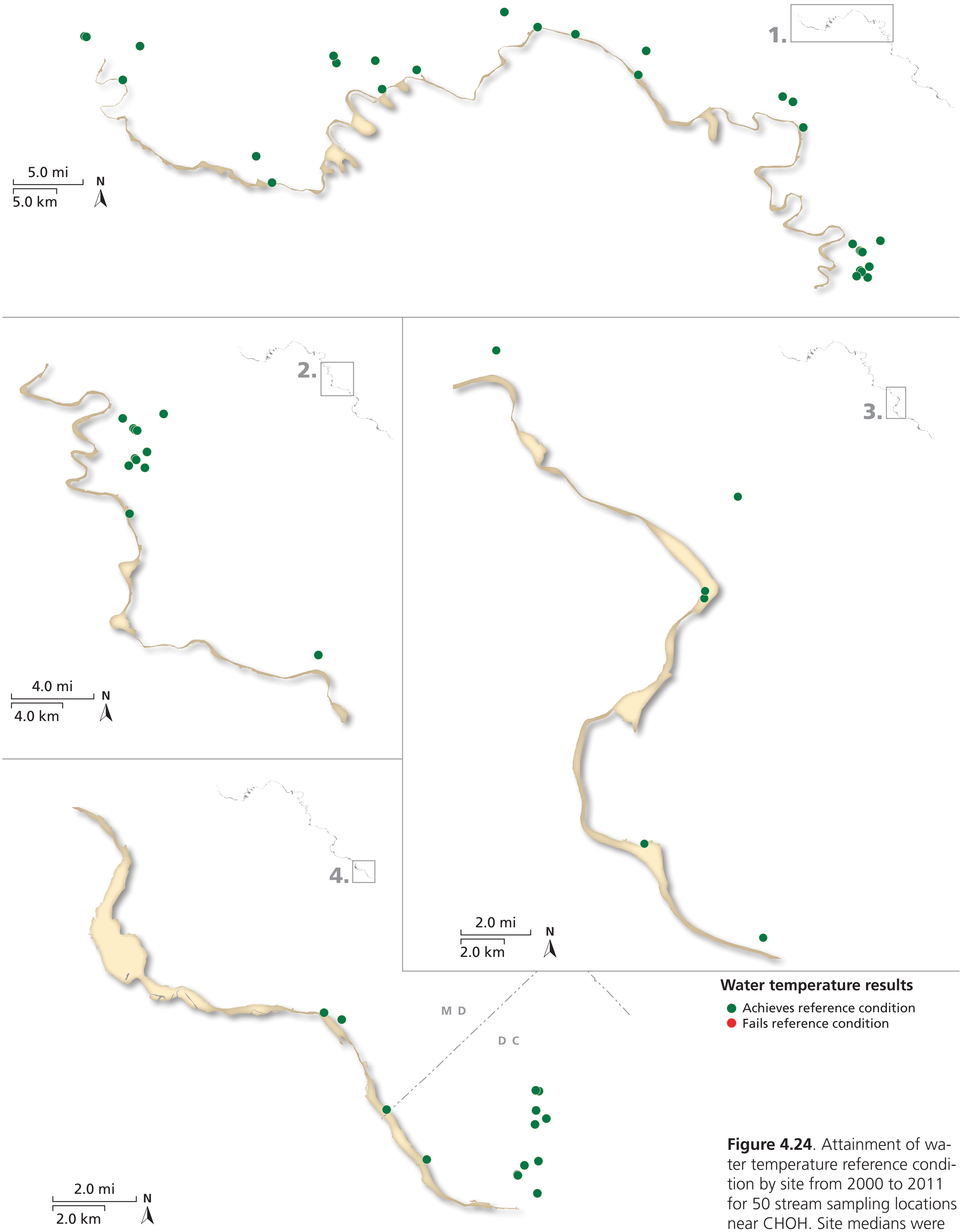

Figure 4.24. Attainment of water temperature reference condition by site from 2000 to 2011 for 50 stream sampling locations near CHOH. Site medians were used for this analysis.

Table 4.16. Median results for water temperature at each site. Locations of monitoring sites are shown in Figure 4.18. 'DC' indicates the site is in Washington, D.C. and is subject to the District's criteria.

Site	Designated use	Median	Site	Designated use	Median
ANT0002	IV-P	13.80	LIC0003	IV-P	12.60
ANT0044	IV-P	12.60	LMO0002	I-P	10.50
ANT0084	IV-P	15.95	LTW0001	I-P	8.75
ANTIX_HAI	IV-P	12.34	LTW0033	I-P	8.20
ANTIX_MIL	I-P	14.33	MDH0000	IV-P	8.95
ANTIX_MUM1	IV-P	12.66	MEA0009	IV-P	12.45
ANTIX_MUM2	IV-P	13.30	MON0004	I-P	14.70
ANTIX_NEW	IV-P	14.06	MON0041	I-P	19.05
ANTIX_ROU	IV-P	14.20	NCRN_ANTI_SHCK	IV-P	14.25
ANTIX_SHA	IV-P	12.83	NCRN_GWMP_MICR	I-P	15.10
BDK0000	III-P	9.55	NCRN_ROCR_BAKE	DC	13.80
BGU0002	I-P	7.70	NCRN_ROCR_BRBR	DC	14.00
BRR0006	I-P	11.55	NCRN_ROCR_DUOA	DC	14.00
CAC0012	IV-P	13.35	NCRN_ROCR_EGWA	DC	17.55
CJB0005	I-P	12.40	NCRN_ROCR_HACR	DC	13.25
CON0005	IV-P	13.75	NCRN_ROCR_KLVA	DC	13.60
CON0051	IV-P	14.20	NCRN_ROCR_NOST	DC	14.05
DIT0002	I-P	5.60	NCRN_ROCR_PYBR	DC	15.35
DXP0005	IV-P	7.65	NCRN_ROCR_ROC3	DC	15.34
EVI0002	IV-P	11.90	NCRN_ROCR_SVPS	DC	12.90
EVI0046	IV-P	10.80	RCM0009	DC	12.80
FIF0004	IV-P	11.00	WIL0013	IV-P	9.80
FIF0085	IV-P	8.80	WQN0509	IV-P	12.95
HOB0010	I-P	7.90	WQN0512	IV-P	11.50
LFB0001	I-P	15.40	WQN0513	IV-P	11.25

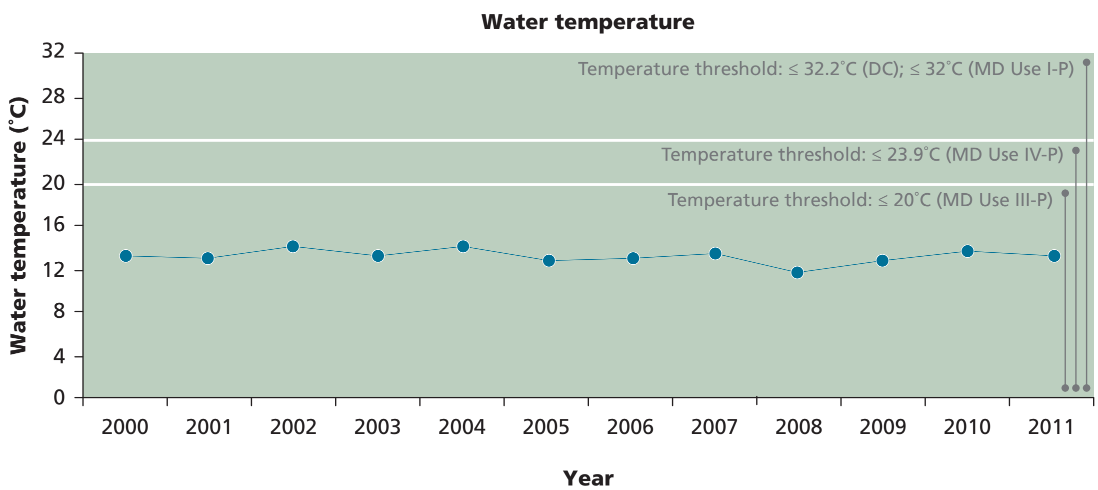

Figure 4.25. Annual median water temperature values (°C) from 2000 to 2011 for 50 stream sampling locations near CHOH. Reference conditions for various stream geographic locations are shown in gray.

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

As ANC was not measured in streams within the park boundary, data from sites upstream of the park were used. Data were downloaded from the U.S. EPA's STORET database (*http://www.epa.gov/storet*). Locations were chosen from waterways upstream of CHOH and within three miles of the park boundary (Figures 4.17, 4.18, Tables 4.10, 4.17). The data analyzed were collected between 2005 and 2011 at 14 sites by National Capital Region Network Inventory & Monitoring staff (Norris and Pieper 2010).

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] $CaCO_3$ = 20 μeq/L) (Southerland et al. 2007, Norris and Sanders 2009) (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 ANC in streams that flow into CHOH was very good, with a median ANC of 1,848 μeq/L and 100% of data points attaining the reference condition of ≥ 200 μeq/L between 2005 and 2011 (Figures 4.26, 4.27, Tables 4.13, 4.17). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.26).

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

Site	Median
EVI0002	1558
EVI0046	1972
NCRN_ANTI_SHCK	4660
NCRN_GWMP_MICR	1924
NCRN_ROCR_BAKE	1316
NCRN_ROCR_BRBR	2024
NCRN_ROCR_DUOA	1984
NCRN_ROCR_EGWA	1148
NCRN_ROCR_HACR	1960
NCRN_ROCR_KLVA	1612
NCRN_ROCR_NOST	1220
NCRN_ROCR_PYBR	1704
NCRN_ROCR_ROC3	1336
NCRN_ROCR_SVPS	2136

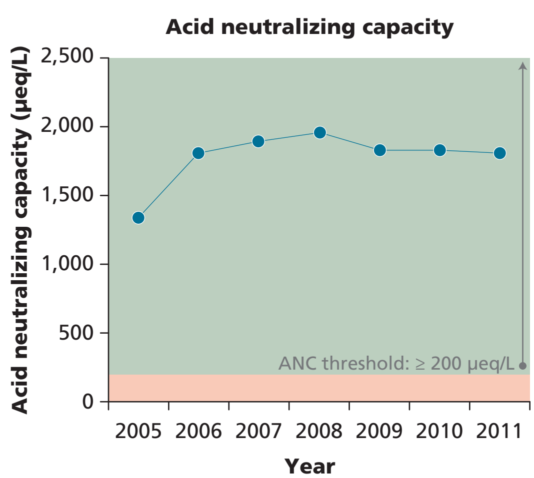

Figure 4.26. Annual median acid neutralizing capacity values (μeq/L) from 2005 to 2011 for 14 stream sampling locations near CHOH). Reference condition (ANC ≥ 200 μeq/L) is shown in gray.

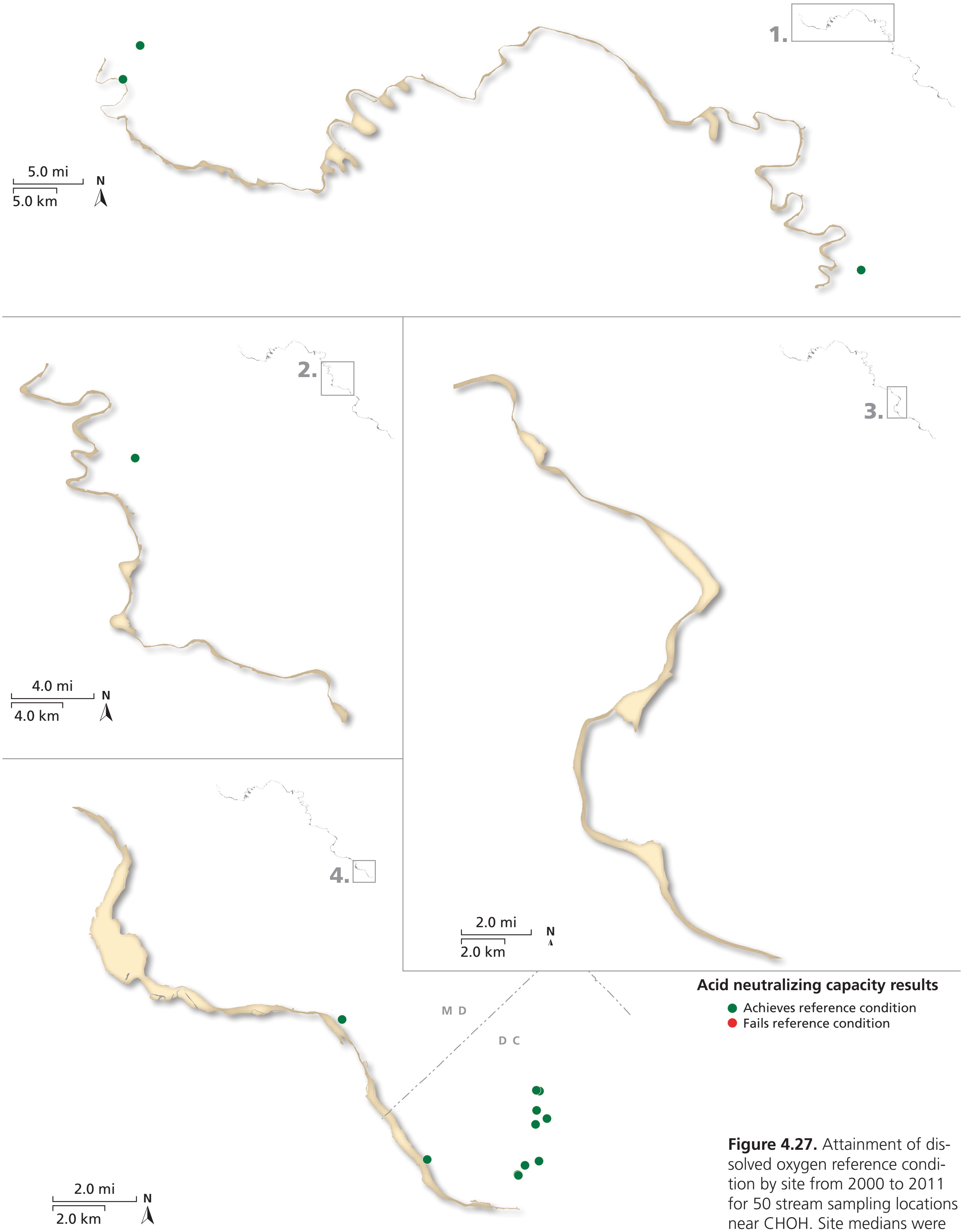

Figure 4.27. Attainment of dissolved oxygen reference condition by site from 2000 to 2011 for 50 stream sampling locations near CHOH. Site medians were used for this analysis.

Sources of expertise

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

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

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Welch, E.B., J.M. Jacoby, and C.W. May. 1998. Stream quality. In: Naiman R.J. and R.E. Bilby (eds). River ecology and management: lessons from the Pacific coastal ecoregion. Springer-Verlag, New York, NY.

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). Conductivity changes with temperature, so 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). Studies in the northest United States have found that deicing compounds alone are significantly elevating the specific conductance of some streams in the region during winter periods (Kaushal et al. 2005, Allan and Castillo 2007).

Data and methods

As specific conductance was not measured in streams within the park boundary, data from sites upstream of the park were used. Data were downloaded from the U.S. EPA's STORET database (*http://www.epa.gov/storet*). Locations were chosen from waterways upstream of CHOH and within three miles of the park boundary (Figures 4.17, 4.18, Tables 4.10, 4.18). The data analyzed were collected between 2000 and 2011 at 50 sites by Antietam National Battlefield, Maryland Department of the Environment, the National Park Service, and the Pennsylvania Department of Environmental Protection.

The reference condition for specific conductance was ≤ 500 µS/cm, above which conditions are said to be degraded (Buchanan et al. 2011) (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 trends

Condition of specific conductance in streams that flow into CHOH was moderate, with a median conductance of 5,041 µS/cm and 49% of data points attaining the reference condition of ≤ 500 µS/cm between 2000 and 2011 (Figures 4.28, 4.29, Tables 4.13, 4.18). 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

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Buchanan, C., K. Foreman, J. Johnson, and A. Griggs. 2011. Development of a basin-wide Benthic Index of Biotic Integrity for non-tidal streams and wadeable rivers in the Chesapeake Bay watershed: Final report to the Chesapeake Bay Program Non-Tidal Water Quality Workgroup. ICPRB Report 11-1. Report prepared for the U.S. Environmental Protection Agency, Chesapeake Bay Program.

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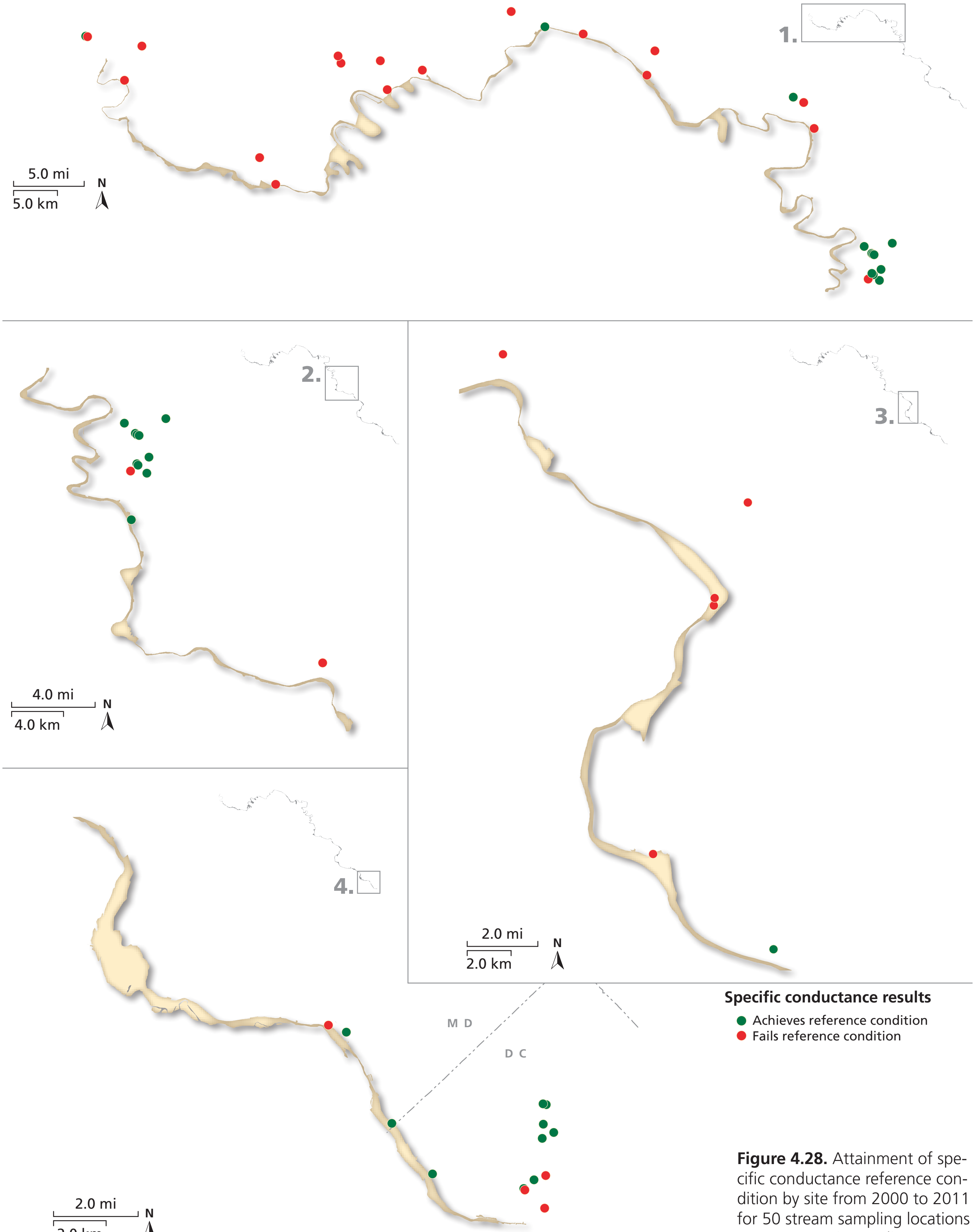

Figure 4.28. Attainment of specific conductance reference condition by site from 2000 to 2011 for 50 stream sampling locations near CHOH. Site medians were used for this analysis.

Table 4.18. Median results for specific conductance at each site. Locations of monitoring sites are shown in Figure 4.18.

Site	Median	Site	Median
ANT0002	553.5	LIC0003	245.0
ANT0044	541.0	LMO0002	183.5
ANT0084	551.0	LTW0001	515.5
ANTIX_HAI	448.0	LTW0033	271.5
ANTIX_MIL	675.5	MDH0000	270.0
ANTIX_MUM1	520.5	MEA0009	633.5
ANTIX_MUM2	519.0	MON0004	348.5
ANTIX_NEW	635.0	MON0041	482.5
ANTIX_ROU	507.0	NCRN_ANTI_SHCK	594.2
ANTIX_SHA	603.5	NCRN_GWMP_MICR	755.0
BDK0000	986.0	NCRN_ROCR_BAKE	681.0
BGU0002	82.0	NCRN_ROCR_BRBR	751.5
BRR0006	239.5	NCRN_ROCR_DUOA	601.5
CAC0012	279.0	NCRN_ROCR_EGWA	419.1
CJB0005	397.0	NCRN_ROCR_HACR	768.0
CON0005	433.5	NCRN_ROCR_KLVA	730.0
CON0051	369.0	NCRN_ROCR_NOST	671.5
DIT0002	167.0	NCRN_ROCR_PYBR	636.5
DXP0005	55.0	NCRN_ROCR_ROC3	422.8
EVI0002	299.0	NCRN_ROCR_SVPS	775.5
EVI0046	297.0	RCM0009	423.5
FIF0004	194.0	WIL0013	191.0
FIF0085	108.0	WQN0509	237.5
HOB0010	254.0	WQN0512	136.7
LFB0001	689.0	WQN0513	189.0

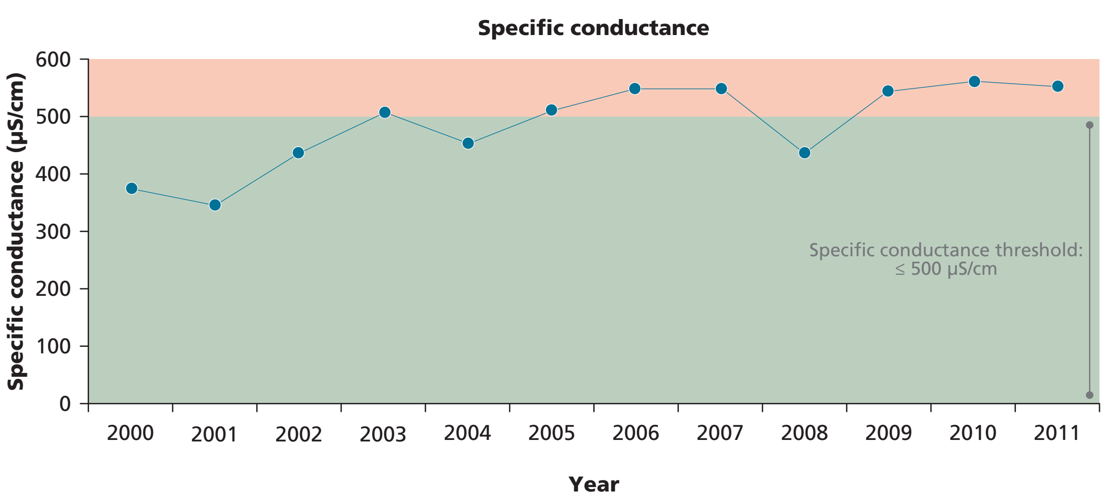

Figure 4.29. Annual median specific conductance values (µS/cm) from 2000 to 2011 for 50 stream sampling locations near CHOH. Reference condition (specific conductance ≤ 500 µS/cm) is shown in gray.

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Radtke, D.B., Davis, J.V., and Wilde, F.D, 1998, Specific electrical conductivity. 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.
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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 2013a).

Data and methods

As nitrate was not measured in streams within the park boundary, data from sites upstream of the park were used. Data were downloaded from the U.S. EPA's STORET database (*http://www.epa.gov/storet*). Locations were chosen from waterways upstream of CHOH and within three miles of the park boundary (Figures 4.17, 4.18, Tables 4.10, 4.19). Data were collected between 2000 and The data analyzed at 49 sites by Antietam National Battlefield, Maryland Department of the Environment, the National Park Service, and the Pennsylvania Department of Environmental Protection.

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 nitrate concentrations 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).

Condition and trend

Condition of nitrate in streams that flow into CHOH was very degraded, with a median nitrate concentration of 3.3 mg/L and 0% of data points attaining the reference condition of 2 mg/L between 2000 and 2011 (Figures 4.30, 4.31, Tables 4.13, 4.19). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.31).

Nitrate concentration peaked in 2004, following two years of above-average streamflow into Chesapeake Bay (USGS 2013b)

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 Resources 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.

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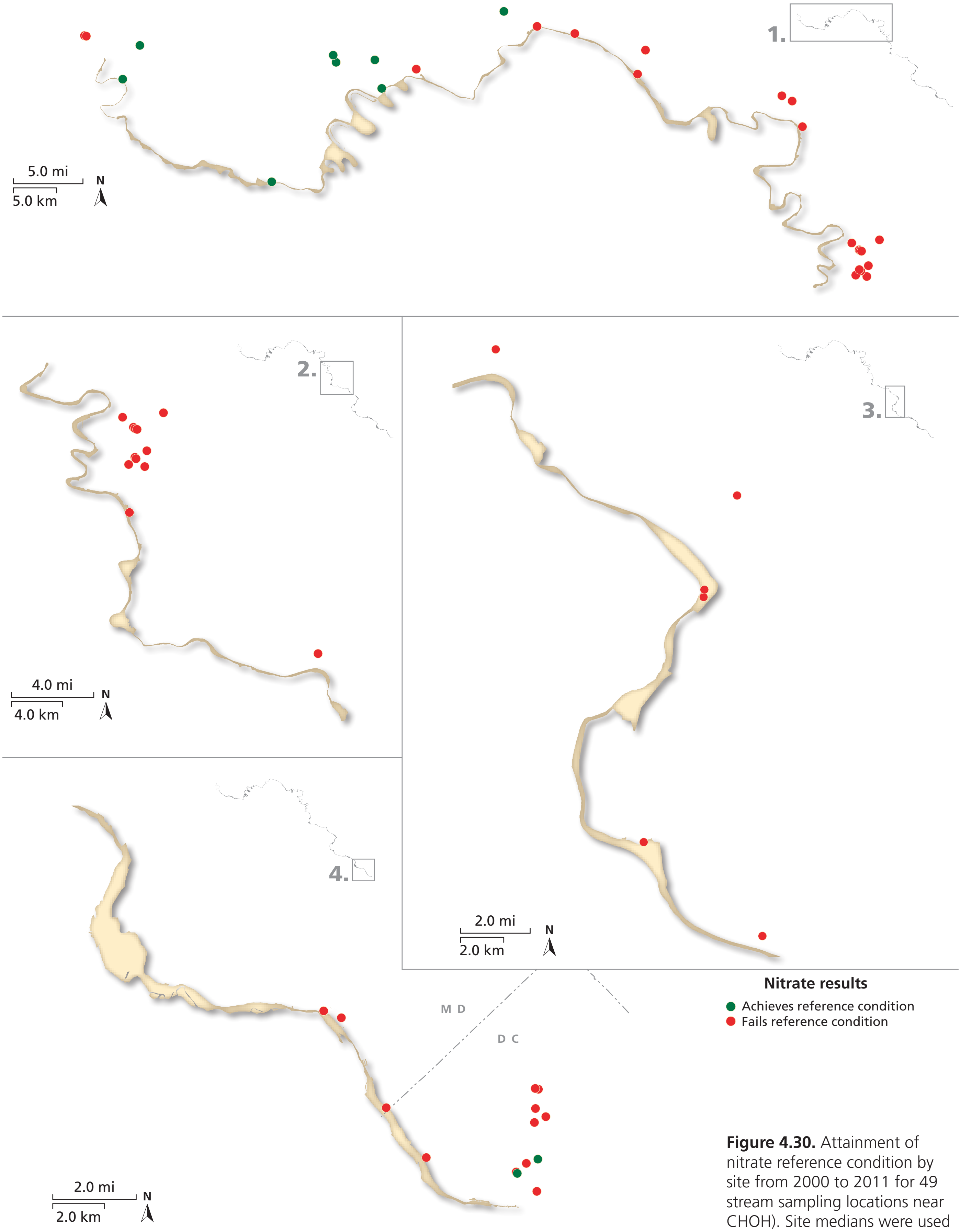

Figure 4.30. Attainment of nitrate reference condition by site from 2000 to 2011 for 49 stream sampling locations near CHOH). Site medians were used for this analysis.

Table 4.19. Median results for nitrate at each site. Locations of monitoring sites are shown in Figure 4.18.

Site	Median
ANT0002	20.75
ANT0044	17.89
ANT0084	13.01
ANTIX_HAI	5.80
ANTIX_MIL	5.90
ANTIX_MUM1	7.15
ANTIX_MUM2	5.30
ANTIX_NEW	2.50
ANTIX_ROU	5.60
ANTIX_SHA	5.55
BDK0000	2.65
BGU0002	0.01
BRR0006	11.10
CAC0012	5.19
CJB0005	4.93
CON0005	15.31
CON0051	17.34
DIT0002	11.14
DXP0005	0.22
EVI0002	0.95
EVI0046	1.23
FIF0004	0.29
FIF0085	0.31
HOB0010	5.82
LFB0001	7.12

Site	Median
LIC0003	3.65
LMO0002	7.95
LTW0001	3.79
LTW0033	1.72
MDH0000	0.60
MEA0009	26.76
MON0004	11.29
MON0041	7.39
NCRN_ANTI_SHCK	6.90
NCRN_GWMP_MICR	2.50
NCRN_ROCR_BAKE	3.90
NCRN_ROCR_BRBR	2.20
NCRN_ROCR_DUOA	3.70
NCRN_ROCR_EGWA	1.50
NCRN_ROCR_HACR	2.30
NCRN_ROCR_KLVA	2.95
NCRN_ROCR_NOST	4.60
NCRN_ROCR_PYBR	2.55
NCRN_ROCR_ROC3	1.60
NCRN_ROCR_SVPS	2.40
RCM0009	3.60
WIL0013	3.78
WQN0509	6.11
WQN0512	2.92

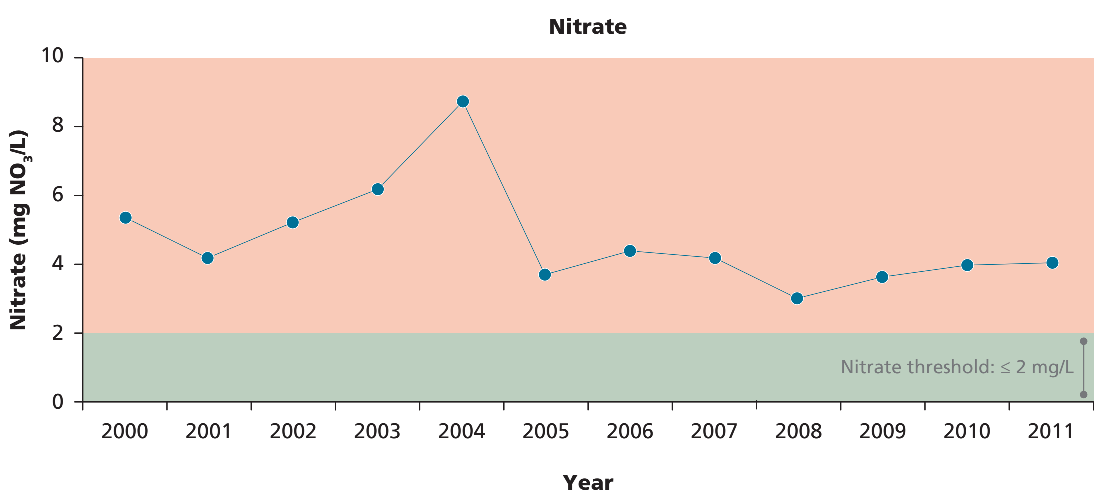

Figure 4.31. Annual median nitrate concentrations (mg NO_3/L) from 2000 to 2011 for 49 stream sampling locations near CHOH. Reference condition ($NO_3 \leq 2.0$ mg/L) is shown in gray.

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

As total phosphorus was not measured in streams within the park boundary, data from sites upstream of the park were used. Data were downloaded from the U.S. EPA's STORET database (*http://www.epa.gov/storet*). Locations were chosen from waterways upstream of CHOH and within three miles of the park boundary (Figures 4.17, 4.18, Tables 4.10, 4.20). The data analyzed were collected between 2000 and 2011 at 50 sites by Antietam National Battlefield, Maryland Department of the Environment, the National Park Service, and the Pennsylvania Department of Environmental Protection.

Two reference conditions were used for total phosphorus, based on the U.S. EPA Ecoregional Nutrient Criteria. These criteria were developed to prevent eutrophication nationwide and are not regulatory (U.S. EPA 2000a and b). 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. CHOH spans two Ecoregions—Ecoregion IX (Southeastern Temperate Forested Plains and Hills) and Ecoregion XI (Central and Eastern Forested Uplands) (Figure 4.17) (U.S. EPA 2000a and b). For streams in Ecoregion IX, the reference condition used was 0.03656 mg P/L (36.56 ppb). For streams in Ecoregion XI, the reference condition used was 0.010 mg P/L (10 ppb) (Table 4.11) (U.S. EPA 2000a and b). 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 streams that flow into CHOH was very degraded, with a median total phosphorus concentration of 0.065 mg/L and 19% of data points attaining the reference condition between 2000 and 2011 (Figures 4.32, 4.33, Tables 4.13, 4.20). Over the data range available, no significant trend was present (p-value > 0.01) (Figure 4.33).

Sources of expertise

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

Literature cited

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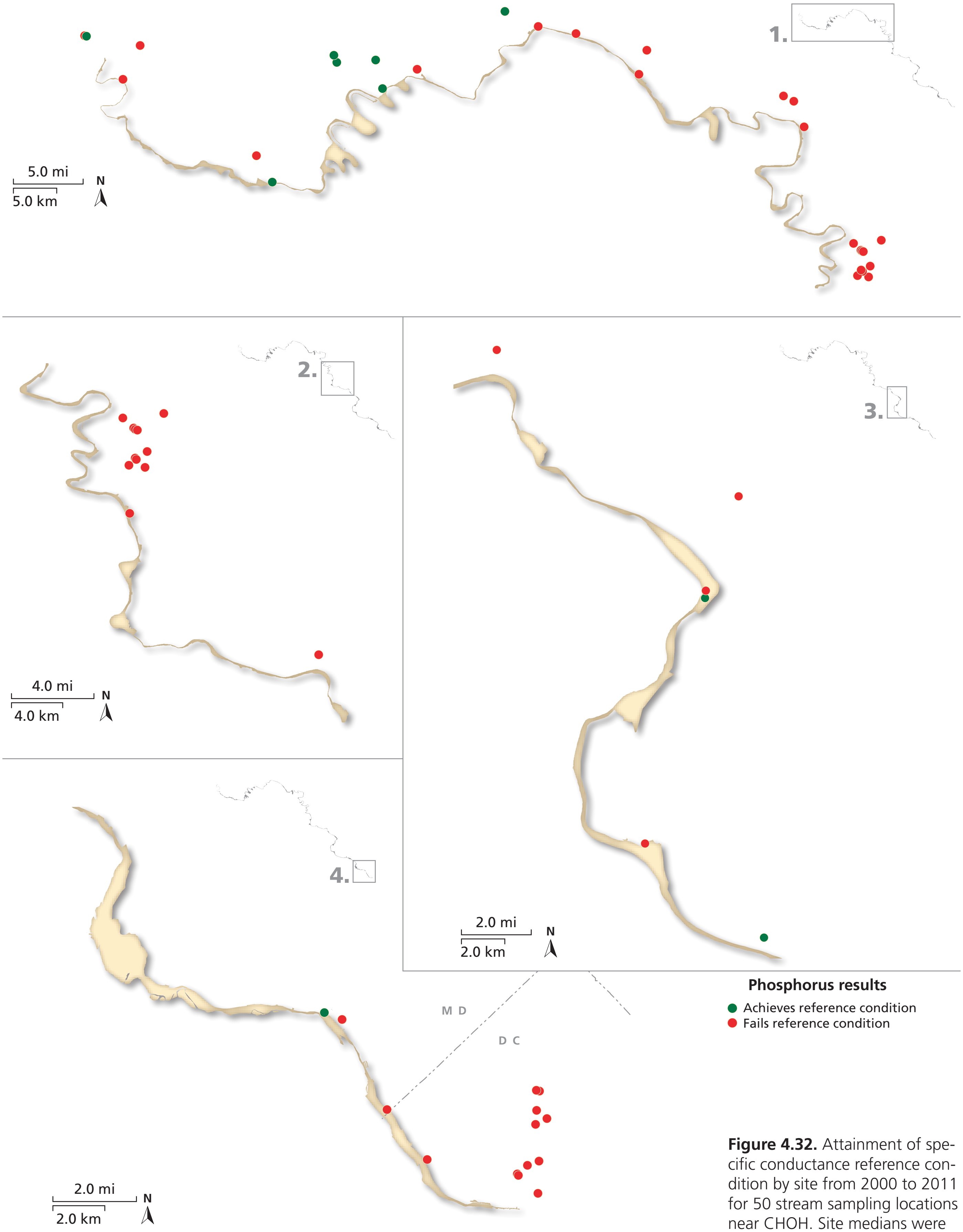

Figure 4.32. Attainment of specific conductance reference condition by site from 2000 to 2011 for 50 stream sampling locations near CHOH. Site medians were used for this analysis.

Table 4.20. Median results for phosphorus at each site. Locations of monitoring sites are shown in Figure 4.18.

Site	Ecoregion	Median
ANT0002	XI	0.110
ANT0044	XI	0.149
ANT0084	XI	0.248
ANTIX_HAI	XI	0.062
ANTIX_MIL	XI	0.085
ANTIX_MUM1	XI	0.073
ANTIX_MUM2	XI	0.082
ANTIX_NEW	XI	0.075
ANTIX_ROU	XI	0.088
ANTIX_SHA	XI	0.091
BDK0000	XI	0.012
BGU0002	XI	0.004
BRR0006	IX	0.505
CAC0012	IX	0.099
CJB0005	IX	0.018
CON0005	XI	0.069
CON0051	XI	0.042
DIT0002	XI	0.016
DXP0005	XI	0.005
EVI0002	XI	0.013
EVI0046	XI	0.013
FIF0004	XI	0.006
FIF0085	XI	0.005
HOB0010	IX	0.036
LFB0001	IX	0.095
LIC0003	XI	0.033
LMO0002	IX	0.021
LTW0001	XI	0.036
LTW0033	XI	0.005
MDH0000	XI	0.002
MEA0009	XI	0.040
MON0004	IX	0.131
MON0041	IX	0.194
NCRN_ANTI_SHCK	XI	0.078
NCRN_GWMP_MICR	IX	0.121
NCRN_ROCR_BAKE	IX	0.106
NCRN_ROCR_BRBR	IX	0.209
NCRN_ROCR_DUOA	IX	0.127
NCRN_ROCR_EGWA	IX	0.090
NCRN_ROCR_HACR	IX	0.238
NCRN_ROCR_KLVA	IX	0.126
NCRN_ROCR_NOST	IX	0.111
NCRN_ROCR_PYBR	IX	0.117
NCRN_ROCR_ROC3	IX	0.101
NCRN_ROCR_SVPS	IX	0.204
RCM0009	IX	0.041
WIL0013	XI	0.010
WQN0509	XI	0.036
WQN0512	XI	0.011
WQN0513	XI	0.011

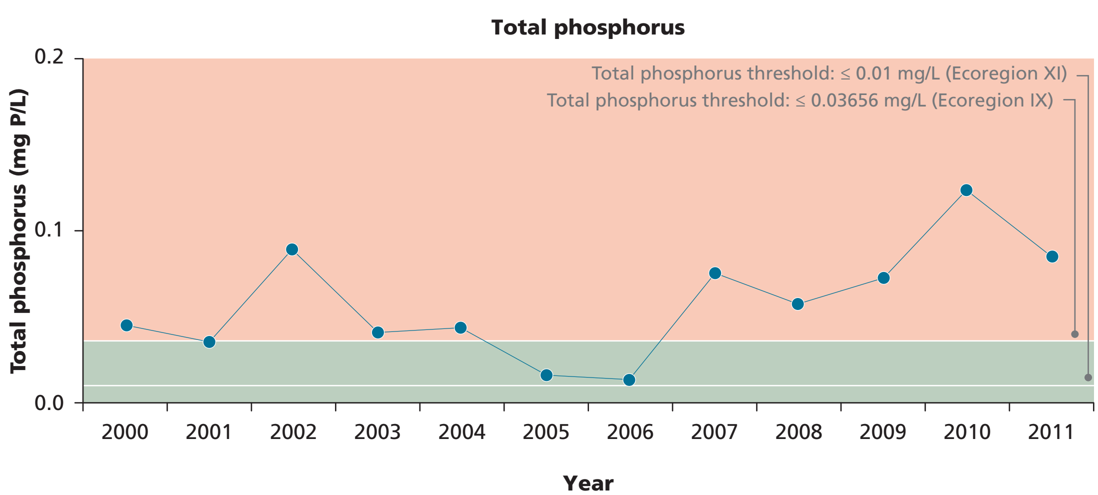

Figure 4.33. Annual median total phosphorus concentrations (mg P/L) from 2000 to 2011 for 50 stream sampling locations near CHOH. Reference conditions for various stream geographic locations are shown in gray.

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 multimetric 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 38 sites between 2003 and 2004 (Figure 4.19, 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).

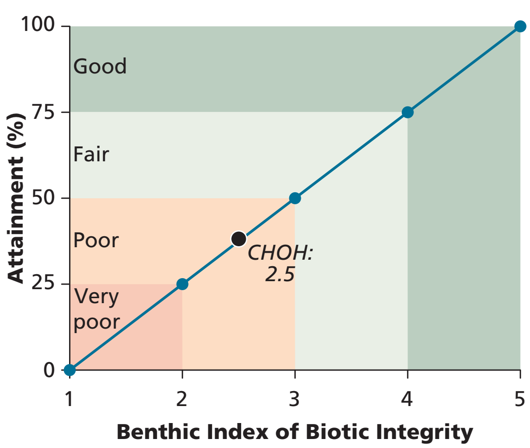

Figure 4.34. Application of the percent attainment categories to the Benthic Index of Biotic Integrity (BIBI) categories. BIBI at CHOH was 2.5 which equated to 38% attainment of the reference condition.

Table 4.21. 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

The range of BIBI scores from 1 to 5 were scaled linearly from 0 to 100% attainment (Figure 4.34, Table 4.21). 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 benthic macroinvertebrates in CHOH was poor, with a median BIBI of 2.5 and 38% attainment of reference condition (Figure 4.35, Tables 4.13, 4.22).

In addition to the data collection and analysis done by MBSS, several other agencies collect macroinvertebrate data within the Chesapeake Bay watershed. These disparate data sources have been included in a new Chesapeake Bay basin-wide BIBI ('Chessie BIBI') analysis method (Buchanan et al. 2011). When this method was applied to the data collected at sites within CHOH and to additional sites in waterways upstream of CHOH and within three miles of the park boundary (2000–2009), the overall attainment was 11% with a very poor condition assessment.

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.

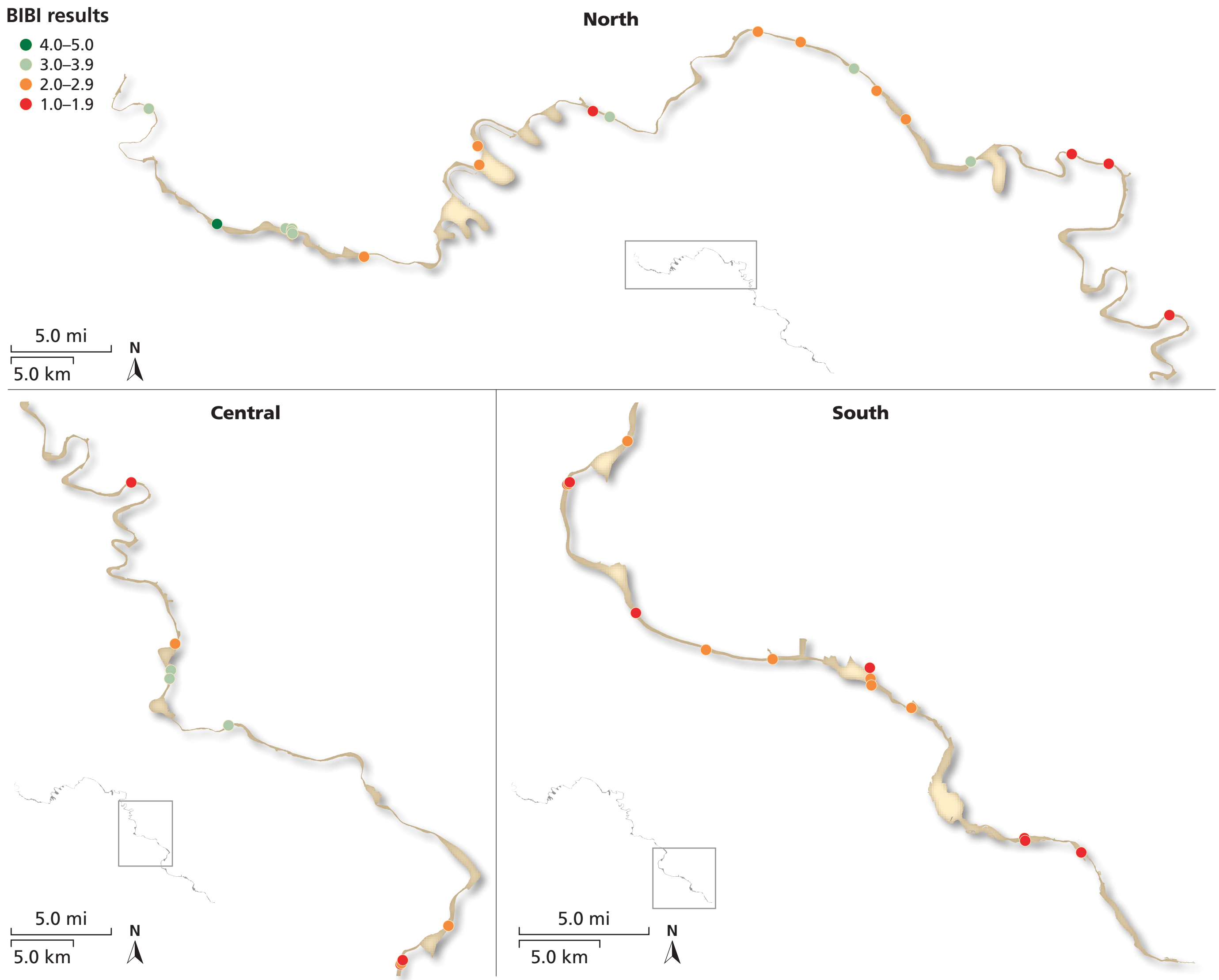

Figure 4.35. Attainment of Benthic Index of Biotic Integrity (BIBI) reference condition by site for 38 stream sampling locations in CHOH.

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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.

Table 4.22. Benthic Index of Biotic Integrity (BIBI) results for CHOH. Monitoring sites are shown in Figure 4.19. UT = unnamed tributary.

Year	Site	Location	BIBI
2003	COCA-101-N-2003	UT Potomac River	2.50
2003	COCA-102-N-2003	UT Potomac River	2.50
2003	COCA-104-N-2003	UT Potomac River	1.75
2003	COCA-105-N-2003	UT Potomac River	3.50
2003	COCA-106-N-2003	UT Potomac River	2.00
2003	COCA-108-N-2003	UT Potomac River	1.75
2003	COCA-109-N-2003	UT Potomac River	1.50
2003	COCA-110-N-2003	UT Potomac River	2.75
2003	COCA-111-N-2003	UT Potomac River	2.00
2003	COCA-112-N-2003	UT Potomac River	4.00
2003	COCA-113-N-2003	Big Run	2.50
2003	COCA-114-N-2003	UT Potomac River	3.75
2003	COCA-115-N-2003	UT Potomac River	1.00
2003	COCA-116-N-2003	UT Potomac River	2.50
2003	COCA-117-N-2003	Minnehaha Branch	1.00
2003	COCA-201-N-2003	UT Potomac River	3.00
2003	COCA-203-N-2003	Ditch Run	2.75
2003	COCA-204-N-2003	Marsh Run	1.25
2003	COCA-205-N-2003	UT Potomac River	2.00
2003	COCA-206-N-2003	Muddy Branch	2.75
2003	COCA-208-N-2003	Rock Run	1.33
2003	COCA-209-N-2003	Rock Run	1.00
2003	COCA-210-N-2003	Muddy Branch	2.25
2003	COCA-211-N-2003	UT Potomac River	2.00
2003	COCA-301-N-2003	Evitts Cr	3.00
2003	COCA-302-N-2003	Seven Springs Run	3.00
2003	COCA-303-N-2003	Seven Springs Run	3.50
2003	COCA-307-N-2003	Horsepen Branch	2.50
2003	COCA-308-N-2003	Watts Branch	2.00
2003	PRLN-201-R-2003	Seven Springs Run UT2	3.75
2004	COCA-118-N-2004	UT Potomac River	3.50
2004	COCA-119-N-2004	UT Potomac River	1.50
2004	COCA-121-N-2004	UT Potomac River	2.00
2004	NCRW-107-N-2004	Israel Creek	3.25
2004	NCRW-206-N-2004	Green Spring Run	3.00
2004	NCRW-208-N-2004	Cabin Branch	1.50
2004	NCRW-305-N-2004	Seven Springs Run	3.00
2004	NCRW-309-N-2004	Muddy Branch	1.75

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 34 sites between 2003 and 2004 (Figure 4.19, Table 4.10). Data were collected during development of 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). Data reported represent one sample 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 (partially degraded), 66–80 (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 4.23).

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 CHOH was partially degraded, with a median PHI of 64 which equated to 48% attainment of reference condition (Figure 4.37, Tables 4.13, 4.24).

No trend analysis was possible with the current data set.

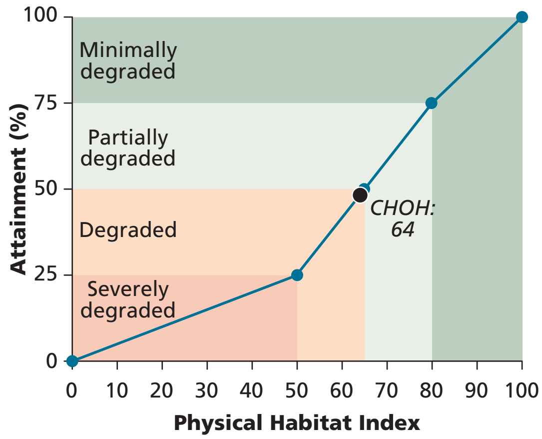

Figure 4.36. Application of the percent attainment categories to the PHI value categories. PHI at CHOH was 64 which equated to 48% attainment of the reference condition.

Table 4.23. 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

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.

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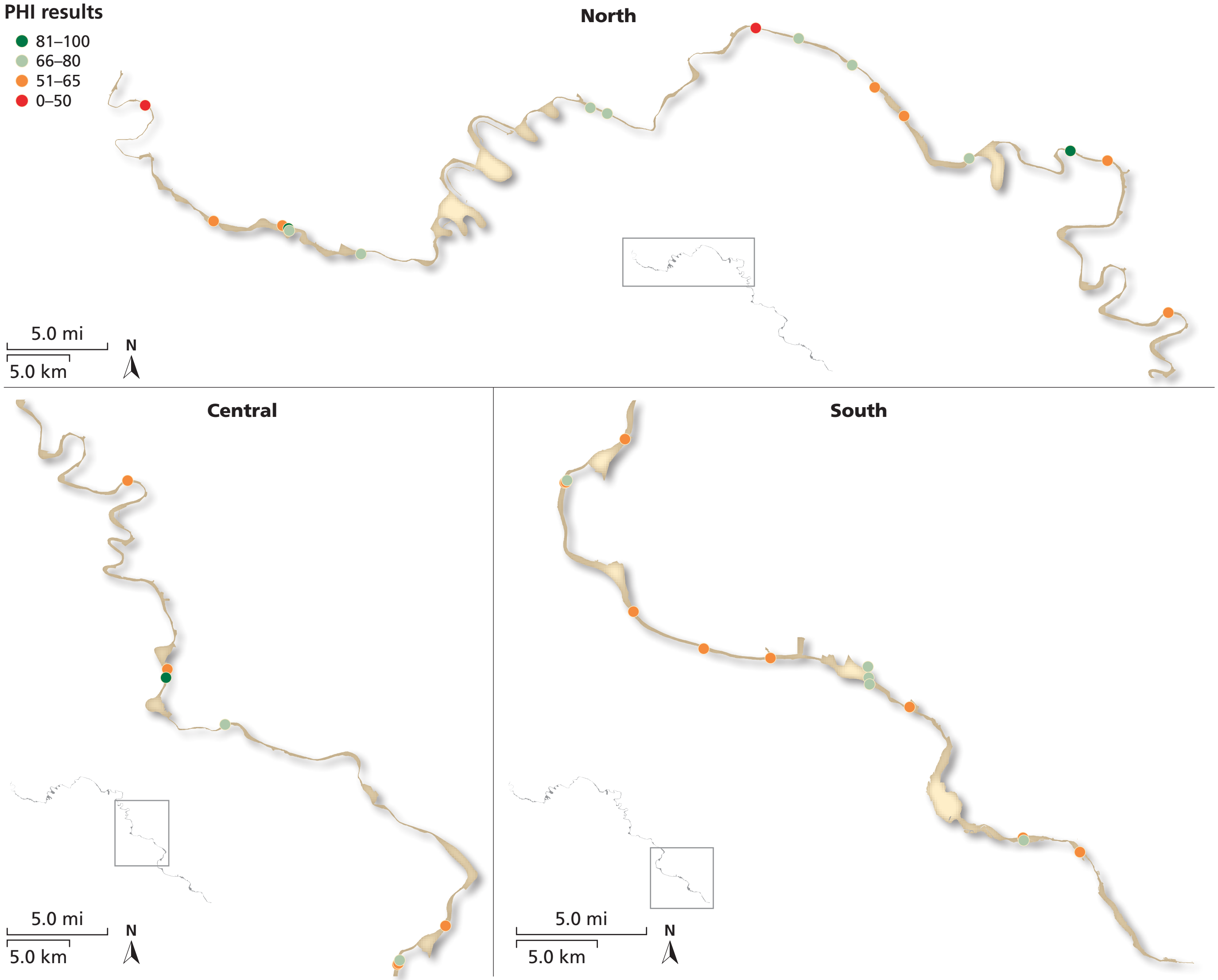

Figure 4.37. Attainment of Physical Habitat Index (PHI) reference condition by site for 34 stream sampling locations in CHOH.

Table 4.24. Physical Habitat Index (PHI) in CHOH. Monitoring sites are shown in Figure 4.19. UT = unnamed tributary.

Year	Site	Location	PHI
2003	COCA-101-N-2003	UT Potomac River	47.1
2003	COCA-102-N-2003	UT Potomac River	58.7
2003	COCA-104-N-2003	UT Potomac River	68.4
2003	COCA-105-N-2003	UT Potomac River	81.3
2003	COCA-108-N-2003	UT Potomac River	65.7
2003	COCA-109-N-2003	UT Potomac River	60
2003	COCA-110-N-2003	UT Potomac River	57
2003	COCA-111-N-2003	UT Potomac River	59.9
2003	COCA-112-N-2003	UT Potomac River	64.4
2003	COCA-113-N-2003	Big Run	70.13
2003	COCA-114-N-2003	UT Potomac River	68.3
2003	COCA-115-N-2003	UT Potomac River	85.1
2003	COCA-117-N-2003	Minnehaha Branch	63.9
2003	COCA-201-N-2003	UT Potomac River	73.9
2003	COCA-203-N-2003	Ditch Run	71
2003	COCA-204-N-2003	Marsh Run	50.9
2003	COCA-205-N-2003	UT Potomac River	60.1
2003	COCA-206-N-2003	Muddy Branch	66.5
2003	COCA-208-N-2003	Rock Run	69.7
2003	COCA-209-N-2003	Rock Run	56.2
2003	COCA-210-N-2003	Muddy Branch	67.3
2003	COCA-301-N-2003	Evitts Cr	44.3
2003	COCA-302-N-2003	Seven Springs Run	81.1
2003	COCA-303-N-2003	Seven Springs Run	53
2003	COCA-307-N-2003	Horsepen Branch	57.3
2003	COCA-308-N-2003	Watts Branch	62.4
2004	COCA-118-N-2004	UT Potomac River	60.4
2004	COCA-119-N-2004	UT Potomac River	61.1
2004	COCA-121-N-2004	UT Potomac River	63.2
2004	NCRW-107-N-2004	Israel Creek	77.1
2004	NCRW-206-N-2004	Green Spring Run	66.6
2004	NCRW-208-N-2004	Cabin Branch	51.1
2004	NCRW-305-N-2004	Seven Springs Run	75.7
2004	NCRW-309-N-2004	Muddy Branch	79.5

4.2.11 *E. coli*

Description

Escherichia coli is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. The U.S. EPA recommends *E. coli* as the best indicator of human health risk from water contact in recreational waters. Most strains of *E. coli* are harmless to humans, but their presence in waterways can indicate fecal contamination and the potential presence of other pathogenic bacteria in recreational and drinking waters (CDC 2011, U.S. EPA 2012).

Data and methods

As *E. coli* was not measured in streams within the park boundary, data from sites upstream of the park were used. Data were downloaded from the U.S. EPA's STORET database (*http://www.epa.gov/storet*). Locations were chosen from waterways upstream of CHOH and within three miles of the park boundary (Figures 4.17, 4.18, Tables 4.10, 4.25). Data were collected between 2002 and 2004 at nine sites by the Maryland Department of the Environment.

Because of the limited spatial and temporal coverage of data for this metric, *E. coli* was not included in the overall assessment of CHOH but is included for informational purposes only.

Condition and trend

The nine sites within the region of CHOH had a median of 201 MPN/100 mL.

Current condition of *E. coli* in streams that flow into CHOH was degraded, with a median MPN/100 mL of 201 (Figure 4.38, Table 4.25).

Table 4.25. Sites and results for *E. coli*. Locations of monitoring sites are shown in Figure 4.18.

Site	Median
ANT0002	165.0
ANT0044	225.0
BDK0000	281.0
CJB0005	180.0
CON0005	208.5
CON0051	187.0
MEA0009	833.5
MON0004	190.0
WIL0013	110.0

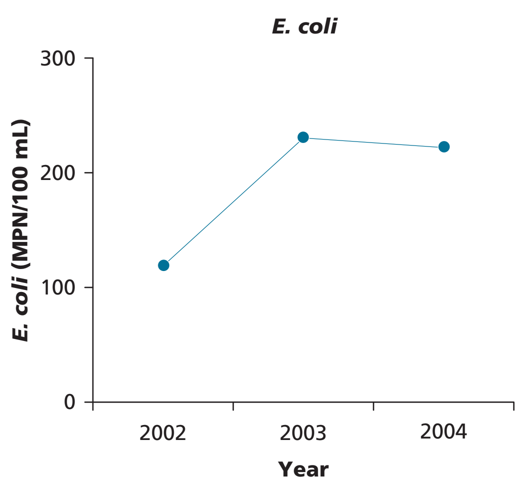

Figure 4.38. Annual median *E. coli* values (MPN/100 mL) from 2002 to 2004 for nine stream sampling locations near CHOH.

Literature cited

CDC (Center for Disease Control and Prevention). 2011. *Escherichia coli* O157:H7 and other Shiga toxin-producing *Escherichia coli* (STEC). Accessed April 9, 2013. *http://www.cdc.gov/nczved/divisions/dfbmd/diseases/ecoli_o157h7*

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.

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District of Columbia Municipal Regulations. 2010. Title 21: Water and Sanitation. Chapter 11: Water Quality Standards.

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4.3 BIOLOGICAL INTEGRITY

4.3.1 Biological integrity summary

Eight metrics were used to assess biological integrity in CHOH—exotic herbaceous species, exotic trees and saplings, forest pest species, native tree seedling regeneration, fish index of biotic integrity (FIBI), bird community index (BCI), deer density, and presence of white-nose syndrome (Table 4.26). Two addition metrics (proportion of area occupied by amphibians and presence of white-nose syndrome) were included for informational purposes but not included in the overall assessment. 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 4.19, forest monitoring sites are shown in Figure 4.39, and bird monitoring sites are shown in Figure 4.40.

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, deer density, and presence of white-nose syndrome, while multiple reference conditions were used for FIBI and BCI (Tables 4.27, 4.28).

CHOH had variable results for biological integrity. The park scored as very good condition for area of exotic trees and

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

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	NCRN I&M	Bates 2009, 2012
Proportion of area occupied by amphibians	NCRN I&M	Mattfeldt et al. 2008
Presence of white-nose syndrome	NCRN I&M	Bates, pers. comm.

Table 4.27. Biological Integrity reference conditions for CHOH.

Metric	Reference condition/s	Sites	Samples	Period
Presence of exotic herbaceous species (% of plots with exotic species)	0% (absence)	66	66	2006–2010
Area of exotic trees & saplings (% of basal area)	< 5%	74	143	2006–2010
Presence of forest pest species (% of trees infested)	< 1%	74	74	2006–2010
Seedling stocking index	> 115	75	75	2007–2010
Fish Index of Biotic Integrity	1.0–1.9; 2.0–2.9; 3.0–3.9; 4.0–5.0	35	35	2003–2004
Bird Community Index	< 40; 40.1–52; 52.1–60; > 60	93	93	2007–2011
Deer density (deer/km^2)	< 8	Park	11	2001–2011
Proportion of area occupied by amphibians	N/A	Park	90	2005–2010
Presence of white-nose syndrome	N/A	1	1	2011

saplings and presence of forest pest species (87% and 95% attainment, respectively). FIBI scored as fair (58% attainment) and BCI scored as medium integrity (48% attainment), while absence of exotic herbaceous species (12% attainment), seedling stocking index (7% attainment), and deer density (0% attainment) all scored as very degraded (Table 4.29). This resulted in an overall biological integrity condition attainment of 43%, or moderate condition.

Literature cited

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Mattfeldt, S.D., E.H. Campbell Grant, and L.L. Bailey. 2008. Amphibian monitoring in the National Capital Region: a focus on lentic and lotic habitats. Natural Resources Technical Report NPS/NRTR/NCRN—2008/088. National Park Service.

Norris, M.E. & G. Sanders. 2009. National Capital Region Network biological stream survey protocol: physical habitat, fish, and aquatic macroinvertebrate vital signs. Natural

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

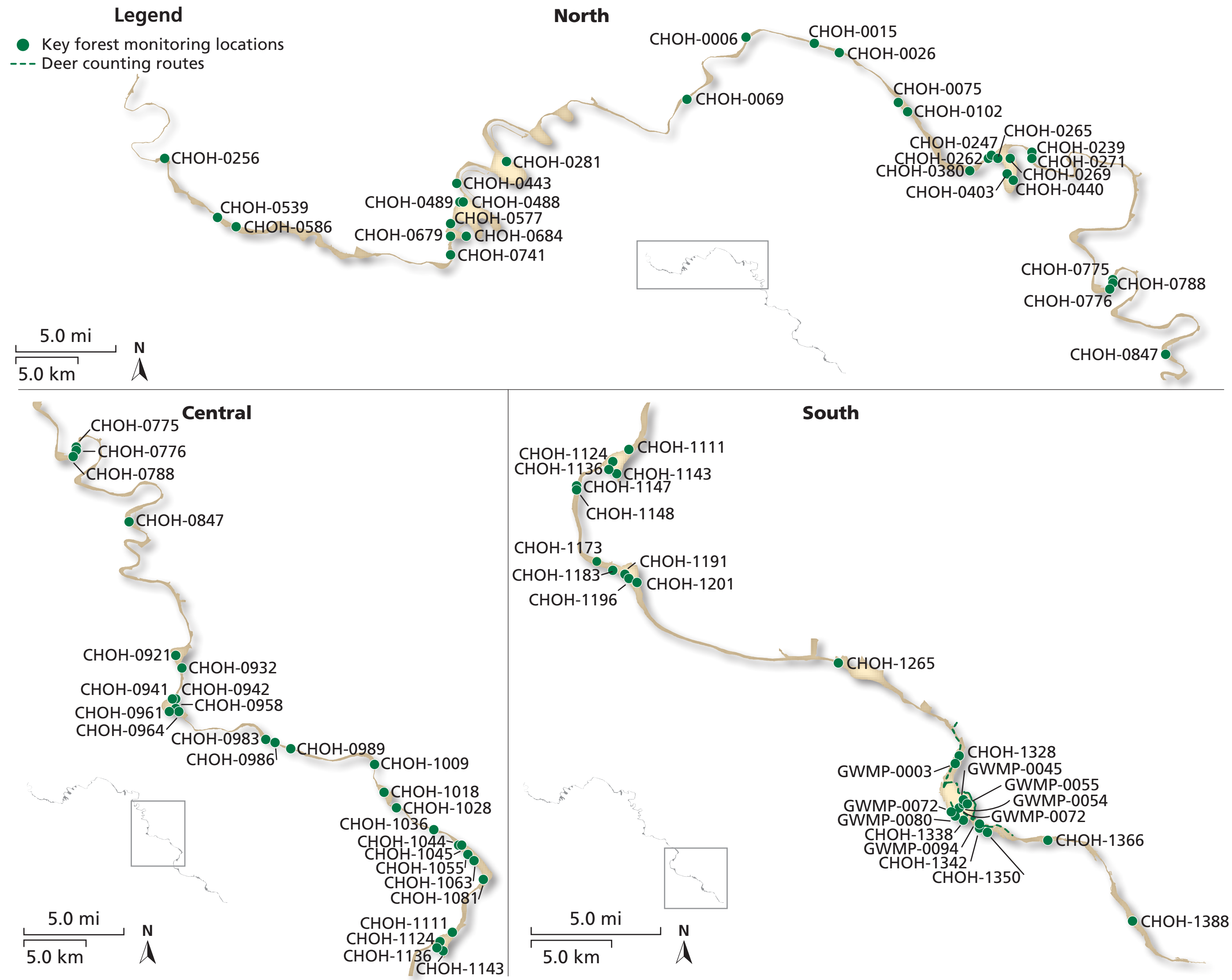
Table 4.28b. Categorical ranking of the reference condition attainment categories for the Fish Index of Biotic Integrity and the Bird Community Index.

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
20–40	0–25% (scaled)	Low integrity

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

Metric	Result	Reference condition	% attainment	Condition	Biological integrity condition
Presence of exotic herbaceous species (% of plots with exotic species)	88%	0% (absence)	12	Very degraded	**43% Moderate**
Area of exotic trees & saplings (% of basal area)	0%	< 5%	87	Very good	
Presence of forest pest species (% of trees infested)	0%	< 1%	95	Very good	
Seedling stocking index	17	> 115	6.7	Very degraded	
Fish Index of Biotic Integrity	3.3	1.0–1.9; 2.0–2.9; 3.0–3.9; 4.0–5.0	58	Fair	
Bird Community Index	47.5	< 40; 40.1–52; 52.1–60; > 60	41	Medium integrity	
Deer density (deer/km²)	45	< 8	0	Very degraded	
Proportion of area occupied by amphibians	0.3	N/A	N/A	N/A	
Presence of white-nose syndrome	0	N/A	N/A	N/A	



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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.

Figure 4.39. Forest monitoring sites and deer counting routes in CHOH.

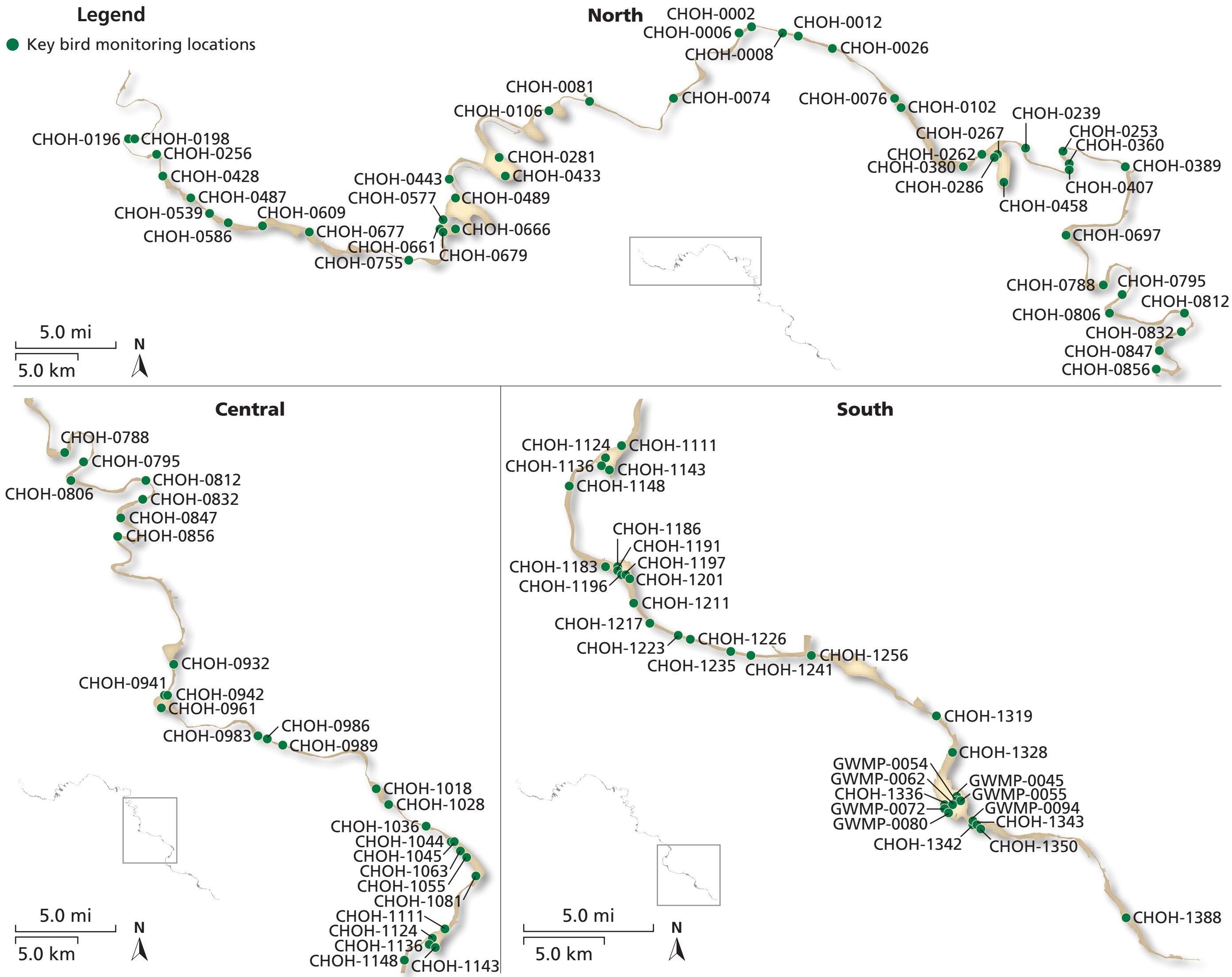

Figure 4.40. Bird monitoring sites in CHOH.

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.

At CHOH, non-native plants are a significant immediate threat to park natural resources and are a particular problem because of the competition they present to the very large number of state rare, threatened, and endangered plant species in the park (NPS 2012). Exotic herbaceous plants make up the majority of exotic plant species found in the forests of the National Capital Region, including CHOH, and so pose a serious problem to park management (Schmit et al. 2010). The most common exotic herbaceous species in CHOH forests are garlic mustard (*Alliaria petiolata*), Indian strawberry (*Duchesnea indica*), Japanese knotweed (*Fallopia japonica*), Japanese honeysuckle (*Lonicera japonica*), Japanese stiltgrass (*Microstegium vimineum*), and multiflora rose (*Rosa multiflora*) (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 4.39, 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. 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 CHOH was very degraded, with 88% of plots containing at least one exotic herbaceous plant. Therefore, only 12% of plots attained the reference condition of having no exotic herbaceous species present (Figure 4.41, 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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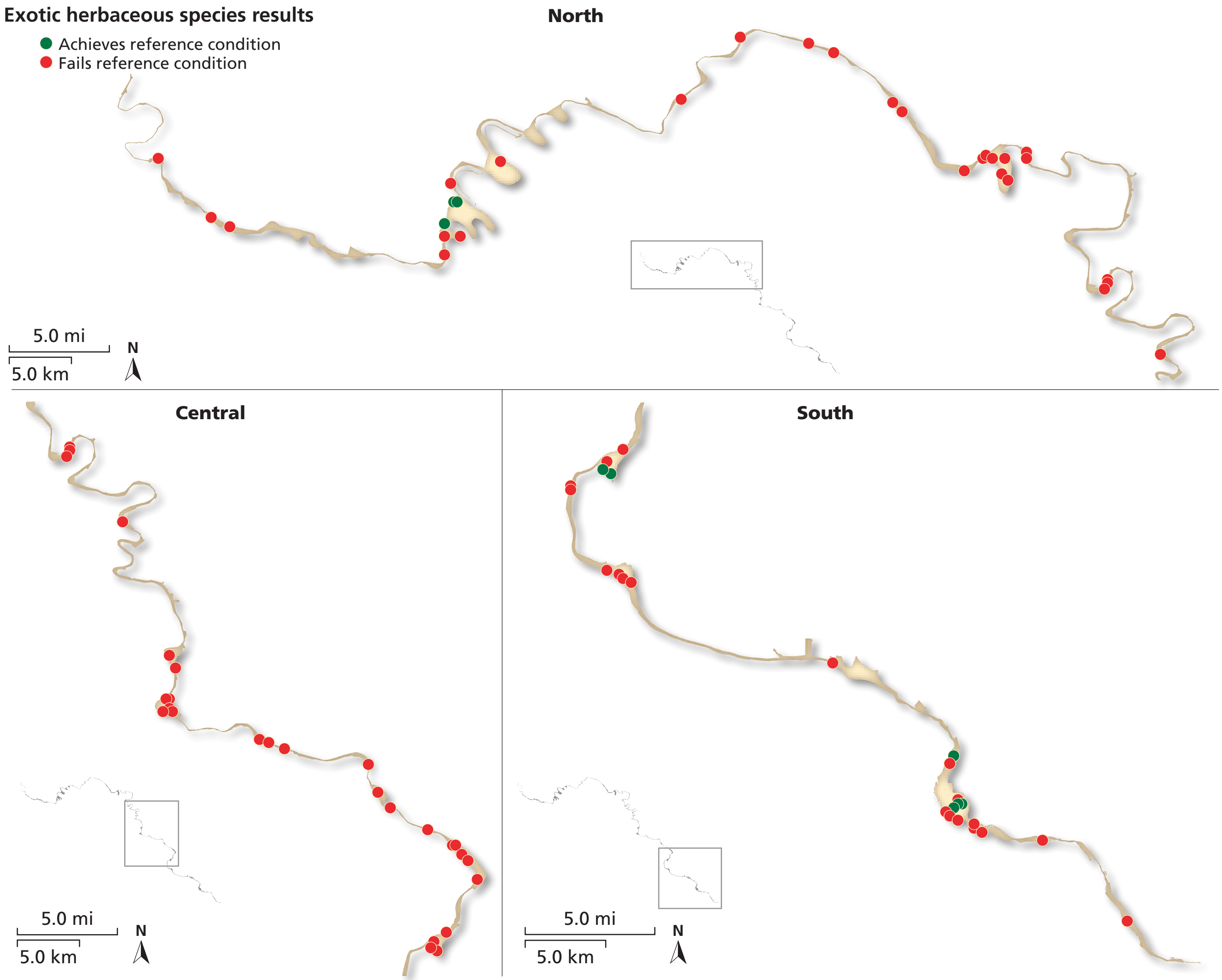

Figure 4.41. Exotic herbaceous species results by site for CHOH.

Report NPS/NCRN/NRTR—2008/125. National Park Service, Fort Collins, CO.

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Table 4.30. Presence of exotic herbaceous plants. Site locations are shown in Figure 4.39.

Site	Year	Exotic plants	Site	Year	Exotic plants
CHOH-0006	2010	Present*	CHOH-0983	2010	Present*
CHOH-0015	2009	Present*	CHOH-0986	2007	Present*
CHOH-0026	2010	Present*	CHOH-0989	2007	Present*
CHOH-0069	2009	Present*	CHOH-1009	2009	Present*
CHOH-0075	2009	Present*	CHOH-1018	2010	Present*
CHOH-0102	2010	Present*	CHOH-1028	2008	Present*
CHOH-0239	2010	Present*	CHOH-1036	2009	Present*
CHOH-0247	2008	Present*	CHOH-1044	2009	Present*
CHOH-0256	2008	Present*	CHOH-1045	2010	Present*
CHOH-0262	2010	Present*	CHOH-1055	2010	Present*
CHOH-0265	2009	Present*	CHOH-1063	2010	Present*
CHOH-0269	2009	Present*	CHOH-1081	2007	Present*
CHOH-0271	2009	Present*	CHOH-1111	2007	Present*
CHOH-0281	2007	Present*	CHOH-1124	2008	Present*
CHOH-0380	2008	Present*	CHOH-1136	2007	Absent
CHOH-0403	2008	Present*	CHOH-1143	2007	Absent
CHOH-0440	2010	Present*	CHOH-1147	2010	Present*
CHOH-0443	2010	Present*	CHOH-1148	2007	Present*
CHOH-0488	2009	Absent	CHOH-1183	2010	Present*
CHOH-0489	2007	Absent	CHOH-1191	2010	Present*
CHOH-0539	2010	Present*	CHOH-1196	2008	Present*
CHOH-0577	2010	Absent	CHOH-1201	2010	Present*
CHOH-0586	2008	Present*	CHOH-1265	2009	Present*
CHOH-0679	2007	Present*	CHOH-1328	2010	Absent
CHOH-0684	2009	Present*	CHOH-1338	2010	Present*
CHOH-0741	2009	Present*	CHOH-1342	2010	Present*
CHOH-0775	2007	Present*	CHOH-1350	2008	Present*
CHOH-0776	2010	Present*	CHOH-1366	2009	Present*
CHOH-0788	2010	Present*	CHOH-1388	2008	Present*
CHOH-0847	2009	Present*	GWMP-0003	2009	Present*
CHOH-0921	2009	Present*	GWMP-0045	2007	Present*
CHOH-0932	2007	Present*	GWMP-0054	2007	Absent
CHOH-0941	2008	Present*	GWMP-0055	2007	Absent
CHOH-0942	2010	Present*	GWMP-0062	2010	Absent
CHOH-0958	2008	Present*	GWMP-0072	2007	Present*
CHOH-0961	2008	Present*	GWMP-0080	2008	Present*
CHOH-0964	2008	Present*	GWMP-0094	2010	Present*

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

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 ubiquitous and growing threat in the National Capital Region. The most common exotic tree and shrub species in CHOH forests are tree of heaven (*Ailanthus altissima*), border privet (*Ligustrum obtusifolium*), autumn olive (*Elaeagnus umbellata*), and Osage orange (*Maclura pomifera*) (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 4.39, 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.

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 CHOH was very good, with a median of 0% of total basal area and 87% of plots attaining the reference condition of ≤ 5% of total basal area (Figure 4.42, Tables 4.29, 4.31).

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.

Literature cited

Mack, R.N., D. Simberloff, W.M. Lonsdale, H. Evans, M. Clout, and F.A. Bazzaz. 2002. Biotic invasions: causes, epidemiology, global consequences, and control. Ecological Applications 10: 689–710.

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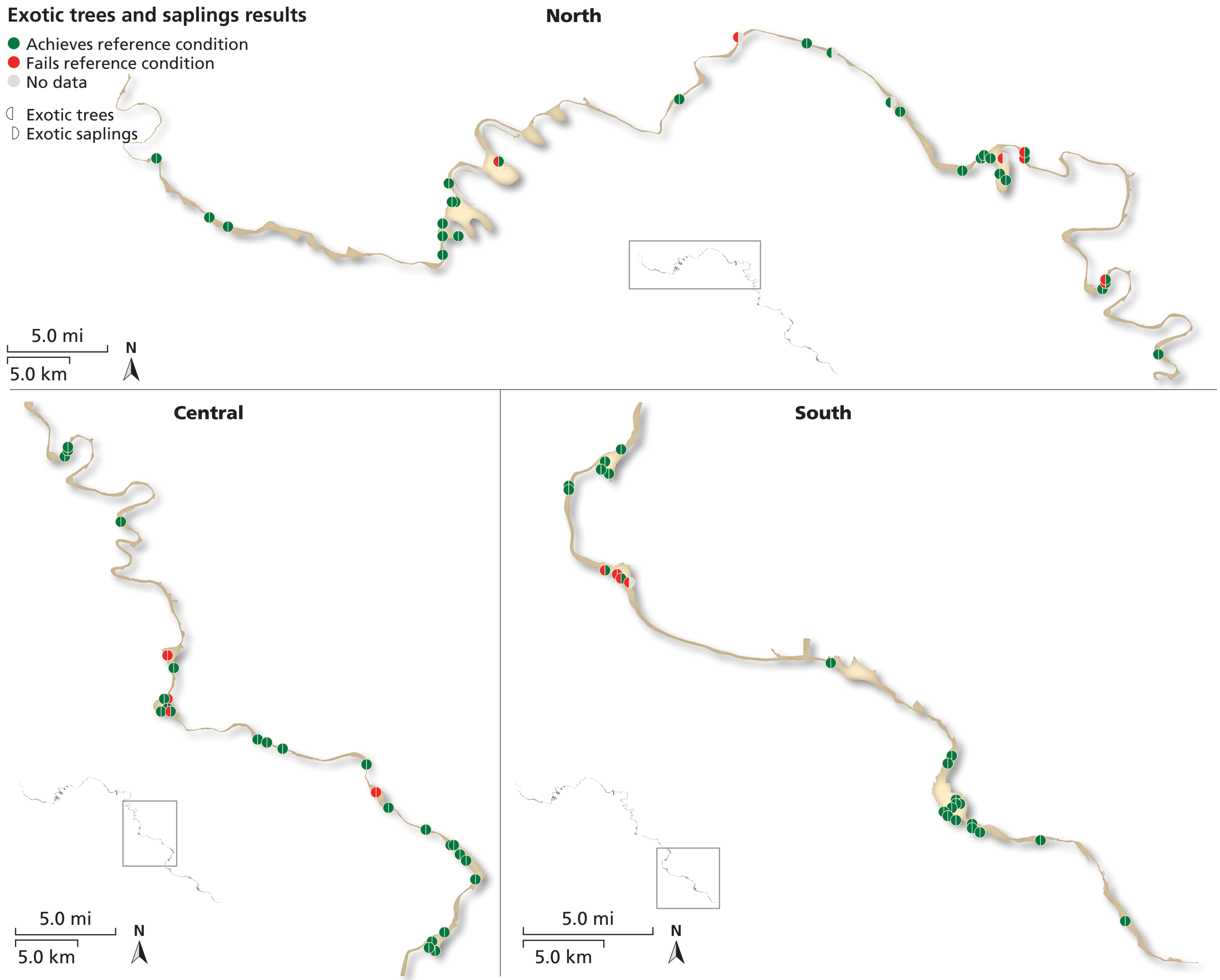

Figure 4.42. Exotic tree and sapling results by site for CHOH.

Vila, M., J.L. Espinar, M. Hejda, P.E. Hulme, V. Jarosik, J.L. Maron, J. Pergl, U. Schaffner, Y. Sun, and P. Pysek. 2011. Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. Ecological Letters 14: 702–708.

Table 4.31. Percent basal area of exotic trees and saplings. Site locations are shown in Figure 4.39.

Site	Year	Exotic trees	Exotic saplings	Site	Year	Exotic trees	Exotic saplings
CHOH-0006	2010	37.6*		CHOH-0983	2010	0	0
CHOH-0015	2009	0	0	CHOH-0986	2007	0	0
CHOH-0026	2010	0		CHOH-0989	2007	0	0
CHOH-0069	2009	2.3	0	CHOH-1009	2009	0	0
CHOH-0075	2009	0		CHOH-1018	2010	14*	10.7*
CHOH-0102	2010	0	0	CHOH-1028	2008	0	0
CHOH-0239	2010	30.9*	0	CHOH-1036	2009	0	0
CHOH-0247	2008	0	0	CHOH-1044	2009	0	0
CHOH-0256	2008	0	0	CHOH-1045	2010	0	0
CHOH-0262	2010	0	0	CHOH-1055	2010	0	0
CHOH-0265	2009	0	0	CHOH-1063	2010	0	0
CHOH-0269	2009	7.0*		CHOH-1081	2007	0	0
CHOH-0271	2009	16.8*	0	CHOH-1111	2007	0	0
CHOH-0281	2007	5.7*	0	CHOH-1124	2008	0	0
CHOH-0380	2008	0	0	CHOH-1136	2007	0	0
CHOH-0403	2008	0	0	CHOH-1143	2007	0	0
CHOH-0440	2010	0	0	CHOH-1147	2010	0	0
CHOH-0443	2010	0	0	CHOH-1148	2007	0	0
CHOH-0488	2009	0	0	CHOH-1183	2010	8.4*	0
CHOH-0489	2007	0	0	CHOH-1191	2010	57.3*	36.3*
CHOH-0539	2010	0	0	CHOH-1196	2008	7.8*	0
CHOH-0577	2010	1.5	0	CHOH-1201	2010	10.9*	
CHOH-0586	2008	0	0	CHOH-1265	2009	0	0
CHOH-0679	2007	0	0	CHOH-1328	2010	0.3	0
CHOH-0684	2009	0	0	CHOH-1338	2010	0	0
CHOH-0741	2009	0	0	CHOH-1342	2010	0	0
CHOH-0775	2007	21.9*	0	CHOH-1350	2008	0	0
CHOH-0776	2010	4.3	0	CHOH-1366	2009	0	0
CHOH-0788	2010	55.2*	0	CHOH-1388	2008	0	0
CHOH-0847	2009	0	0	GWMP-0003	2009	0	0
CHOH-0921	2009	15.4*	100*	GWMP-0045	2007	0	0
CHOH-0932	2007	1.8	0	GWMP-0054	2007	0	0
CHOH-0941	2008	0.9	0	GWMP-0055	2007	0	0
CHOH-0942	2010	2.5	47.2*	GWMP-0062	2010	0	0
CHOH-0958	2008	0.4	0	GWMP-0072	2007	0	0
CHOH-0961	2008	3.0	0	GWMP-0080	2008	0	0
CHOH-0964	2008	42.5*	0	GWMP-0094	2010	0	0

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

4.3.4 Forest pests

Description

Forests in CHOH have historically been impacted by pests such as the gypsy moth (*Lymantria dispar*), and diseases such as the chestnut blight and dogwood anthracnose. The spread of the emerald ash borer (*Agrilus planipennis*) also poses a future threat to the park.

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 2009).

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.

Data and methods

Forest monitoring took place annually but not all plots were measured every year (Schmit et al. 2009a) (Figure 4.39, 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 CHOH was very good, with a median of 0% of trees infested and 95% of data points attaining the reference condition of having no forest pest species present (Figure 4.43, Tables 4.29, 4.32).

Dogwood anthracnose was found on one tree in plot CHOH-0847 in 2009, while gypsy moth was found in trees in plots that were monitored in 2006 and 2008 (Schmit and Campbell 2007, 2008, Schmit et al. 2009b, 2010).

At the time of this report, emerald ash borer was not detected in any of the monitoring plots but it has been detected in the western edge of the park and it is expected that it will eventually be found in the monitoring plots.

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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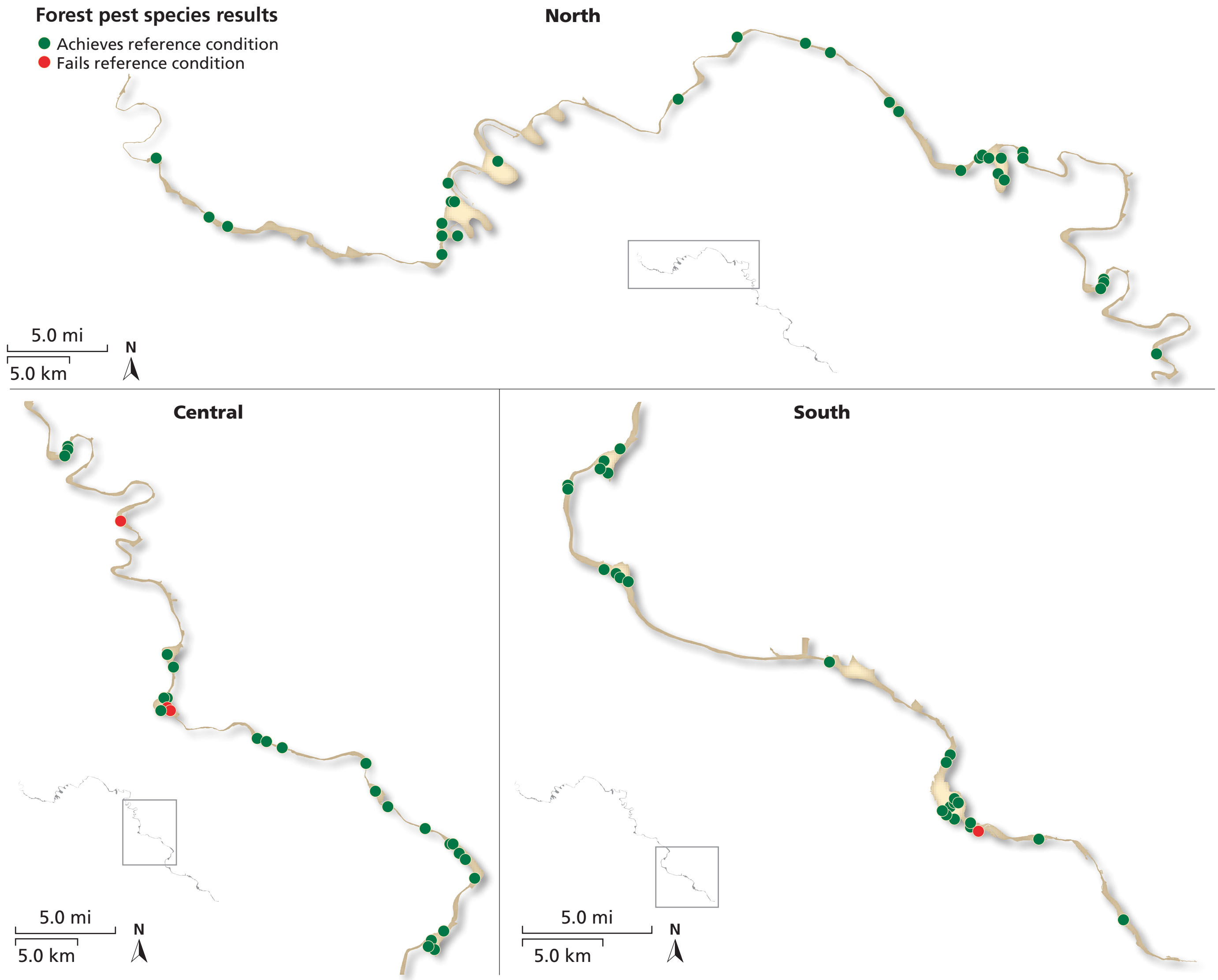

Figure 4.43. Forest pest species results by site for CHOH.

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Table 4.32. Percent of trees with evidence of forest pest species. Site locations are shown in Figure 4.39.

Site	Year	% trees with pests
CHOH-0006	2010	0
CHOH-0015	2009	0
CHOH-0026	2010	0
CHOH-0069	2009	0
CHOH-0075	2009	0
CHOH-0102	2010	0
CHOH-0239	2010	0
CHOH-0247	2008	0
CHOH-0256	2008	0
CHOH-0262	2010	0
CHOH-0265	2009	0
CHOH-0269	2009	0
CHOH-0271	2009	0
CHOH-0281	2007	0
CHOH-0380	2008	0
CHOH-0403	2008	0
CHOH-0440	2010	0
CHOH-0443	2010	0
CHOH-0488	2009	0
CHOH-0489	2007	0
CHOH-0539	2010	0
CHOH-0577	2010	0
CHOH-0586	2008	0
CHOH-0679	2007	0
CHOH-0684	2009	0
CHOH-0741	2009	0
CHOH-0775	2007	0
CHOH-0776	2010	0
CHOH-0788	2010	0
CHOH-0847	2009	1*
CHOH-0921	2009	0
CHOH-0932	2007	0
CHOH-0941	2008	0
CHOH-0942	2010	0
CHOH-0958	2008	4*
CHOH-0961	2008	0
CHOH-0964	2008	3*
CHOH-0983	2010	0
CHOH-0986	2007	0
CHOH-0989	2007	0
CHOH-1009	2009	0
CHOH-1018	2010	0
CHOH-1028	2008	0
CHOH-1036	2009	0
CHOH-1044	2009	0
CHOH-1045	2010	0
CHOH-1055	2010	0
CHOH-1063	2010	0
CHOH-1081	2007	0
CHOH-1111	2007	0
CHOH-1124	2008	0
CHOH-1136	2007	0
CHOH-1143	2007	0
CHOH-1147	2010	0
CHOH-1148	2007	0
CHOH-1183	2010	0
CHOH-1191	2010	0
CHOH-1196	2008	0
CHOH-1201	2010	0
CHOH-1265	2009	0
CHOH-1328	2010	0
CHOH-1338	2010	0
CHOH-1342	2010	0
CHOH-1350	2008	3*
CHOH-1366	2009	0
CHOH-1388	2008	0
GWMP-0003	2009	0
GWMP-0045	2007	0
GWMP-0054	2007	0
GWMP-0055	2007	0
GWMP-0062	2010	0
GWMP-0072	2007	0
GWMP-0080	2008	0
GWMP-0094	2010	0

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

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, Horsley 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 4.39, 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 CHOH was very poor, with a median index value of 17 and 6.7% of data points attaining the reference condition of > 115 (Figure 4.44, Tables 4.29, 4.33).

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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Tierson, W.C., E.F. Patric, and D.F. Behrend. 1966. Influence of white-tailed deer on a northern hardwood forest. Journal of Forestry 64: 801–805.

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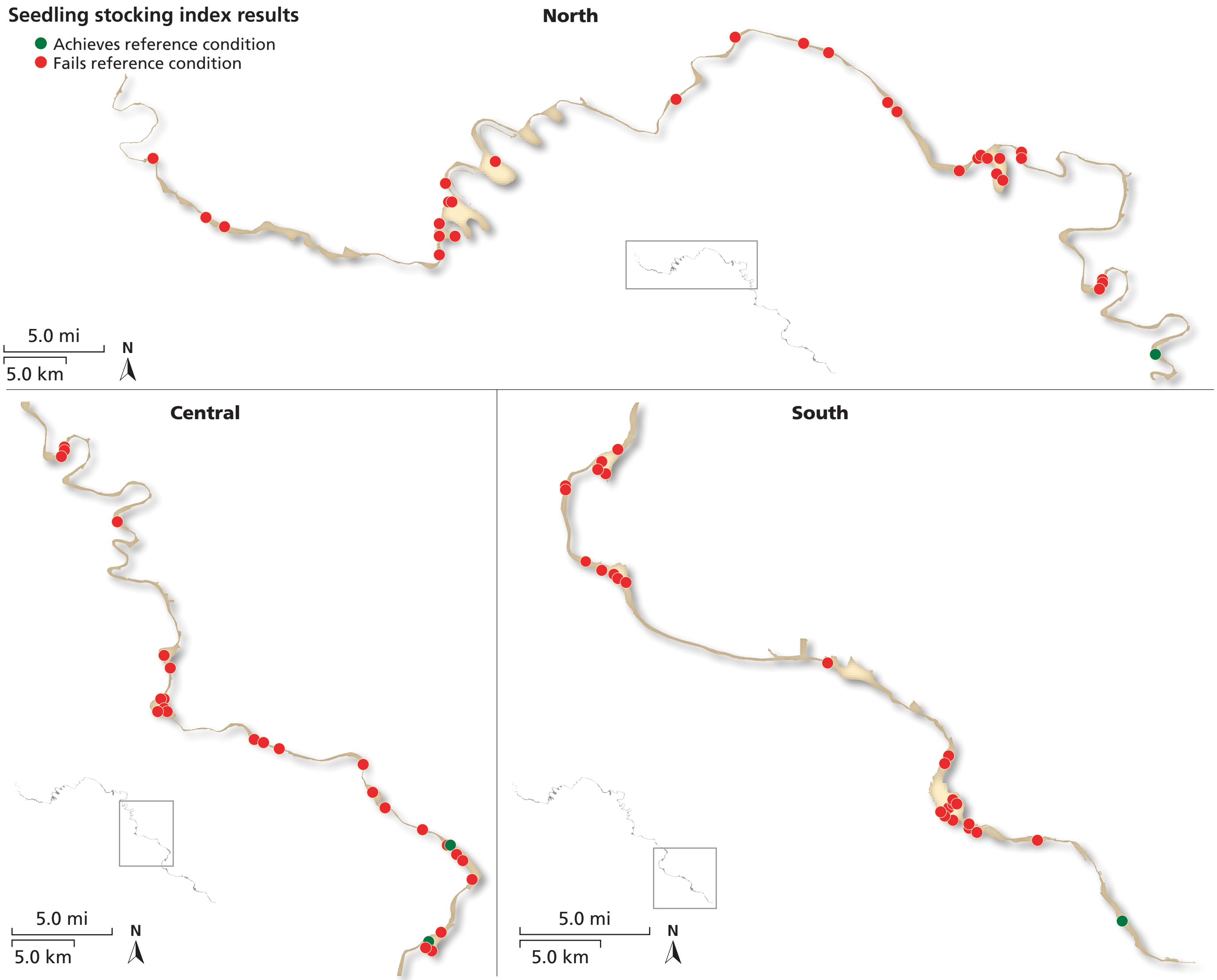

Figure 4.44. Seedling stocking index results by site for CHOH.

Table 4.33. Seedling stocking index values. Site locations are shown in Figure 4.39.

Site	Year	Index
CHOH-0006	2010	0*
CHOH-0015	2009	7*
CHOH-0026	2010	1*
CHOH-0069	2009	29.25*
CHOH-0075	2009	1*
CHOH-0102	2010	0*
CHOH-0239	2010	6*
CHOH-0247	2008	17.75*
CHOH-0256	2008	3*
CHOH-0262	2010	69.75*
CHOH-0265	2009	1*
CHOH-0269	2009	31*
CHOH-0271	2009	17.25*
CHOH-0281	2007	68.25*
CHOH-0380	2008	17*
CHOH-0403	2008	6*
CHOH-0440	2010	51.25*
CHOH-0443	2010	23.25*
CHOH-0488	2009	2*
CHOH-0489	2007	2*
CHOH-0539	2010	0*
CHOH-0577	2010	12.75*
CHOH-0586	2008	2*
CHOH-0679	2007	3*
CHOH-0684	2009	22*
CHOH-0741	2009	0*
CHOH-0775	2007	89.5*
CHOH-0776	2010	17*
CHOH-0788	2010	3*
CHOH-0847	2009	196.75
CHOH-0921	2009	2*
CHOH-0932	2007	54.5*
CHOH-0941	2008	56.75*
CHOH-0942	2010	0*
CHOH-0958	2008	17*
CHOH-0961	2008	69*
CHOH-0964	2008	30.75*
CHOH-0983	2010	8.5*
CHOH-0986	2007	1*
CHOH-0989	2007	27.5*
CHOH-1009	2009	40.5*
CHOH-1018	2010	55.25*
CHOH-1028	2008	25.25*
CHOH-1036	2009	52.75*
CHOH-1044	2009	83.5*
CHOH-1045	2010	159.75
CHOH-1055	2010	1*
CHOH-1063	2010	6*
CHOH-1081	2007	1*
CHOH-1111	2007	29.25*
CHOH-1124	2008	133.25
CHOH-1136	2007	4.25*
CHOH-1143	2007	5.25*
CHOH-1147	2010	20.25*
CHOH-1148	2007	6.25*
CHOH-1173	2011	7*
CHOH-1183	2010	11.25*
CHOH-1191	2010	17*
CHOH-1196	2008	7*
CHOH-1201	2010	3*
CHOH-1265	2009	61*
CHOH-1328	2010	6.25*
CHOH-1338	2010	18.75*
CHOH-1342	2010	39.75*
CHOH-1350	2008	30*
CHOH-1366	2009	85.5*
CHOH-1388	2008	137
GWMP-0003	2009	5.25*
GWMP-0045	2007	20.5*
GWMP-0054	2007	0*
GWMP-0055	2007	21*
GWMP-0062	2010	5.25*
GWMP-0072	2007	4.25*
GWMP-0080	2008	4.25*
GWMP-0094	2010	280.25

* Values outside of reference condition of > 115.

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 35 sites between 2003 and 2004 (Figure 4.19, 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 4.45, 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 CHOH was fair, with a median FIBI of 3.3 and 58% of data points attaining reference condition (Figures 4.45, 4.46, Tables 4.29, 4.35).

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

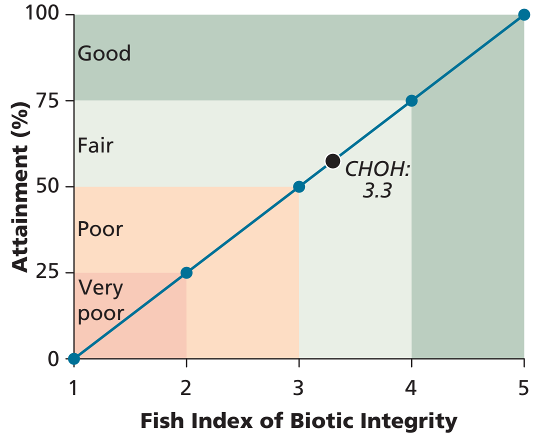

Figure 4.45. Application of the percent attainment categories to the Fish Index of Biotic Integrity (FIBI) value categories. FIBI at CHOH was 3.3 which equated to 58% attainment of the reference condition.

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.

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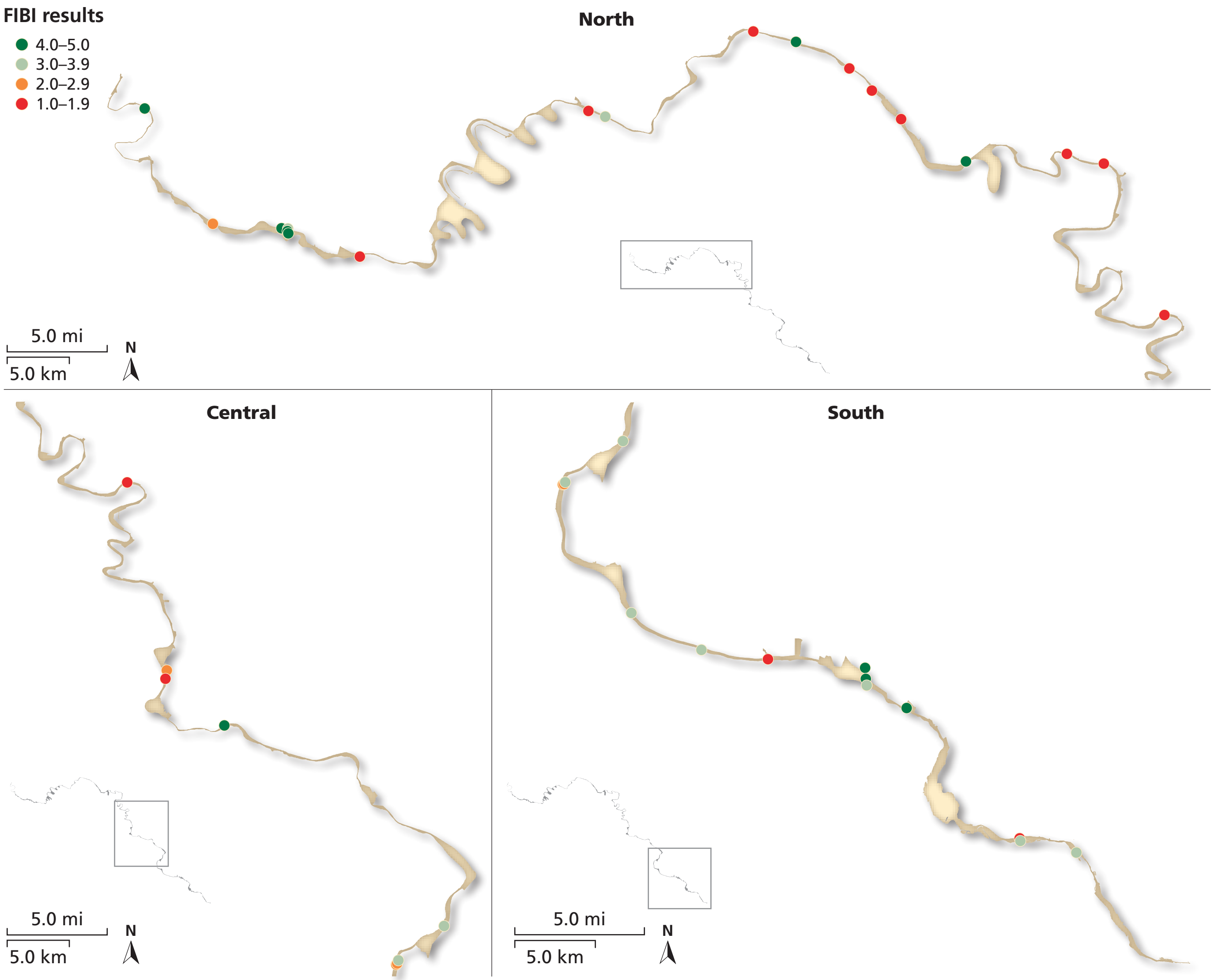

Figure 4.46. Attainment of Fish Index of Biotic Integrity (FIBI) reference condition by site for 35 stream sampling locations in CHOH.

Table 4.35. Fish Index of Biotic Integrity (FIBI) in CHOH. Monitoring sites are shown in Figure 4.19. UT = unnamed tributary.

Year	Site	Location	FIBI
2003	COCA-101-N-2003	UT Potomac River	1.33
2003	COCA-102-N-2003	UT Potomac River	3.33
2003	COCA-104-N-2003	UT Potomac River	1.00
2003	COCA-105-N-2003	UT Potomac River	1.33
2003	COCA-108-N-2003	UT Potomac River	3.33
2003	COCA-109-N-2003	UT Potomac River	2.33
2003	COCA-110-N-2003	UT Potomac River	1.33
2003	COCA-111-N-2003	UT Potomac River	2.33
2003	COCA-112-N-2003	UT Potomac River	2.67
2003	COCA-113-N-2003	Big Run	1.00
2003	COCA-114-N-2003	UT Potomac River	1.00
2003	COCA-115-N-2003	UT Potomac River	1.00
2003	COCA-117-N-2003	Minnehaha Branch	3.33
2003	COCA-201-N-2003	UT Potomac River	3.67
2003	COCA-203-N-2003	Ditch Run	4.00
2003	COCA-204-N-2003	Marsh Run	2.33
2003	COCA-205-N-2003	UT Potomac River	2.67
2003	COCA-206-N-2003	Muddy Branch	3.33
2003	COCA-208-N-2003	Rock Run	3.33
2003	COCA-209-N-2003	Rock Run	2.67
2003	COCA-210-N-2003	Muddy Branch	4.00
2003	COCA-301-N-2003	Evitts Cr	4.33
2003	COCA-302-N-2003	Seven Springs Run	5.00
2003	COCA-303-N-2003	Seven Springs Run	4.67
2003	COCA-307-N-2003	Horsepen Branch	3.33
2003	COCA-308-N-2003	Watts Branch	4.00
2003	PRLN-201-R-2003	Seven Springs Run UT2	3.33
2004	COCA-118-N-2004	UT Potomac River	2.00
2004	COCA-119-N-2004	UT Potomac River	1.33
2004	COCA-121-N-2004	UT Potomac River	1.00
2004	NCRW-107-N-2004	Israel Creek	4.00
2004	NCRW-206-N-2004	Green Spring Run	4.67
2004	NCRW-208-N-2004	Cabin Branch	3.00
2004	NCRW-305-N-2004	Seven Springs Run	5.00
2004	NCRW-309-N-2004	Muddy Branch	5.00

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 93 forest sites between 2007 and 2011 (Figure 4.40, 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 4.47, 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).

Chesapeake and Ohio Canal National Historical Park ranges over three BCRs—the Appalachian, the Piedmont, and the Coastal Plain. However, the use of the Appalachian guild assignment and BCI scoring framework described in O'Connell et al. (1998) was adopted to evaluate all NCRN parks, including CHOH (Ladin and Shriver in press).

Condition and trend

The 2011 BCI in forest sites of CHOH showed medium integrity, with a median of 47.5 and 41% attainment of reference condition (Figure 4.48, Tables 4.29, 4.37).

Sources of expertise

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

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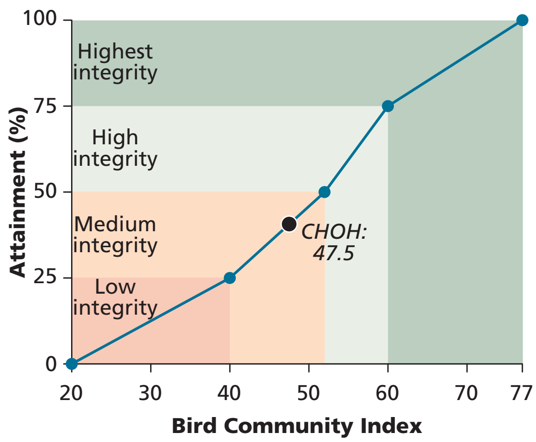

Figure 4.47. Application of the percent attainment categories to the BCI value categories. BCI at CHOH was 47.5 which equated to 41% attainment of the reference condition.

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

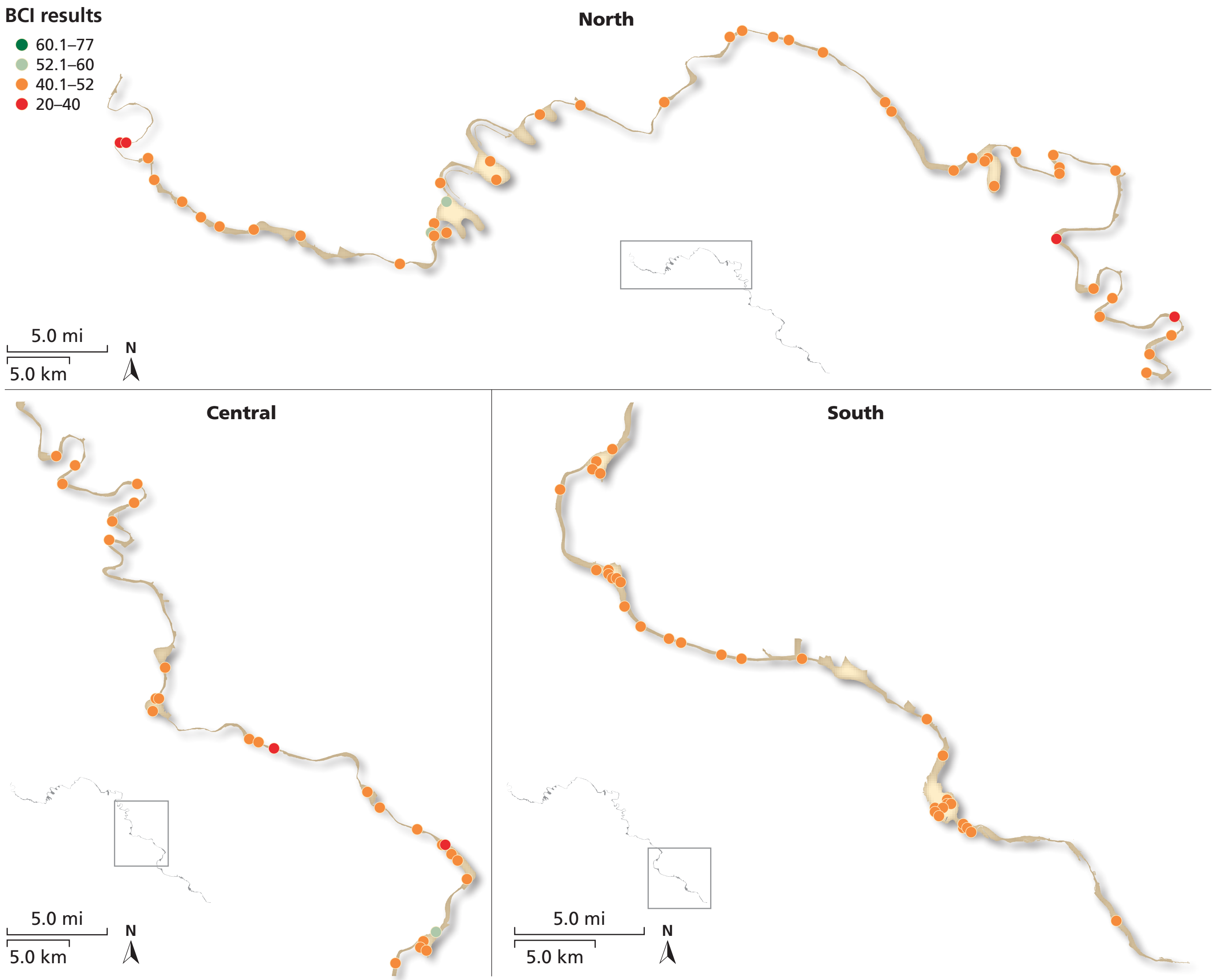

Figure 4.48. Bird Community Index (BCI) condition by site from 2007 to 2011 in 93 monitoring locations in CHOH. Site medians were used for this analysis.

Table 4.37. Median Bird Community Index (BCI) scores in CHOH. Monitoring sites are shown in Figure 4.40.

Site	Median	Site	Median	Site	Median
CHOH-0002	41.0	CHOH-0586	44.0	CHOH-1124	50.5
CHOH-0006	44.5	CHOH-0609	49.5	CHOH-1136	51.5
CHOH-0008	42.0	CHOH-0661	54.5	CHOH-1143	45.5
CHOH-0012	47.5	CHOH-0666	40.5	CHOH-1148	47.8
CHOH-0026	49.0	CHOH-0677	45.0	CHOH-1183	43.0
CHOH-0074	46.5	CHOH-0679	44.5	CHOH-1186	47.5
CHOH-0076	50.0	CHOH-0697	38.0	CHOH-1191	49.0
CHOH-0081	51.5	CHOH-0755	51.0	CHOH-1196	49.0
CHOH-0102	48.0	CHOH-0788	44.0	CHOH-1197	48.0
CHOH-0106	49.5	CHOH-0795	43.0	CHOH-1201	48.0
CHOH-0196	37.0	CHOH-0806	46.8	CHOH-1211	46.5
CHOH-0198	36.0	CHOH-0812	37.8	CHOH-1217	49.5
CHOH-0239	41.5	CHOH-0832	49.5	CHOH-1223	41.5
CHOH-0253	47.3	CHOH-0847	48.0	CHOH-1226	48.0
CHOH-0256	43.5	CHOH-0856	49.0	CHOH-1235	46.5
CHOH-0262	48.0	CHOH-0932	52.0	CHOH-1241	47.0
CHOH-0267	50.0	CHOH-0941	50.5	CHOH-1256	41.0
CHOH-0281	43.5	CHOH-0942	45.5	CHOH-1319	50.5
CHOH-0286	47.0	CHOH-0961	50.0	CHOH-1328	51.0
CHOH-0360	47.5	CHOH-0983	47.0	CHOH-1336	47.0
CHOH-0380	48.5	CHOH-0986	50.5	CHOH-1342	51.5
CHOH-0389	47.0	CHOH-0989	39.0	CHOH-1343	50.5
CHOH-0407	47.0	CHOH-1018	49.5	CHOH-1350	46.5
CHOH-0428	46.0	CHOH-1028	44.0	CHOH-1388	48.5
CHOH-0433	50.5	CHOH-1036	46.8	GWMP-0045	44.5
CHOH-0443	48.0	CHOH-1044	50.8	GWMP-0054	43.5
CHOH-0458	49.5	CHOH-1045	38.5	GWMP-0055	49.0
CHOH-0487	50.0	CHOH-1055	44.0	GWMP-0062	50.5
CHOH-0489	58.5	CHOH-1063	43.0	GWMP-0072	51.5
CHOH-0539	45.5	CHOH-1081	50.0	GWMP-0080	46.0
CHOH-0577	48.5	CHOH-1111	52.5	GWMP-0094	46.0

4.3.9 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 in the Great Falls area of the park was estimated annually between 2001 and 2011 using distance counts (Bates 2006, 2009, 2012) (Figure 4.39, Table 4.26). 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.

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 CHOH was very degraded, with 0% of years attaining the reference condition of 8.0 deer/km^2 (Figure 4.49, 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 45 deer/km^2 for all years (Figure 4.49, Table A-3). As such, deer population density for 2001–2011 attains 0% of reference condition and indicates a very degraded condition.

There were no major changes in overall deer population size during the decade of monitoring (Figure 4.49, Table A-3).

Sources of expertise

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

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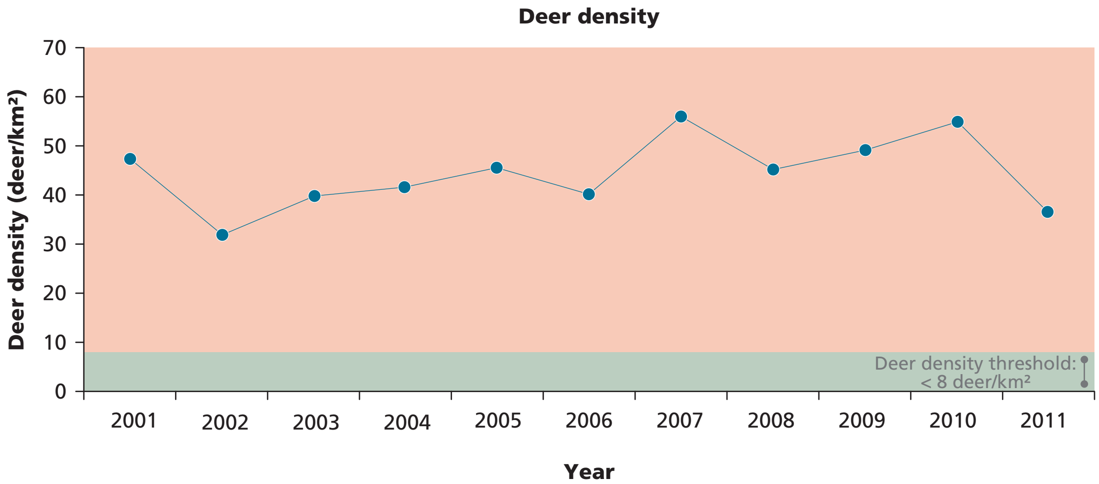

Figure 4.49. Annual mean deer density (deer/km^2) from 2001 to 2011 in CHOH. Reference condition (< 8 deer/km^2) is shown in gray.

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4.3.8 Proportion of area occupied by amphibians

Description

Amphibians are among the first animals that hibernate to emerge in the spring and, as a result, provide food for predators when other food sources are less available (Mattfeldt et al. 2008, Campbell Grant et al. 2011). Adult amphibians are secondary and tertiary consumers and larvae are primary consumers in forest and pond ecosystems (Dunson 1982). Predatory salamander larvae are important in determining abundance of zooplankton and aquatic insects (Dodson 1970, Dodson and Dodson 1971), and tadpoles are important in determining types and amounts of phytoplankton, magnitude of nutrient cycling, and levels of primary production (Seale 1980).

Data and methods

Data were collected between 2005 and 2010 in the Potomac Gorge area of CHOH (in the vicinity of Great Falls) (Table 4.26, Figure 2.2). Data were collected in accordance with the National Capital Region Amphibian Monitoring Protocol (Bailey et al. 2007). The proportion of area occupied (PAO) for each species ranges from 0 to 1, with 0 indicating that no potential sites were occupied and 1 indicating that all potential sites were occupied (Campbell Grant et al. 2011).

Because of the limited spatial coverage of data for this metric, the proportion of area occupied by amphibians was not included in the overall assessment of CHOH but is included for informational purposes only.

Condition and trend

The PAO in CHOH was a median of 0.3 over the period 2005–2010 (Tables 4.29, 4.38).

Table 4.38. Proportion of area occupied by amphibians (PAO) in CHOH**.** Maximum value = 1.0.

Year	PAO
2005	0.38
2006	0.39
2007	0.40
2008	0.35
2009	0.34
2010	0.28

Sources of expertise

Geoff Sanders, Data Manager, Center for Urban Ecology, National Park Service.

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4.3.10 Presence of white-nose syndrome

Description

White-nose syndrome (WNS) is a deadly disease affecting hibernating bats. Named for the white fungus (*Geomyces destructans*) that appears on the muzzle and other body parts of hibernating bats, WNS is associated with extensive mortality of bats in eastern North America. First documented in New York in the winter of 2006–2007, WNS has spread rapidly across the eastern United States and Canada, and the fungus that causes WNS has been detected as far west as Oklahoma. WNS has killed more than one million bats in the Northeast and Canada (Blehert et al. 2011).

More than half of the 45 bat species living in the United States rely on hibernation for winter survival. Eleven cave-hibernating bats, including four endangered species and subspecies are already affected by or are potentially at risk from WNS (U.S. Fish & Wildlife Service 2011).

Data and methods

Because of the variable spatial distribution of WNS within the park, the presence of this disease was not included in the overall assessment of CHOH but is included for informational purposes only.

Condition and trend

The three tunnels in the park—Indigo, Stickpile, and Kessler Tunnels—are important bat hibernacula. WNS has not been observed in the bats of the park's tunnels as of early 2011 (S. Bates and M. Carter, pers. comm.). All of the nine bat species documented in CHOH (big brown bats [*Eptesicus fuscus*], silver-haired bats [*Lasionycteris noctivagans*], eastern red bats [*Lasiurus borealis*], hoary bats [*Lasiurus cinereus*], little brown bats [*Myotis lucifugus*], northern myotis [*Myotis septentrionalis*], eastern pipistrelles/tricolor bats [*Pipistrellus subflavus/Perimyotis subflavus*], the globally rare and state-endangered eastern small-footed myotis [*Myotis leibii*], and the globally rare, state and federally endangered Indiana bat [*Myotis sodalis*])have been found in the tunnels of the park, so the absence of WNS from these locations is encouraging (Gates and Johnson 2005, Johnson and Gates 2007a, b, c).

However, WNS has been observed in Washington County in March 2012, in the Roundtop Mine complex—an abandoned cement mine owned by the park. Studies conducted in the mine complex also documented a severe decline in the overall bat population from the previous five-year average and the lowest number recorded since regular monitoring began in 1998 (CHOH 2012).

Sources of expertise

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

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4.4 LANDSCAPE DYNAMICS

4.4.1 Landscape dynamics summary

Four metrics were used to assess landscape dynamics in CHOH—forest interior area, forest cover, impervious surface, and road density (measured at two different scales) (Table 4.39). 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 4.40) and the data were compared to these reference conditions to obtain the percent attainment and converted to the condition assessment for that metric (Table 4.41).

CHOH scored as very good for forest cover within the park, for impervious surface at both scales, and for road density within the park (all 100% attainment). Forest interior area at both scales was degraded (34% and 38% attainment, respectively). Forest cover and road density at the 5x park area scale were very degraded (both 0% attainment) (Table 4.42). This resulted in an overall landscape dynamics condition attainment of 59%, or moderate 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.

Table 4.39. Ecological monitoring framework data for Landscape Dynamics provided by agencies and specific sources included in the assessment of CHOH.

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 4.40. Landscape Dynamics reference conditions for CHOH.

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	2010
Road density (within park + 5x buffer)	< 1.5 km/km^2	Park	1	2010

2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77: 858–864.

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 4.41. 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 4.42. Summary of resource condition assessment of Landscape Dynamics in CHOH.

Metric	Result	Reference condition	% attainment	Condition	Landscape dynamics condition
Forest interior area (within park)	34%	% of total potential forest area translates to % attainment	34%	Degraded	**59%** **Moderate**
Forest interior area (within park + 5x buffer)	38%	% of total potential forest area translates to % attainment	38%	Degraded	
Forest cover (within park)	69%	> 59%	100%	Very good	
Forest cover (within park + 5x buffer)	50%	> 59%	0%	Very degraded	
Impervious surface (within park)	1.1%	< 10%	100%	Very good	
Impervious surface (within park + 5x buffer)	4.7%	< 10%	100%	Very good	
Road density (within park)	1.2 km/km^2	< 1.5 km/km^2	100%	Very good	
Road density (within park + 5x buffer)	2.3 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 4.39) 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 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 4.50, Table 4.40). 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 4.41).

Table 4.43. Forest interior area (%) in CHOH.

Area	Interior area (%)
Park	34
Park + 5x area	38
Park + 30 km	51

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 CHOH at the scale of the park and at the scale of the park plus the 5x buffer was 34% and 38%, respectively (Figure 4.50, Tables 4.42, 4.43). This indicated degraded condition at both scales. Note: forest interior area 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.

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.

Jones, C., J. McCann, and S. McConville. 2000. A guide to the conservation of forest interior dwelling birds in the Chesapeake Bay Critical Area. Report to the Critical Area Commission for the Chesapeake and Atlantic Coastal Bays. Accessed April 9, 2013. *http://www.dnr.state.md.us/irc/docs/00009691.pdf*

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Temple, S.A. 1986. Predicting impacts of habitat fragmentation on forest birds: a comparison of two models. In: Verner, J., M.L. Morrison, and C.J. Ralph (eds). Wildlife 2000: modeling

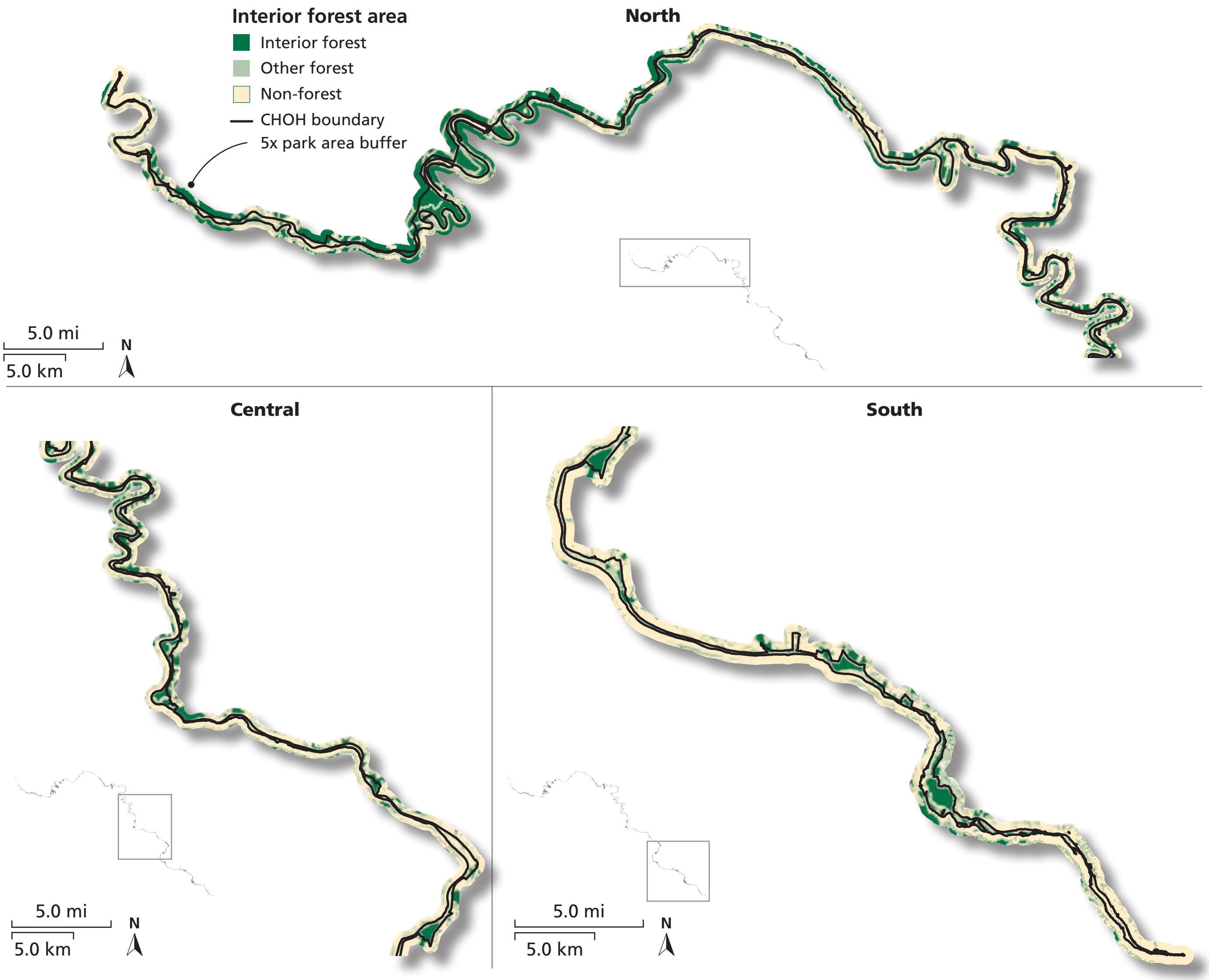

Figure 4.50. Extent of forest interior area in and around CHOH in 2006. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

habitat relationships of terrestrial vertebrates. University of Wisconsin Press, Madison, WI.

4.4.3 Forest cover

Description

Forest is the dominant historical land use in the region surrounding Chesapeake and Ohio Canal National Historical Park and is still the dominant land use within the park itself (Figure 2.4) (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 4.39). 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 4.51, Table 4.40). 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.

Table 4.44. Forest cover (%) in CHOH.

Area	Forest cover (%)
Park	69
Park + 5x area	50*
Park + 30 km	49*

* Values outside of reference condition of > 59%.

Condition and trend

At the scale of the park, forest cover in CHOH was 69% in CHOH which exceeded the reference condition of 59%, resulting in 100% attainment of reference condition and indicating very good condition (Figure 4.51, Tables 4.42, 4.44).

However, when a buffer of five times the park area was added, forest cover reduced to 50%. This did not meet the reference condition of 59%, resulting in 0% attainment of reference condition and indicating very degraded condition (Table 4.44). Note: forest cover 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.

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.

Gardner, R.H., B.T. Milne, M.G. Turner, and R.V. O'Neill. 1987. Neutral models for the analysis of broad-scale landscape pattern. Landscape Ecology 1: 19–28.

Hargis, C.D., J.A. Bissonette, and J.L. David. 1998. The behavior of landscape metrics commonly used in the study of habitat fragmentation. Landscape Ecology 13: 167–186.

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.

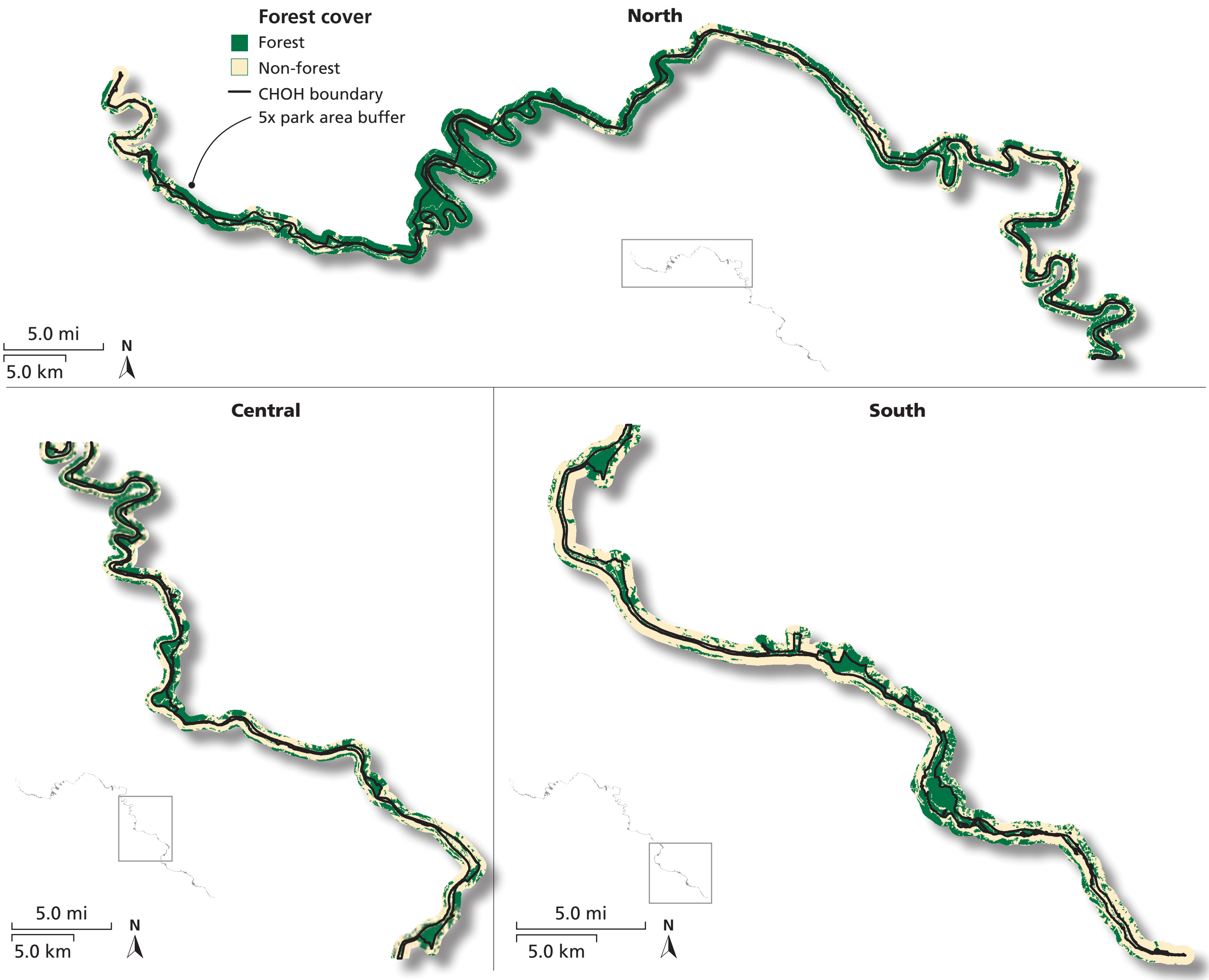

Figure 4.51. Extent of forest and non-forest landcover within and around CHOH in 2006. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

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*

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.

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.

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 4.39).

An impervious surface threshold of < 10% 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 4.40). 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 CHOH at the scale of the park and at the scale of the park plus the 5x buffer was 1.1% and 4.7%, respectively. These were both below the reference condition of 10% impervious surface, resulting in 100% attainment and very good condition at both scales (Figure 4.52, Tables 4.42, 4.45). Note: impervious surface 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. Impervious surface (%) in CHOH.

Area	Impervious surface (%)
Park	1.1
Park + 5x area	4.7
Park + 30 km	4.2

* Values outside of reference condition of < 10%.

Areas adjacent to the park with the highest cover of impervious surface include the city of Cumberland, MD, and the Washington, D.C. metropolitan area, at the park's western and eastern origins, 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.

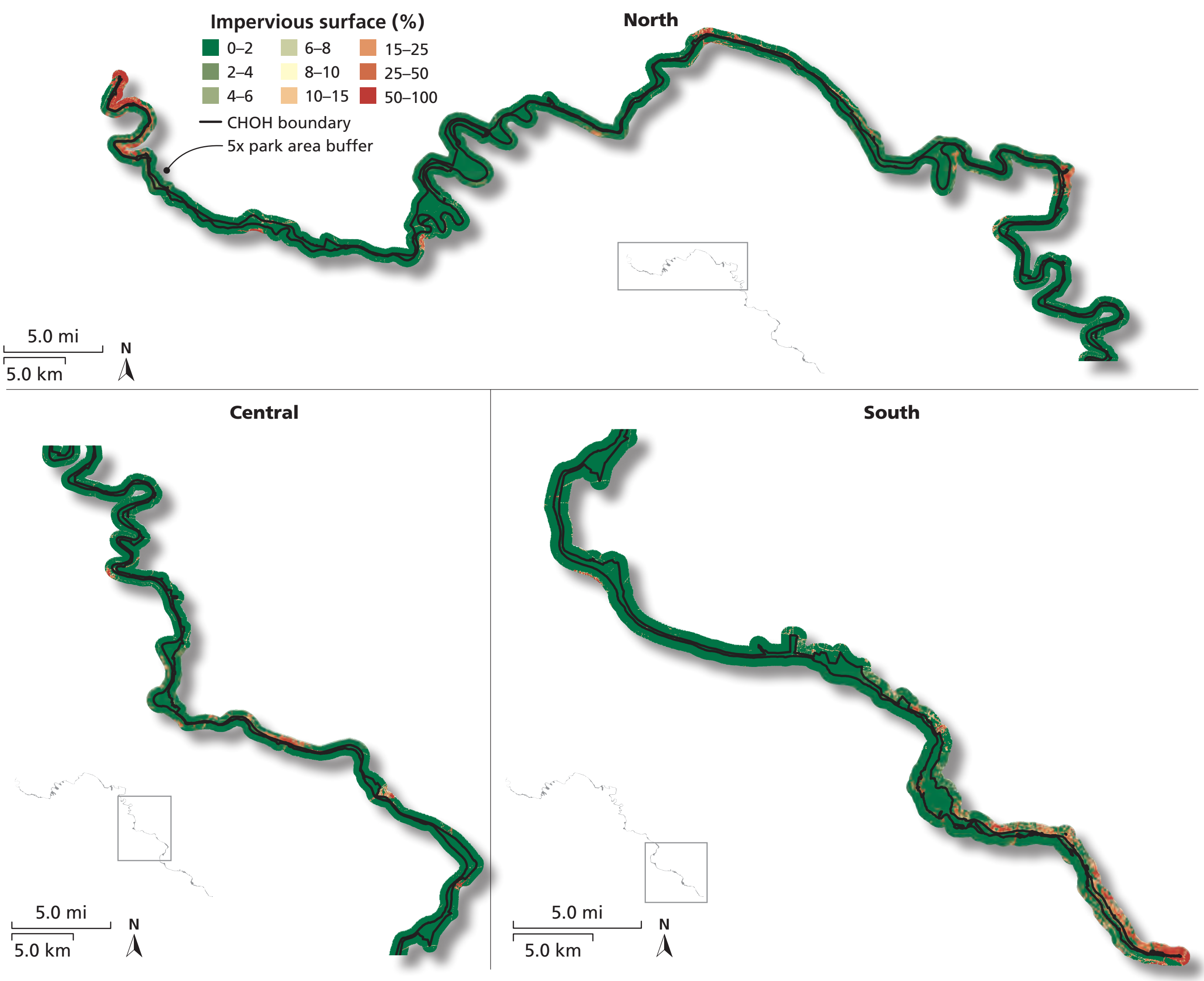

Figure 4.52. Percent impervious surface within and around CHOH in 2006. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

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 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 4.39). 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 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 (Figures 4.53, 4.54, Table 4.40). 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 CHOH was 1.2 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 (Tables 4.42, 4.46).

However, when a buffer of five times the park area was added, road density increased to 2.3 km/km^2. This did not meet the reference condition, resulting in 0% attainment of reference condition and indicating very degraded condition (Figure 4.53, Tables 4.42, 4.46). Note: road density at an additional scale (park boundary plus a 30 km buffer is also shown in Table 4.46 for reference but was not included in the current assessment.

Table 4.46. Road density (km/km^2) in CHOH.

Area	Road density (km/km^2)
Park	1.2
Park + 5x area	2.3*
Park + 30 km	3.1*

* 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.

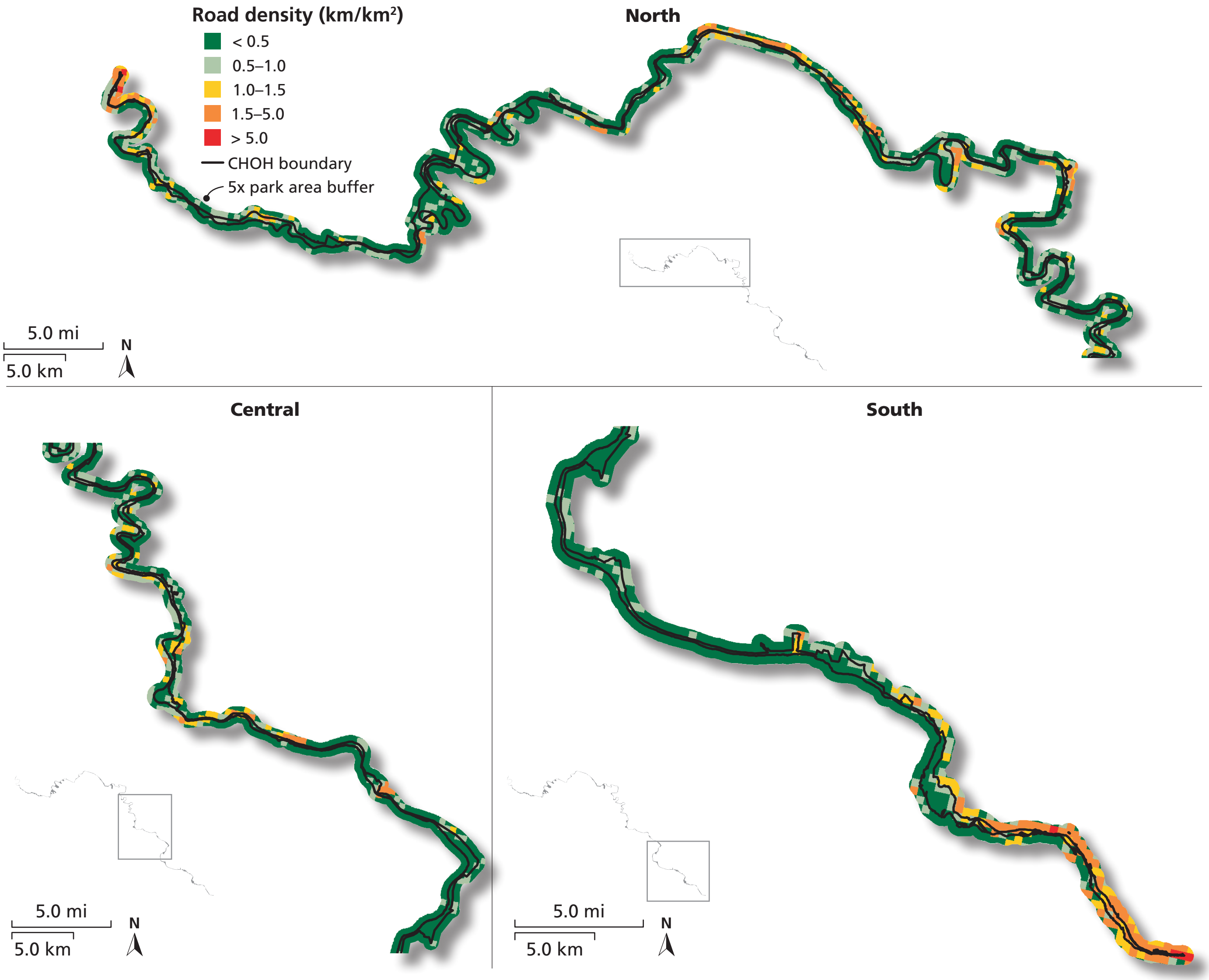

Figure 4.53. Road density within and around CHOH in 2010. The 5x area buffer is an area five times the total area of the park, evenly distributed as a 'buffer' around the entire park boundary.

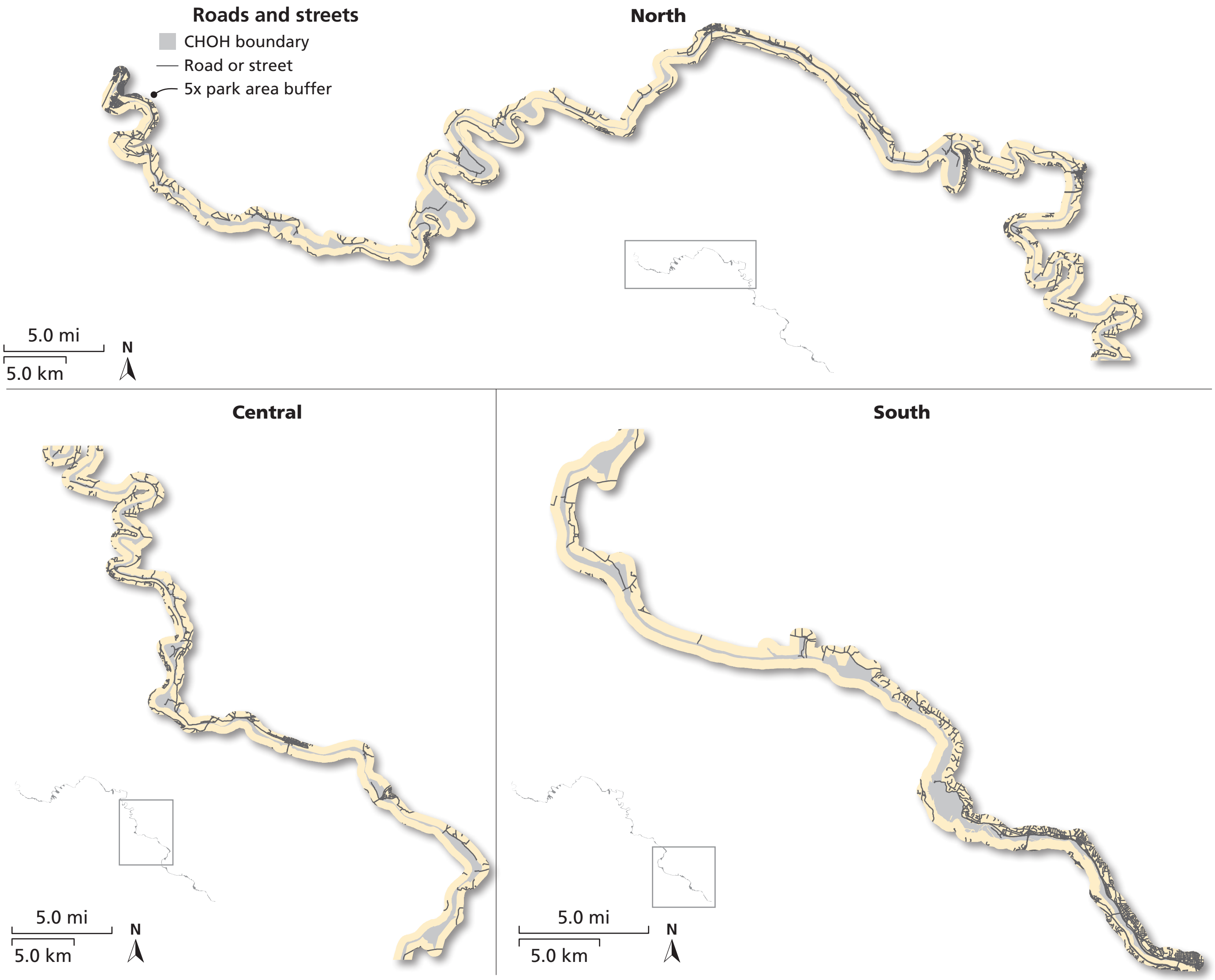

Figure 4.54. Map of roads and streets in and around CHOH in 2010. This is the base map from which the above map was generated.

Chapter 5: Discussion

5.1 PARK NATURAL RESOURCE CONDITION

Overall, natural resources in Chesapeake and Ohio Canal National Historical Park were in a moderate condition, with 44% achievement of reference conditions (Table 5.1).

Table 5.1. Natural resource condition assessment of CHOH.

Vital Sign	Reference condition attainment	Current condition
Air Quality	12%	Very degraded
Water Resources	60%	Good
Biological Integrity	43%	Moderate
Landscape Dynamics	59%	Moderate
Chesapeake and Ohio Canal National Historical Park	**44%**	**Moderate**

5.1.1 Air quality

Air quality was in a very degraded condition, with 12% 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. The 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 CHOH.

Metric	Condition
Wet sulfur deposition	Significant concern
Wet nitrogen deposition	Significant concern
Ozone (ppb)	Moderate
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.

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

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

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 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*)

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

Data gaps	Justification	Research needs
• Ecological thresholds for mercury wet deposition	• Wet deposition is monitored but the only available reference condition 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 condition and possible effects on park habitats and species.

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

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 good condition overall, with 60% attainment of reference conditions (Tables 5.1, 5.5). No water resources metrics (apart from Benthic Index of Biotic Integrity [BIBI] and Physical Habitat Index [PHI]) were measured inside the park boundary which necessitated the use of data collected upstream of the park. It is recommended to establish regular water quality monitoring within the park boundary (Table 5.6). Nutrients (nitrogen and phosphorus), specific conductance, BIBI, and PHI were in moderate to very degraded condition while pH,

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

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

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

Key findings	Management implications	Recommended next steps
• Water quality parameters are not measured within the park	• Need to rely on data collected by other agencies outside the park boundaries	• Establish regular water quality monitoring within the park boundary
• Benthic Index of Biotic Integrity (BIBI) and Physical Habitat Index (PHI) data have not been updated since 2004	• Current status of BIBI and PHI are poorly known	• Update and regularly repeat BIBI and PHI monitoring
• Very degraded condition for nitrogen and phosphorus	• Affects stream flora and fauna • Reduces quality of visitor experience	• Reduce non-point source nutrient inputs from watershed (in partnership with agencies) • Continue riparian buffer establishment
• 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 CHOH.

Data gaps	Justification	Research needs
• Detailed knowledge of wetland intactness and functionality	• Need to know where to prioritize management actions	• Delineate wetlands and perform feasibility study identifying potential restoration sites
• Sources of stormwater influxes to the canal and river are not well known	• Need to know where to prioritize management actions	• Identify sources of stormwater
• Extent to which contaminants from neighboring lands are reaching the Canal and river	• Need to know where to prioritize management actions	• Identify sources and composition of contaminants entering the park
• Karst features in and around the park are poorly understood	• Karst landscapes influence water flows into and through the park	• Initial inventory of sensitive karst areas has been completed and data analysis currently underway (Tudek and Vesper, in press)
• Upstream sediment sources are not well known	• Need to know where to prioritize management actions	• Identify sources and composition of alluvial sediment being deposited
• Specific conductance is showing a degrading trend	• Affects stream flora and fauna	• Identify conductance-sensitive organisms and locations for management initiatives

dissolved oxygen, water temperature and acid neutralizing capacity were very good, 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 showed a significant degrading trend. Several data gaps and research recommendations revolve around water in the park, including wetland delineation, sources of stormwater, contaminants, and sediments, and the karst geology of the park (Table 5.7).

Climate change

Many of the streams flowing through the park into the Potomac River are designated as Natural Trout Waters, Nontidal Cold Water and Public Water Supply or as Recreational Trout Waters and Public Water Supply. These streams are characterized by cold water temperatures. Water temperature increase is one of the most immediate threats from climate change, and this would result in the loss of trout from these streams.

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.

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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 very degraded. 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).

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

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

The first (and so far, the only) deer with chronic wasting disease in Maryland was found in November 2010 in Allegany County in Green Ridge State Forest which is adjacent to CHOH (M. Carter, pers. comm.). Chronic wasting disease is a fatal, neurological disease known to occur in white-tailed deer, mule deer, moose, and elk and is similar to mad-cow disease, scrapie in sheep, and Creutzfeldt–Jacob Disease in humans.

Other monitoring recommendations include expanding amphibian monitoring, updating and repeating Fish Index of Biotic Integrity (FIBI) monitoring, and continuing to monitor pests and diseases (Table 5.9).

Forest pest species were in a very good condition; however, emerald ash borer has been detected in the park but has not yet shown up in the regularly monitored forest

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

Key findings	Management implications	Recommended next steps
• Deer overpopulation may be impacting forest regeneration and agriculture • Deer are only monitored in the Great Falls area	• Increased herbivory reducing desired plant and bird species, and lowering yields in agricultural areas • More road collisions • Potential for spread of chronic wasting disease • Deer densities outside Great Falls are not well known	• Develop a deer management plan • Implement deer population control measures • Expand deer monitoring beyond Great Falls area • Target deer monitoring in areas with sensitive habitats and where there is a known impact on agricultural operations
• 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
• Amphibian monitoring is limited to the Potomac Gorge area only	• Little knowledge of amphibians beyond the Potomac Gorge, and the geographic limitation prevented amphibians from being included in this assessment	• Expand amphibian monitoring beyond the Potomac Gorge area
• Fish Index of Biotic Integrity (FIBI) data have not been updated since 2004	• Current status of BIBI and PHI are poorly known	• Update and regularly repeat FIBI monitoring
• White-nose syndrome has been detected in the park	• Has the potential to spread throughout the park	• Continue to monitor bat populations within the park and throughout the region
• White-nose syndrome is absent from the three tunnels in the park	• Tunnes are important bat hibernacula	• Continue to protect the tunnels of the park to make every effort to keep them free of WNS
• Emerald ash borer has been detected in the park	• Has the potential to spread throughout the park	• Continue to monitor for emerald ash borer 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

plots. It is expected that it is only a matter of time until emerald ash borer does appear in the monitoring plots.

Although white-nose syndrome has been detected in the park, the absence of this disease from the tunnels of the park is very encouraging and research and management efforts should focus on continuing to protect the tunnels and finding out potential reasons for the absence of this disease. Emerald ash borer and white-nose syndrome are two of the biggest threats facing the park and it is worrisome that both have recently reached the park.

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).

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

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
• Limited knowledge about why the tunnels of the park remain free of white-nose syndrome	• The three tunnels of the park are important bat hibernacula	• Research into the reasons why the tunnels remain free of white-nose syndrome, with application to management of the tunnels

5.1.4 Landscape dynamics

Landscape dynamics were in a moderate condition overall, with 59% attainment of reference conditions (Tables 5.1, 5.11). Forest interior was in a degraded condition both inside and adjacent to the park. This was mostly due to the linear shape of the park which limits the amount of potential forest interior area. Forest cover inside the park was in a very good condition but was in very degraded condition adjacent to the park. This relates to the proximity of the park to the Potomac River which is a non-forest land cover. Management opportunities for the park relating to these two results include maintaining and improving the quality of existing forest habitat within the park (Table 5.12).

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

Metric	Condition
Forest interior area (within park)	Degraded
Forest interior area (within park + 5x buffer)	Degraded
Forest cover (within park)	Very good
Forest cover (within park + 5x buffer)	Very degraded
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	**Moderate**

Impervious surface and road density within the park were both in very good condition. Impervious surface adjacent to the park was also in very good condition; however, road density at the same scale was very degraded. High road density has implications for wildlife mortality and could also result in increased surface runoff and stormwater entering the park. With development increasing near the park, it can be expected that impervious surface and road density will increase in the areas surrounding the park in the future. Management options include maintaining or increasing pervious surfaces within the park and installing stormwater retention basins (Table 5.12).

Climate change

Research needs for the park mostly relate to its function as a habitat corridor in the region (Table 5.13). How climate change may affect the park's resources and habitats should be an ongoing research focus.

Literature cited

Tudek, J.K. and D.J. Vesper. In press. A review of the karst resources of the Antietam National Battlefield, the Harpers Ferry National Historical Park, and the Chesapeake and Ohio Canal National Historical Park. Draft Natural Resource Technical Report.

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

Key findings	Management implications	Recommended next steps
• Forest interior area is degraded	• Degraded forest interior area is a result of the linear shape of the park • Nevertheless, lack of forest interior area reduces habitat available for forest interior dwelling species	• Maintain quality of existing forest habitat by managing for exotic species and forest pests
• Forest cover is good inside the park but very degraded adjacent to the park	• Degraded condition outside the park is due in part to the proximity of the Potomac River—a non-forested land cover • However, lack of forest cover surrounding the park results in fragmented habitat for forest species	• Maintain quality of existing forest habitat by managing for exotic species and forest pests
• Impervious surface is very low	• Slows the flow of surface runoff/stormwater entering park streams	• Continue to maintain pervious surfaces within the park
• Road density is 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 CHOH.

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
• Wetland corridor function	• Needed for migration and movement of fauna	• Assessment of current and potential use by fauna
• 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 thresholds 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
510595001	2000–2002	14.6
	2001–2003	14.1
	2002–2004	13.8
	2003–2005	14.0
	2004–2006	13.7
	2005–2007	13.7
	2006–2008	12.7
	2007–2009	11.7
511071005	2000–2002	13.8
	2001–2003	13.6
	2002–2004	13.6
	2003–2005	13.9
	2004–2006	13.6
	2005–2007	13.2
	2006–2008	12.2
	2007–2009	11.2
	2008–2010	10.3
	2009–2011	9.5
540030003	2000–2002	16.3
	2001–2003	16.4
	2002–2004	16.3
	2003–2005	16.2
	2004–2006	15.8
	2005–2007	15.9
	2006–2008	15.0
	2007–2009	14.0
	2008–2010	12.8
	2009–2011	11.8
Overall median		**13.5**

Table A-2. Water quality data. Site locations are shown in Figures 4.17 and 4.18 and thresholds are shown in Table 4.11.

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANT0002	3/25/02	8.00	10.80	8.00		536.00	15.01	0.136
ANT0002	4/22/02	8.00	9.00	15.50		544.00	11.04	0.257
ANT0002	5/20/02	8.10	10.30	13.10		492.00	10.89	0.162
ANT0002	7/29/02	7.90	7.10	25.10		482.00	10.87	0.211
ANT0002	8/28/02	8.20	7.10	21.80		541.00	11.65	0.209
ANT0002	9/30/02	8.10	9.30	17.00		461.00	11.22	0.360
ANT0002	10/9/02	8.30	9.30	13.60		635.00	14.72	0.176
ANT0002	10/23/02	8.10	10.60	10.20		627.00	18.34	0.124
ANT0002	11/12/02	8.40	9.50	12.50		572.00	18.10	0.102
ANT0002	11/26/02	8.20	12.30	7.30		566.00	23.39	0.093
ANT0002	12/4/02	9.60	12.90	0.70		594.00	23.43	0.054
ANT0002	12/18/02	7.90	12.10	4.30		526.00	23.60	0.102
ANT0002	1/8/03	9.30	12.30	5.20		566.00	25.50	0.093
ANT0002	1/23/03	8.00	13.50	-0.10		590.00	27.79	0.053
ANT0002	2/5/03	8.20	12.20	4.60		567.00	24.49	0.048
ANT0002	3/5/03	8.20	11.10	5.60		555.00	21.73	0.099
ANT0002	3/19/03	8.00	10.70	10.60		431.00	18.18	0.098
ANT0002	4/23/03	8.20	10.00	11.80		499.00	20.00	0.089
ANT0002	5/7/03	8.20	9.80	14.00		517.00	20.86	0.089
ANT0002	5/21/03	7.90	9.40	14.20		444.00	18.21	0.151
ANT0002	6/4/03	7.70	9.10	14.00		390.00	15.10	0.945
ANT0002	6/18/03	8.00	9.30	15.80		528.00	23.25	0.125
ANT0002	6/25/03	7.80	8.90	17.70		517.00	22.86	0.120
ANT0002	7/9/03	8.00	8.20	20.70		548.00	23.73	0.078
ANT0002	7/23/03	8.00	7.70	21.00		556.00	24.84	0.083
ANT0002	8/6/03	8.20	8.50	21.10		582.00	24.36	0.191
ANT0002	8/20/03	8.30	8.40	20.80		558.00	21.87	0.241
ANT0002	8/27/03	8.20	7.60	19.70		573.00	23.19	0.146
ANT0002	9/10/03	8.30	8.80	16.80		591.00	23.83	0.097
ANT0002	9/24/03	7.90	8.60	16.30		419.00	14.25	0.277
ANT0002	10/8/03	8.30	9.90	13.20		573.00	24.06	0.061
ANT0002	10/22/03	8.30	9.40	13.10		574.00	23.72	0.072
ANT0002	1/26/09	8.10	13.60	1.40		574.00	23.40	0.034
ANT0002	2/23/09	8.70	13.60	3.10		552.00	20.42	0.030
ANT0002	3/23/09	8.70	10.50	7.40		552.00	19.67	0.111
ANT0002	4/27/09	8.00	6.80	18.70		428.00	12.71	0.131
ANT0002	5/26/09	8.00	7.90	19.10		521.00	19.41	0.121
ANT0002	6/22/09	8.20	7.90	19.40		550.00	21.82	0.135
ANT0002	7/27/09	8.10	7.60	21.40		577.00	17.35	0.123
ANT0002	8/24/09	8.20	7.80	21.80		604.00	21.22	0.113
ANT0002	9/21/09	7.60	8.60	17.20		627.00	21.76	0.103
ANT0002	10/26/09	8.10	9.90	11.50		612.00	20.65	0.125
ANT0002	11/16/09	8.00	10.10	10.50		612.00	19.63	0.078
ANT0002	12/16/09	7.90	9.20	5.90		497.00	17.59	0.108

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANT0044	1/20/00	7.80	12.00	1.00		550.00	20.28	0.215
ANT0044	2/16/00	8.00	12.90	5.40		518.00	16.48	0.141
ANT0044	3/8/00	8.10	11.70	11.90		493.00	15.44	0.107
ANT0044	4/12/00	8.10	10.40	12.00		461.00	15.20	0.074
ANT0044	5/10/00	8.00	7.70	21.00		501.00	16.74	0.177
ANT0044	6/14/00	8.10	8.30	19.70		530.00	17.71	0.181
ANT0044	7/12/00	8.20	8.30	20.60		539.00	19.85	0.190
ANT0044	8/9/00	8.00	7.80	22.30		542.00	18.98	0.177
ANT0044	9/13/00	8.00	7.60	21.10		535.00	17.26	0.195
ANT0044	10/18/00	7.80	8.50	14.20		587.00	19.85	0.174
ANT0044	11/16/00	8.20	11.40	6.00		596.00	18.66	0.207
ANT0044	12/6/00	7.90	13.10	1.50		575.00	20.48	0.174
ANT0044	1/10/01	7.80	11.20	0.60		566.00	19.89	0.088
ANT0044	2/7/01	7.90	11.20	5.40		531.00	18.50	0.117
ANT0044	3/21/01	8.20	10.80	8.00		468.00	14.78	0.104
ANT0044	4/18/01	8.00	10.50	9.20		453.00	15.89	0.125
ANT0044	5/16/01	8.40	10.10	15.00		541.00	17.88	0.128
ANT0044	6/20/01	7.80	7.20	22.50		554.00	16.51	0.205
ANT0044	7/25/01	8.00	7.50	24.70		575.00	17.17	0.149
ANT0044	8/8/01	7.70	7.40	24.60		567.00	16.61	0.171
ANT0044	9/19/01	7.90	9.60	16.70		579.00	17.55	0.116
ANT0044	10/18/01	8.00	9.30	10.10		593.00	15.45	0.178
ANT0044	11/7/01	8.60	11.20	7.60		600.00	14.04	0.262
ANT0044	12/19/01	8.70	11.00	7.20		599.00	17.77	0.112
ANT0044	1/24/02	8.20	10.90	6.00		631.00	18.76	0.094
ANT0044	2/21/02	8.40	9.00	7.60		619.00	20.96	0.196
ANT0044	3/21/02	8.30	9.90	8.20		523.00	15.09	0.242
ANT0044	3/25/02	8.00	11.30	7.90		530.00	15.03	0.128
ANT0044	4/18/02	8.20	7.10	21.60		510.00	10.83	0.263
ANT0044	4/22/02	8.10	8.90	14.90		543.00	11.59	0.252
ANT0044	5/16/02	8.10	8.90	15.70		466.00	12.10	0.168
ANT0044	5/20/02	8.00	9.70	13.10		489.00	10.67	0.159
ANT0044	6/12/02	8.00	6.90	24.30		540.00	12.92	0.184
ANT0044	7/25/02	8.10	6.60	24.00		563.00	12.17	0.182
ANT0044	7/29/02	7.90	6.80	25.10		534.00	12.15	0.187
ANT0044	8/21/02	8.00	6.90	23.50		623.00	11.85	0.173
ANT0044	8/28/02	8.10	6.80	21.90		554.00	12.58	0.224
ANT0044	9/25/02	7.80	8.40	17.50		510.00	11.74	0.585
ANT0044	9/30/02	5.10	8.50	17.30		458.00	11.79	0.349
ANT0044	10/9/02	8.30	11.50	13.50		631.00	14.68	0.163
ANT0044	10/23/02	8.10	10.60	10.20		624.00	17.89	0.129
ANT0044	11/12/02	8.30	9.20	12.50		580.00	18.19	0.105
ANT0044	11/26/02	8.50	11.50	7.60		566.00	22.50	0.092
ANT0044	12/4/02	9.20	12.80	0.90		598.00	23.74	0.075
ANT0044	12/18/02	8.00	11.90	4.20		531.00	24.22	0.089

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANT0044	1/8/03	8.80	12.00	5.10		569.00	25.89	0.090
ANT0044	1/23/03	8.00	13.40	-0.20		600.00	28.32	0.049
ANT0044	2/5/03	8.20	12.20	4.30		593.00	24.40	0.045
ANT0044	3/5/03	8.10	10.90	5.70		569.00	22.88	0.098
ANT0044	3/19/03	7.90	10.70	10.10		433.00	18.53	0.095
ANT0044	4/23/03	8.10	9.80	11.50		500.00	20.40	0.081
ANT0044	5/7/03	8.20	9.80	13.70		522.00	21.10	0.091
ANT0044	5/21/03	7.90	9.20	14.00		450.00	18.87	0.153
ANT0044	6/4/03	7.70	9.30	13.60		385.00	14.83	0.867
ANT0044	6/18/03	8.00	9.20	15.60		531.00	23.29	0.120
ANT0044	6/25/03	7.80	8.80	17.30		522.00	23.21	0.125
ANT0044	7/9/03	7.90	8.10	20.50		555.00	24.12	0.079
ANT0044	7/23/03	7.90	7.70	20.40		559.00	24.48	0.087
ANT0044	8/6/03	8.10	7.90	20.70		585.00	24.36	0.171
ANT0044	8/20/03	8.20	8.10	20.40		566.00	22.32	0.214
ANT0044	8/27/03	8.10	7.50	19.40		577.00	23.37	0.128
ANT0044	9/10/03	8.30	8.60	16.50		596.00	24.14	0.093
ANT0044	9/24/03	8.00	8.80	18.10		425.00	14.29	0.245
ANT0044	10/8/03	8.20	9.80	12.90		580.00	24.63	0.060
ANT0044	10/22/03	8.30	9.00	13.00		579.00	23.72	0.068
ANT0044	11/6/03	8.40	9.50	15.60		534.00		
ANT0044	11/13/03	8.50	11.00	10.10		489.00		
ANT0044	11/20/03	8.40	9.90	11.80		449.00		
ANT0044	12/4/03	8.90	12.60	5.00		520.00		
ANT0044	12/11/03	7.80	10.80	7.90		329.00		
ANT0044	12/18/03	8.70	12.30	4.90		509.00		
ANT0044	1/8/04	8.30	13.00	2.60		532.00		
ANT0044	1/23/04	8.20	13.60	0.80		567.00		
ANT0044	1/29/04	8.20	13.70	0.50		549.00		
ANT0044	2/9/04	8.10	12.90	3.10		488.00		
ANT0044	2/20/04	8.10	11.60	6.90		542.00		
ANT0044	2/25/04	8.40	12.00	6.00		539.00		
ANT0044	3/4/04	8.10	10.50	10.00		477.00		
ANT0044	3/8/04	8.30	11.60	9.20		474.00		
ANT0044	3/18/04	8.40	12.70	6.80		507.00		
ANT0044	4/8/04	8.10	10.30	10.60		462.00		
ANT0044	4/13/04	8.00	10.70	8.90		401.00		
ANT0044	4/22/04	7.90	8.90	17.40		497.00		
ANT0044	5/13/04	7.90	8.80	18.70		510.00		
ANT0044	5/19/04	7.90	8.40	18.10		480.00		
ANT0044	5/27/04	8.00	8.30	18.70		448.00		
ANT0044	6/10/04	8.00	8.40	19.20		532.00		
ANT0044	6/15/04	7.80	8.00	20.00		421.00		
ANT0044	6/24/04	7.90	8.70	18.80		557.00		
ANT0044	7/9/04	7.90	8.00	21.20		552.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANT0044	7/22/04	8.30	7.80	21.90		566.00		
ANT0044	7/27/04	8.20	7.80	20.60		575.00		
ANT0044	8/12/04	8.20	7.90	21.00		587.00		
ANT0044	8/26/04	8.30	8.20	20.80		597.00		
ANT0044	8/31/04	8.00	8.00	22.30		599.00		
ANT0044	9/10/04	8.30	8.20	19.40		572.00		
ANT0044	9/18/04	8.10	8.00	18.90		431.00		
ANT0044	9/23/04	8.20	9.00	16.60		563.00		
ANT0044	10/7/04	8.30	10.10	12.60		571.00		
ANT0044	10/21/04	8.40	9.80	12.10		553.00		
ANT0044	10/26/04	8.00	9.90	11.70		567.00		
ANT0044	11/10/04	8.40	11.80	6.90		580.00		
ANT0044	11/22/04	8.20	9.70	11.40		561.00		
ANT0044	12/8/04	8.30	11.20	8.70		508.00		
ANT0044	12/15/04	8.90	12.60	4.70		501.00		
ANT0044	12/21/04	8.40	11.50	2.20		541.00		
ANT0044	1/5/05	8.40	10.60	9.50		519.00		
ANT0044	1/13/05	8.20	12.90	8.80		487.00		
ANT0044	1/20/05	8.40	15.80	3.20		490.00		
ANT0044	2/2/05	8.60	13.00	2.90		548.00		
ANT0044	2/14/05	8.20	11.90	5.40		524.00		
ANT0044	2/22/05	8.50	11.50	6.20		502.00		
ANT0044	3/16/05	8.40	11.50	6.20		499.00		
ANT0044	4/14/05	8.30	10.90	11.50		516.00		
ANT0044	4/27/05	8.20	9.60	13.20		521.00		
ANT0044	5/5/05	8.10	10.50	12.20		528.00		
ANT0044	5/19/05	8.10	8.50	15.90		546.00		
ANT0044	6/8/05	8.10	7.70	22.00		540.00		
ANT0044	6/23/05	8.20	8.00	19.40		579.00		
ANT0044	7/13/05	8.10	7.20	24.00		567.00		
ANT0044	7/27/05	8.20	7.50	25.60		535.00		
ANT0044	8/4/05	8.20	7.40	24.10		552.00		
ANT0044	8/18/05	8.10	7.80	22.20		526.00		
ANT0044	9/15/05	8.30	7.60	21.00		598.00		
ANT0044	9/21/05	8.30	7.60	19.40		617.00		
ANT0044	10/20/05	8.20	9.10	14.10		612.00		
ANT0044	10/27/05	8.20	10.50	9.40		503.00		
ANT0044	11/3/05	8.40	10.70	10.70		605.00		
ANT0044	11/21/05	8.50	12.50	6.40		606.00		
ANT0044	12/1/05	8.10	10.90	8.50		371.00		
ANT0044	12/15/05	8.60	13.30	0.70		600.00		
ANT0084	3/25/02	7.90	10.90	8.30		555.00	15.43	0.132
ANT0084	4/22/02	8.00	8.80	14.30		554.00	12.56	0.264
ANT0084	5/20/02	8.00	9.90	13.30		483.00	10.84	0.169
ANT0084	7/29/02	8.00	6.40	25.20		548.00	13.46	0.264

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANT0084	8/28/02	8.10	6.60	22.00		560.00	13.77	0.231
ANT0084	9/30/02	8.00	8.40	17.60		465.00	12.45	0.391
ANTIX_HAI	3/1/00	9.80	9.80	12.00			5.10	
ANTIX_HAI	4/15/00	8.15	8.10	10.10			2.50	
ANTIX_HAI	5/1/00	7.85	5.80	11.70			3.70	
ANTIX_HAI	5/15/00	7.84	4.80	12.20			4.60	
ANTIX_HAI	6/1/00	7.88	3.40	13.10			4.20	
ANTIX_HAI	6/15/00	7.78	5.00	14.20			3.30	
ANTIX_HAI	7/1/00	7.67	3.30	14.60			5.20	
ANTIX_HAI	7/15/00	7.77	5.20	15.60			6.50	
ANTIX_HAI	8/1/00	7.57	2.60	16.40			4.90	
ANTIX_HAI	9/1/00	7.62	5.70	15.60			5.30	
ANTIX_HAI	10/1/00	7.69	3.30	13.70			5.10	
ANTIX_HAI	3/1/01	7.57	7.20	8.70			8.20	
ANTIX_HAI	4/1/01	7.65	8.20	10.20			6.40	
ANTIX_HAI	5/1/01	7.68	5.40	10.80			5.40	
ANTIX_HAI	5/15/01	7.68	10.20	11.90			7.60	
ANTIX_HAI	6/1/01	7.78	5.80	13.40			9.70	
ANTIX_HAI	6/15/01	7.60	4.70	13.80			7.10	
ANTIX_HAI	7/1/01	7.40	2.50	13.60			7.20	
ANTIX_HAI	7/15/01	7.60	0.95	14.40			4.20	
ANTIX_HAI	8/1/01	7.61	1.16	15.40			5.60	
ANTIX_HAI	9/1/01	7.57	1.25	14.00			5.00	
ANTIX_HAI	10/1/01	7.66	2.11	11.80			5.20	
ANTIX_HAI	3/1/02	7.88	3.21	6.90			2.80	
ANTIX_HAI	4/1/02	8.02	3.25	7.70			2.60	
ANTIX_HAI	4/15/02	8.13	4.33	9.80			3.60	
ANTIX_HAI	5/1/02	7.86	5.80	11.10			6.40	
ANTIX_HAI	5/15/02	8.03	4.31	12.20			7.20	
ANTIX_HAI	6/1/02	7.83	14.46	13.80			9.30	
ANTIX_HAI	6/15/02	7.92	3.33	14.30			6.70	
ANTIX_HAI	7/1/02	8.04	3.02	14.30			5.20	
ANTIX_HAI	7/15/02	7.88	1.43	16.00			5.40	
ANTIX_HAI	8/1/02	7.86	2.06	16.40			5.40	
ANTIX_HAI	9/1/02	8.06	0.58	15.00			5.90	
ANTIX_HAI	10/1/02	7.26	6.30	14.20			6.00	
ANTIX_HAI	3/1/03	7.26	7.99	13.30			5.00	
ANTIX_HAI	4/1/03	7.36	6.80	9.90			4.30	
ANTIX_HAI	4/15/03	7.18	6.36	10.40			4.30	
ANTIX_HAI	5/1/03	7.12	5.50	11.20			5.60	
ANTIX_HAI	5/15/03	7.08	7.63	11.20			6.10	
ANTIX_HAI	6/1/03	6.87	7.90	11.70			5.80	
ANTIX_HAI	6/15/03	6.94	7.50	12.60			5.60	
ANTIX_HAI	7/1/03	7.10	4.80	13.40			6.20	
ANTIX_HAI	7/15/03	7.22	3.50	14.10			8.00	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_HAI	8/1/03	7.28	3.23	14.50			6.30	
ANTIX_HAI	8/15/03	7.24	3.20	14.90			4.30	
ANTIX_HAI	9/1/03	6.92	3.52	15.20			4.30	
ANTIX_HAI	10/1/03	7.20	4.31	14.30			5.80	
ANTIX_HAI	3/1/04	7.36	6.05	8.89			4.40	
ANTIX_HAI	4/1/04	7.29	8.10	10.00			6.90	
ANTIX_HAI	4/15/04	7.37	7.87	11.11			10.00	
ANTIX_HAI	5/1/04	7.45	5.78	11.11			5.80	
ANTIX_HAI	5/15/04	7.33	4.80	12.22			6.90	
ANTIX_HAI	6/1/04	7.29	5.50	12.78			8.60	
ANTIX_HAI	6/15/04	7.29	4.70	12.22			7.70	
ANTIX_HAI	7/1/04	7.19		14.90			4.30	
ANTIX_HAI	7/15/04	7.21		15.50			6.20	
ANTIX_HAI	8/1/04	7.50	3.30	16.40			5.90	
ANTIX_HAI	8/15/04	7.02	1.86	17.40			4.80	
ANTIX_HAI	9/1/04	6.87	0.62	16.40			6.80	
ANTIX_HAI	10/1/04	7.02	2.70	13.00			4.80	
ANTIX_HAI	2/1/05	6.48		9.88		439.00	6.50	
ANTIX_HAI	2/15/05	7.20	5.37	9.31		457.00	9.20	
ANTIX_HAI	3/1/05	7.30	6.74	9.44		445.00	5.60	
ANTIX_HAI	3/15/05	7.17	8.52	10.17		350.00	5.50	
ANTIX_HAI	4/1/05	7.12	8.25	10.57		349.00	6.70	
ANTIX_HAI	4/15/05	7.29	6.75	11.77		362.00	5.30	
ANTIX_HAI	5/1/05	7.45	6.15	11.23		431.00	3.60	
ANTIX_HAI	5/15/05	7.28	4.84	11.31		436.00	5.20	
ANTIX_HAI	6/1/05	7.38	2.78	12.62		437.00	4.70	
ANTIX_HAI	6/15/05	7.26	2.45	13.31		445.00	7.40	
ANTIX_HAI	7/1/05	7.36	2.33	15.61		489.00	4.00	
ANTIX_HAI	7/15/05	7.18	1.68	15.74		492.00	3.30	
ANTIX_HAI	8/1/05	7.26	2.34	15.73		502.00	4.50	
ANTIX_HAI	8/15/05	7.31	3.51	16.50		501.00	5.50	
ANTIX_HAI	9/1/05	6.97	3.40	15.43		475.00	4.00	
ANTIX_HAI	9/15/05	7.74	4.86	13.15		473.00	3.40	
ANTIX_HAI	10/1/05	7.50	6.57	14.22		458.00	7.00	
ANTIX_HAI	10/15/05	7.18	6.42	13.20		453.00	11.00	
ANTIX_HAI	11/1/05	7.15	4.76	13.27		455.00	7.00	
ANTIX_HAI	11/15/05	6.94	8.60	13.29		394.00	5.40	
ANTIX_HAI	12/1/05	7.14	6.64	11.35		459.00	12.30	
ANTIX_HAI	12/15/05	7.10	7.59	11.76		665.00	7.30	
ANTIX_HAI	1/1/06	5.86	7.02	11.48		431.00	7.40	
ANTIX_HAI	2/1/06	7.27	6.82	10.24		435.00	2.50	
ANTIX_HAI	3/1/06	6.76	6.48	9.00		450.00	7.10	
ANTIX_HAI	3/15/06						6.00	
ANTIX_HAI	4/1/06	5.63	6.63	10.59		462.00	6.00	
ANTIX_HAI	5/1/06	5.21	4.03	11.87		460.00	7.20	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_HAI	6/1/06	5.72	9.04	12.75		397.00	8.10	
ANTIX_HAI	7/1/06	4.90	4.07	14.55		439.00	6.40	
ANTIX_HAI	8/1/06	5.10	3.43	15.14		456.00	2.80	
ANTIX_HAI	9/1/06	4.96	3.80	14.45		468.00	5.90	
ANTIX_HAI	10/1/06	6.86	6.61	14.05		448.00	7.60	
ANTIX_HAI	11/1/06	7.16	6.05	13.43		443.00	6.00	
ANTIX_HAI	12/1/06	6.99	7.58	12.19		425.00	6.90	
ANTIX_HAI	1/1/07	6.99	7.58	12.19		425.00	6.90	
ANTIX_HAI	2/1/07	6.98	6.05	9.47		456.00	0.10	
ANTIX_HAI	3/1/07	7.06	8.69	9.94		446.00	3.90	
ANTIX_HAI	3/15/07						2.20	
ANTIX_HAI	4/1/07	5.65	7.55	10.77		448.00	7.20	
ANTIX_HAI	5/1/07	5.84	3.45	11.69		448.00	6.30	
ANTIX_HAI	6/1/07						6.60	
ANTIX_HAI	7/1/07	5.72	2.83	13.91		470.00	6.10	
ANTIX_HAI	8/1/07	5.52	1.47	15.23		477.00	5.70	
ANTIX_HAI	10/1/07	6.56	5.09	13.37		511.00	4.40	
ANTIX_HAI	11/1/07	5.94	5.96	11.80		496.00	5.80	
ANTIX_HAI	12/1/07	6.93	7.57	12.80		464.00	6.20	
ANTIX_HAI	1/1/08	6.73	9.16	11.51		443.00	4.90	
ANTIX_HAI	2/1/08	6.75	7.44	9.96		457.00	2.40	
ANTIX_HAI	3/1/08	7.25	7.65	10.75		449.00	4.30	
ANTIX_HAI	4/1/08	7.14	10.50	11.42		410.00	5.00	
ANTIX_HAI	5/1/08	7.09	7.46	11.79		415.00	7.00	
ANTIX_HAI	6/1/08	7.24	6.57	12.48		417.00	7.30	
ANTIX_HAI	7/1/08	7.04	5.90	13.27		428.00	4.80	
ANTIX_HAI	8/1/08	7.13	3.97	13.75		440.00	3.70	
ANTIX_HAI	9/1/08	7.03	3.47	14.39		458.00	5.70	
ANTIX_HAI	10/1/08	7.24	3.78	10.69		477.00	1.40	
ANTIX_HAI	11/1/08	7.29	5.07	9.58		485.00	0.40	
ANTIX_HAI	12/1/08	6.92	7.80	12.82		447.00	5.50	
ANTIX_HAI	1/1/09	7.16	6.87	11.51		449.00	11.20	
ANTIX_HAI	2/1/09	6.88	7.29	9.45		471.00		
ANTIX_HAI	3/1/09	6.59	7.31	8.28		467.00	5.50	
ANTIX_HAI	3/15/09	6.00	7.95	9.86		427.00	5.90	
ANTIX_HAI	4/1/09	5.88	9.64	10.98		433.00	4.10	
ANTIX_HAI	5/1/09	6.11	6.28	11.89		413.00	3.00	
ANTIX_HAI	6/1/09	5.80	5.77	12.11		423.00	5.60	
ANTIX_HAI	7/1/09	6.62	3.60	12.92		423.00	5.30	
ANTIX_HAI	8/1/09	7.20	4.28	13.54		450.00	6.10	
ANTIX_HAI	9/1/09	7.25	4.53	13.25		460.00	6.30	
ANTIX_HAI	10/1/09	7.38	3.93	12.00		474.00	5.90	
ANTIX_HAI	11/1/09	7.22	4.70	11.60		488.00	6.70	
ANTIX_HAI	12/1/09	7.33	7.57	11.40		465.00	7.10	
ANTIX_HAI	1/1/10	7.17	9.13	11.07		392.00	5.90	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_HAI	2/1/10	7.28	8.79	9.88		443.00	6.00	
ANTIX_HAI	3/1/10	6.90	8.63	10.61		415.00	5.90	
ANTIX_HAI	4/1/10	7.23	5.87	11.16		458.00	4.90	0.111
ANTIX_HAI	5/1/10	7.21	4.68	11.62		504.00	4.50	0.111
ANTIX_HAI	6/1/10	7.06				495.00	5.50	0.134
ANTIX_HAI	9/1/10	6.95	8.69	14.66		426.00	7.30	0.238
ANTIX_HAI	10/1/10	6.99	5.28	14.18		463.00	6.40	0.095
ANTIX_HAI	11/1/10	7.21	7.72	12.83		463.00	5.10	0.098
ANTIX_HAI	12/1/10	7.28	6.61	11.15		468.00	8.00	0.082
ANTIX_HAI	1/1/11	7.36	7.66	8.07		456.00	7.70	0.065
ANTIX_HAI	2/1/11	7.19	8.93	11.06		422.00	6.70	0.029
ANTIX_HAI	3/1/11	7.22	7.70	10.86		427.00	7.10	0.062
ANTIX_HAI	4/1/11	6.81	9.06	11.23		364.00	5.70	0.055
ANTIX_HAI	5/1/11	6.67	7.78	11.33		427.00	6.00	0.039
ANTIX_HAI	6/1/11		6.26	12.46		433.00	4.90	0.049
ANTIX_HAI	7/1/11	6.71	4.99	13.68		450.00	5.20	0.059
ANTIX_HAI	8/1/11	6.97		14.43		463.00	5.40	0.052
ANTIX_HAI	9/1/11	6.98		14.44		436.00	5.60	0.062
ANTIX_HAI	10/1/11	7.14	7.65	13.93		417.00	6.40	0.036
ANTIX_HAI	11/1/11	7.20	7.68	13.60		430.00	7.10	0.036
ANTIX_HAI	12/1/11	7.28	8.05	13.09		445.00	6.80	
ANTIX_MIL	3/1/00	7.90	11.10	11.20			5.20	
ANTIX_MIL	4/1/00	8.29	12.10	12.00			7.40	
ANTIX_MIL	5/1/00	7.93	8.90	18.20			8.20	
ANTIX_MIL	5/15/00	7.96	7.00	15.70			5.60	
ANTIX_MIL	6/1/00	8.07	8.20	17.70			3.40	
ANTIX_MIL	6/15/00	7.96	7.30	16.10			7.10	
ANTIX_MIL	7/1/00	7.50	4.60	17.70			4.90	
ANTIX_MIL	7/15/00	7.70	10.90	18.80			8.40	
ANTIX_MIL	8/1/00	7.57	7.90	20.00			4.60	
ANTIX_MIL	9/15/00	7.64	7.20	15.90			5.70	
ANTIX_MIL	10/15/00	7.75	11.40	19.20			4.50	
ANTIX_MIL	3/1/01	7.94	12.40	6.20			4.20	
ANTIX_MIL	4/1/01	7.95	11.20	11.50			7.70	
ANTIX_MIL	5/1/01	7.90	7.20	10.50			4.10	
ANTIX_MIL	5/15/01	7.85	6.80	11.80			5.90	
ANTIX_MIL	6/1/01	7.80	9.80	15.20			13.20	
ANTIX_MIL	6/15/01	7.46	7.83	16.30			8.60	
ANTIX_MIL	7/1/01	7.85	6.50	15.40			6.40	
ANTIX_MIL	8/1/01	7.60	4.77	19.40			4.80	
ANTIX_MIL	9/15/01	7.88	7.11	17.70			3.60	
ANTIX_MIL	10/15/01	8.15	7.66	14.00			5.50	
ANTIX_MIL	4/1/02	8.25	16.68	8.70			6.30	
ANTIX_MIL	4/15/02	8.69	12.12	12.20			2.10	
ANTIX_MIL	5/1/02	7.97	9.27	16.20			1.40	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MIL	5/15/02	7.75	10.19	14.80			3.20	
ANTIX_MIL	6/1/02	7.85	7.88	18.80			6.20	
ANTIX_MIL	6/15/02	7.68	8.89	18.80			11.00	
ANTIX_MIL	7/1/02	8.38	10.00	18.00			5.30	
ANTIX_MIL	7/15/02	7.77	7.40	20.40			9.90	
ANTIX_MIL	8/1/02	7.92	5.98	22.70			9.20	
ANTIX_MIL	9/15/02	8.22	7.27	20.00			8.90	
ANTIX_MIL	10/15/02	6.86	9.08	16.00			4.80	
ANTIX_MIL	3/1/03	7.18	8.62	10.10			6.60	
ANTIX_MIL	4/1/03	7.52	8.51	10.10			7.80	
ANTIX_MIL	4/15/03	7.37	7.63	11.00			5.10	
ANTIX_MIL	5/1/03	7.13	8.48	13.10			10.00	
ANTIX_MIL	5/15/03	6.94	7.82	12.10			8.70	
ANTIX_MIL	6/1/03	7.19	6.60	13.20			6.90	
ANTIX_MIL	6/15/03	7.12	7.50	13.60			9.00	
ANTIX_MIL	7/1/03	7.02	7.80	14.80			9.60	
ANTIX_MIL	7/15/03	7.17	8.58	16.80			9.00	
ANTIX_MIL	8/1/03	7.33	7.49	17.80			5.90	
ANTIX_MIL	8/15/03	7.06	7.97	17.20			7.80	
ANTIX_MIL	9/15/03	6.90	7.44	16.60			7.70	
ANTIX_MIL	10/15/03	7.14	7.35	17.60			6.60	
ANTIX_MIL	3/1/04	7.96	10.20	10.55			4.90	
ANTIX_MIL	4/1/04	7.34	12.00	12.22			2.50	
ANTIX_MIL	4/15/04	7.37	10.00	11.67			8.50	
ANTIX_MIL	5/1/04	7.31	8.45	11.67			7.70	
ANTIX_MIL	5/15/04	7.28	7.68	13.33			8.10	
ANTIX_MIL	6/1/04	7.18	7.87	13.33			5.10	
ANTIX_MIL	6/15/04	7.14	7.45	14.44			7.20	
ANTIX_MIL	7/1/04	7.34		19.10			7.80	
ANTIX_MIL	7/15/04	7.39		18.40			7.00	
ANTIX_MIL	8/1/04	7.54	6.56	20.20			6.40	
ANTIX_MIL	8/15/04	7.33	5.53	21.90			5.60	
ANTIX_MIL	9/15/04	7.12	9.24	18.30			4.60	
ANTIX_MIL	10/15/04	6.95	7.18	15.80			5.30	
ANTIX_MIL	2/1/05	7.28	12.53	10.31		685.00	6.50	
ANTIX_MIL	2/15/05	6.57	9.93	9.28		673.00	3.70	
ANTIX_MIL	3/1/05	6.89	9.26	9.70		676.00	3.90	
ANTIX_MIL	3/15/05	6.97	9.20	10.53		520.00	5.20	
ANTIX_MIL	4/1/05	5.54	9.08	10.72		509.00	4.80	
ANTIX_MIL	4/15/05	6.28	10.84	12.40		521.00	6.20	
ANTIX_MIL	5/1/05	6.66	10.19	11.95		626.00	3.70	
ANTIX_MIL	5/15/05	7.44	10.68	13.29		623.00	1.80	
ANTIX_MIL	6/1/05	6.98	8.81	16.56		648.00	4.70	
ANTIX_MIL	6/15/05	7.60	8.40	18.23		646.00	5.40	
ANTIX_MIL	7/1/05	7.02	8.83	16.67		739.00	5.70	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MIL	7/15/05	7.25	7.94	18.46		732.00	3.80	
ANTIX_MIL	8/1/05	7.31	7.61	20.77		756.00	4.20	
ANTIX_MIL	8/15/05	7.52	7.27	21.50		750.00	3.50	
ANTIX_MIL	9/1/05	7.82	7.37	20.21		696.00	3.10	
ANTIX_MIL	9/15/05	8.00	8.29	16.64		657.00	1.00	
ANTIX_MIL	10/1/05	7.48	9.50	15.95		733.00	2.70	
ANTIX_MIL	10/15/05	6.94	9.12	15.41		714.00	5.70	
ANTIX_MIL	11/1/05	7.57	10.67	15.04		713.00	4.10	
ANTIX_MIL	11/15/05	5.60	9.06	11.68		629.00	0.00	
ANTIX_MIL	12/1/05	6.07	10.10	11.64		705.00	0.35	
ANTIX_MIL	12/15/05	5.61	8.30	11.95		435.00	7.30	
ANTIX_MIL	1/1/06	7.23	9.81	11.55		645.00	8.00	
ANTIX_MIL	2/1/06	6.27	10.72	9.51		656.00	10.10	
ANTIX_MIL	3/1/06	6.30	12.73	10.21		654.00	7.80	
ANTIX_MIL	4/1/06	5.97	10.74	11.35		676.00	6.30	
ANTIX_MIL	5/1/06	6.52	9.10	16.21		684.00	8.40	
ANTIX_MIL	6/1/06	5.76	8.17	15.36		630.00	9.00	
ANTIX_MIL	7/1/06	5.49	9.66	18.90		677.00	6.40	
ANTIX_MIL	8/1/06	6.31	7.38	20.39		679.00	9.70	
ANTIX_MIL	9/1/06	5.61	8.92	16.83		706.00	4.90	
ANTIX_MIL	10/1/06	7.03	8.85	15.69		685.00	9.90	
ANTIX_MIL	11/1/06	6.34	9.11	14.18		657.00	6.20	
ANTIX_MIL	12/1/06	6.92	7.86	12.47		667.00	5.50	
ANTIX_MIL	1/1/07	9.92	7.86	12.47		666.00	5.50	
ANTIX_MIL	2/1/07	5.92	9.73	9.68		672.00	5.10	
ANTIX_MIL	3/1/07	6.28	10.10	9.53		618.00	2.30	
ANTIX_MIL	3/15/07						8.50	
ANTIX_MIL	4/1/07	5.74	8.85	11.36		634.00	10.00	
ANTIX_MIL	5/1/07	6.06	10.00	13.42		659.00	11.90	
ANTIX_MIL	7/1/07	6.42	4.92	20.27		663.00	9.60	
ANTIX_MIL	8/1/07	5.84	8.34	19.38		749.00	7.60	
ANTIX_MIL	9/1/07	7.51	12.01	23.77		695.00	8.30	
ANTIX_MIL	10/1/07	6.07	9.67	15.62		755.00	9.80	
ANTIX_MIL	11/1/07	6.39	10.29	12.09		747.00	7.30	
ANTIX_MIL	12/1/07	6.04	9.47	12.93		694.00	4.20	
ANTIX_MIL	1/1/08	6.84	10.09	11.13		695.00	2.90	
ANTIX_MIL	2/1/08	6.08	9.93	9.98		727.00	1.20	
ANTIX_MIL	3/1/08	5.49	10.03	10.55		669.00	4.00	
ANTIX_MIL	4/1/08	6.64	9.34	11.87		637.00	5.10	
ANTIX_MIL	5/1/08	6.70	9.29	12.89		628.00	5.90	
ANTIX_MIL	6/1/08	7.28	9.15	19.34		662.00	5.40	
ANTIX_MIL	7/1/08	6.09	7.90	17.04		684.00	1.10	
ANTIX_MIL	8/1/08	7.30	6.51	21.36		691.00	2.70	
ANTIX_MIL	9/1/08	7.59	8.04	19.62		730.00	7.50	
ANTIX_MIL	10/1/08	5.84	10.76	11.39		682.00	1.20	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MIL	11/1/08	6.39	9.69	9.07		672.00	2.00	
ANTIX_MIL	12/1/08	6.82	9.53	13.02		677.00	1.00	
ANTIX_MIL	1/1/09	6.16	8.95	11.31		666.00	1.50	
ANTIX_MIL	2/1/09	6.60	10.61	7.79		690.00	1.90	
ANTIX_MIL	3/1/09	6.42	11.21	7.66		683.00	6.30	
ANTIX_MIL	3/15/09	6.44	8.89	9.11		739.00	3.50	
ANTIX_MIL	4/1/09	5.83	9.85	12.56		678.00	1.50	
ANTIX_MIL	5/1/09	6.02	8.70	13.71		667.00	2.80	
ANTIX_MIL	6/1/09	6.17	9.47	15.92		675.00	2.50	
ANTIX_MIL	7/1/09	6.58	6.97	16.36		694.00	3.00	
ANTIX_MIL	8/1/09	7.47	7.97	17.52		690.00	7.90	
ANTIX_MIL	9/1/09	7.26	6.24	16.37		693.00	7.40	
ANTIX_MIL	10/1/09	7.63	8.36	14.85		730.00	7.40	
ANTIX_MIL	11/1/09	7.01	9.02	14.22		721.00	7.80	
ANTIX_MIL	12/1/09	7.15	8.77	12.17		670.00	8.10	
ANTIX_MIL	1/1/10	7.20	8.68	10.82		569.00	6.60	
ANTIX_MIL	2/1/10	7.18	10.47	8.16		578.00	5.80	
ANTIX_MIL	3/1/10	7.21	9.06	11.21		588.00	4.90	
ANTIX_MIL	4/1/10	7.17	8.59	12.12		630.00	5.00	0.085
ANTIX_MIL	5/1/10	7.11	8.23	13.12		682.00	5.20	0.085
ANTIX_MIL	6/1/10	7.41	7.85	18.18		696.00	5.80	0.127
ANTIX_MIL	7/1/10	7.67	7.11	22.17		654.00	4.80	0.192
ANTIX_MIL	8/1/10	7.78	5.77	21.42		640.00	4.40	0.212
ANTIX_MIL	9/1/10	7.14	7.61	18.22		713.00	9.80	0.245
ANTIX_MIL	10/1/10	7.65	9.13	16.13		693.00	8.00	0.375
ANTIX_MIL	11/1/10	7.24	8.13	12.81		566.00	7.40	0.072
ANTIX_MIL	12/1/10	7.54	9.82	9.02		696.00	10.75	0.082
ANTIX_MIL	1/1/11	7.75	11.62	4.58		701.00	10.10	0.163
ANTIX_MIL	2/1/11	7.21	10.21	9.79		663.00	9.60	0.059
ANTIX_MIL	3/1/11	7.27	9.69	10.03		648.00	7.70	0.108
ANTIX_MIL	4/1/11	6.82	9.23	11.75		558.00	9.40	0.068
ANTIX_MIL	5/1/11	6.86	8.70	13.13		613.00	8.90	0.072
ANTIX_MIL	6/1/11		7.94	16.98		641.00	7.40	0.085
ANTIX_MIL	7/1/11	7.25	5.90	20.50		660.00	5.10	0.095
ANTIX_MIL	8/1/11	7.23	7.73	19.19		698.00	7.40	0.059
ANTIX_MIL	9/1/11	7.05	8.73	17.49		731.00	7.50	0.095
ANTIX_MIL	10/1/11	6.91	7.43	15.11		727.00	9.80	0.065
ANTIX_MIL	11/1/11	6.95	8.80	14.05		651.00	9.20	0.046
ANTIX_MIL	12/1/11	7.09	8.99	12.94		656.00	9.70	
ANTIX_MUM1	3/1/00	7.93	9.30	13.30			8.50	
ANTIX_MUM1	4/1/00	8.11	8.70	11.20			6.00	
ANTIX_MUM1	5/1/00	7.98	8.20	12.10			6.00	
ANTIX_MUM1	5/15/00	8.12	8.20	11.20			4.20	
ANTIX_MUM1	6/1/00	7.98	7.40	12.20			8.50	
ANTIX_MUM1	6/15/00	7.80	7.10	12.10			10.30	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MUM1	7/1/00	7.01	7.10	11.80			10.00	
ANTIX_MUM1	7/15/00	7.82	8.10	12.50			8.00	
ANTIX_MUM1	8/1/00	7.87	6.60	12.90			9.00	
ANTIX_MUM1	9/1/00	7.84	6.10	16.00			9.00	
ANTIX_MUM1	10/1/00	7.75	6.90	12.40			6.60	
ANTIX_MUM1	3/1/01	8.35		7.90			5.60	
ANTIX_MUM1	4/1/01	7.73	7.80	11.00			3.50	
ANTIX_MUM1	5/1/01	7.68	8.00	11.70			4.40	
ANTIX_MUM1	5/15/01	7.50	6.80	12.00			7.70	
ANTIX_MUM1	6/1/01	7.60	4.60	16.63			3.90	
ANTIX_MUM1	6/15/01	7.60	6.30	13.00			7.60	
ANTIX_MUM1	7/1/01	7.50	6.70	13.00			7.20	
ANTIX_MUM1	7/15/01	7.50	5.80	13.20			6.90	
ANTIX_MUM1	8/1/01	7.42	7.30	13.70			10.20	
ANTIX_MUM1	9/1/01	7.45	5.67	13.70			5.90	
ANTIX_MUM1	10/1/01	7.50	6.08	13.20			7.80	
ANTIX_MUM1	3/1/02	8.11	4.88	10.00			6.10	
ANTIX_MUM1	4/1/02	7.70	6.00	9.00			3.80	
ANTIX_MUM1	4/15/02	8.45	5.65	10.40			2.80	
ANTIX_MUM1	5/1/02	7.70	4.04	13.00			7.74	
ANTIX_MUM1	5/15/02	7.66	5.05	12.90			6.60	
ANTIX_MUM1	6/1/02	7.66	6.08	14.00			7.70	
ANTIX_MUM1	6/15/02	7.63	7.05	13.80			7.00	
ANTIX_MUM1	7/1/02	7.83	5.96	13.50			6.40	
ANTIX_MUM1	7/15/02	7.68	5.33	14.00			4.70	
ANTIX_MUM1	8/1/02	7.71	4.42	14.40			9.60	
ANTIX_MUM1	9/1/02	7.62	3.64	14.20			9.20	
ANTIX_MUM1	10/1/02	7.22	5.45	13.30			6.30	
ANTIX_MUM1	3/1/03	7.20	5.71	12.10			7.80	
ANTIX_MUM1	4/1/03	7.21	5.91	11.30			6.80	
ANTIX_MUM1	4/15/03	7.19	5.10	11.50			6.20	
ANTIX_MUM1	5/1/03	6.98	5.23	12.20			7.70	
ANTIX_MUM1	5/15/03	7.07	5.43	12.50			8.10	
ANTIX_MUM1	6/1/03	6.92	6.80	12.90			5.20	
ANTIX_MUM1	6/15/03	6.99	7.00	12.80			9.00	
ANTIX_MUM1	7/1/03	7.11	7.20	12.80			8.40	
ANTIX_MUM1	7/15/03	7.19	4.18	12.90			7.40	
ANTIX_MUM1	8/1/03	7.32	6.82	13.10			4.80	
ANTIX_MUM1	8/15/03	7.35	4.29	13.00			5.20	
ANTIX_MUM1	9/1/03	7.06	4.61	12.90			5.10	
ANTIX_MUM1	10/1/03	7.20	4.40	13.30			4.40	
ANTIX_MUM1	3/1/04	7.03	6.05	10.55			5.90	
ANTIX_MUM1	4/1/04	7.28	6.35	11.67			4.00	
ANTIX_MUM1	4/15/04	7.15	6.10	11.67			5.80	
ANTIX_MUM1	5/1/04	7.32	5.77	12.22			6.50	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MUM1	5/15/04	7.33	6.55	12.78			7.30	
ANTIX_MUM1	6/1/04	7.24	6.21	12.78			7.50	
ANTIX_MUM1	6/15/04	7.27	7.97	12.78			5.30	
ANTIX_MUM1	7/1/04	7.40		13.60			5.00	
ANTIX_MUM1	7/15/04	7.30		12.60			9.00	
ANTIX_MUM1	8/1/04	7.53	7.11	14.10			7.60	
ANTIX_MUM1	8/15/04	7.00	5.52	14.00			8.80	
ANTIX_MUM1	9/1/04	6.85	5.64	13.90			6.70	
ANTIX_MUM1	10/1/04	7.08	6.23	12.50			7.10	
ANTIX_MUM1	2/1/05	7.09	8.32	11.63		510.00	7.20	
ANTIX_MUM1	2/15/05	7.26	6.59	11.66		515.00	4.50	
ANTIX_MUM1	3/1/05	7.19	7.49	11.59		514.00	5.70	
ANTIX_MUM1	3/15/05	7.21	6.57	11.27		441.00	5.60	
ANTIX_MUM1	4/1/05	7.05	7.07	11.86		401.00	6.40	
ANTIX_MUM1	4/15/05	7.30	7.85	12.83		396.00	7.50	
ANTIX_MUM1	5/1/05	7.35	7.76	12.75		472.00	3.20	
ANTIX_MUM1	5/15/05	7.26	7.99	12.43		480.00	5.80	
ANTIX_MUM1	6/1/05	7.45	7.17	12.52		484.00	7.70	
ANTIX_MUM1	6/15/05	7.28	6.91	12.67		491.00	8.50	
ANTIX_MUM1	7/1/05	7.27	6.87	12.73		548.00	7.90	
ANTIX_MUM1	7/15/05	7.11	6.12	12.84		554.00	6.90	
ANTIX_MUM1	8/1/05	7.28	6.40	12.96		565.00	8.80	
ANTIX_MUM1	8/15/05	7.20	5.78	13.16		576.00	8.00	
ANTIX_MUM1	9/1/05	7.38	5.73	13.12		547.00	7.50	
ANTIX_MUM1	9/15/05	7.40	6.16	12.69		553.00	3.30	
ANTIX_MUM1	10/1/05	7.24	8.20	13.05		536.00	3.90	
ANTIX_MUM1	10/15/05	7.19	7.94	13.05		531.00	5.60	
ANTIX_MUM1	11/1/05	6.86	7.27	12.96		537.00	8.30	
ANTIX_MUM1	11/15/05	7.08	7.25	12.75		520.00	7.30	
ANTIX_MUM1	12/1/05	5.81	11.63	7.98		529.00	8.30	
ANTIX_MUM1	12/15/05	7.10	6.78	12.24		524.00	7.10	
ANTIX_MUM1	1/1/06	7.16	7.49	12.28		508.00	8.90	
ANTIX_MUM1	2/1/06	7.30	7.62	11.86		508.00	7.60	
ANTIX_MUM1	3/1/06	6.82	8.18	12.01		507.00	9.10	
ANTIX_MUM1	3/15/06	6.90						
ANTIX_MUM1	4/1/06	6.90	6.98	12.34		518.00	6.60	
ANTIX_MUM1	5/1/06	5.44	7.17	12.63		526.00	1.20	
ANTIX_MUM1	6/1/06	5.22	9.67	13.09		514.00	9.20	
ANTIX_MUM1	7/1/06	4.95	8.59	12.71		526.00	11.10	
ANTIX_MUM1	8/1/06	5.47	6.98	12.91		542.00	10.20	
ANTIX_MUM1	9/1/06	5.18	6.83	13.00		558.00	9.80	
ANTIX_MUM1	10/1/06	5.74	7.69	12.88		561.00	13.70	
ANTIX_MUM1	11/1/06	6.74	7.70	12.99		544.00	10.80	
ANTIX_MUM1	12/1/06	7.05	7.36	12.40		533.00	6.50	
ANTIX_MUM1	1/1/07	7.05	7.36	12.40		533.00	6.50	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MUM1	2/1/07	7.01	7.23	12.18		530.00	6.80	
ANTIX_MUM1	3/15/07						10.30	
ANTIX_MUM1	3/1/07	7.08	7.88	11.67		521.00	14.40	
ANTIX_MUM1	4/1/07	6.08	7.75	12.34		493.00	9.80	
ANTIX_MUM1	5/1/07	5.67	7.37	12.65		493.00	12.60	
ANTIX_MUM1	7/1/07	5.26	7.11	13.00		518.00	10.40	
ANTIX_MUM1	8/1/07	5.24	6.46	13.15		540.00	11.40	
ANTIX_MUM1	9/1/07	5.30	5.25	13.32		547.00	11.30	
ANTIX_MUM1	10/1/07	6.46	5.76	12.23		567.00	7.00	
ANTIX_MUM1	11/1/07	5.63	4.71	11.98		572.00	3.90	
ANTIX_MUM1	12/1/07	6.88	12.16	8.18		504.00	10.90	
ANTIX_MUM1	1/1/08	6.86	8.61	12.20		538.00	3.70	
ANTIX_MUM1	2/1/08	6.98	7.78	11.92		537.00	3.00	
ANTIX_MUM1	3/1/08	7.25	8.18	12.19		504.00	6.70	
ANTIX_MUM1	4/1/08	6.74	7.65	12.45		498.00	5.50	
ANTIX_MUM1	5/1/08	7.00	7.38	12.60		487.00	8.10	
ANTIX_MUM1	6/1/08	6.74	7.14	12.66		471.00	6.80	
ANTIX_MUM1	7/1/08	8.04	9.41	17.35		503.00	0.30	
ANTIX_MUM1	8/1/08	6.47	8.18	13.46		514.00	3.10	
ANTIX_MUM1	9/1/08	7.05	7.41	13.85		533.00	3.40	
ANTIX_MUM1	10/1/08	7.20	8.50	12.16		539.00	1.80	
ANTIX_MUM1	11/1/08	7.41	8.97	11.14		544.00	1.30	
ANTIX_MUM1	12/1/08	6.93	8.99	12.65		538.00	2.40	
ANTIX_MUM1	1/1/09	7.18	8.19	12.26		527.00	1.80	
ANTIX_MUM1	2/1/09	6.85	6.55	11.88		537.00	7.30	
ANTIX_MUM1	3/1/09	7.09	6.41	11.69		535.00	4.90	
ANTIX_MUM1	3/15/09					532.00		
ANTIX_MUM1	4/1/09	6.49	8.25	12.64		520.00	6.00	
ANTIX_MUM1	5/1/09	6.04	8.62	12.59		502.00	6.10	
ANTIX_MUM1	6/1/09	5.86	7.10	12.60		499.00	6.00	
ANTIX_MUM1	7/1/09	6.82	5.71	12.79		520.00	6.70	
ANTIX_MUM1	8/1/09	7.13	6.63	12.77		528.00	8.80	
ANTIX_MUM1	9/1/09	7.01	5.00	12.85		551.00	8.60	
ANTIX_MUM1	10/1/09	7.21	4.55	12.65		562.00	8.20	
ANTIX_MUM1	11/1/09	7.11	4.85	12.68		570.00	7.30	
ANTIX_MUM1	12/1/09	7.24	6.71	12.06		528.00	10.00	
ANTIX_MUM1	1/1/10	7.28	7.15	11.70		475.00	8.50	
ANTIX_MUM1	2/1/10	7.32	7.68	11.34		479.00	7.40	
ANTIX_MUM1	3/1/10	7.16	7.40	12.08		457.00	7.30	
ANTIX_MUM1	4/1/10	7.22	7.93	12.56		469.00	6.00	0.026
ANTIX_MUM1	5/1/10	7.27	7.43	12.65		511.00	6.30	0.098
ANTIX_MUM1	6/1/10	7.20	7.49	12.86		511.00	5.90	0.157
ANTIX_MUM1	7/1/10	7.15	7.09	13.17		496.00	5.20	0.150
ANTIX_MUM1	8/1/10	7.13	5.94	13.03		502.00	5.00	0.173
ANTIX_MUM1	9/1/10	7.18	5.91	13.00		523.00	6.10	0.183

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MUM1	10/1/10	7.20	7.03	12.99		527.00	8.20	0.108
ANTIX_MUM1	11/1/10	7.11	7.38	12.60		552.00	9.70	0.059
ANTIX_MUM1	12/1/10	7.18	6.96	12.14		534.00	9.40	0.114
ANTIX_MUM1	1/1/11	7.35	7.41	11.37		531.00	8.90	0.042
ANTIX_MUM1	2/1/11	7.21	7.59	11.98		531.00	9.50	0.101
ANTIX_MUM1	3/1/11	7.03	7.33	11.91		492.00	9.20	0.098
ANTIX_MUM1	4/1/11	6.96	7.78	12.41		467.00	7.20	0.000
ANTIX_MUM1	5/1/11	6.96	8.11	12.74		462.00	8.20	0.065
ANTIX_MUM1	6/1/11		8.19	12.76		461.00	7.70	0.065
ANTIX_MUM1	7/1/11	6.98	7.74	12.98		475.00	4.00	0.052
ANTIX_MUM1	8/1/11	6.82	7.23	12.91		503.00	6.90	0.033
ANTIX_MUM1	9/1/11	6.74	7.24	12.95		512.00	7.00	0.078
ANTIX_MUM1	10/1/11	7.12	7.50	12.85		542.00	8.80	0.068
ANTIX_MUM1	11/1/11	6.98	7.92	13.02		520.00	10.00	0.039
ANTIX_MUM1	12/1/11	7.08	7.93	12.81		505.00	10.20	
ANTIX_MUM2	3/1/00	8.34	11.00	13.30			5.00	
ANTIX_MUM2	4/1/00	8.60	11.60	10.00			2.50	
ANTIX_MUM2	5/1/00	8.68	10.50	12.70			5.30	
ANTIX_MUM2	5/15/00	8.82	10.60	13.20			2.60	
ANTIX_MUM2	6/1/00	8.68	10.90	14.30			6.50	
ANTIX_MUM2	6/15/00	8.54	8.00	15.70			5.20	
ANTIX_MUM2	7/1/00	7.88	8.70	13.80			7.00	
ANTIX_MUM2	7/15/00	8.10	10.10	15.20			10.50	
ANTIX_MUM2	8/1/00	8.17	8.70	15.00			8.60	
ANTIX_MUM2	9/1/00	8.05	9.50	13.20			5.60	
ANTIX_MUM2	10/1/00	8.28	10.20	12.80			2.90	
ANTIX_MUM2	3/1/01	8.40	11.50	7.40			2.50	
ANTIX_MUM2	4/1/01	8.40	11.40	6.80			7.10	
ANTIX_MUM2	5/1/01	8.49	16.00	11.40			4.10	
ANTIX_MUM2	5/15/01	8.28	9.70	13.80			0.90	
ANTIX_MUM2	6/1/01	8.16	8.80	16.50			3.50	
ANTIX_MUM2	6/15/01	8.10	8.60	17.50			5.20	
ANTIX_MUM2	7/1/01	8.39	8.82	16.00			7.30	
ANTIX_MUM2	7/15/01	8.40	8.19	18.00			2.90	
ANTIX_MUM2	8/1/01	8.22	8.08	18.70			3.30	
ANTIX_MUM2	9/1/01	8.20	7.86	17.00			3.50	
ANTIX_MUM2	10/1/01	8.24	8.60	12.00			5.60	
ANTIX_MUM2	4/1/02	6.95	13.20	6.90			2.50	
ANTIX_MUM2	4/15/02	9.13	11.70	9.70			1.10	
ANTIX_MUM2	5/1/02	8.56	20.00	7.61			4.10	
ANTIX_MUM2	5/15/02	8.51	8.81	17.70			0.10	
ANTIX_MUM2	6/1/02	8.43	8.84	16.80			6.80	
ANTIX_MUM2	6/15/02	8.38	8.97	18.10			7.70	
ANTIX_MUM2	7/1/02	8.70	9.30	16.10			2.30	
ANTIX_MUM2	7/15/02	8.15	8.28	19.80			1.00	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MUM2	8/1/02	8.47	6.11	25.50			4.60	
ANTIX_MUM2	10/1/02	7.77	10.43	12.00			4.00	
ANTIX_MUM2	3/1/03	8.06	9.12	11.12			5.40	
ANTIX_MUM2	4/1/03	8.08	10.48	8.70			3.70	
ANTIX_MUM2	4/15/03	8.09	8.39	10.90			3.50	
ANTIX_MUM2	5/1/03	7.84	8.11	13.70			2.00	
ANTIX_MUM2	5/15/03	7.72	8.92	10.70			6.40	
ANTIX_MUM2	6/1/03	7.41	8.70	14.10			5.30	
ANTIX_MUM2	6/15/03	7.62	9.30	15.20			5.80	
ANTIX_MUM2	7/1/03	7.87	8.80	16.90			6.50	
ANTIX_MUM2	7/15/03	7.95	9.39	16.60			6.30	
ANTIX_MUM2	8/1/03	8.02	9.26	16.20			6.80	
ANTIX_MUM2	8/15/03	7.97	9.15	17.20			4.40	
ANTIX_MUM2	9/1/03	7.57	9.14	16.50			4.70	
ANTIX_MUM2	10/1/03	7.83	10.03	13.80			5.10	
ANTIX_MUM2	3/1/04	7.90	10.90	7.78			2.50	
ANTIX_MUM2	4/1/04	8.15	11.09	10.00			9.80	
ANTIX_MUM2	4/15/04	7.97	10.10	12.22			6.60	
ANTIX_MUM2	5/1/04	7.99	9.57	14.44			6.70	
ANTIX_MUM2	5/15/04	7.96	8.47	15.56			5.90	
ANTIX_MUM2	6/1/04	7.84	8.28	17.22			5.40	
ANTIX_MUM2	6/15/04	7.97	8.77	15.56			6.50	
ANTIX_MUM2	7/1/04	8.10		17.00			6.30	
ANTIX_MUM2	7/15/04	7.88		16.10			3.80	
ANTIX_MUM2	8/1/04	8.00	9.33	17.90			5.80	
ANTIX_MUM2	8/15/04	7.39	6.49	20.90			3.00	
ANTIX_MUM2	9/1/04	7.66	8.83	16.80			5.10	
ANTIX_MUM2	10/1/04	7.72	8.54	13.00			3.60	
ANTIX_MUM2	2/1/05	8.08	14.63	8.91		511.00	5.80	
ANTIX_MUM2	2/15/05	7.72	11.41	7.78		520.00	3.50	
ANTIX_MUM2	3/1/05	8.15	12.02	8.31		520.00	2.70	
ANTIX_MUM2	3/15/05	6.98	11.21	8.83		423.00	3.00	
ANTIX_MUM2	4/1/05	7.94	11.19	10.98		406.00	3.90	
ANTIX_MUM2	4/15/05	8.16	10.29	13.16		413.00	4.50	
ANTIX_MUM2	5/1/05	7.45	10.20	11.96		488.00	1.30	
ANTIX_MUM2	5/15/05	8.16	10.30	14.64		489.00	3.40	
ANTIX_MUM2	6/1/05	8.07	9.05	17.28		495.00	4.60	
ANTIX_MUM2	6/15/05	8.09	8.80	17.11		500.00	5.40	
ANTIX_MUM2	7/1/05	8.03	8.43	19.19		562.00	4.10	
ANTIX_MUM2	7/15/05	8.05	8.15	20.05		564.00	4.00	
ANTIX_MUM2	8/1/05	8.04	8.46	20.09		573.00	6.10	
ANTIX_MUM2	8/15/05	8.01	8.38	19.68		583.00	2.70	
ANTIX_MUM2	9/1/05	8.16	8.75	17.97		548.00	7.20	
ANTIX_MUM2	9/15/05	8.14	10.20	13.57		552.00	0.50	
ANTIX_MUM2	10/1/05	7.70	10.42	12.91		534.00	1.80	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MUM2	10/15/05	7.26	10.55	11.70		522.00	5.70	
ANTIX_MUM2	11/1/05	7.67	9.72	12.37		540.00	5.10	
ANTIX_MUM2	11/15/05	7.61	9.90	11.70		474.00	4.60	
ANTIX_MUM2	12/1/05	7.11	7.19	12.26		530.00	2.90	
ANTIX_MUM2	12/15/05	7.86	10.63	9.06		523.00	6.70	
ANTIX_MUM2	1/1/06	8.06	11.09	10.16		506.00	8.60	
ANTIX_MUM2	2/1/06	5.79	12.58	6.33		478.00	7.80	
ANTIX_MUM2	3/1/06	6.35	12.11	9.17		506.00	8.60	
ANTIX_MUM2	4/1/06	6.75	10.64	11.24		517.00	5.60	
ANTIX_MUM2	5/1/06	6.84	9.15	16.42		528.00	2.00	
ANTIX_MUM2	6/1/06	5.93	8.93	16.95		501.00	8.50	
ANTIX_MUM2	7/1/06	6.19	9.28	18.63		531.00	10.90	
ANTIX_MUM2	7/15/06		8.85					
ANTIX_MUM2	8/1/06	6.39	8.85	19.15		550.00	8.00	
ANTIX_MUM2	9/1/06	6.59	9.94	14.36		560.00	7.70	
ANTIX_MUM2	10/1/06	6.16	9.68	13.01		540.00	9.50	
ANTIX_MUM2	11/1/06	6.77	10.96	12.28		531.00	7.80	
ANTIX_MUM2	12/1/06	7.31	11.37	9.06		521.00	5.40	
ANTIX_MUM2	1/1/07	7.31	11.37	9.06		521.00	5.40	
ANTIX_MUM2	2/1/07	7.74	12.20	6.12		530.00	7.40	
ANTIX_MUM2	3/1/07	7.58	13.03	5.37		521.00	7.20	
ANTIX_MUM2	3/15/07						6.30	
ANTIX_MUM2	4/1/07	6.88	10.38	13.66		501.00	8.20	
ANTIX_MUM2	5/1/07	6.65	9.94	13.97		499.00	7.20	
ANTIX_MUM2	6/1/07						8.60	
ANTIX_MUM2	7/1/07	6.82	9.24	17.24		519.00	8.10	
ANTIX_MUM2	8/1/07	6.46	8.82	18.50		540.00	9.10	
ANTIX_MUM2	9/1/07	6.74	7.97	18.44		540.00	3.70	
ANTIX_MUM2	10/1/07	6.50	10.71	10.28		560.00	4.70	
ANTIX_MUM2	11/1/07	5.98	10.48	7.37		559.00	3.70	
ANTIX_MUM2	12/1/07	7.60	11.71	9.54		520.00	4.40	
ANTIX_MUM2	1/1/08	6.49	12.30	10.09		518.00	3.20	
ANTIX_MUM2	2/1/08	7.76	11.97	6.91		528.00	3.60	
ANTIX_MUM2	3/1/08	7.70	11.14	10.20		506.00	6.00	
ANTIX_MUM2	4/1/08	7.21	10.39	11.48		501.00	4.10	
ANTIX_MUM2	5/1/08	7.64	10.13	13.01		491.00	6.10	
ANTIX_MUM2	6/1/08	8.16	9.13	17.22		492.00	0.30	
ANTIX_MUM2	7/1/08	7.09	8.29	12.64		486.00	4.00	
ANTIX_MUM2	8/1/08	8.14	9.55	16.51		467.00		
ANTIX_MUM2	9/1/08	8.21	9.20	17.45		534.00	1.60	
ANTIX_MUM2	10/1/08	7.19	11.07	7.71		550.00	0.00	
ANTIX_MUM2	11/1/08	7.97	12.74	5.12		547.00	0.30	
ANTIX_MUM2	12/1/08	7.54	10.33	11.84		516.00	1.60	
ANTIX_MUM2	1/1/09	7.75	11.91	7.21		343.00	1.30	
ANTIX_MUM2	2/1/09	7.89	11.72	8.01		522.00		

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_MUM2	3/1/09	7.52	12.51	6.07		529.00	4.60	
ANTIX_MUM2	3/15/09	7.60	11.79	8.03		489.00	2.80	
ANTIX_MUM2	4/1/09	7.20	11.76	14.28		510.00	1.90	
ANTIX_MUM2	5/1/09	7.18	11.86	15.59		511.00	3.60	
ANTIX_MUM2	6/1/09	7.99	9.09	17.25		510.00	3.10	
ANTIX_MUM2	7/1/09	8.19	8.21	17.70		529.00	2.10	
ANTIX_MUM2	8/1/09	8.11	10.37	14.94		522.00	7.20	
ANTIX_MUM2	9/1/09	7.81	10.06	12.85		551.00	7.80	
ANTIX_MUM2	10/1/09	8.10	10.38	10.89		560.00	6.80	
ANTIX_MUM2	11/1/09	7.63	10.04	11.36		548.00	5.90	
ANTIX_MUM2	12/1/09	8.05	11.82	6.30		491.00	7.80	
ANTIX_MUM2	1/1/10	7.82	11.19	7.39		463.00	6.90	
ANTIX_MUM2	2/1/10	7.96	11.60	7.50		486.00	5.80	
ANTIX_MUM2	3/1/10	7.90	10.56	11.73		470.00	5.47	
ANTIX_MUM2	4/1/10	8.17	10.57	14.31		477.00	5.80	0.140
ANTIX_MUM2	5/1/10	8.14	9.11	14.72		524.00	5.30	0.219
ANTIX_MUM2	6/1/10	8.21	8.56	18.79		528.00	5.30	0.170
ANTIX_MUM2	7/1/10	8.20	7.91	21.45		512.00	4.30	0.127
ANTIX_MUM2	8/1/10	8.21	8.30	19.07		518.00	3.90	0.117
ANTIX_MUM2	9/1/10	7.95	8.65	16.78		513.00	9.50	0.179
ANTIX_MUM2	10/1/10	8.20	9.15	14.38		527.00	7.30	0.267
ANTIX_MUM2	11/1/10	7.62	10.28	10.65		351.00	5.60	0.114
ANTIX_MUM2	12/1/10	8.04	12.27	6.10		531.00	9.50	0.072
ANTIX_MUM2	1/1/11	8.10	13.78	1.87		538.00	8.80	0.052
ANTIX_MUM2	2/1/11	7.98	10.98	9.30		517.00	8.50	0.082
ANTIX_MUM2	3/1/11	7.94	11.33	8.79		497.00	9.00	0.082
ANTIX_MUM2	4/1/11	7.54	10.21	12.69		474.00	6.40	0.062
ANTIX_MUM2	5/1/11	7.63	9.93	14.94		496.00	7.00	0.059
ANTIX_MUM2	6/1/11		9.38	16.88		483.00	7.60	0.121
ANTIX_MUM2	7/1/11	7.97	8.75	18.53		499.00	5.20	0.075
ANTIX_MUM2	8/1/11	8.02	8.91	17.89		526.00	5.00	0.065
ANTIX_MUM2	9/1/11	7.76	9.07	16.43		535.00	5.40	0.049
ANTIX_MUM2	10/1/11						6.50	0.065
ANTIX_MUM2	11/1/11	7.62	10.67	11.46		515.00	8.00	0.049
ANTIX_MUM2	12/1/11	7.91	11.58	10.95		509.00	8.90	
ANTIX_NEW	3/1/01	8.34	11.50	8.40			1.14	
ANTIX_NEW	4/1/01	8.17	10.30	14.50			4.30	
ANTIX_NEW	5/1/01	8.40	10.40	12.70			2.80	
ANTIX_NEW	5/15/01	8.38	14.80	14.90			2.00	
ANTIX_NEW	6/1/01	8.17	9.00	19.30			3.30	
ANTIX_NEW	6/15/01	8.20	8.90	15.90			3.20	
ANTIX_NEW	7/1/01	8.35	8.80	15.10			2.60	
ANTIX_NEW	7/15/01	8.25	8.73	18.00			1.40	
ANTIX_NEW	8/1/01	8.15	8.76	18.80			1.90	
ANTIX_NEW	9/1/01	8.35	9.80	14.90			1.70	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_NEW	10/1/01	8.32	9.65	10.70			2.90	
ANTIX_NEW	3/1/02	8.27	14.85	9.30			2.80	
ANTIX_NEW	4/1/02	8.45	15.00	9.30			1.30	
ANTIX_NEW	4/15/02	8.96	13.05	11.70			2.10	
ANTIX_NEW	5/1/02	8.93	10.10	15.40			3.50	
ANTIX_NEW	5/15/02	8.92	7.67	20.10			4.60	
ANTIX_NEW	6/1/02	8.89	9.36	16.40			2.00	
ANTIX_NEW	6/15/02	8.86	7.32	22.30			2.20	
ANTIX_NEW	7/1/02	9.02	9.85	15.20			1.80	
ANTIX_NEW	7/15/02	8.23	7.88	20.80			1.20	
ANTIX_NEW	8/1/02	8.77	6.89	21.80			0.70	
ANTIX_NEW	9/1/02	8.76	5.84	21.70			0.30	
ANTIX_NEW	10/1/02	8.05	10.12	11.60			2.50	
ANTIX_NEW	3/1/03	7.97	10.33	14.70			2.90	
ANTIX_NEW	4/1/03	8.27	9.47	10.50			2.30	
ANTIX_NEW	4/15/03	7.93	8.88	11.10			4.80	
ANTIX_NEW	5/1/03	7.91	8.33	13.20			2.70	
ANTIX_NEW	5/15/03	7.74	8.86	12.80			3.10	
ANTIX_NEW	6/1/03	7.50	10.10	14.80			3.30	
ANTIX_NEW	6/15/03	7.74	10.10	15.40			2.90	
ANTIX_NEW	7/1/03	7.71	9.70	14.30			3.00	
ANTIX_NEW	7/15/03	8.02	9.34	16.00			2.10	
ANTIX_NEW	8/1/03	8.15	9.59	15.90			0.80	
ANTIX_NEW	8/15/03	8.14	9.64	15.60			0.30	
ANTIX_NEW	9/1/03	7.75	9.95	14.20			3.10	
ANTIX_NEW	10/1/03	7.74	10.34	11.30			2.60	
ANTIX_NEW	3/1/04	8.12	10.61	9.44			2.00	
ANTIX_NEW	4/1/04	8.30	10.42	14.40			2.30	
ANTIX_NEW	4/15/04	7.97	10.38	12.78			5.40	
ANTIX_NEW	5/1/04	8.03	9.41	14.44			2.50	
ANTIX_NEW	5/15/04	7.77	8.88	14.44			3.50	
ANTIX_NEW	6/1/04	7.83	9.19	13.33			4.20	
ANTIX_NEW	6/15/04	7.87	8.84	14.44			2.80	
ANTIX_NEW	7/1/04	8.07		15.40			1.90	
ANTIX_NEW	7/15/04	7.99		16.30			1.80	
ANTIX_NEW	8/1/04	8.16	13.04	16.50			1.50	
ANTIX_NEW	8/15/04	7.92	8.46	19.00			0.60	
ANTIX_NEW	9/1/04	7.82	9.64	16.80			1.20	
ANTIX_NEW	10/1/04	7.95	8.94	12.10			3.20	
ANTIX_NEW	2/1/05	8.10	13.90	11.28		439.00	2.70	
ANTIX_NEW	2/15/05	8.06	11.31	8.55		457.00	1.00	
ANTIX_NEW	3/1/05	8.13	11.77	9.77		445.00	1.50	
ANTIX_NEW	3/15/05	7.91	10.79	10.49		350.00	1.60	
ANTIX_NEW	4/1/05	8.01	11.32	13.84		349.00	3.20	
ANTIX_NEW	4/15/05	8.08	10.01	15.16		362.00	2.40	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_NEW	5/1/05	8.09	10.54	12.02		431.00	0.70	
ANTIX_NEW	5/15/05	8.10	10.77	14.31		436.00	1.00	
ANTIX_NEW	6/1/05	8.10	9.48	17.27		437.00	2.10	
ANTIX_NEW	6/15/05	8.13	9.69	17.04		445.00	1.30	
ANTIX_NEW	7/1/05	8.08	9.41	17.78		489.00	2.00	
ANTIX_NEW	7/15/05	8.00	9.07	16.67		492.00	3.40	
ANTIX_NEW	8/1/05	8.06	9.20	17.98		502.00	1.60	
ANTIX_NEW	8/15/05	8.13	9.23	18.86		501.00	1.80	
ANTIX_NEW	9/1/05	8.03	9.23	15.66		475.00	8.00	
ANTIX_NEW	9/15/05	7.98	11.16	10.67		473.00	2.00	
ANTIX_NEW	10/1/05	8.14	11.04	10.96		458.00	2.50	
ANTIX_NEW	10/15/05	7.74	11.18	9.94		453.00	9.50	
ANTIX_NEW	11/1/05	7.92	10.87	11.33		455.00	2.10	
ANTIX_NEW	11/15/05	7.21	10.31	11.24		394.00	3.00	
ANTIX_NEW	12/1/05	8.10	12.70	6.73		459.00	1.70	
ANTIX_NEW	12/15/05	6.46	11.43	7.55		665.00	4.30	
ANTIX_NEW	1/1/06	8.08	11.62	9.82		630.00	3.10	
ANTIX_NEW	2/1/06	8.22	12.15	9.07		615.00	3.00	
ANTIX_NEW	3/1/06	5.95	14.16	7.28		599.00	2.90	
ANTIX_NEW	4/1/06	6.77	11.29	13.67		634.00	3.60	
ANTIX_NEW	5/1/06	6.46	9.53	17.96		644.00	1.90	
ANTIX_NEW	6/1/06	6.52	9.22	14.27		634.00	4.40	
ANTIX_NEW	7/1/06	6.22	9.62	17.13		643.00	2.70	
ANTIX_NEW	8/1/06	6.65	8.53	19.05		638.00	2.70	
ANTIX_NEW	9/1/06	6.47	9.58	14.17		675.00	2.10	
ANTIX_NEW	10/1/06	6.22	10.96	10.16		675.00	5.50	
ANTIX_NEW	11/1/06	7.54	10.90	12.42		652.00	7.80	
ANTIX_NEW	12/1/06	6.65	11.30	8.99		628.00	5.00	
ANTIX_NEW	1/1/07	6.65	11.30	8.99		628.00	5.00	
ANTIX_NEW	2/1/07	6.85	12.51	5.09		624.00	8.20	
ANTIX_NEW	3/1/07	7.14	11.92	9.72		638.00	1.10	
ANTIX_NEW	3/15/07						3.50	
ANTIX_NEW	4/1/07	7.08	10.59	15.30		619.00	3.70	
ANTIX_NEW	5/1/07	6.88	9.78	13.84		621.00	3.70	
ANTIX_NEW	7/1/07	6.95	8.83	17.72		601.00	3.10	
ANTIX_NEW	8/1/07	7.01	7.42	18.37		701.00	3.00	
ANTIX_NEW	9/1/07	7.53	5.91	19.11		755.00	2.20	
ANTIX_NEW	10/1/07	6.17	10.69	7.79		568.00	1.50	
ANTIX_NEW	11/1/07	6.25	11.78	6.67		716.00	1.10	
ANTIX_NEW	12/1/07	7.63	12.37	8.84		737.00	2.60	
ANTIX_NEW	1/1/08	6.53	11.71	8.80		712.00	1.60	
ANTIX_NEW	2/1/08	7.75	11.77	7.22		683.00	2.00	
ANTIX_NEW	3/1/08	8.17	11.48	10.86		649.00	0.90	
ANTIX_NEW	4/1/08	8.01	12.75	12.66		652.00	1.50	
ANTIX_NEW	5/1/08	7.96	9.98	14.65		635.00	3.20	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_NEW	6/1/08	8.00	9.56	16.39		633.00	3.00	
ANTIX_NEW	7/1/08	7.97	8.64	18.57		673.00	0.80	
ANTIX_NEW	8/1/08	7.91	9.71	15.30		422.00	0.20	
ANTIX_NEW	9/1/08	7.94	8.84	17.44		682.00	2.10	
ANTIX_NEW	10/1/08	7.71	11.04	7.22		684.00	0.50	
ANTIX_NEW	11/1/08	8.01	13.27	4.76		699.00	0.00	
ANTIX_NEW	12/1/08	7.72	10.86	10.46		717.00	1.10	
ANTIX_NEW	1/1/09	8.03	11.58	8.14		669.00	0.40	
ANTIX_NEW	2/1/09	7.82	11.28	8.80		632.00		
ANTIX_NEW	3/1/09	7.73	11.74	8.85		612.00	1.50	
ANTIX_NEW	3/15/09	8.00	9.53	14.94		640.00	1.40	
ANTIX_NEW	4/1/09	7.29	12.41	15.25		655.00	1.10	
ANTIX_NEW	5/1/09	7.25	9.06	13.94		642.00	0.50	
ANTIX_NEW	6/1/09	6.92	8.50	17.11		639.00	1.00	
ANTIX_NEW	7/1/09	7.87	8.38	16.86		646.00	1.00	
ANTIX_NEW	8/1/09	8.10	9.23	14.40		646.00	1.80	
ANTIX_NEW	9/1/09	7.83	7.25	12.46		656.00	2.50	
ANTIX_NEW	10/1/09	8.16	9.14	9.84		724.00	2.50	
ANTIX_NEW	11/1/09	7.43	8.54	10.81		813.00	3.00	
ANTIX_NEW	12/1/09	8.14	11.29	6.68		671.00	4.20	
ANTIX_NEW	1/1/10	7.64	10.05	9.48		614.00	4.10	
ANTIX_NEW	2/1/10	8.18	10.79	10.71		695.00	2.80	
ANTIX_NEW	3/1/10	7.83	10.20	10.99		627.00	2.90	
ANTIX_NEW	4/1/10	8.15	6.02	15.15		648.00	2.10	0.039
ANTIX_NEW	5/1/10	8.11	9.17	14.47		738.00	2.60	0.209
ANTIX_NEW	6/1/10	8.02	8.64	15.56		696.00	3.00	0.261
ANTIX_NEW	7/1/10	7.93	7.84	17.79		634.00	2.00	0.232
ANTIX_NEW	8/1/10	7.98	7.75	15.91		617.00	1.80	0.140
ANTIX_NEW	9/1/10	8.04	8.57	14.83		730.00	4.30	0.196
ANTIX_NEW	10/1/10	7.93	7.88	12.10		728.00	2.70	0.098
ANTIX_NEW	11/1/10	8.13	10.32	10.28		634.00	5.10	0.068
ANTIX_NEW	12/1/10	8.12	12.98	3.69		685.00	4.75	0.065
ANTIX_NEW	2/1/11	8.03	10.26	10.58		671.00	4.00	0.059
ANTIX_NEW	3/1/11	8.05	10.93	10.14		656.00	4.20	0.052
ANTIX_NEW	4/1/11	7.65	9.76	12.42		598.00	3.60	0.046
ANTIX_NEW	5/1/11	7.73	10.32	13.83		622.00	3.30	0.108
ANTIX_NEW	6/1/11		9.18	15.42		616.00	2.80	
ANTIX_NEW	7/1/11	8.05	8.76	16.77		619.00	2.40	0.059
ANTIX_NEW	8/1/11	8.09	9.12	16.32		658.00	1.50	0.261
ANTIX_NEW	9/1/11	7.85	8.88	14.56		686.00	3.10	0.055
ANTIX_NEW	10/1/11	7.97	11.35	9.51		686.00	4.20	0.082
ANTIX_NEW	11/1/11	7.98	10.62	11.24		670.00	4.60	0.039
ANTIX_NEW	12/1/11	7.97	11.30	11.21		636.00	4.50	
ANTIX_ROU	3/1/00	8.40	11.20	14.00			4.30	
ANTIX_ROU	4/15/00	8.55	11.00	9.00			3.10	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_ROU	5/1/00	8.46	9.90	14.00			6.50	
ANTIX_ROU	5/15/00	8.38	9.30	13.90			3.40	
ANTIX_ROU	6/1/00	8.34	10.20	13.90			6.50	
ANTIX_ROU	6/15/00	8.25	8.00	16.00			5.60	
ANTIX_ROU	7/1/00	7.93	7.80	17.50			5.10	
ANTIX_ROU	7/15/00	7.90	8.80	18.70			9.30	
ANTIX_ROU	8/1/00	7.94	8.30	17.40			5.80	
ANTIX_ROU	9/1/00	8.05	9.00	13.60			6.80	
ANTIX_ROU	10/1/00	8.29	9.80	11.40			6.10	
ANTIX_ROU	3/1/01	8.30		6.90			4.30	
ANTIX_ROU	4/1/01	8.28		10.80			2.90	
ANTIX_ROU	5/1/01	8.20	9.80	12.00			3.40	
ANTIX_ROU	5/15/01	8.03	8.50	14.70			5.90	
ANTIX_ROU	6/1/01	8.00	8.20	17.40			4.60	
ANTIX_ROU	6/15/01	8.00	8.60	17.50			3.10	
ANTIX_ROU	7/1/01	8.07	8.12	17.30			5.50	
ANTIX_ROU	7/15/01	8.90	7.60	18.00			3.40	
ANTIX_ROU	8/1/01	8.07	7.40	19.60			2.70	
ANTIX_ROU	9/1/01	8.17	8.01	18.80			4.10	
ANTIX_ROU	4/1/02	8.57	15.47	7.70			1.50	
ANTIX_ROU	4/15/02	8.75	12.33	10.50			3.30	
ANTIX_ROU	5/1/02	8.42	8.43	18.30			6.50	
ANTIX_ROU	5/15/02	8.22	9.35	14.80			4.40	
ANTIX_ROU	6/1/02	8.16	8.55	16.80			8.30	
ANTIX_ROU	6/15/02	8.07	8.22	18.10			8.70	
ANTIX_ROU	7/1/02	8.28	8.00	17.90			3.30	
ANTIX_ROU	7/15/02	7.96	7.34	19.20			1.90	
ANTIX_ROU	8/1/02	8.18	6.39	24.00			2.40	
ANTIX_ROU	10/1/02	7.82	9.04	18.80			6.90	
ANTIX_ROU	3/1/03	8.06	10.00	11.10			6.60	
ANTIX_ROU	4/1/03	8.36	10.58	8.40			6.20	
ANTIX_ROU	4/15/03	8.19	7.90	12.60			4.70	
ANTIX_ROU	5/1/03	7.90	8.16	14.40			1.10	
ANTIX_ROU	5/15/03	7.77	8.91	13.10			6.40	
ANTIX_ROU	6/1/03	7.56	9.50	14.40			7.00	
ANTIX_ROU	6/15/03	7.77	9.70	15.70			5.60	
ANTIX_ROU	7/1/03	7.96	9.60	17.80			5.40	
ANTIX_ROU	7/15/03	8.00	6.85	22.10			3.90	
ANTIX_ROU	8/1/03	8.15	8.11	19.00			4.20	
ANTIX_ROU	8/15/03	8.05	9.06	18.40			3.10	
ANTIX_ROU	9/1/03	7.77	9.55	17.30			4.20	
ANTIX_ROU	10/1/03	7.98	14.50	12.70			7.30	
ANTIX_ROU	3/1/04	8.28	11.00	7.22			1.00	
ANTIX_ROU	4/1/04	8.22	10.94	11.67			5.70	
ANTIX_ROU	4/15/04	8.18	10.24	12.22			9.10	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_ROU	5/1/04	8.19	9.35	15.56			6.70	
ANTIX_ROU	5/15/04	8.09	8.75	17.22			5.60	
ANTIX_ROU	6/1/04	8.01	8.43	17.22			6.00	
ANTIX_ROU	6/15/04	8.08	8.58	17.78			5.60	
ANTIX_ROU	7/1/04	8.08		18.90			6.20	
ANTIX_ROU	7/15/04	7.91		18.60			7.40	
ANTIX_ROU	8/1/04	8.08	11.44	16.90			5.40	
ANTIX_ROU	8/15/04	7.92	8.67	20.30			3.70	
ANTIX_ROU	9/1/04	7.76	9.30	17.00			6.00	
ANTIX_ROU	10/1/04	7.77	9.30	12.70			4.00	
ANTIX_ROU	2/1/05	8.37	14.97	9.08		498.00	6.60	
ANTIX_ROU	2/15/05	7.70	11.94	6.50		510.00	2.10	
ANTIX_ROU	3/1/05	8.13	12.39	7.72		500.00	2.40	
ANTIX_ROU	3/15/05	7.90	11.93	8.57		411.00	3.10	
ANTIX_ROU	4/1/05	8.17	10.68	13.05		393.00	6.70	
ANTIX_ROU	4/15/05	8.27	10.52	14.14		396.00	5.00	
ANTIX_ROU	5/1/05	8.09	10.38	11.85		481.00	2.50	
ANTIX_ROU	5/15/05	8.04	10.21	15.05		280.00	1.50	
ANTIX_ROU	6/1/05	7.99	8.64	18.33		495.00	3.60	
ANTIX_ROU	6/15/05	8.01	8.77	19.75		503.00	3.20	
ANTIX_ROU	7/1/05	8.06	8.56	21.24		558.00	2.40	
ANTIX_ROU	7/15/05	8.07	8.36	21.60		564.00	1.60	
ANTIX_ROU	8/1/05	7.93	7.20	23.51		576.00	3.00	
ANTIX_ROU	8/15/05	8.08	7.90	21.03		578.00	3.40	
ANTIX_ROU	9/1/05	8.25	8.78	19.90		544.00	5.60	
ANTIX_ROU	9/15/05	8.20	9.37	19.75		555.00	3.30	
ANTIX_ROU	10/1/05	8.14	11.04	10.96		717.00	2.50	
ANTIX_ROU	10/15/05	8.04	10.69	12.45		508.00	11.40	
ANTIX_ROU	11/1/05	7.98	10.13	12.89		530.00	5.10	
ANTIX_ROU	11/15/05	7.69	10.04	11.94		465.00	3.20	
ANTIX_ROU	12/1/05	7.69	12.93	6.30		515.00	1.00	
ANTIX_ROU	12/15/05	8.06	11.59	8.63		507.00	7.10	
ANTIX_ROU	1/1/06	8.10	11.31	10.29		493.00	7.10	
ANTIX_ROU	2/1/06	7.62	12.62	6.50		482.00	5.70	
ANTIX_ROU	3/1/06	6.10	12.65	10.66		457.00	6.30	
ANTIX_ROU	4/1/06	7.93	10.58	12.21		509.00	4.30	
ANTIX_ROU	5/1/06	6.10	8.05	18.90		531.00	7.70	
ANTIX_ROU	6/1/06	5.70	9.16	17.19		493.00	9.90	
ANTIX_ROU	7/1/06	6.81	8.91	21.01		526.00	6.90	
ANTIX_ROU	8/1/06	6.87	8.26	21.60		540.00	7.90	
ANTIX_ROU	8/15/06						6.50	
ANTIX_ROU	9/1/06	6.22	7.39	16.74		570.00		
ANTIX_ROU	10/1/06	6.46	9.62	13.77		530.00	8.70	
ANTIX_ROU	11/1/06	7.68	11.02	12.34		521.00	8.10	
ANTIX_ROU	12/1/06	7.73	11.77	9.25		513.00	5.90	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_ROU	1/1/07	7.73	11.77	9.25		513.00	5.90	
ANTIX_ROU	2/1/07	7.00	13.46	4.92		524.00	15.40	
ANTIX_ROU	3/1/07	7.13	13.04	6.50		487.00	6.50	
ANTIX_ROU	3/15/07						7.00	
ANTIX_ROU	4/1/07	6.95	10.48	14.17		483.00	9.60	
ANTIX_ROU	5/1/07	6.92	9.47	16.65		491.00	6.40	
ANTIX_ROU	6/1/07						4.20	
ANTIX_ROU	7/1/07	7.40	8.95	20.90		505.00	8.60	
ANTIX_ROU	8/1/07	7.24	9.05	20.34		545.00	8.20	
ANTIX_ROU	9/1/07	6.78	7.80	20.95		516.00	5.70	
ANTIX_ROU	10/1/07	7.88	9.78	15.94		563.00	6.00	
ANTIX_ROU	11/1/07	6.75	10.53	10.56		569.00	3.70	
ANTIX_ROU	12/1/07	6.88	12.16	8.18		504.00	5.70	
ANTIX_ROU	1/1/08	7.20	12.73	9.10		474.00	5.00	
ANTIX_ROU	2/1/08	6.93	12.72	6.37		513.00	6.80	
ANTIX_ROU	3/1/08	7.92	11.79	9.71		491.00	2.80	
ANTIX_ROU	4/1/08	7.98	10.74	11.86		476.00	5.40	
ANTIX_ROU	5/1/08	7.99	9.76	14.20		470.00	5.90	
ANTIX_ROU	6/1/08	8.12	9.08	18.49		486.00	4.50	
ANTIX_ROU	7/1/08	8.10	9.27	20.18		497.00	2.80	
ANTIX_ROU	8/1/08	8.16	9.65	17.97		514.00	3.80	
ANTIX_ROU	9/1/08	7.86	6.45	18.63		540.00	1.30	
ANTIX_ROU	10/1/08	8.02	11.29	8.73		547.00	2.20	
ANTIX_ROU	11/1/08	8.14	12.99	6.45		540.00	0.80	
ANTIX_ROU	12/1/08	7.57	10.54	11.91		502.00	0.30	
ANTIX_ROU	1/1/09	7.89	12.45	6.46		501.00	0.90	
ANTIX_ROU	2/1/09	7.85	12.52	7.55		509.00		
ANTIX_ROU	3/1/09	7.78	12.83	6.73		498.00	5.30	
ANTIX_ROU	3/15/09	7.85	11.65	9.90		503.00	3.60	
ANTIX_ROU	4/1/09	7.45	11.30	16.14		494.00	1.90	
ANTIX_ROU	5/1/09	7.53	11.37	16.62		504.00	4.00	
ANTIX_ROU	6/1/09	7.62	7.88	20.91		448.00	3.60	
ANTIX_ROU	7/1/09	8.18	8.36	18.83		517.00	1.30	
ANTIX_ROU	8/1/09	8.39	9.60	16.07		519.00	7.40	
ANTIX_ROU	9/1/09	8.31	10.33	12.57		545.00	8.10	
ANTIX_ROU	10/1/09	8.26	10.55	10.15		550.00	6.40	
ANTIX_ROU	11/1/09	8.04	10.53	11.39		532.00	5.70	
ANTIX_ROU	12/1/09	8.19	12.20	6.77		505.00	7.50	
ANTIX_ROU	1/1/10	7.95	11.36	7.51		441.00	6.60	
ANTIX_ROU	2/1/10	8.18	11.67	7.29		468.00	6.10	
ANTIX_ROU	3/1/10	8.19	10.16	12.71		454.00	5.80	
ANTIX_ROU	4/1/10	8.14	9.71	15.81		466.00	5.10	
ANTIX_ROU	5/1/10	7.85	8.00	16.09		523.00	5.80	0.091
ANTIX_ROU	6/1/10	8.14	7.84	21.94		521.00	5.20	0.228
ANTIX_ROU	7/1/10	8.08	7.71	24.26		515.00	3.30	0.147

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_ROU	8/1/10	8.13	7.42	22.11		512.00	3.20	0.117
ANTIX_ROU	9/1/10	7.78	12.83	6.73		498.00	9.70	0.157
ANTIX_ROU	10/1/10	8.20	9.14	15.23		516.00	7.20	0.160
ANTIX_ROU	11/1/10	7.81	10.48	10.75		387.00	6.20	0.157
ANTIX_ROU	12/1/10	8.16	13.24	4.70		523.00	9.80	0.088
ANTIX_ROU	1/1/11	7.97	13.88	1.75		544.00	9.10	0.121
ANTIX_ROU	2/1/11	8.09	11.80	9.07		497.00	8.80	0.065
ANTIX_ROU	3/1/11	8.04	11.94	7.91		473.00	9.70	0.068
ANTIX_ROU	4/1/11	7.67	10.59	12.37		455.00	7.80	0.052
ANTIX_ROU	5/1/11	7.74	10.07	15.26		480.00	6.60	0.055
ANTIX_ROU	6/1/11		8.78	18.21		486.00	6.90	0.065
ANTIX_ROU	7/1/11	8.18	7.73	20.38		507.00	4.80	0.091
ANTIX_ROU	8/1/11	8.26	9.02	18.25		526.00	4.90	0.085
ANTIX_ROU	9/1/11	8.04	9.38	16.67		520.00	5.50	0.055
ANTIX_ROU	10/1/11	7.82	10.68	11.57		520.00	7.40	0.042
ANTIX_ROU	11/1/11	7.96	11.01	11.45		494.00	7.90	0.055
ANTIX_ROU	12/1/11	7.91	12.02	10.50		490.00	8.80	
ANTIX_SHA	11/1/05	8.07	10.60	12.71			2.90	
ANTIX_SHA	11/15/05	7.86	10.25	12.25			1.70	
ANTIX_SHA	12/15/05	8.09	10.78	8.68			2.80	
ANTIX_SHA	1/1/06	7.38	11.10	11.24		621.00	6.30	
ANTIX_SHA	2/1/06	8.30	12.00	9.61		606.00	1.90	
ANTIX_SHA	3/1/06	8.24	12.30	11.34		571.00	6.40	
ANTIX_SHA	4/1/06	7.35	10.80	13.72		601.00	4.70	
ANTIX_SHA	5/1/06	6.67	10.10	17.70		583.00	6.40	
ANTIX_SHA	6/1/06	6.41	10.00	14.96		657.00	6.80	
ANTIX_SHA	7/1/06	6.17	10.30	16.39		593.00	5.70	
ANTIX_SHA	8/1/06	6.21	10.40	16.22		471.00	2.30	
ANTIX_SHA	9/1/06	6.88	10.20	14.65		428.00	5.70	
ANTIX_SHA	10/1/06	7.43	10.60	12.72		621.00	3.40	
ANTIX_SHA	11/1/06	7.72	11.20	13.00		633.00	6.90	
ANTIX_SHA	12/1/06	7.87	11.00	11.43		550.00	4.50	
ANTIX_SHA	1/1/07	7.87	11.00	11.43		550.00	4.50	
ANTIX_SHA	2/1/07	7.88	11.50	8.90		589.00	1.30	
ANTIX_SHA	3/1/07	7.93	11.50	11.02		635.00	5.30	
ANTIX_SHA	3/15/07						5.80	
ANTIX_SHA	4/1/07	6.95	11.00	14.13		601.00	6.50	
ANTIX_SHA	5/1/07	7.06	10.30	14.20		587.00	4.60	
ANTIX_SHA	6/1/07						6.70	
ANTIX_SHA	7/1/07	6.90	10.20	17.06		551.00	6.40	
ANTIX_SHA	8/1/07	6.70	9.78	16.62		599.00	6.50	
ANTIX_SHA	9/1/07	6.73	8.95	17.56		367.00	6.90	
ANTIX_SHA	10/1/07	7.11	11.40	11.33		630.00	4.60	
ANTIX_SHA	11/1/07	6.69	11.10	10.49		559.00	1.60	
ANTIX_SHA	12/1/07	7.48	12.20	9.70		670.00	3.60	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_SHA	1/1/08	7.55	11.40	10.36		662.00	1.10	
ANTIX_SHA	2/1/08	8.00	11.60	9.01		659.00	2.40	
ANTIX_SHA	3/1/08	8.24	11.10	11.89		495.00	4.90	
ANTIX_SHA	4/1/08	8.01	12.50	12.83		638.00	5.00	
ANTIX_SHA	5/1/08	7.88	10.40	13.90		613.00	4.70	
ANTIX_SHA	6/1/08	8.01	10.40	15.23		585.00	4.10	
ANTIX_SHA	7/1/08	8.01	10.10	16.49		578.00	0.90	
ANTIX_SHA	8/1/08	8.10	9.07	16.26		570.00	1.60	
ANTIX_SHA	9/1/08	7.87	10.50	14.57		589.00	0.40	
ANTIX_SHA	10/1/08	8.10	10.60	11.50		589.00	4.10	
ANTIX_SHA	11/1/08	8.25	12.00	9.22		594.00	0.80	
ANTIX_SHA	12/1/08	7.95	11.30	11.73		655.00	2.80	
ANTIX_SHA	1/1/09	8.06	11.30	10.24		631.00	3.10	
ANTIX_SHA	2/1/09	7.95	11.00	11.03		597.00		
ANTIX_SHA	3/1/09	7.99	10.70	11.88		591.00	4.50	
ANTIX_SHA	3/15/09	8.04	9.14	15.01		624.00	4.50	
ANTIX_SHA	4/1/09	7.43	11.90	17.15		606.00	4.50	
ANTIX_SHA	5/1/09	7.36	9.69	14.60		414.00	4.40	
ANTIX_SHA	6/1/09	7.02	9.72	15.89		588.00	4.70	
ANTIX_SHA	7/1/09	7.75	9.10	15.79		575.00	4.10	
ANTIX_SHA	8/1/09	8.16	10.60	14.72		565.00	5.70	
ANTIX_SHA	9/1/09	8.30	10.20	13.28		578.00	6.20	
ANTIX_SHA	10/1/09	8.30	10.50	12.87		604.00	5.60	
ANTIX_SHA	11/1/09	8.22	10.30	12.04		621.00	5.40	
ANTIX_SHA	12/1/09	8.27	11.50	9.21		659.00	6.50	
ANTIX_SHA	1/1/10	8.08	10.20	11.34		643.00	7.30	
ANTIX_SHA	2/1/10	8.20	11.10	11.17		677.00	6.10	
ANTIX_SHA	3/1/10	8.00	10.30	12.41		607.00	6.60	
ANTIX_SHA	4/1/10	8.19	10.60	14.88		589.00	5.50	0.068
ANTIX_SHA	5/1/10	8.10	9.70	14.20		656.00	5.40	0.157
ANTIX_SHA	6/1/10	8.06	9.67	14.85		621.00	5.60	0.173
ANTIX_SHA	7/1/10	7.06	3.37	12.50		495.00	5.80	0.179
ANTIX_SHA	8/1/10	8.14	9.17	14.70		566.00	5.90	0.170
ANTIX_SHA	9/1/10	8.07	9.30	14.87		686.00	5.90	0.196
ANTIX_SHA	10/1/10	8.12	9.44	12.97		625.00	6.10	0.140
ANTIX_SHA	11/1/10	8.03	10.50	11.10		626.00	5.70	0.114
ANTIX_SHA	12/1/10	8.32	12.50	8.23		615.00	7.10	0.101
ANTIX_SHA	1/1/11	8.29	13.76	4.43		634.00	7.10	0.091
ANTIX_SHA	2/1/11	8.04	10.39	11.41		680.00	7.50	0.085
ANTIX_SHA	3/1/11	8.00	11.03	11.36		631.00	10.00	0.085
ANTIX_SHA	4/1/11	7.80	10.65	12.89		629.00	7.70	0.091
ANTIX_SHA	5/1/11	7.73	10.84	14.20		603.00	6.70	0.078
ANTIX_SHA	6/1/11		10.21	14.91		573.00	6.50	
ANTIX_SHA	7/1/11	8.09	10.16	14.99		566.00	5.10	0.075
ANTIX_SHA	8/1/11	7.99	10.25	15.27		590.00	6.10	0.052

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
ANTIX_SHA	9/1/11	7.89	10.35	14.51		608.00	6.50	0.068
ANTIX_SHA	10/1/11	8.10	11.11	11.65		669.00	6.70	0.042
ANTIX_SHA	11/1/11	8.05	10.78	11.88		643.00	7.00	0.065
ANTIX_SHA	12/1/11	8.06	11.43	12.06		615.00	7.60	0.012
BDK0000	3/8/01	7.70	11.30	6.60		1091.00	3.34	0.012
BDK0000	3/27/01	7.80	12.60	3.60		674.00	5.28	0.013
BDK0000	4/3/01	8.00	11.50	6.20		702.00	4.79	0.015
BDK0000	8/22/01	7.30	9.80	14.10		1058.00	0.99	0.016
BDK0000	8/28/01	7.40	7.70	15.50		1056.00	0.90	0.020
BDK0000	9/6/01	7.20	10.00	13.10		1075.00	0.82	0.005
BDK0000	10/8/02	7.90	10.20	10.00		1196.00	1.00	0.004
BDK0000	10/15/02	8.60	10.80	8.90		1149.00	1.69	0.015
BDK0000	10/17/02	8.30	9.80	11.70		847.00	5.17	0.008
BDK0000	10/21/02	7.70	8.60	9.10		1126.00	1.98	0.008
BDK0000	10/23/02	7.40	8.80	8.80		1114.00	1.58	0.011
BDK0000	11/7/02	7.80	10.80	7.80		675.00	5.68	0.017
BDK0000	11/12/02	7.90	10.60	10.00		822.00	3.21	0.017
BDK0000	11/13/02	7.80	11.00	9.40		590.00	5.89	0.173
BDK0000	11/15/02	7.70	10.40	7.70		711.00	7.06	0.007
BDK0000	11/18/02	8.20	10.70	7.40		568.00	5.80	0.004
BDK0000	11/20/02	7.70	11.30	5.70		653.00	2.58	0.007
BDK0000	12/2/02	8.30	12.90	2.30		954.00	1.98	0.005
BDK0000	12/9/02	8.50	12.90	1.50		1050.00	5.92	0.047
BDK0000	12/17/02	8.60	12.40	3.30		866.00	7.19	0.006
BDK0000	1/7/03	7.70	12.50	3.10		679.00	3.00	0.006
BDK0000	2/3/03	8.30	12.00	5.60		1045.00	1.62	0.042
BDK0000	3/18/03	7.70	10.50	9.10		450.00	8.34	0.016
BDK0000	4/1/03	8.20	11.30	6.80		836.00	3.28	0.065
BDK0000	4/15/03	8.20	10.60	11.60		682.00	4.48	0.127
BDK0000	4/21/03	8.00	10.10	11.20		831.00	2.73	0.013
BDK0000	4/28/03	8.30	10.60	11.80		967.00	1.76	0.163
BDK0000	5/5/03	8.00	10.40	10.90		663.00	1.88	0.034
BDK0000	5/19/03	8.00	10.80	11.10		564.00	5.41	0.051
BDK0000	6/2/03	8.10	10.50	11.90		613.00	4.70	0.009
BDK0000	6/16/03	8.10	9.90	13.90		811.00	2.78	0.007
BDK0000	7/7/03	8.20	9.60	15.70		1052.00	1.32	0.007
BDK0000	7/21/03	8.10	9.70	15.30		1136.00	0.88	0.011
BDK0000	8/4/03	8.00	9.50	14.70		1169.00	0.86	0.009
BDK0000	8/18/03	8.20	9.30	15.20		1285.00	0.61	0.110
BDK0000	9/8/03	8.10	9.30	15.10		1329.00	0.68	0.023
BDK0000	9/22/03	8.10	9.20	15.40		991.00	3.13	0.017
BDK0000	10/7/03	8.00	10.20	9.60		1019.00	2.11	0.007
BDK0000	10/21/03	8.10	9.40	13.60		1021.00	1.49	0.010
BDK0000	12/8/03	8.00	12.60	4.10		1040.00	2.39	0.014
BDK0000	2/9/04	7.90	12.50	1.00		992.00	5.00	0.012

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
BDK0000	2/10/04	8.00	11.60	5.20		981.00	4.47	0.010
BDK0000	2/12/04	8.00	11.90	4.50		1033.00	4.65	0.012
BDK0000	3/29/04	8.10	10.30	9.30		825.00	3.68	0.005
BDK0000	1/14/09	8.00	12.60	1.80		929.00	2.86	0.005
BDK0000	2/18/09	7.70	12.00	4.70		867.00	2.82	0.015
BDK0000	3/17/09	8.00	10.60	8.90		1110.00	1.70	0.059
BDK0000	4/21/09	7.00	10.20	9.50		470.00	5.23	0.004
BDK0000	5/19/09	8.20	10.80	10.40		927.00	0.79	0.009
BDK0000	6/16/09	8.00	9.10	13.70		1055.00	1.05	
BDK0000	7/21/09	8.20	9.00	15.40		1048.00	1.79	0.007
BDK0000	8/18/09	7.90	9.00	15.90		1298.00	0.64	0.012
BDK0000	9/15/09	7.40	9.10	14.70		1473.00	0.74	0.007
BDK0000	10/20/09	8.10	10.20	9.80		1305.00	1.03	0.002
BDK0000	11/9/09	8.00	10.70	9.90		1267.00	1.08	0.096
BDK0000	12/15/09	7.50	10.60	7.30		596.00	4.92	0.002
BGU0002	1/15/08	8.80	12.80	3.10		82.00	0.45	0.005
BGU0002	2/6/08	7.80	11.40	6.80		75.00	0.00	0.033
BGU0002	3/4/08	7.80	11.50	6.60		82.00	0.00	0.002
BGU0002	4/7/08	7.10	11.20	7.70		88.00	0.00	0.003
BGU0002	5/5/08	7.10	10.40	10.40		74.00	0.00	0.006
BGU0002	6/2/08	8.60	10.10	13.00		72.00	0.00	0.005
BGU0002	7/7/08	7.40	8.00	18.80		124.00	0.27	0.010
BGU0002	8/4/08	7.60	6.70	19.20		152.00	0.21	0.002
BGU0002	11/18/08	6.90	11.40	4.70		119.00	0.02	0.002
BGU0002	12/2/08						0.02	0.471
BRR0006	1/24/08	8.30	16.20	-0.10		340.00	13.80	0.179
BRR0006	2/14/08	7.20	14.00	0.90		266.00	10.78	0.181
BRR0006	3/12/08	7.60	12.00	6.00		214.00	14.14	0.221
BRR0006	4/16/08	8.90	13.80	10.40		197.00	6.20	0.057
BRR0006	5/14/08	6.70	9.60	12.70		156.00	11.42	0.670
BRR0006	6/11/08	6.90	7.10	22.60		210.00	10.41	0.583
BRR0006	7/16/08	7.70	7.50	22.40		228.00	6.38	1.927
BRR0006	8/13/08	7.70	7.70	19.00		227.00	7.29	1.667
BRR0006	9/17/08	7.80	7.50	17.90		464.00	16.68	5.716
BRR0006	10/16/08	7.60	8.40	17.20		552.00	22.62	0.429
BRR0006	11/13/08	8.00	9.10	8.30		251.00	0.93	0.539
BRR0006	12/10/08	7.80	11.30	5.40		283.00	15.11	0.066
CAC0012	10/17/00	7.70	8.90	13.90		267.00	6.25	0.095
CAC0012	11/15/00	8.00	11.40	6.70		260.00	6.71	0.082
CAC0012	12/5/00	7.60	13.20	0.20		252.00	8.27	0.082
CAC0012	1/9/01	7.50	12.90	0.00		232.00	12.44	0.061
CAC0012	2/6/01	7.60	12.50	3.60		252.00	12.43	0.027
CAC0012	3/20/01	8.80	13.90	5.60		230.00	7.13	0.074
CAC0012	4/17/01	7.60	10.40	10.00		215.00	7.26	0.072
CAC0012	5/15/01	7.80	9.80	15.20		233.00	6.87	0.106

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
CAC0012	6/19/01	8.20	9.40	23.50		263.00	7.64	0.127
CAC0012	7/24/01	8.20	8.40	25.90		306.00	3.50	0.139
CAC0012	8/7/01	8.30	8.70	26.80		297.00	2.49	0.098
CAC0012	9/18/01	7.90	9.50	16.80		325.00	3.70	0.116
CAC0012	10/17/01	7.70	9.40	11.70		320.00	1.34	0.092
CAC0012	11/6/01	8.10	12.60	7.50		350.00	0.84	0.120
CAC0012	12/18/01	8.10	11.40	7.70		300.00	4.48	0.097
CAC0012	1/23/02	7.90	13.60	1.70		325.00	7.32	0.089
CAC0012	2/20/02	7.80	12.80	4.40		300.00	5.53	0.754
CAC0012	3/20/02	7.50	10.50	7.70		293.00	5.26	0.084
CAC0012	3/26/02	7.00	10.90	7.60		286.00	9.17	0.154
CAC0012	4/17/02	7.80	8.90	22.10		243.00	1.75	0.139
CAC0012	4/23/02	8.00	10.60	12.80		276.00	3.31	0.112
CAC0012	5/15/02	8.20	10.10	14.70		187.00	2.67	0.088
CAC0012	5/21/02	7.70	11.00	12.00		245.00	3.53	0.147
CAC0012	6/11/02	7.90	8.00	24.90		245.00	2.61	0.267
CAC0012	7/24/02	7.60	7.50	25.50		258.00	3.74	0.242
CAC0012	7/30/02	7.50	7.20	25.60		287.00	2.93	0.132
CAC0012	8/20/02	7.70	7.60	27.10		315.00	1.22	0.181
CAC0012	8/27/02	7.70	7.40	22.10		355.00	2.94	0.500
CAC0012	9/24/02			19.00			6.12	0.186
CAC0012	10/1/02	7.60	8.70	16.60		265.00	3.59	0.053
CAC0012	1/27/09	8.70	14.40	0.00		259.00	12.54	0.026
CAC0012	2/24/09	7.90	12.50	0.20		284.00	8.85	0.028
CAC0012	3/24/09	9.00	13.20	5.80		285.00	5.29	0.073
CAC0012	4/29/09	7.80	8.50	18.30		245.00	6.50	0.107
CAC0012	5/27/09	7.60	8.80	15.20		246.00	6.83	0.100
CAC0012	6/23/09	7.90	8.00	20.80		280.00	9.22	0.168
CAC0012	7/28/09	8.10	9.70	23.40		274.00	4.62	0.124
CAC0012	8/25/09	7.90	7.50	21.80		316.00	4.69	0.117
CAC0012	9/22/09	7.20	7.70	19.10		323.00	4.97	0.086
CAC0012	10/27/09	7.90	9.60	11.60		279.00	2.94	0.034
CAC0012	11/23/09	7.00	11.00	7.50		293.00	5.12	0.047
CAC0012	12/7/09	7.30	12.70	2.80		288.00	10.96	0.019
CJB0005	10/18/00	8.00	9.50	15.10		441.00	5.15	0.048
CJB0005	11/16/00	7.70	12.80	4.40		380.00	0.75	0.018
CJB0005	12/6/00	7.70	14.10	0.30		371.00	4.79	0.039
CJB0005	1/10/01	7.40	13.50	-0.10		250.00	8.30	0.038
CJB0005	2/7/01	7.60	13.80	2.40		868.00	5.55	0.239
CJB0005	3/21/01	7.60	13.10	7.00		360.00	3.08	0.073
CJB0005	4/18/01	7.60	10.50	8.40		351.00	3.67	0.020
CJB0005	5/16/01	7.90	9.70	13.60		480.00	4.88	0.020
CJB0005	6/20/01	7.90	8.80	21.30		367.00	3.59	0.012
CJB0005	7/25/01	8.00	7.90	23.60		433.00	4.23	0.013
CJB0005	8/8/01	7.90	7.60	23.80		490.00	3.84	0.013

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
CJB0005	9/19/01	7.90	10.10	16.40		413.00	3.71	0.016
CJB0005	10/18/01	7.80	10.50	9.20		315.00	1.42	0.008
CJB0005	11/7/01	7.80	11.90	7.50		465.00	1.23	0.012
CJB0005	12/19/01	7.90	13.00	6.20		340.00	2.69	0.017
CJB0005	1/24/02	7.70	12.00	5.20		4400.00	6.46	0.007
CJB0005	2/21/02	7.90	12.30	7.20		588.00	4.20	0.040
CJB0005	3/21/02	7.40	11.90	7.70		292.00	3.57	0.012
CJB0005	4/18/02	7.70	8.10	20.70		458.00	1.59	0.018
CJB0005	5/16/02	8.20	10.00	13.60		381.00	2.08	0.015
CJB0005	6/12/02	7.70	8.00	21.90		397.00	2.97	0.072
CJB0005	7/25/02	7.60	8.20	23.00		136.00	4.18	0.014
CJB0005	8/21/02	7.70	7.60	23.10		454.00	0.20	0.006
CJB0005	9/25/02	8.00	9.40	16.60		424.00	0.63	0.010
CJB0005	10/7/02	8.20	9.40	19.00		360.00	0.22	0.017
CJB0005	10/21/02	7.90	10.80	11.60		299.00	3.58	0.133
CJB0005	11/6/02	6.40	10.20	10.30		44.00	2.99	0.085
CJB0005	11/18/02	7.90	11.60	7.60		173.00	1.98	0.013
CJB0005	12/2/02	8.80	13.50	1.90		395.00	5.96	0.034
CJB0005	12/16/02	8.00	12.20	5.20		642.00	5.73	0.025
CJB0005	1/6/03	8.90	13.10	2.60		1204.00	6.65	0.011
CJB0005	1/21/03	7.60	14.00	0.10		1100.00	8.74	0.022
CJB0005	2/3/03	8.20	14.50	1.50		928.00	7.86	0.045
CJB0005	3/3/03	7.30	12.90	1.80		920.00	5.48	0.017
CJB0005	3/17/03	8.40	11.70	11.20		563.00	5.80	0.011
CJB0005	4/21/03	8.90	12.20	12.80		445.00	4.69	0.011
CJB0005	5/5/03	8.10	10.60	12.50		457.00	5.94	0.032
CJB0005	5/19/03	7.80	10.40	12.40		344.00	4.93	0.023
CJB0005	6/2/03	8.00	10.20	14.70		449.00	6.51	0.046
CJB0005	6/16/03	7.70	8.80	19.20		353.00	5.52	0.030
CJB0005	6/23/03	7.70	9.00	17.50		372.00	6.63	0.028
CJB0005	7/7/03	7.70	8.20	22.40		361.00	5.90	0.012
CJB0005	7/21/03	7.80	8.60	21.50		408.00	6.76	0.026
CJB0005	8/4/03	7.70	8.60	22.20		360.00	6.35	0.038
CJB0005	8/18/03	7.90	8.50	21.80		277.00	5.10	0.016
CJB0005	8/25/03	8.10	8.70	19.70		421.00	6.62	0.019
CJB0005	9/8/03	8.00	8.80	18.70		369.00	6.14	0.031
CJB0005	9/22/03	7.50	7.30	19.20		349.00	4.98	0.011
CJB0005	10/6/03	7.90	10.40	12.20		400.00	7.20	0.016
CJB0005	10/20/03	8.20	10.60	10.80		390.00	6.53	0.014
CJB0005	1/22/09	7.40	15.40	0.20		552.00	9.33	0.098
CON0005	1/20/00	8.10	12.90	-0.10		445.00	17.92	0.117
CON0005	2/16/00	7.50	12.30	3.10		317.00	17.68	0.043
CON0005	3/8/00	8.00	9.90	9.80		411.00	13.99	0.032
CON0005	4/12/00	8.10	9.80	12.00		350.00	11.59	0.045
CON0005	5/10/00	8.20	6.70	22.60		397.00	13.20	0.146

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
CON0005	6/14/00	8.00	8.00	20.10		440.00	15.86	0.092
CON0005	7/12/00	8.20	7.30	21.80		492.00	16.61	0.110
CON0005	8/9/00	8.00	6.90	24.80		433.00	14.98	0.131
CON0005	9/13/00	8.20	7.40	21.80		473.00	14.54	0.063
CON0005	10/17/00	8.00	8.40	14.10		529.00	15.38	0.086
CON0005	11/15/00	8.40	12.00	7.00		457.00	12.91	0.049
CON0005	12/5/00	8.30	14.20	0.50		457.00	13.92	0.067
CON0005	1/9/01	7.70	10.70	0.00		489.00	18.44	0.049
CON0005	2/6/01	7.00	11.10	4.10		424.00	19.23	0.036
CON0005	3/20/01	8.20	12.00	6.90		348.00	14.37	0.193
CON0005	4/17/01	7.50	9.50	10.20		298.00	12.95	0.063
CON0005	5/15/01	8.50	10.30	15.90		473.00	15.58	0.138
CON0005	6/19/01	7.90	7.70	23.70		451.00	16.26	0.044
CON0005	7/24/01	8.00	9.30	27.20		439.00	15.00	0.095
CON0005	8/7/01	8.10	8.10	28.30		453.00	13.20	0.074
CON0005	9/18/01	7.90	10.80	18.10		443.00	10.97	0.065
CON0005	10/17/01	7.80	8.30	11.90		511.00	10.99	0.030
CON0005	11/6/01	8.20	9.30	7.90		526.00	9.17	0.080
CON0005	12/18/01	8.80	11.40	7.30		484.00	12.50	0.037
CON0005	1/23/02	8.10	12.40	2.20		475.00	14.62	0.074
CON0005	2/20/02	8.90	11.30	6.20		488.00	14.30	0.179
CON0005	3/20/02	8.20	10.30	7.30		396.00	10.53	0.071
CON0005	3/26/02	7.90	8.20	7.80		366.00	19.20	0.154
CON0005	4/17/02	7.70	7.40	19.10		330.00	15.57	0.128
CON0005	4/22/02	8.00	8.90	13.40		366.00	14.46	0.060
CON0005	5/15/02	8.10	9.50	14.80		370.00	11.72	0.116
CON0005	5/20/02	7.80	9.20	11.80		277.00	13.62	0.109
CON0005	6/11/02	7.80	6.90	25.10		417.00	12.68	0.150
CON0005	7/24/02	8.10	7.40	26.60		466.00	5.27	0.124
CON0005	8/20/02	7.70	5.00	25.80		485.00	2.60	0.142
CON0005	8/26/02	7.50	6.30	23.70		464.00	13.33	0.121
CON0005	9/24/02	7.80	8.10	19.40		455.00	9.02	0.130
CON0005	9/30/02	7.70	8.30	17.30		457.00	25.44	0.043
CON0005	11/3/03	8.10	10.00	13.30		373.00	16.50	0.078
CON0005	11/17/03	8.10	11.10	8.50		403.00	17.27	0.046
CON0005	12/1/03	8.10	11.50	6.00		351.00	17.39	0.047
CON0005	12/15/03	8.10	12.80	3.00		328.00	17.50	0.051
CON0005	1/5/04	8.00	10.50	8.40		398.00	18.64	0.034
CON0005	1/20/04	8.00	13.30	-0.20		434.00	19.48	0.035
CON0005	2/2/04	7.90	13.80	-0.20		481.00	20.89	0.031
CON0005	2/17/04	8.30	13.60	1.10		466.00	18.38	0.038
CON0005	3/1/04	7.90	11.80	5.30		388.00	17.89	0.026
CON0005	3/15/04	8.10	12.10	6.70		384.00	15.25	0.034
CON0005	4/5/04	8.20	12.40	6.50		321.00	14.00	0.072
CON0005	4/19/04	7.90	9.20	15.40		341.00	15.16	0.048

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
CON0005	5/10/04	8.00	8.30	18.10		371.00	16.45	0.089
CON0005	5/24/04	7.80	7.40	21.80		409.00	17.01	0.105
CON0005	6/7/04	7.80	8.70	16.10		376.00	18.03	0.068
CON0005	6/21/04	8.00	8.10	19.10		418.00	19.58	0.049
CON0005	7/6/04	7.90	7.20	25.00		477.00	17.69	0.087
CON0005	7/19/04	8.20	7.60	21.50		445.00	18.75	0.067
CON0005	8/9/04	8.20	8.10	19.70		472.00	19.34	0.098
CON0005	8/23/04	8.10	8.20	20.20		343.00	14.53	0.053
CON0005	9/7/04	8.30	8.00	20.70		510.00	16.82	0.134
CON0005	9/20/04	7.80	8.80	15.10		259.00	12.03	0.056
CON0005	10/4/04	8.10	9.30	14.90		373.00	16.17	0.043
CON0005	10/18/04	8.10	10.10	10.70		438.00	16.12	0.042
CON0051	11/3/03	8.30	9.10	13.20		364.00	16.52	0.021
CON0051	11/17/03	8.10	10.80	8.30		385.00	17.34	0.041
CON0051	12/1/03	8.10	11.30	6.00		336.00	17.40	0.052
CON0051	1/5/04	8.00	10.20	8.20		369.00	18.25	0.033
CON0051	1/20/04	8.00	13.70	-0.20		411.00	19.69	0.033
CON0051	2/2/04	8.00	14.30	-0.20		446.00	21.51	0.024
CON0051	2/17/04	8.50	13.40	0.50		426.00	19.08	0.039
CON0051	3/1/04	8.00	11.20	5.00		361.00	16.06	0.025
CON0051	3/15/04	8.10	11.60	6.40		356.00	17.20	0.037
CON0051	4/5/04	8.20	12.20	6.10		291.00	14.05	0.054
CON0051	4/19/04	7.90	8.90	14.90		331.00	15.06	0.042
CON0051	5/10/04	7.90	8.00	17.30		351.00	16.46	0.100
CON0051	5/24/04	7.80	7.50	21.50		360.00	17.73	0.102
CON0051	6/7/04	7.90	8.60	15.80		339.00	18.56	0.063
CON0051	6/21/04	7.90	8.10	18.60		410.00	19.61	0.033
CON0051	7/6/04	7.80	6.50	24.00		428.00	18.01	0.087
CON0051	7/19/04	8.20	7.20	21.00		435.00	19.15	0.080
CON0051	8/9/04	8.20	7.80	19.10		443.00	20.05	0.092
CON0051	8/23/04	8.10	8.00	19.20		338.00	14.72	0.045
CON0051	9/7/04	8.10	6.50	20.00		494.00	17.34	0.126
CON0051	9/20/04	7.80	8.80	15.00		259.00	12.16	0.048
CON0051	10/4/04	8.10	9.40	14.20		369.00	16.12	0.030
CON0051	10/18/04	8.10	10.40	10.40		425.00	16.29	0.008
DIT0002	1/28/08	6.60	13.60	0.40		167.00	12.38	0.012
DIT0002	2/19/08	6.40	13.00	3.20		163.00	15.22	0.014
DIT0002	3/17/08	6.80	12.50	3.40		157.00	11.35	0.100
DIT0002	4/21/08	6.60	10.10	11.60		98.00	8.04	0.016
DIT0002	5/19/08	7.60	10.10	12.00		145.00	11.14	0.019
DIT0002	6/16/08	6.30	8.20	18.50		171.00	0.00	0.021
DIT0002	7/21/08	6.20	2.10	20.00		720.00	1.74	0.006
DIT0002	11/24/08	8.10	11.70	1.60		214.00	0.14	0.017
DIT0002	12/15/08	7.00	11.90	5.60		197.00	19.86	0.002
DXP0005	1/14/08	7.00	12.00	3.90		52.00	0.58	0.004

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
DXP0005	2/5/08	6.60	12.30	4.70		51.00	0.57	0.006
DXP0005	3/3/08	7.20	12.70	2.30		53.00	0.39	0.002
DXP0005	4/7/08	6.80	11.30	7.80		52.00	0.22	0.003
DXP0005	5/5/08	7.30	9.90	11.80		46.00	0.20	0.006
DXP0005	6/2/08	6.90	9.60	13.20		49.00	0.22	0.006
DXP0005	7/7/08	7.30	8.20	19.40		58.00	0.47	0.011
DXP0005	8/4/08	7.50	7.80	17.70		97.00	0.43	0.007
DXP0005	9/8/08	6.50	6.40	16.00		75.00	0.22	0.007
DXP0005	10/27/08	7.60	9.40	7.50		87.00	0.00	0.002
DXP0005	11/17/08	7.00	10.90	5.90		59.00	0.01	0.003
DXP0005	12/1/08	7.50	11.90	2.20		57.00	0.18	0.003
EVI0002	1/18/00	8.50	14.10	-0.20		448.00	1.12	0.104
EVI0002	2/14/00	7.30	12.20	0.50		537.00	5.01	0.013
EVI0002	3/6/00	8.20	11.10	9.20		228.00	1.87	0.009
EVI0002	4/10/00	8.60	12.10	11.90		205.00	1.34	0.013
EVI0002	5/8/00	8.40	9.10	22.50		218.00	0.83	0.017
EVI0002	6/12/00	8.30	8.40	23.70		215.00	0.92	0.013
EVI0002	7/10/00	8.40	8.00	24.90		210.00	0.46	0.041
EVI0002	8/7/00	7.70	8.80	19.90		411.00	6.02	0.143
EVI0002	9/12/00	7.70	7.60	20.60		318.00	7.66	0.010
EVI0002	10/11/00	7.90	11.20	10.40		328.00	0.03	0.011
EVI0002	11/2/00	8.00	11.00	7.50		303.00	0.00	0.005
EVI0002	12/11/00	7.90	13.40	0.40		316.00	1.00	0.014
EVI0002	1/17/01	7.40	12.50	0.00		342.00	1.48	0.006
EVI0002	2/13/01	7.70	12.40	2.80		333.00	1.39	0.014
EVI0002	3/8/01	7.20	11.70	3.00		500.00	2.63	0.015
EVI0002	3/13/01	7.60	10.20	6.20		408.00	1.78	0.010
EVI0002	3/26/01	7.90	12.60	4.00		240.00	2.05	0.008
EVI0002	4/3/01	8.50	12.20	7.80		240.00	1.94	0.022
EVI0002	4/11/01	8.00	9.50	12.90		216.00	1.92	0.010
EVI0002	5/8/01	7.50	9.00	13.50		307.00	1.53	0.020
EVI0002	6/12/01	7.50	8.20	19.40		301.00	1.31	0.012
EVI0002	7/17/01	7.50	8.40	20.50		331.00	0.37	0.022
EVI0002	8/14/01	7.90	7.80	21.90		348.00	2.16	0.012
EVI0002	8/21/01	7.90	9.00	20.80		296.00	0.69	0.035
EVI0002	8/27/01	7.60	6.70	21.20		291.00	0.88	0.013
EVI0002	9/6/01	8.00	9.50	20.00		276.00	0.72	0.025
EVI0002	9/11/01	8.40	9.10	16.00		269.00	0.81	0.009
EVI0002	10/10/01	7.50	11.10	7.50		258.00	0.00	0.006
EVI0002	11/14/01	8.10	11.80	6.40		264.00	0.00	0.007
EVI0002	12/11/01	8.80	13.10	6.00		345.00	0.57	0.009
EVI0002	1/15/02	8.50	12.80	2.60		344.00	0.82	0.005
EVI0002	2/12/02	8.00	12.20	0.40		359.00	0.51	0.007
EVI0002	3/12/02	8.50	11.80	5.90		347.00	0.00	0.011
EVI0002	4/9/02	8.30	10.20	12.40		292.00	0.03	0.015

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
EVI0002	5/7/02	8.00	9.70	15.90		250.00	0.55	0.010
EVI0002	6/18/02	8.30	9.10	19.50		299.00	1.08	0.018
EVI0002	7/16/02	7.80	8.80	23.30		266.00	0.95	0.020
EVI0002	8/13/02	8.50	8.80	24.90		231.00	0.33	0.019
EVI0002	9/17/02	8.20	7.70	19.60		250.00	0.47	0.011
EVI0002	1/14/09	8.90	13.80	-0.20	1543	273.00	1.65	0.008
EVI0002	2/18/09	8.00	13.10	1.70	1378	242.00	1.45	0.011
EVI0002	3/17/09	7.80	10.70	7.10	976	333.00	1.34	0.042
EVI0002	4/21/09	7.00	10.10	10.40	1303	205.00	1.81	0.009
EVI0002	5/19/09	8.00	9.60	12.30	1572	222.00	0.54	0.014
EVI0002	6/16/09	7.70	8.10	19.80	1742	245.00	1.02	
EVI0002	7/21/09	8.10	7.80	20.20	1860	301.00	2.11	0.024
EVI0002	8/18/09	8.00	7.30	23.00	1149	329.00	0.85	0.015
EVI0002	9/15/09	7.90	8.20	18.70	2066	265.00	0.58	0.010
EVI0002	10/20/09	7.80	10.70	8.40	2216	340.00	0.09	0.018
EVI0002	11/9/09	8.10	11.30	8.10	2130	338.00	0.00	0.014
EVI0002	12/15/09	7.00	11.40	5.70	1464	319.00	3.34	0.012
EVI0046	3/8/01	7.30	11.70	2.90		472.00	2.61	0.012
EVI0046	3/26/01	7.90	12.50	4.10		234.00	2.04	0.007
EVI0046	4/3/01	8.40	12.10	7.50		233.00	2.04	0.016
EVI0046	8/21/01	7.60	8.10	20.00		282.00	1.12	0.017
EVI0046	8/27/01	8.10	6.50	21.40		311.00	1.21	0.013
EVI0046	9/6/01	7.70	9.10	19.10		265.00	1.04	0.011
EVI0046	2/18/09	7.90	12.40	2.10	1315	225.00	1.53	0.011
EVI0046	3/17/09	7.90	10.40	7.00	1808	300.00	1.44	0.031
EVI0046	4/21/09	7.10	10.00	10.80	1280	194.00	1.67	0.007
EVI0046	5/19/09	7.90	9.80	11.00	1462	208.00	1.23	0.021
EVI0046	6/16/09	7.70	9.30	12.90	2327	1104.00	0.65	
EVI0046	7/21/09	8.00	7.20	19.40	1972	297.00	1.55	0.020
EVI0046	8/18/09	8.00	7.10	23.30	2150	312.00	1.12	0.013
EVI0046	9/15/09	8.00	7.90	18.50	2023	258.00	1.08	0.017
EVI0046	10/20/09	7.70	9.90	7.40	2117	311.00	0.24	0.009
EVI0046	11/9/09	8.10	11.40	8.20	2055	307.00	0.18	0.012
EVI0046	12/15/09	7.10	11.30	5.70	1431	304.00	1.67	0.010
FIF0004	10/19/00	7.30	8.40	12.40		194.00	0.05	0.017
FIF0004	11/14/00	7.60	11.20	7.20		177.00	0.49	0.001
FIF0004	12/13/00	7.20	11.80	0.20		194.00	0.63	0.008
FIF0004	1/8/01	7.10	11.60	-0.10		195.00	1.46	0.011
FIF0004	2/5/01	7.60	12.60	0.50		90.00	3.04	0.004
FIF0004	3/19/01	8.30	12.70	3.10		102.00	1.60	0.036
FIF0004	4/16/01	7.90	10.70	10.20		68.00	1.79	0.004
FIF0004	5/14/01	7.70	9.30	13.00		122.00	0.31	0.007
FIF0004	6/18/01	7.10	7.80	19.90		139.00	0.29	0.008
FIF0004	7/23/01	7.10	7.00	21.40		199.00	0.24	0.006
FIF0004	8/6/01	7.70	6.40	23.90		196.00	0.18	0.008

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
FIF0004	9/17/01	7.20	7.80	16.00		210.00	0.06	0.010
FIF0004	10/16/01	7.10	7.40	11.80		196.00	0.00	0.005
FIF0004	11/5/01	6.90	8.10	9.00		224.00	0.00	0.006
FIF0004	12/17/01	8.10	12.20	5.50		350.00	0.04	0.007
FIF0004	1/22/02	7.10	13.20	0.40		230.00	0.98	0.004
FIF0004	2/19/02	7.20	11.90	0.50		270.00	0.17	0.009
FIF0004	3/19/02	7.60	11.50	5.80		315.00	1.41	0.012
FIF0004	4/16/02	7.50	10.00	12.40		80.00	1.96	0.008
FIF0004	5/14/02	6.90	9.80	12.90		85.00	0.56	0.004
FIF0004	6/10/02	7.30	8.50	20.30		130.00	0.33	0.006
FIF0004	7/23/02	7.10	5.90	24.60		160.00	0.09	0.012
FIF0004	8/19/02	7.30	6.30	25.00		234.00	0.03	0.038
FIF0004	9/23/02	7.20	5.80	21.80		271.00	0.07	0.005
FIF0004	1/14/08	7.10	12.20	3.90		91.00	1.13	0.006
FIF0004	2/5/08	6.40	12.60	4.40		95.00	0.94	0.002
FIF0004	3/3/08	7.10	13.00	2.40		125.00	0.81	0.002
FIF0004	4/7/08	6.60	11.20	8.60		107.00	0.29	0.003
FIF0004	5/5/08	7.30	10.20	12.60		83.00	0.43	0.003
FIF0004	6/2/08	7.00	9.20	15.50		86.00	0.30	0.003
FIF0004	7/7/08	7.50	7.70	23.20		188.00	0.03	0.006
FIF0004	8/4/08	7.50	6.90	21.50		224.00	0.04	0.006
FIF0004	9/8/08	6.10	7.20	20.10		281.00	0.03	0.006
FIF0004	10/27/08	7.50	10.40	8.50		265.00	0.00	0.002
FIF0004	11/17/08	6.80	11.30	6.30		279.00	0.01	0.004
FIF0004	12/1/08	7.30	11.90	2.30		211.00	0.07	0.005
FIF0085	1/14/08	7.10	12.30	3.90		80.00	0.98	0.006
FIF0085	2/5/08	6.70	12.70	4.20		72.00	0.88	0.002
FIF0085	3/3/08	7.20	13.10	2.40		108.00	0.71	0.003
FIF0085	4/7/08	7.90	11.50	7.90		98.00	0.31	0.004
FIF0085	5/5/08	7.40	10.30	12.60		73.00	0.52	0.006
FIF0085	6/2/08	7.00	9.20	15.80		106.00	0.40	0.003
FIF0085	7/7/08	7.60	8.00	23.10		235.00	0.29	0.004
FIF0085	8/4/08	7.70	8.70	21.70		306.00	0.24	0.007
FIF0085	9/8/08	6.40	8.10	18.10		388.00	0.18	0.005
FIF0085	10/27/08	7.50	10.00	8.80		419.00	0.15	0.006
FIF0085	11/17/08	7.10	10.80	6.20		227.00	0.11	0.010
HOB0010	1/24/08	7.90	13.70	0.00		322.00	10.71	0.047
HOB0010	2/14/08	7.20	13.50	1.70		268.00	15.33	0.026
HOB0010	3/12/08	7.50	11.30	5.50		264.00	13.17	0.021
HOB0010	4/16/08	7.90	12.00	10.30		236.00	2.90	0.068
HOB0010	5/14/08	7.00	8.60	13.20		191.00	8.02	0.059
HOB0010	6/11/08	6.70	5.70	22.40		250.00	2.10	0.063
HOB0010	7/16/08	7.60	6.30	21.80		258.00	0.69	0.017
HOB0010	12/10/08	7.70	10.80	5.30		249.00	3.62	0.122
LFB0001	1/24/08	8.10	13.40	2.60		837.00	9.99	0.123

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
LFB0001	2/14/08	7.30	13.50	4.10		759.00	8.95	0.086
LFB0001	3/12/08	8.70	11.00	10.00		731.00	8.95	0.095
LFB0001	4/16/08	9.10	11.80	15.40		665.00	5.59	0.074
LFB0001	5/14/08	8.20	9.50	15.90		714.00	9.45	0.094
LFB0001	6/11/08	7.20	7.50	26.70		322.00	7.12	0.136
LFB0001	7/16/08	8.30	7.50	25.20		555.00	6.39	0.084
LFB0001	8/13/08	8.60	9.00	22.60		689.00	5.97	0.080
LFB0001	9/17/08	8.30	8.20	19.80		730.00	6.61	0.640
LFB0001	11/13/08	7.90	10.10	10.80		144.00	2.29	0.248
LFB0001	12/10/08	8.10	10.70	9.30		585.00	9.42	0.014
LIC0003	1/20/00	8.00	12.90	-0.20		280.00	5.34	
LIC0003	2/16/00	7.10	13.00	0.50		161.00	5.55	0.016
LIC0003	3/8/00	8.00	10.30	8.50		186.00	3.06	0.013
LIC0003	4/11/00	8.10	10.20	10.70		166.00	2.63	0.018
LIC0003	5/8/00	8.70	8.30	23.10		216.00	2.96	0.036
LIC0003	6/14/00	7.80	7.80	21.00		221.00	4.90	0.020
LIC0003	7/11/00	8.10	11.10	22.80		216.00	4.95	0.056
LIC0003	8/9/00	7.80	7.50	23.10		201.00	3.68	0.033
LIC0003	9/13/00	8.00	7.60	21.20		289.00	5.04	0.022
LIC0003	10/17/00	7.80	9.20	12.70		338.00	4.47	0.037
LIC0003	11/15/00	7.80	10.60	6.50		244.00	2.80	0.007
LIC0003	12/5/00	7.80	12.50	-0.10		245.00	3.65	0.034
LIC0003	1/9/01	7.40	11.40	-0.20		271.00	6.82	0.027
LIC0003	2/6/01	7.10	12.60	2.10		185.00	6.59	0.023
LIC0003	3/20/01	8.20	12.30	4.80		142.00	4.37	0.061
LIC0003	4/17/01	7.10	10.20	8.80		106.00	3.95	0.033
LIC0003	5/15/01	8.30	9.20	14.30		269.00	4.89	0.095
LIC0003	6/19/01	7.60	7.40	21.20		178.00	3.99	0.038
LIC0003	7/24/01	7.80	7.70	23.30		325.00	2.83	0.054
LIC0003	8/7/01	7.50	7.20	24.30		342.00	2.96	0.034
LIC0003	9/18/01	7.60	9.60	15.10		349.00	2.16	0.032
LIC0003	10/17/01	7.60	8.10	10.70		324.00	0.60	0.013
LIC0003	11/6/01	8.00	8.90	7.00		353.00	0.06	0.015
LIC0003	12/18/01	8.40	10.60	6.20		291.00	2.83	0.016
LIC0003	1/23/02	7.80	13.30	0.80		262.00	4.87	0.014
LIC0003	2/20/02	8.20	10.80	2.60		275.00	3.09	0.074
LIC0003	3/20/02	8.00	10.70	6.90		189.00	2.80	0.051
LIC0003	4/17/02	7.40	8.30	17.00		128.00	2.89	0.035
LIC0003	5/15/02	8.00	9.20	13.60		159.00	2.56	0.056
LIC0003	6/11/02	7.60	7.20	22.90		220.00	3.31	0.064
LIC0003	7/24/02	7.80	6.60	24.10		325.00	0.84	0.055
LIC0003	8/20/02	7.90	6.70	24.00		347.00	0.56	0.037
LIC0003	9/24/02	7.90	8.10	17.20		333.00	1.48	0.019
LIC0003	1/28/08	6.60	13.70	0.30		214.00	6.66	0.026
LIC0003	2/19/08	6.50	12.70	3.20		167.00	6.45	0.021

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
LIC0003	3/17/08	6.80	11.40	5.90		175.00	6.65	0.141
LIC0003	4/21/08	6.90	9.30	12.70		96.00	3.51	0.031
LIC0003	5/19/08	7.40	9.50	12.60		143.00	5.03	0.069
LIC0003	6/16/08	7.10	7.20	22.00		286.00	6.52	0.050
LIC0003	7/21/08	7.90	7.20	25.40		324.00	4.13	0.036
LIC0003	8/25/08	8.10	8.30	22.00		355.00	3.84	0.022
LIC0003	9/25/08	8.30	9.00	15.50		337.00	2.46	0.013
LIC0003	10/20/08	8.20	10.00	8.00		379.00	1.74	0.027
LIC0003	11/24/08	8.80	14.60	0.80		312.00	2.61	0.052
LIC0003	12/15/08	7.40	12.40	4.60		179.00	8.92	0.015
LMO0002	1/24/08	8.00	14.30	-0.10		226.00	9.73	0.050
LMO0002	2/14/08	7.30	14.40	0.60		228.00	9.23	0.010
LMO0002	3/12/08	7.80	12.00	5.40		196.00	10.34	0.016
LMO0002	4/16/08	7.90	11.70	9.00		172.00	5.82	0.048
LMO0002	5/14/08	6.70	10.10	12.00		145.00	8.61	0.051
LMO0002	6/11/08	7.00	8.00	21.40		179.00	8.28	0.024
LMO0002	7/16/08	7.80	7.90	20.90		163.00	7.62	0.018
LMO0002	8/13/08	8.00	8.60	19.20		179.00	5.28	0.018
LMO0002	9/17/08	8.10	8.60	17.10		190.00	5.28	0.024
LMO0002	10/16/08	7.90	8.50	16.50		181.00	5.75	0.027
LMO0002	11/13/08	8.10	10.70	8.00		196.00	2.44	0.008
LMO0002	12/10/08	7.90	11.70	5.60		186.00	8.67	0.010
LTW0001	1/14/08	7.10	12.60	4.60		273.00	3.91	0.009
LTW0001	2/5/08	6.30	11.80	5.00		278.00	3.56	0.003
LTW0001	3/3/08	7.40	13.00	3.00		384.00	3.64	0.008
LTW0001	4/7/08	7.30	11.50	8.70		391.00	3.35	0.011
LTW0001	5/5/08	7.60	10.30	12.50		316.00	2.52	0.026
LTW0001	6/2/08	8.00	8.90	14.20		425.00	2.76	0.180
LTW0001	7/7/08	7.80	7.10	22.00		647.00	4.56	0.433
LTW0001	8/4/08	7.80	7.50	20.50		839.00	5.80	0.101
LTW0001	9/8/08	7.80	8.00	18.30		760.00	6.42	0.046
LTW0001	10/27/08	8.30	9.60	8.80		658.00	4.57	0.081
LTW0001	11/17/08	8.40	11.60	6.80		606.00	3.67	0.313
LTW0001	12/1/08	7.60	11.50	3.60		669.00	4.50	0.006
LTW0033	1/14/08	7.30	11.70	4.80		183.00	2.96	0.006
LTW0033	2/5/08	7.10	11.70	5.40		194.00	2.49	0.002
LTW0033	3/3/08	7.40	12.30	5.50		194.00	2.37	0.003
LTW0033	4/7/08	7.50	11.30	8.50		217.00	2.09	0.005
LTW0033	5/5/08	7.50	10.20	12.60		160.00	1.54	0.004
LTW0033	6/2/08	7.70	8.50	16.30		186.00	1.15	0.005
LTW0033	7/7/08	7.70	7.60	21.50		394.00	1.74	0.008
LTW0033	8/4/08	7.70	6.10	19.40		470.00	1.38	0.009
LTW0033	9/8/08	6.40	6.60	17.10		413.00	1.70	0.007
LTW0033	10/27/08	8.10	9.50	7.90		447.00	1.04	0.010
LTW0033	11/17/08	8.00	11.10	5.40		326.00	0.33	0.004

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
LTW0033	12/1/08	7.40	11.70	3.10		371.00	3.02	0.002
MDH0000	1/14/08	7.10	11.90	4.20		194.00	1.72	0.002
MDH0000	2/5/08	6.30	12.30	4.60		208.00	3.01	0.002
MDH0000	3/3/08	7.00	12.80	2.10		282.00	1.28	0.002
MDH0000	4/7/08	6.40	11.30	7.80		258.00	0.66	0.002
MDH0000	5/5/08	7.10	10.30	10.40		181.00	0.66	0.004
MDH0000	6/2/08	6.90	9.00	13.20		217.00	0.50	0.002
MDH0000	7/7/08	6.30	5.70	17.00		282.00	0.54	0.004
MDH0000	10/27/08	7.30	8.20	11.60		384.00	0.33	0.002
MDH0000	11/17/08	6.60	8.70	10.10		395.00	0.09	0.002
MDH0000	12/1/08	7.10	12.20	3.40		385.00	0.28	0.019
MEA0009	11/3/03	8.30	10.10	12.60		630.00	25.91	0.021
MEA0009	11/17/03	8.00	10.60	10.40		625.00	26.11	0.031
MEA0009	12/1/03	8.00	10.50	8.90		610.00	26.77	0.039
MEA0009	12/15/03	8.10	11.10	7.30		589.00	25.85	0.084
MEA0009	1/5/04	7.90	10.30	8.70		577.00	27.04	0.028
MEA0009	1/20/04	7.90	12.30	2.90		622.00	30.57	0.040
MEA0009	2/2/04	7.90	13.40	0.00		617.00	32.60	0.032
MEA0009	2/17/04	8.30	12.10	3.90		656.00	30.51	0.035
MEA0009	3/1/04	7.90	11.20	6.90		578.00	23.95	0.029
MEA0009	3/15/04	8.00	11.30	8.30		607.00	27.93	0.026
MEA0009	4/5/04	8.10	12.50	7.30		600.00	23.90	0.036
MEA0009	4/19/04	7.90	10.80	12.30		604.00	24.18	0.028
MEA0009	5/10/04	7.90	9.60	14.40		615.00	30.40	0.053
MEA0009	5/24/04	7.80	9.10	17.00		590.00	28.67	0.069
MEA0009	6/7/04	7.80	9.60	14.40		617.00	28.20	0.036
MEA0009	6/21/04	7.90	9.80	14.20		635.00	29.92	0.060
MEA0009	7/6/04	8.00	9.30	19.50		607.00	31.15	0.035
MEA0009	7/19/04	8.20	9.20	16.80		609.00	29.30	0.040
MEA0009	8/9/04	8.10	9.20	17.20		613.00	26.75	0.052
MEA0009	8/23/04	8.30	9.10	19.10		639.00	23.45	0.054
MEA0009	9/7/04	8.10	8.40	17.90		611.00	22.88	0.054
MEA0009	9/20/04	8.10	9.60	13.50		692.00	22.79	0.045
MEA0009	10/4/04	8.10	9.80	13.30		681.00	25.06	0.027
MEA0009	10/18/04	7.90	9.90	11.40		662.00	24.65	0.083
MEA0009	1/27/09	8.40	12.80	2.10		723.00	33.97	0.018
MEA0009	2/24/09	7.80	13.80	0.20		746.00	31.32	0.027
MEA0009	3/24/09	8.70	12.80	2.80		712.00	27.49	0.033
MEA0009	4/29/09	8.00	9.80	14.50		749.00	24.59	0.051
MEA0009	5/27/09	8.20	9.20	12.70		722.00	32.33	0.053
MEA0009	6/23/09	8.10	8.90	16.70		706.00	30.75	0.044
MEA0009	7/28/09	8.10	8.00	19.20		673.00	25.15	0.056
MEA0009	8/25/09	8.10	8.20	20.10		665.00	26.44	0.055
MEA0009	9/22/09	8.00	7.90	18.60		663.00	25.42	0.073
MEA0009	10/27/09	8.00	7.80	11.20		753.00	24.24	0.042

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
MEA0009	11/23/09	9.30	8.00	7.60		749.00	22.29	0.044
MEA0009	12/7/09	7.20	11.40	5.30		736.00	28.26	0.116
MON0004	10/17/00	8.10	8.70	14.70		391.00	13.69	0.137
MON0004	11/15/00	7.70	10.10	7.80		400.00	9.96	0.148
MON0004	12/5/00	7.70	12.50	0.70		354.00	14.27	0.160
MON0004	1/9/01	7.80	12.50	-0.20		372.00	17.59	0.089
MON0004	2/6/01	7.50	12.60	2.60		337.00	15.92	0.059
MON0004	3/20/01	7.70	11.40	6.60		290.00	9.87	0.154
MON0004	4/17/01	7.50	8.80	11.50		253.00	8.04	0.149
MON0004	5/15/01	8.10	8.60	16.40		349.00	11.29	0.135
MON0004	6/19/01	7.80	7.00	23.40		362.00	9.39	0.187
MON0004	7/24/01	8.90	7.40	26.00		434.00	8.23	0.210
MON0004	8/6/01	8.40	7.10	27.20		427.00	10.29	0.249
MON0004	9/18/01	8.00	7.90	17.90		552.00	17.43	0.232
MON0004	10/17/01	7.80	8.40	13.10		469.00	12.56	0.208
MON0004	11/6/01	7.80	9.80	8.90		505.00	10.27	0.155
MON0004	12/18/01	8.00	10.60	8.30		222.00	11.96	0.134
MON0004	1/23/02	8.00	13.50	3.70		565.00	16.02	0.123
MON0004	2/20/02	8.00	12.40	5.80		450.00	14.65	0.149
MON0004	3/6/02	8.30	11.60	3.00		424.00	11.06	0.159
MON0004	3/20/02	7.60	10.10	8.60		375.00	9.05	0.136
MON0004	4/3/02	7.50	8.60	14.00		319.00	11.19	0.136
MON0004	4/17/02	7.50	6.20	21.00		320.00	4.21	0.132
MON0004	5/1/02	7.50	8.40	15.30		304.00	4.80	0.164
MON0004	5/15/02	7.90	8.10	16.30		326.00	6.03	0.187
MON0004	6/11/02	7.60	6.30	25.00		387.00	7.64	0.211
MON0004	7/10/02	8.10	6.60	26.10		506.00	4.58	0.344
MON0004	7/24/02	8.10	6.40	27.40		524.00	5.88	0.325
MON0004	8/7/02	8.20	7.30	24.40		484.00	5.81	0.241
MON0004	8/20/02	8.00	7.00	27.90		603.00	2.98	0.261
MON0004	9/11/02	8.20	8.30	23.40		540.00	8.00	0.360
MON0004	9/24/02			20.00			9.43	0.080
MON0004	11/3/03	7.90	8.80	14.20		285.00	13.38	0.045
MON0004	11/17/03	7.90	10.50	9.10		293.00	13.29	0.098
MON0004	12/1/03	8.10	11.00	6.40		242.00	11.82	0.080
MON0004	12/15/03	7.70	12.30	3.50		296.00	12.58	0.043
MON0004	1/6/04	8.30	10.90	6.40		282.00	14.61	0.033
MON0004	1/21/04	7.70	13.90	-0.10		346.00	17.98	0.068
MON0004	2/18/04	7.50	12.80	1.60		313.00	13.93	0.038
MON0004	3/2/04	7.80	11.50	7.20		279.00	11.58	0.031
MON0004	3/16/04	7.90	11.20	7.60		286.00	11.54	0.041
MON0004	4/6/04	7.70	10.10	6.90		255.00	10.53	0.055
MON0004	4/20/04	7.50	8.50	17.70		250.00	10.16	0.065
MON0004	5/11/04	7.70	7.70	20.50		282.00	10.56	0.100
MON0004	5/25/04	7.60	6.40	23.40		292.00	10.70	0.131

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
MON0004	6/8/04	7.40	8.10	18.10		247.00	12.29	0.096
MON0004	6/22/04	7.60	7.40	21.60		295.00	11.83	0.042
MON0004	7/7/04	7.90	6.10	25.50		340.00	9.23	0.089
MON0004	7/20/04	7.80	6.50	22.90		368.00	11.77	0.098
MON0004	8/10/04	7.80	7.30	22.40		377.00	12.62	0.160
MON0004	8/24/04	7.70	6.70	22.10		284.00	9.12	0.088
MON0004	9/8/04	7.90	7.00	22.30		438.00	12.61	0.202
MON0004	9/21/04	7.60	7.70	17.60		253.00	8.93	0.093
MON0004	10/5/04	7.80	8.60	16.20		320.00	13.46	0.045
MON0004	10/19/04	8.00	9.50	12.50		352.00	11.44	0.047
MON0004	1/24/08	8.10	13.60	0.20		456.00	15.59	0.299
MON0004	2/14/08	7.20	13.40	0.60		346.00	12.78	0.064
MON0004	3/12/08	7.90	10.40	6.30		278.00	13.11	0.046
MON0004	4/16/08	8.00	9.40	12.20		287.00	8.54	0.138
MON0004	5/14/08	7.20	8.80	14.40		200.00	8.40	0.207
MON0004	6/11/08	6.90	6.10	24.40		306.00	11.73	0.087
MON0004	7/16/08	7.80	6.30	24.20		376.00	9.90	0.090
MON0004	8/13/08	7.90	6.90	22.30		497.00	11.81	0.134
MON0004	9/17/08	7.80	6.80	20.20		373.00	9.61	0.054
MON0004	10/16/08	8.00	7.70	18.10		436.00	12.46	0.031
MON0004	11/13/08	8.00	10.00	9.30		441.00	10.44	0.039
MON0004	12/10/08	7.60	11.80	4.00		375.00	14.48	0.159
MON0041	3/6/02	8.10	11.60	3.30		449.00	11.70	0.146
MON0041	4/3/02	7.50	9.00	14.20		324.00	11.21	0.141
MON0041	5/1/02	7.50	8.30	14.90		313.00	5.20	0.230
MON0041	7/10/02	7.90	6.10	25.60		522.00	6.00	0.314
MON0041	8/7/02	8.10	7.20	23.70		516.00	6.57	0.286
MON0041	9/11/02	8.00	8.30	23.20		551.00	8.21	0.072
NCRN_ANTI_SHCK	5/23/05	8.09	10.50	13.30			4.60	
NCRN_ANTI_SHCK	6/2/05	8.14	10.85	14.75	3740	534.00	4.90	
NCRN_ANTI_SHCK	6/30/05	8.13	9.97	16.77	3920	502.00	5.00	
NCRN_ANTI_SHCK	10/11/05	8.18	9.81	14.60	2200	631.00	9.30	
NCRN_ANTI_SHCK	11/17/05	8.27	8.60	10.20	3720	600.00	9.30	
NCRN_ANTI_SHCK	12/14/05	8.03	5.81	7.50	3592	618.00	5.40	
NCRN_ANTI_SHCK	1/26/06	7.83	11.55	10.40	4120	585.00	11.70	
NCRN_ANTI_SHCK	2/28/06	8.25	8.56	10.85	4300	551.00	9.90	
NCRN_ANTI_SHCK	3/23/06	8.36	9.00	11.50	4180	531.00	9.80	
NCRN_ANTI_SHCK	4/12/06	8.32	3.53	14.30	2100	534.00	14.30	
NCRN_ANTI_SHCK	5/18/06	8.26	1.98	13.30	4200	558.00	8.80	
NCRN_ANTI_SHCK	6/28/06	8.11	8.98	16.00	4420	656.00	9.00	
NCRN_ANTI_SHCK	7/26/06	8.26	9.33	16.60	4180	586.00	10.60	
NCRN_ANTI_SHCK	8/14/06	7.67	8.46	17.90	3980	570.00	10.20	
NCRN_ANTI_SHCK	10/12/06	8.22	9.32	14.30	4820	339.10	10.30	
NCRN_ANTI_SHCK	11/17/06	8.26	9.27	13.05	4720	657.00	10.90	
NCRN_ANTI_SHCK	12/18/06	8.27	8.30	13.05	4800	598.00	2.10	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ANTI_SHCK	1/25/07	7.38	9.90	10.10	4780	586.50	1.55	0.121
NCRN_ANTI_SHCK	2/22/07	8.41	9.41	11.60	4820	614.00	2.44	0.049
NCRN_ANTI_SHCK	3/27/07	8.30	8.98	13.10	5280	634.67	5.49	0.020
NCRN_ANTI_SHCK	5/16/07	8.20	8.72	15.80	4820	571.75	5.95	0.117
NCRN_ANTI_SHCK	6/5/07	8.24	7.83	15.30	4500	576.00	4.35	0.059
NCRN_ANTI_SHCK	7/11/07	8.00	10.34	15.60	4580	561.00	7.78	0.101
NCRN_ANTI_SHCK	8/13/07	8.15	8.27	17.90	4240	557.00	3.90	0.075
NCRN_ANTI_SHCK	8/30/07	8.23	7.77	17.30	4440	595.00	5.00	0.072
NCRN_ANTI_SHCK	10/17/07	8.24	8.66	14.40	4260	581.00	5.30	0.068
NCRN_ANTI_SHCK	11/14/07	8.41	8.84	13.10	4920	616.00	7.90	0.108
NCRN_ANTI_SHCK	12/19/07	8.41	10.23	9.50	5280	691.00	9.30	0.075
NCRN_ANTI_SHCK	1/22/08		9.45	7.40	5140	571.00	8.90	0.098
NCRN_ANTI_SHCK	2/19/08	8.10	10.69	10.30	5180	671.00	8.00	0.095
NCRN_ANTI_SHCK	3/20/08	8.24	8.65	10.70	4140	575.50	9.30	0.072
NCRN_ANTI_SHCK	4/14/08	8.29	11.61	12.95	5300	605.00	8.30	0.065
NCRN_ANTI_SHCK	5/7/08	8.27	12.09	15.55	5320	611.00	8.30	0.055
NCRN_ANTI_SHCK	6/18/08	8.07	9.91	14.82	5300	597.25	7.90	0.088
NCRN_ANTI_SHCK	7/30/08	8.02	9.57	15.55	4824	590.00	6.20	0.055
NCRN_ANTI_SHCK	8/13/08	7.53	9.55	14.80	4380	582.50	8.00	0.062
NCRN_ANTI_SHCK	9/18/08	7.96	9.47	14.40	4800	596.00	6.70	0.075
NCRN_ANTI_SHCK	10/22/08	8.21	10.44	10.80	4660	587.50	6.30	0.078
NCRN_ANTI_SHCK	11/19/08	8.28	11.79	7.50	4960	612.50	6.30	0.046
NCRN_ANTI_SHCK	2/4/09	8.20	14.60	8.10	5060	635.00	8.00	0.055
NCRN_ANTI_SHCK	4/6/09	8.26	9.85	12.90	5380	628.50	6.30	0.065
NCRN_ANTI_SHCK	6/9/09	8.09	9.70	15.60	5280	594.20	7.00	0.078
NCRN_ANTI_SHCK	7/8/09	8.22	10.00	14.90	4660	559.30	6.70	0.078
NCRN_ANTI_SHCK	7/21/09	8.23	10.05	15.60	6680	574.25	6.00	0.055
NCRN_ANTI_SHCK	8/17/09	8.21	9.30	17.20	4660	581.70	6.50	0.059
NCRN_ANTI_SHCK	9/15/09	8.32	9.70	16.40	4320	574.20	6.00	0.059
NCRN_ANTI_SHCK	10/13/09	8.31	10.40	13.40	4560	585.00	6.20	0.059
NCRN_ANTI_SHCK	11/10/09	8.40	10.90	13.40	5800	606.60	5.90	
NCRN_ANTI_SHCK	12/8/09	8.37	11.90	9.90	4640	595.70	5.80	0.046
NCRN_ANTI_SHCK	1/12/10	8.22	11.80	9.60	5120	633.20	6.30	
NCRN_ANTI_SHCK	2/9/10						0.00	0.147
NCRN_ANTI_SHCK	3/9/10	8.14	10.30	13.20	4760	410.20	6.30	0.241
NCRN_ANTI_SHCK	4/6/10	8.16	10.80	15.50	4900	610.00	6.70	0.183
NCRN_ANTI_SHCK	5/4/10	8.28	10.20	15.30	4640	598.30	7.30	0.055
NCRN_ANTI_SHCK	6/8/10	8.14	9.90	15.10	4020	516.55	6.90	0.082
NCRN_ANTI_SHCK	7/13/10	8.14	9.30	16.20	4160	575.90	6.60	0.062
NCRN_ANTI_SHCK	8/9/10	8.18	8.90	17.70	4100	566.80	6.90	0.173
NCRN_ANTI_SHCK	9/15/10	8.18	9.70	15.70	4140	571.70	7.90	0.173
NCRN_ANTI_SHCK	10/13/10	7.48	9.89	13.85	3880	449.20	8.20	0.307
NCRN_ANTI_SHCK	11/8/10	8.30	10.70	11.50	4660	635.30	7.60	0.271
NCRN_ANTI_SHCK	1/5/11	8.39	10.40	10.70	4420	611.80	7.10	0.134
NCRN_ANTI_SHCK	2/7/11	8.26	11.90	10.40	4600	688.40	5.90	0.134

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ANTI_SHCK	3/9/11	8.02	10.60	11.20	4980	697.00	8.10	0.150
NCRN_ANTI_SHCK	4/4/11	8.11	10.20	14.20	5440	637.00	7.20	0.108
NCRN_ANTI_SHCK	5/2/11	7.92	9.70	13.60	4920	616.60	8.50	0.248
NCRN_ANTI_SHCK	6/6/11	7.93	10.00	14.70	4400	595.10	6.60	0.068
NCRN_ANTI_SHCK	7/11/11	8.03	9.20	16.40	4000	574.90	6.40	0.189
NCRN_ANTI_SHCK	8/16/11	8.13	9.40	16.30	4720	622.00	6.90	0.163
NCRN_ANTI_SHCK	9/13/11	8.05	9.60	16.10	4900	635.00	7.90	0.515
NCRN_GWMP_MICR	6/8/05	7.81	9.39	18.80	1624	650.00	2.50	
NCRN_GWMP_MICR	9/27/05	7.41	3.70	19.55	1208	679.00	2.20	
NCRN_GWMP_MICR	11/1/05	7.76	10.67	10.30	220	690.00	2.80	
NCRN_GWMP_MICR	12/5/05	7.71	10.32	4.80	1320	3629.00	0.50	
NCRN_GWMP_MICR	1/5/06	7.37	4.85	6.90	1980	735.00	1.90	
NCRN_GWMP_MICR	2/16/06	7.45	10.27	4.80	712	1544.00	1.30	
NCRN_GWMP_MICR	3/13/06	7.97	5.65	12.40	1824	714.00	2.30	
NCRN_GWMP_MICR	4/6/06	7.88	2.75	9.90	1928	700.00	1.50	
NCRN_GWMP_MICR	5/2/06	7.85	1.88	12.00	1952	678.00	2.40	
NCRN_GWMP_MICR	6/15/06	7.73	5.51	17.30	1848	593.00	1.00	
NCRN_GWMP_MICR	7/12/06	7.62	5.98	21.80	2000	722.00	2.70	
NCRN_GWMP_MICR	8/7/06	7.73	6.27	23.60	848	206.40	1.00	
NCRN_GWMP_MICR	9/25/06	7.41	8.18	17.60	2136	812.00	2.80	
NCRN_GWMP_MICR	10/19/06	7.84	6.92	15.50	1900	512.50	2.10	
NCRN_GWMP_MICR	12/5/06	8.08	9.55	3.80	1820	706.00	2.70	
NCRN_GWMP_MICR	1/12/07	7.93	10.78	4.90	1808	646.50	4.10	
NCRN_GWMP_MICR	2/16/07						0.00	0.036
NCRN_GWMP_MICR	4/2/07	7.90	9.38	11.60	1136	1074.00	1.89	0.023
NCRN_GWMP_MICR	5/9/07	7.88	8.05	14.50	1984	769.50	2.91	0.124
NCRN_GWMP_MICR	6/7/07	7.97	7.53	18.00	1992	755.00	1.54	0.075
NCRN_GWMP_MICR	7/24/07	7.65	5.72	19.90	2272	791.00	1.30	0.150
NCRN_GWMP_MICR	8/22/07	7.88	7.55	19.00	2120	492.00	0.60	
NCRN_GWMP_MICR	9/25/07						0.00	
NCRN_GWMP_MICR	10/23/07						0.00	
NCRN_GWMP_MICR	11/19/07						0.00	
NCRN_GWMP_MICR	12/17/07						0.00	0.068
NCRN_GWMP_MICR	1/31/08	7.66	13.11	2.25	2176	1691.00	3.20	0.065
NCRN_GWMP_MICR	2/27/08	8.14	11.12	4.90	2112	3528.00	3.30	0.111
NCRN_GWMP_MICR	3/19/08	8.53	11.80	10.10	2184	859.00	2.80	0.082
NCRN_GWMP_MICR	6/23/08	7.98	9.82	21.15	2220	769.00	3.40	0.062
NCRN_GWMP_MICR	8/26/08	8.06	7.84	19.90	594	837.00	2.60	0.137
NCRN_GWMP_MICR	10/22/08	7.94	14.50	11.10	2140	612.50	2.50	0.160
NCRN_GWMP_MICR	11/19/08	7.93	11.96	6.05	2280	587.50	1.80	0.075
NCRN_GWMP_MICR	2/4/09	7.92	19.80	2.50	1912	2754.50	3.70	0.078
NCRN_GWMP_MICR	4/6/09	8.28	9.26	13.70	2096	749.50	3.00	0.147
NCRN_GWMP_MICR	6/9/09	7.93	8.20	21.20	1600	387.00	2.00	0.104
NCRN_GWMP_MICR	7/8/09	8.02	9.10	18.80	2184	698.00	3.60	0.108
NCRN_GWMP_MICR	7/21/09	8.07	8.10	20.50	2240	728.00	3.40	0.078

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_GWMP_MICR	8/17/09	8.01	7.60	22.40	2232	722.00	3.00	0.202
NCRN_GWMP_MICR	9/15/09	7.95	8.60	19.00	1680	707.00	6.30	0.124
NCRN_GWMP_MICR	10/13/09	7.94	9.70	13.00	2032	717.00	3.00	0.095
NCRN_GWMP_MICR	11/10/09	8.06	10.50	12.40	2280	675.00	1.30	0.075
NCRN_GWMP_MICR	12/8/09	8.18	13.00	6.40	1952	1126.00	2.90	0.055
NCRN_GWMP_MICR	1/12/10	8.15	14.50	1.90	1888	1270.00	3.10	
NCRN_GWMP_MICR	2/9/10						0.00	0.124
NCRN_GWMP_MICR	3/9/10	8.95	12.30	9.40	1744	909.00	1.50	0.196
NCRN_GWMP_MICR	4/6/10	8.98	10.10	19.00	1832	822.00	2.60	0.166
NCRN_GWMP_MICR	5/4/10	7.87	8.00	19.00	1920	777.00	2.00	0.082
NCRN_GWMP_MICR	6/8/10	7.95	9.10	19.00	2112	774.00	2.70	0.160
NCRN_GWMP_MICR	7/13/10	7.88	7.80	22.60	1080	464.50	1.80	0.111
NCRN_GWMP_MICR	8/9/10	7.94	8.00	23.20	2200	781.00	2.90	0.209
NCRN_GWMP_MICR	9/15/10	7.71	8.90	17.60	1984	796.00	3.20	0.192
NCRN_GWMP_MICR	10/13/10	7.33	9.49	15.10	1120	796.00	4.80	0.228
NCRN_GWMP_MICR	11/8/10	7.95	11.30	8.60	2040	745.00	2.50	0.209
NCRN_GWMP_MICR	12/6/10	8.16	13.80	3.00	1656	795.70	3.70	0.127
NCRN_GWMP_MICR	1/5/11	7.92	12.90	8.10	1848	971.00	3.70	0.117
NCRN_GWMP_MICR	2/7/11	7.98	13.80	4.90	1656	1064.00	1.90	
NCRN_GWMP_MICR	3/9/11						0.00	0.111
NCRN_GWMP_MICR	4/4/11	8.77	12.00	12.90	1808	824.00	2.70	0.189
NCRN_GWMP_MICR	5/2/11	8.09	9.70	15.60	2008	836.00	2.70	0.186
NCRN_GWMP_MICR	6/8/11	7.86	8.20	19.90	1776	792.00	2.10	0.098
NCRN_GWMP_MICR	7/12/11	7.90	7.10	23.40	2096	440.60	1.10	0.130
NCRN_GWMP_MICR	8/8/11	7.74	6.80	28.00	2200	445.20	0.80	0.183
NCRN_GWMP_MICR	9/13/11	7.94	8.60	20.40	1496	815.00	2.70	0.323
NCRN_ROCR_BAKE	11/8/05	7.33	6.98	13.00	1080	667.00	3.60	
NCRN_ROCR_BAKE	1/26/06	6.83	12.29	6.65	960	615.00	6.30	
NCRN_ROCR_BAKE	2/28/06	7.82	10.04	5.50	920	659.00	3.90	
NCRN_ROCR_BAKE	4/12/06	8.05	3.14	13.35	1024	606.00	2.90	
NCRN_ROCR_BAKE	5/18/06	7.39	2.51	14.20	1168	567.00	4.30	
NCRN_ROCR_BAKE	1/12/07	7.55	10.79	6.20	1048	644.00	5.50	0.241
NCRN_ROCR_BAKE	2/23/07	7.82	10.62	6.45	1088	938.50	3.93	0.134
NCRN_ROCR_BAKE	3/27/07	8.59	9.90	14.55	1024	663.25	4.10	0.055
NCRN_ROCR_BAKE	5/14/07	7.36	7.22	14.25	1288	592.25	4.05	0.150
NCRN_ROCR_BAKE	10/3/07	6.99	6.31	18.70	1472	650.00	5.70	0.137
NCRN_ROCR_BAKE	11/1/07	7.48	5.37	13.40	1448	625.00	4.60	0.108
NCRN_ROCR_BAKE	11/26/07	7.33	7.29	9.40	1568	694.00	4.60	0.095
NCRN_ROCR_BAKE	1/8/08	7.40	11.63	8.90	1184	706.00	4.90	0.082
NCRN_ROCR_BAKE	2/4/08	7.37	10.27	6.50	1320	831.00	5.50	0.068
NCRN_ROCR_BAKE	3/4/08	8.18	11.14	10.90	1336	871.00	4.90	0.091
NCRN_ROCR_BAKE	4/1/08	7.62	9.38	10.05	1528	704.00	5.20	0.075
NCRN_ROCR_BAKE	4/29/08	7.61	8.51	12.20	1648	615.50	3.90	0.104
NCRN_ROCR_BAKE	6/17/08	7.37	8.76	18.40	2456	581.00	3.40	0.082
NCRN_ROCR_BAKE	7/15/08	7.46	6.64	20.10		564.75	3.30	0.082

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_BAKE	8/20/08	7.48	7.19	19.80	1528	648.50	3.90	0.108
NCRN_ROCR_BAKE	9/10/08	7.64	8.04	19.50	1528	580.00	3.40	0.078
NCRN_ROCR_BAKE	10/22/08	7.44	9.91	10.75	1912	731.00	4.00	0.085
NCRN_ROCR_BAKE	11/19/08	7.58	10.61	6.15	1776	667.50	3.30	0.059
NCRN_ROCR_BAKE	2/4/09	7.69	15.22	3.05	1336	1023.00	5.10	0.052
NCRN_ROCR_BAKE	4/7/09	7.41	10.97	8.15	1296	718.50	4.50	0.117
NCRN_ROCR_BAKE	6/9/09	7.58	8.50	19.30	1368	456.20	3.40	0.101
NCRN_ROCR_BAKE	7/8/09	7.63	9.00	18.20	1416	552.70	4.50	0.127
NCRN_ROCR_BAKE	7/21/09	7.59	8.40	19.50	1856	702.00	3.80	0.095
NCRN_ROCR_BAKE	8/17/09	7.55	6.30	21.90	1600	663.00	3.80	0.114
NCRN_ROCR_BAKE	9/15/09	7.54	6.90	19.20	1404	661.00	3.80	0.088
NCRN_ROCR_BAKE	10/13/09	7.55	7.80	13.80	1560	681.00	3.70	0.082
NCRN_ROCR_BAKE	11/10/09	7.43	8.80	12.90	1552	707.00	4.00	0.068
NCRN_ROCR_BAKE	12/8/09	7.69	12.20	7.00	1168	764.00	3.60	0.052
NCRN_ROCR_BAKE	1/12/10	7.76	14.30	2.80	1192	724.00	3.50	
NCRN_ROCR_BAKE	2/9/10						0.00	0.095
NCRN_ROCR_BAKE	3/9/10	8.49	12.60	10.80	1080	707.00	3.60	0.192
NCRN_ROCR_BAKE	4/6/10	8.16	10.90	19.10	1208	698.00	3.90	0.248
NCRN_ROCR_BAKE	5/4/10	7.62	8.00	17.50	1304	681.00	3.70	0.098
NCRN_ROCR_BAKE	6/8/10	7.52	7.90	17.70	1256	692.00	3.60	0.124
NCRN_ROCR_BAKE	7/13/10	7.47	7.10	21.50	880	454.80	2.60	0.117
NCRN_ROCR_BAKE	8/9/10	7.45	6.30	22.50	1440	642.00	3.30	0.251
NCRN_ROCR_BAKE	9/15/10	7.54	8.60	18.00	1312	683.00	5.10	0.202
NCRN_ROCR_BAKE	10/13/10	7.06	8.55	15.50	1216	739.00	5.40	0.267
NCRN_ROCR_BAKE	11/8/10	7.45	9.80	9.70	1368	743.00	4.20	0.307
NCRN_ROCR_BAKE	12/6/10	7.62	12.60	4.20	1072	768.00	5.00	0.222
NCRN_ROCR_BAKE	1/5/11	7.67	13.60	9.10	1104	783.00	5.00	0.127
NCRN_ROCR_BAKE	2/7/11	7.64	13.10	5.30	1224	1060.00	3.50	0.108
NCRN_ROCR_BAKE	3/9/11	7.66	11.50	7.40	1136	810.00	3.40	0.104
NCRN_ROCR_BAKE	4/4/11	8.14	11.70	13.80	1192	648.00	4.40	0.117
NCRN_ROCR_BAKE	5/2/11	7.48	8.50	14.90	1320	772.00	3.50	0.111
NCRN_ROCR_BAKE	6/8/11	7.27	7.40	19.40	1160	754.00	2.60	0.091
NCRN_ROCR_BAKE	7/12/11	7.40	6.25	22.00	1560	675.50	2.10	0.085
NCRN_ROCR_BAKE	8/8/11	7.30	5.90	23.40	1608	673.00	1.90	0.228
NCRN_ROCR_BAKE	9/13/11	7.60	7.70	20.20	2056	787.00	3.40	0.603
NCRN_ROCR_BRBR	6/27/05	7.92	7.15	21.30	1752	720.67	1.60	
NCRN_ROCR_BRBR	10/4/05	7.82	8.31	18.17	1280	727.00	1.80	
NCRN_ROCR_BRBR	11/3/05	7.82	7.60	10.60	1560	719.00	2.70	
NCRN_ROCR_BRBR	12/8/05	7.87	8.56	1.85	708	1004.00	1.10	
NCRN_ROCR_BRBR	1/3/06	7.71	5.28	7.90	940	456.70	2.60	
NCRN_ROCR_BRBR	2/14/06	8.02	13.54	4.35	1712	2299.00	1.30	
NCRN_ROCR_BRBR	3/8/06	8.89	8.96	5.70	1856	697.30	1.50	
NCRN_ROCR_BRBR	4/4/06	8.55	6.59	13.10	1448	564.50	1.10	
NCRN_ROCR_BRBR	5/4/06	8.45	2.63	16.90	1176	658.00	2.70	
NCRN_ROCR_BRBR	6/1/06	7.79	2.96	21.70	2256	657.00	3.00	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_BRBR	7/20/06	7.97	7.51	24.10	1216	651.00	4.00	
NCRN_ROCR_BRBR	8/3/06	8.00	5.99	25.90	2144	739.00	4.30	
NCRN_ROCR_BRBR	9/12/06	7.56	8.80	18.00	2240	621.00	2.10	
NCRN_ROCR_BRBR	10/11/06	7.88	7.71	16.35	1896	690.60	3.80	
NCRN_ROCR_BRBR	11/21/06	8.14	10.08	7.27	3200	737.67	3.60	
NCRN_ROCR_BRBR	12/21/06	8.53	10.03	6.40	2048	750.33	0.00	
NCRN_ROCR_BRBR	1/30/07		13.96	1.35	2064	804.98	1.05	0.055
NCRN_ROCR_BRBR	3/19/07	8.32	12.19	4.37	1984	747.67	1.61	0.098
NCRN_ROCR_BRBR	4/18/07	8.61	12.92	9.83	1864	670.13	2.10	0.147
NCRN_ROCR_BRBR	5/22/07	7.88	7.24	16.00	1328	768.75	1.93	0.264
NCRN_ROCR_BRBR	6/25/07	7.88	7.31	20.80	2192	757.00	1.60	0.205
NCRN_ROCR_BRBR	7/30/07	7.69	5.59	24.20	1544	470.30	0.60	0.280
NCRN_ROCR_BRBR	9/4/07	8.55	9.54	22.00	2344	773.00	1.70	0.264
NCRN_ROCR_BRBR	10/11/07	7.67	4.79	17.40	2248	688.00	2.00	0.258
NCRN_ROCR_BRBR	11/5/07	8.09	9.13	9.50	2472	763.00	3.50	0.512
NCRN_ROCR_BRBR	12/3/07	7.66	8.28	8.10	1360	298.40	1.80	0.170
NCRN_ROCR_BRBR	1/24/08		13.90	0.50	2312	1004.00	3.10	0.170
NCRN_ROCR_BRBR	2/20/08	8.10	11.49	3.10	2320	895.00	2.90	0.127
NCRN_ROCR_BRBR	3/18/08	8.46	11.42	8.22	2408	782.00	2.30	0.101
NCRN_ROCR_BRBR	4/8/08	8.27	11.10	9.42	2384	738.83	2.70	0.160
NCRN_ROCR_BRBR	6/16/08	7.99	8.14	21.60	2024	804.75	2.70	0.134
NCRN_ROCR_BRBR	7/14/08	7.70	7.32	22.80	1096	179.38	1.50	0.209
NCRN_ROCR_BRBR	8/21/08	8.30	8.43	20.85	2184	801.50	2.80	0.248
NCRN_ROCR_BRBR	9/11/08	8.10	7.54	20.05	2136	711.75	2.40	0.232
NCRN_ROCR_BRBR	10/8/08	8.24	10.46	13.38	2376	761.50	2.90	0.163
NCRN_ROCR_BRBR	10/28/08	7.72	9.75	10.73	1136	355.47	1.30	0.199
NCRN_ROCR_BRBR	11/24/08	8.02	12.72	2.75	1864	812.00	2.60	0.144
NCRN_ROCR_BRBR	1/13/09	8.33	14.45	2.73	1880	751.50	3.20	0.098
NCRN_ROCR_BRBR	2/9/09	8.42	13.85	4.05	2208	1095.50	2.70	0.082
NCRN_ROCR_BRBR	4/8/09	8.75	14.71	9.95	2048	825.50	2.20	0.153
NCRN_ROCR_BRBR	5/20/09	8.20	10.07	15.47	2320	755.00	2.90	0.144
NCRN_ROCR_BRBR	6/29/09	8.01	8.00	20.57	2384	775.67	2.30	0.261
NCRN_ROCR_BRBR	8/5/09	7.97	7.63	22.10	2472	779.33	2.90	0.235
NCRN_ROCR_BRBR	9/1/09	8.09	8.75	18.20	2232	767.00	2.60	0.199
NCRN_ROCR_BRBR	9/29/09	8.02	8.95	15.80	1544	653.50	2.20	0.209
NCRN_ROCR_BRBR	10/27/09	7.55	10.00	13.30	800	171.30	0.60	0.186
NCRN_ROCR_BRBR	11/24/09	7.94	10.50	11.50	1624	257.03	0.60	
NCRN_ROCR_BRBR	12/22/09						0.00	0.098
NCRN_ROCR_BRBR	1/26/10	8.68	14.93	7.37	1992	955.00	2.40	
NCRN_ROCR_BRBR	2/23/10						0.00	0.228
NCRN_ROCR_BRBR	3/30/10	8.49	13.40	9.97	2136	814.33	1.80	0.179
NCRN_ROCR_BRBR	4/22/10	8.08	11.17	13.83	2064	757.00	2.00	0.280
NCRN_ROCR_BRBR	5/18/10	7.87	9.20	14.00	1616	617.90	2.30	0.264
NCRN_ROCR_BRBR	6/22/10	7.84	7.45	21.95	1472	765.00	2.50	0.251
NCRN_ROCR_BRBR	7/27/10	7.86	7.30	22.75	2024	733.50	2.00	0.261

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_BRBR	8/25/10	7.90	7.30	20.70	1992	1088.50	3.80	0.581
NCRN_ROCR_BRBR	9/27/10	7.60	6.93	19.60	1832	530.67	2.10	0.219
NCRN_ROCR_BRBR	10/26/10	7.21	7.41	15.98	2240	819.25	3.00	0.307
NCRN_ROCR_BRBR	11/22/10	7.97	10.30	10.63	2072	879.33	3.00	
NCRN_ROCR_BRBR	12/15/10						0.00	
NCRN_ROCR_BRBR	1/24/11						0.00	0.232
NCRN_ROCR_BRBR	2/16/11	8.50	16.90	3.70	2128	1028.00	1.40	0.241
NCRN_ROCR_BRBR	3/21/11	8.11	11.83	10.10	784	320.90	2.00	0.215
NCRN_ROCR_BRBR	4/18/11	8.56	12.77	13.20	1992	751.00	1.10	0.287
NCRN_ROCR_BRBR	5/16/11	7.65	6.87	18.70	1712	620.67	1.10	0.280
NCRN_ROCR_BRBR	6/27/11	7.96	7.90	21.45	2448	881.50	2.20	0.290
NCRN_ROCR_BRBR	7/25/11	8.18	8.17	25.97	2352	843.00	2.20	0.215
NCRN_ROCR_BRBR	8/23/11	7.74	7.85	20.50	2152	753.00	1.90	0.179
NCRN_ROCR_BRBR	9/26/11	7.96	8.65	20.75	2272	838.50	2.50	0.114
NCRN_ROCR_DUOA	10/3/07	7.78	7.79	18.30	1872	593.00	5.40	0.153
NCRN_ROCR_DUOA	11/1/07	7.79	8.34	13.00	1904	588.00	4.40	0.101
NCRN_ROCR_DUOA	11/26/07	7.80	8.75	9.90	1856	586.00	5.00	0.127
NCRN_ROCR_DUOA	1/8/08	7.79	12.51	8.80	1848	579.00	4.80	0.130
NCRN_ROCR_DUOA	2/4/08	7.79	9.67	7.20	1984	661.00	4.80	0.124
NCRN_ROCR_DUOA	3/4/08	8.39	10.19	10.30	1912	601.50	4.30	0.134
NCRN_ROCR_DUOA	4/1/08	7.83	10.34	10.40	2088	556.00	4.90	0.147
NCRN_ROCR_DUOA	4/29/08	8.04	10.75	12.90	2144	527.50	3.80	0.108
NCRN_ROCR_DUOA	6/17/08	7.93	11.67	18.70	2304	523.50	4.00	0.098
NCRN_ROCR_DUOA	7/15/08	7.80	7.76	19.80	1416	559.50	2.90	0.101
NCRN_ROCR_DUOA	8/20/08	7.99	8.01	18.95	2096	584.50	4.50	0.101
NCRN_ROCR_DUOA	9/10/08	7.95	8.43	19.20	2016	540.00	3.00	0.104
NCRN_ROCR_DUOA	10/8/08	7.99	9.92	14.00	2024	531.50	2.70	0.108
NCRN_ROCR_DUOA	10/28/08	7.90	9.98	10.90	1024	429.70	3.10	0.170
NCRN_ROCR_DUOA	11/24/08	7.97	11.56	6.00	1840	558.50	1.60	0.183
NCRN_ROCR_DUOA	1/13/09	8.04	12.68	4.60	1856	544.50	3.70	0.091
NCRN_ROCR_DUOA	2/9/09	8.27	17.30	6.00	2976	767.50	4.00	0.108
NCRN_ROCR_DUOA	5/20/09	8.24	10.10	15.00	2920	589.40	4.10	0.121
NCRN_ROCR_DUOA	6/29/09	8.18	8.70	19.40	2816	608.00	3.70	0.124
NCRN_ROCR_DUOA	8/5/09	8.21	8.50	21.10	3072	633.00	4.90	0.124
NCRN_ROCR_DUOA	9/1/09	8.26	9.10	18.20	2832	614.00	3.80	0.127
NCRN_ROCR_DUOA	9/29/09	8.17	9.30	16.30	2528	636.00	3.60	0.179
NCRN_ROCR_DUOA	10/27/09	7.97	10.00	14.00	1592	399.70	1.50	0.088
NCRN_ROCR_DUOA	11/24/09	8.08	9.85	12.30	2240	489.05	0.00	
NCRN_ROCR_DUOA	12/22/09						0.00	0.091
NCRN_ROCR_DUOA	1/26/10	8.64	12.40	8.00	1936	677.60	3.40	
NCRN_ROCR_DUOA	2/23/10						0.00	0.235
NCRN_ROCR_DUOA	3/30/10	8.28	11.30	11.70	2256	500.60	3.50	0.124
NCRN_ROCR_DUOA	4/22/10	7.75	10.10	13.30	2144	709.00	3.60	0.225
NCRN_ROCR_DUOA	5/18/10	7.99	9.70	13.90	1680	574.40	3.50	0.153
NCRN_ROCR_DUOA	6/22/10	8.03	8.40	20.90	1160	662.00	5.40	0.130

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_DUOA	7/27/10	7.94	7.70	22.00	1928	643.00	4.00	0.121
NCRN_ROCR_DUOA	8/25/10	7.99	7.90	20.00	2088	680.00	4.40	0.277
NCRN_ROCR_DUOA	9/27/10	7.85	8.40	19.20	1992	511.00	4.00	0.124
NCRN_ROCR_DUOA	10/26/10	7.03	9.14	16.00	1864	643.00	4.40	0.209
NCRN_ROCR_DUOA	11/22/10	7.94	9.80	11.40	1664	641.00	4.80	0.130
NCRN_ROCR_DUOA	12/15/10	7.77	14.10	5.60	1784	638.90	4.80	
NCRN_ROCR_DUOA	1/24/11						0.00	0.163
NCRN_ROCR_DUOA	2/16/11	8.05	14.20	5.20	1720	670.10	3.60	0.130
NCRN_ROCR_DUOA	3/21/11	8.22	11.40	11.50	1392	435.70	3.00	0.160
NCRN_ROCR_DUOA	4/18/11	7.95	9.80	13.10	2136	650.00	3.00	0.235
NCRN_ROCR_DUOA	5/16/11	7.74	8.20	16.90	1824	629.00	3.30	0.108
NCRN_ROCR_DUOA	6/27/11	7.94	8.00	19.70	2048	646.00	3.70	0.372
NCRN_ROCR_DUOA	7/25/11	7.91	6.90	23.70	1792	604.00	3.50	0.238
NCRN_ROCR_DUOA	8/23/11	7.79	8.50	19.70	2080	612.00	2.90	0.111
NCRN_ROCR_DUOA	9/26/11	7.81	8.40	19.80	2112	665.00	3.70	0.408
NCRN_ROCR_EGWA	6/27/05	8.25	8.57	24.00	1264	450.40	1.00	
NCRN_ROCR_EGWA	10/4/05	8.01	5.96	19.22	1120	618.67	0.90	
NCRN_ROCR_EGWA	11/3/05	7.86	8.21	10.80	980	399.20	1.80	
NCRN_ROCR_EGWA	12/8/05	7.50	11.50	2.00	1220	1105.00	0.60	
NCRN_ROCR_EGWA	1/3/06	7.64	5.13	5.80	1020	444.20	3.10	
NCRN_ROCR_EGWA	2/14/06	7.55	12.22	3.20	928	2577.00	0.90	
NCRN_ROCR_EGWA	3/8/06	8.91	6.89	6.05	1072	433.05	1.20	
NCRN_ROCR_EGWA	4/4/06	7.70	3.91	15.10	952	432.60	1.10	
NCRN_ROCR_EGWA	5/4/06	8.58	2.92	19.20	592	392.30	2.60	
NCRN_ROCR_EGWA	6/1/06	8.10	2.47	24.80	1360	389.50	1.80	
NCRN_ROCR_EGWA	7/20/06	8.23	7.26	27.00	1472	389.50	1.80	
NCRN_ROCR_EGWA	8/3/06	8.17	6.40	28.40	1616	424.40	2.50	
NCRN_ROCR_EGWA	9/12/06	7.91	9.09	19.30	1496	384.20	1.20	
NCRN_ROCR_EGWA	10/11/06	8.03	8.61	16.30	1176	303.70	2.50	
NCRN_ROCR_EGWA	11/21/06	7.94	10.84	8.58	880	238.00	1.90	
NCRN_ROCR_EGWA	12/21/06	8.62	9.90	5.87	1208	392.27	0.00	
NCRN_ROCR_EGWA	3/19/07	7.81	10.45	6.00	864	557.00	4.06	0.085
NCRN_ROCR_EGWA	4/18/07	7.89	10.95	9.60	840	293.70	5.23	0.068
NCRN_ROCR_EGWA	5/22/07	7.82	6.12	18.80	1432	413.80	1.79	0.065
NCRN_ROCR_EGWA	6/25/07	8.28	7.50	22.60	992	492.50	0.70	0.104
NCRN_ROCR_EGWA	7/30/07	7.93	5.99	25.20	1600	406.30	0.60	0.160
NCRN_ROCR_EGWA	9/4/07	8.25	5.89	22.70	1960	612.00	0.90	0.780
NCRN_ROCR_HACR	10/4/05	7.72	7.99	17.85	1296	844.00	1.40	
NCRN_ROCR_HACR	11/3/05	7.93	8.91	10.40	1580	847.00	2.70	
NCRN_ROCR_HACR	12/8/05	7.80	12.20	2.40	1910	1737.00	1.40	
NCRN_ROCR_HACR	1/3/06	7.73	4.78	7.50	1440	601.00	3.30	
NCRN_ROCR_HACR	2/14/06	7.53	11.30	4.85	1568	1696.00	1.80	
NCRN_ROCR_HACR	3/8/06	8.48	8.30	5.80	1664	772.00	1.70	
NCRN_ROCR_HACR	4/4/06	7.93	4.01	13.10	1664	727.00	1.80	
NCRN_ROCR_HACR	5/4/06	7.58	2.14	16.10	1288	717.00	4.20	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_HACR	6/1/06	7.73	2.30	21.40	2440	748.00	3.90	
NCRN_ROCR_HACR	7/20/06	7.83	7.05	23.30	2064	782.00	3.80	
NCRN_ROCR_HACR	8/3/06	7.88	5.82	24.90	2176	743.00	3.60	
NCRN_ROCR_HACR	9/12/06	7.51	8.82	17.40	2096	804.00	2.30	
NCRN_ROCR_HACR	10/11/06	7.77	7.96	15.85	1848	810.00	13.50	
NCRN_ROCR_HACR	11/21/06	7.97	10.66	7.50	2000	758.00	3.50	
NCRN_ROCR_HACR	12/21/06	8.15	8.73	7.50	2016	819.00	0.00	
NCRN_ROCR_HACR	1/30/07		12.90	2.50	1560	807.00	1.17	0.166
NCRN_ROCR_HACR	3/19/07	8.06	11.32	5.60	1304	645.50	2.66	0.173
NCRN_ROCR_HACR	4/18/07	7.86	10.24	10.60	1576	599.25	2.59	0.202
NCRN_ROCR_HACR	5/22/07	7.82	7.31	16.20	1896	656.50	2.54	0.254
NCRN_ROCR_HACR	6/25/07	7.86	6.73	20.30	1960	637.00	1.40	0.300
NCRN_ROCR_HACR	7/30/07	7.86	6.63	22.50	2232	582.00	1.00	0.336
NCRN_ROCR_HACR	9/4/07	7.74	5.78	20.50	1728	813.00	2.00	
NCRN_ROCR_HACR	10/11/07						0.00	0.225
NCRN_ROCR_HACR	11/5/07	7.78	7.62	9.30	2232	914.00	4.40	0.225
NCRN_ROCR_HACR	12/3/07	7.83	9.47	7.90	1896	553.00	2.00	0.199
NCRN_ROCR_HACR	1/24/08		12.89	1.40	2160	1103.00	3.50	0.215
NCRN_ROCR_HACR	2/20/08	8.00	11.29	3.70	1976	1000.00	2.90	0.166
NCRN_ROCR_HACR	3/18/08	8.48	10.76	8.40	1968	770.00	2.10	0.153
NCRN_ROCR_HACR	4/8/08	8.19	12.39	9.25	2016	739.00	2.70	0.258
NCRN_ROCR_HACR	6/16/08	7.90	8.24	20.35	2424	820.00	3.20	0.192
NCRN_ROCR_HACR	7/14/08	7.72	8.11	22.20	1008	203.95	1.70	0.509
NCRN_ROCR_HACR	8/21/08	8.00	7.45	19.30	2368	841.00	3.00	0.294
NCRN_ROCR_HACR	9/11/08	8.08	7.92	18.90	1952	791.50	2.10	0.323
NCRN_ROCR_HACR	10/8/08	7.97	9.78	12.90	2112	807.50	2.70	0.267
NCRN_ROCR_HACR	10/28/08	7.87	10.10	9.80	1824	523.50	1.70	0.202
NCRN_ROCR_HACR	11/24/08	7.93	12.28	3.80	2120	812.50	1.70	0.127
NCRN_ROCR_HACR	1/13/09	7.99	11.49	3.85		723.50	3.00	0.137
NCRN_ROCR_HACR	2/9/09	8.05	15.01	3.80	2024	1102.50	2.70	0.147
NCRN_ROCR_HACR	4/8/09	8.48	12.13	9.50	1984	842.50	2.90	0.170
NCRN_ROCR_HACR	5/20/09	7.96	9.00	15.40	2080	768.00	2.70	0.274
NCRN_ROCR_HACR	6/29/09	8.08	8.50	19.60	2336	747.00	2.30	0.205
NCRN_ROCR_HACR	8/5/09	8.04	8.60	21.10	1992	764.00	3.10	0.219
NCRN_ROCR_HACR	9/1/09	8.10	9.10	17.10	2056	805.00	4.40	0.173
NCRN_ROCR_HACR	9/29/09	8.02	9.70	14.90	1792	746.00	2.00	0.235
NCRN_ROCR_HACR	10/27/09	7.61	10.50	13.30	624	128.00	0.50	0.356
NCRN_ROCR_HACR	11/24/09	7.88	10.20	12.10	1712	412.70	0.40	
NCRN_ROCR_HACR	12/22/09						0.00	0.130
NCRN_ROCR_HACR	1/26/10	8.30	12.90	7.40	1912	799.00	2.10	
NCRN_ROCR_HACR	2/23/10						0.00	0.232
NCRN_ROCR_HACR	3/30/10	8.09	12.50	10.20	1976	768.00	2.20	0.170
NCRN_ROCR_HACR	4/22/10	7.74	10.40	13.20	2072	516.60	2.50	0.267
NCRN_ROCR_HACR	5/18/10	8.00	10.10	13.60	1712	641.00	2.30	0.352
NCRN_ROCR_HACR	6/22/10	7.99	8.30	21.50	1384	674.00	3.20	0.241

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_HACR	7/27/10	7.90	7.10	21.80	2008	787.00	1.90	0.251
NCRN_ROCR_HACR	8/25/10	8.01	8.00	19.60	1920	790.00	3.20	0.404
NCRN_ROCR_HACR	9/27/10	7.86	8.20	19.10	2008	596.00	2.90	0.238
NCRN_ROCR_HACR	10/26/10	7.32	6.38	15.70	2136	795.00	2.80	0.303
NCRN_ROCR_HACR	11/22/10	8.00	10.40	11.00	1832	792.00	2.70	0.261
NCRN_ROCR_HACR	12/15/10	7.78	14.80	4.30	1944	811.30	7.80	
NCRN_ROCR_HACR	1/24/11						0.00	0.228
NCRN_ROCR_HACR	2/16/11	8.25	15.40	3.60	1904	1014.00	1.70	0.192
NCRN_ROCR_HACR	3/21/11	7.79	10.60	10.30	1112	439.70	2.10	0.258
NCRN_ROCR_HACR	4/18/11	7.82	9.50	13.10	1688	705.00	1.80	0.359
NCRN_ROCR_HACR	5/16/11	7.65	7.90	17.70	1696	693.00	1.50	0.261
NCRN_ROCR_HACR	6/27/11	7.91	7.90	20.30	2240	850.00	1.90	0.724
NCRN_ROCR_HACR	7/25/11	8.00	6.80	24.70	2368	691.00	2.50	0.258
NCRN_ROCR_HACR	8/23/11	7.76	8.10	19.10	2144	734.00	1.40	0.248
NCRN_ROCR_HACR	9/26/11	7.91	8.30	20.20	2016	746.00	2.40	0.108
NCRN_ROCR_KLVA	10/27/09	7.61	9.80	13.60	1328	349.30	1.30	0.078
NCRN_ROCR_KLVA	11/24/09	7.64	10.02	11.60	1704	384.40	0.00	
NCRN_ROCR_KLVA	12/22/09						0.00	0.065
NCRN_ROCR_KLVA	1/26/10	7.59	12.70	7.20	1304	750.40	3.30	
NCRN_ROCR_KLVA	2/23/10						0.00	0.176
NCRN_ROCR_KLVA	3/30/10	7.63	12.10	10.40	1752	702.00	3.00	0.065
NCRN_ROCR_KLVA	4/22/10	7.42	9.50	12.50	1504	712.00	3.50	0.222
NCRN_ROCR_KLVA	5/18/10	7.57	9.70	13.60	1320	550.70	3.10	0.196
NCRN_ROCR_KLVA	6/22/10	7.63	7.60	21.00	1232	836.00	4.30	
NCRN_ROCR_KLVA	7/27/10						0.00	0.091
NCRN_ROCR_KLVA	8/25/10	7.59	7.00	20.00	1880	792.00	4.30	0.398
NCRN_ROCR_KLVA	9/27/10	7.61	8.40	19.40	1920	506.70	2.30	0.085
NCRN_ROCR_KLVA	10/26/10	6.59	7.20	15.30	1984	731.00	3.80	0.192
NCRN_ROCR_KLVA	11/22/10	7.52	9.40	10.50	1568	729.00	3.70	0.127
NCRN_ROCR_KLVA	12/15/10	7.58	14.30	4.80	1632	707.20	3.40	
NCRN_ROCR_KLVA	1/24/11						0.00	0.300
NCRN_ROCR_KLVA	2/16/11	7.69	14.30	3.70	1592	815.30	2.70	0.124
NCRN_ROCR_KLVA	3/21/11	7.26	10.90	10.50	1264	540.60	3.20	0.150
NCRN_ROCR_KLVA	4/18/11	7.32	9.40	12.60	1496	720.00	1.90	0.176
NCRN_ROCR_KLVA	5/16/11	7.11	6.30	16.40	1584	746.00	2.30	0.114
NCRN_ROCR_KLVA	6/27/11	7.31	5.90	19.80	2200	918.00	2.70	0.153
NCRN_ROCR_KLVA	7/25/11	7.12	3.70	24.50	2376	1081.00	2.90	0.095
NCRN_ROCR_KLVA	8/23/11	7.49	7.30	19.00	1992	772.00	3.70	0.075
NCRN_ROCR_KLVA	9/26/11	7.57	8.00	19.80	2616	812.00	3.20	0.258
NCRN_ROCR_NOST	10/3/07	7.47	3.82	19.50	1680	702.00	5.80	0.189
NCRN_ROCR_NOST	11/1/07	7.57	6.95	13.30	1304	639.00	4.60	0.085
NCRN_ROCR_NOST	11/26/07	7.52	7.69	9.60	1216	648.00	5.80	0.088
NCRN_ROCR_NOST	1/8/08	7.62	11.68	9.60	1016	634.00	5.90	0.091
NCRN_ROCR_NOST	2/4/08	7.60	10.90	7.10	1248	694.00	5.40	0.153
NCRN_ROCR_NOST	3/4/08	8.30	10.49	11.70	1280	633.50	5.00	0.238

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_NOST	4/1/08	7.80	9.48	14.25	1280	538.50	5.10	0.140
NCRN_ROCR_NOST	4/29/08	7.71	8.58	12.85	1408	589.00	4.70	0.098
NCRN_ROCR_NOST	6/17/08	7.67	8.09	18.90	1416	604.50	4.60	0.098
NCRN_ROCR_NOST	7/15/08	7.59	6.71	20.52	568	625.75	4.30	0.098
NCRN_ROCR_NOST	8/20/08	7.59	4.14	20.05	1272	680.00	4.90	0.085
NCRN_ROCR_NOST	9/10/08	7.69	7.20	19.60	1016	608.00	4.10	0.091
NCRN_ROCR_NOST	10/8/08	7.48	5.09	14.20	912	651.00	4.90	0.101
NCRN_ROCR_NOST	10/28/08	7.41	6.66	10.80	1128	406.00	3.00	0.065
NCRN_ROCR_NOST	11/24/08	7.51	5.94	5.70	1384	656.50	4.90	0.049
NCRN_ROCR_NOST	1/13/09	7.86	10.14	4.20	1480	648.50	4.80	0.072
NCRN_ROCR_NOST	2/9/09	8.06	13.81	5.60	1360	732.00	2.60	0.088
NCRN_ROCR_NOST	5/20/09	7.66	7.50	14.70	1280	703.50	5.00	0.085
NCRN_ROCR_NOST	6/29/09	7.72	7.70	19.35	1240	682.00	4.50	0.098
NCRN_ROCR_NOST	8/5/09						5.00	0.108
NCRN_ROCR_NOST	9/1/09	7.44	5.60	18.30	1320	666.00	5.00	0.117
NCRN_ROCR_NOST	9/29/09	7.48	6.00	15.90	1304	638.00	4.40	0.114
NCRN_ROCR_NOST	10/27/09	7.58	9.00	13.90	976	281.40	1.30	0.072
NCRN_ROCR_NOST	11/24/09	7.75	9.60	12.10	1240	382.90	0.00	
NCRN_ROCR_NOST	12/22/09						0.00	0.049
NCRN_ROCR_NOST	1/26/10	8.34	12.00	7.90	960	738.00	4.50	
NCRN_ROCR_NOST	2/23/10						0.00	0.179
NCRN_ROCR_NOST	3/30/10	8.34	10.90	12.35	2336	745.00	4.40	0.085
NCRN_ROCR_NOST	4/22/10	7.78	8.70	13.50	1120	705.00	4.40	0.215
NCRN_ROCR_NOST	5/18/10	7.53	8.50	13.90	1008	531.80	4.20	0.219
NCRN_ROCR_NOST	6/22/10	7.44	5.80	21.30	720	699.00	5.60	0.140
NCRN_ROCR_NOST	7/27/10	7.44	6.10	21.40	1136	677.00	4.20	0.095
NCRN_ROCR_NOST	8/25/10	7.63	4.90	20.30	1184	714.00	5.40	0.326
NCRN_ROCR_NOST	9/27/10	7.36	3.20	20.70	1288	439.00	3.70	0.095
NCRN_ROCR_NOST	10/26/10	6.56	6.25	16.40	1104	704.00	5.50	0.179
NCRN_ROCR_NOST	11/22/10	7.34	8.30	12.25	1144	792.00	5.70	0.166
NCRN_ROCR_NOST	12/15/10	7.61	14.50	5.00	984	713.50	4.90	
NCRN_ROCR_NOST	1/24/11						0.00	0.111
NCRN_ROCR_NOST	2/16/11	8.09	13.80	6.00	1184	804.00	3.90	0.196
NCRN_ROCR_NOST	3/21/11	8.08	10.40	12.00	864	498.30	2.70	0.179
NCRN_ROCR_NOST	4/18/11	7.53	7.90	13.35	1168	731.00	3.60	0.307
NCRN_ROCR_NOST	5/16/11	7.32	6.95	17.10	1072	685.00	3.60	0.176
NCRN_ROCR_NOST	6/27/11	7.39	6.10	20.10	1224	713.00	4.60	0.271
NCRN_ROCR_NOST	7/25/11	7.32	4.70	24.60	1336	709.50	4.90	0.219
NCRN_ROCR_NOST	8/23/11	7.49	5.95	20.80	1424	629.00	4.10	0.179
NCRN_ROCR_NOST	9/26/11	7.50	6.95	19.90	1144	745.00	5.40	0.209
NCRN_ROCR_PYBR	10/4/05	7.46	7.23	19.00	1232	653.00	1.80	
NCRN_ROCR_PYBR	11/3/05	7.85	9.23	10.40	1340	624.00	2.70	
NCRN_ROCR_PYBR	12/8/05	7.42	8.78	1.95	1400	792.00	2.40	
NCRN_ROCR_PYBR	1/3/06	7.58	4.54	7.30	970	389.95	3.90	
NCRN_ROCR_PYBR	2/14/06	7.52	11.63	4.50	1328	1170.50	2.20	

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_PYBR	3/8/06	8.08	8.68	6.70	1464	546.00	2.30	
NCRN_ROCR_PYBR	4/4/06	7.61	3.78	15.00	1256	451.60	1.70	
NCRN_ROCR_PYBR	5/4/06	8.36	3.39	21.40	1488	552.00	5.30	
NCRN_ROCR_PYBR	6/1/06	8.23	2.96	25.60	1512	574.00	4.40	
NCRN_ROCR_PYBR	7/20/06	7.67	5.99	23.10	1776	458.60	2.30	
NCRN_ROCR_PYBR	8/3/06	8.44	8.73	29.40	1872	633.00	3.70	
NCRN_ROCR_PYBR	9/12/06	7.51	7.96	18.70	1776	655.00	3.30	
NCRN_ROCR_PYBR	10/11/06	7.97	7.03	16.60	1768	593.00	3.90	
NCRN_ROCR_PYBR	11/21/06	7.96	11.50	7.30	1600	606.00	5.40	
NCRN_ROCR_PYBR	12/21/06	8.51	11.53	6.50	1528	595.50	0.00	
NCRN_ROCR_PYBR	1/30/07		15.12	0.85	1312	556.64	1.70	0.026
NCRN_ROCR_PYBR	3/19/07	8.12	12.87	6.20	1216	587.33	2.89	0.062
NCRN_ROCR_PYBR	4/18/07	8.61	14.01	11.10	1208	518.67	2.30	0.121
NCRN_ROCR_PYBR	5/22/07	7.73	7.99	19.35	1480	646.50	4.09	0.104
NCRN_ROCR_PYBR	6/25/07	8.23	8.59	22.50	1768	670.00	1.50	0.130
NCRN_ROCR_PYBR	7/30/07	8.30	7.53	24.60	1856	586.00	1.50	0.104
NCRN_ROCR_PYBR	9/4/07	8.76	9.45	23.30	3048	640.00	2.00	0.163
NCRN_ROCR_PYBR	10/11/07	7.59	6.68	17.50	2304	658.00	3.10	0.108
NCRN_ROCR_PYBR	11/5/07	7.84	8.80	9.00	1928	644.00	4.00	0.150
NCRN_ROCR_PYBR	12/3/07	7.44	6.41	7.20	1264	317.10	2.00	0.088
NCRN_ROCR_PYBR	1/24/08		12.98	0.50	1848	694.00	3.80	0.095
NCRN_ROCR_PYBR	2/20/08	8.20	12.66	3.18	1760	700.00	3.50	0.065
NCRN_ROCR_PYBR	3/18/08	8.61	12.42	8.78	1848	614.33	2.50	0.072
NCRN_ROCR_PYBR	4/8/08	8.20	12.79	9.67	1848	587.75	2.00	0.101
NCRN_ROCR_PYBR	6/16/08	8.14	9.47	23.40	2344	674.75	3.90	0.127
NCRN_ROCR_PYBR	7/14/08	7.36	6.11	23.70	904	209.02	1.70	0.078
NCRN_ROCR_PYBR	8/21/08	8.12	9.89	21.80	2160	693.50	2.40	0.124
NCRN_ROCR_PYBR	10/8/08	7.97	9.51	13.70	1704	655.50	3.00	0.104
NCRN_ROCR_PYBR	10/28/08	7.43	8.10	9.65	1544	393.98	2.00	0.078
NCRN_ROCR_PYBR	11/24/08	7.74	12.45	3.40	1936	663.00	3.20	0.101
NCRN_ROCR_PYBR	1/13/09	7.94	13.66	2.85	1888	629.00	3.40	
NCRN_ROCR_PYBR	2/9/09	7.91	15.90	3.25	1640	776.50	3.50	0.088
NCRN_ROCR_PYBR	5/20/09	8.21	10.30	20.45	1720	628.50	3.80	0.117
NCRN_ROCR_PYBR	6/29/09	7.74	7.75	23.30	1824	625.00	3.00	0.124
NCRN_ROCR_PYBR	8/5/09	7.74	7.35	23.35	2000	661.00	3.30	0.114
NCRN_ROCR_PYBR	9/1/09	8.26	10.40	19.45	1656	642.50	4.00	0.127
NCRN_ROCR_PYBR	9/29/09	7.81	9.55	16.00	2096	665.50	2.30	0.117
NCRN_ROCR_PYBR	10/27/09	7.24	8.00	13.50	744	168.80	0.80	0.117
NCRN_ROCR_PYBR	11/24/09	7.50	9.90	11.30	1160	268.85	1.40	
NCRN_ROCR_PYBR	12/22/09						0.00	0.049
NCRN_ROCR_PYBR	1/26/10	8.07	14.30	6.90	1552	714.00	2.50	
NCRN_ROCR_PYBR	2/23/10						0.00	0.160
NCRN_ROCR_PYBR	3/30/10	7.78	12.85	11.00	1888	590.50	2.80	0.085
NCRN_ROCR_PYBR	4/22/10	7.40	8.80	15.70	1560	611.00	3.10	0.199
NCRN_ROCR_PYBR	5/18/10	7.55	8.60	14.30	1328	541.60	2.90	0.245

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_PYBR	6/22/10	7.88	9.00	24.40	1472	738.00	2.80	0.124
NCRN_ROCR_PYBR	7/27/10	7.70	6.40	24.50	2080	719.00	1.80	0.114
NCRN_ROCR_PYBR	8/25/10	8.04	8.40	21.30	1864	698.00	3.60	0.349
NCRN_ROCR_PYBR	9/27/10	7.60	5.75	20.00	2088	581.00	2.90	0.121
NCRN_ROCR_PYBR	10/26/10	7.13	6.68	16.45	1936	693.50	3.40	0.199
NCRN_ROCR_PYBR	11/22/10	7.76	10.80	10.60	1648	723.00	3.50	
NCRN_ROCR_PYBR	12/15/10						0.00	
NCRN_ROCR_PYBR	1/24/11						0.00	0.114
NCRN_ROCR_PYBR	2/16/11	7.97	15.50	3.10	1704	778.10	1.90	0.114
NCRN_ROCR_PYBR	3/21/11	7.87	11.80	11.40	800	349.40	2.60	0.140
NCRN_ROCR_PYBR	4/18/11	7.75	11.20	14.10	1576	626.50	1.50	0.202
NCRN_ROCR_PYBR	5/16/11	7.40	6.90	20.60	1552	675.00	1.20	0.144
NCRN_ROCR_PYBR	6/27/11	7.83	7.70	22.60	2144	737.00	1.90	0.111
NCRN_ROCR_PYBR	7/25/11	8.28	9.45	28.15	1928	751.00	1.40	0.124
NCRN_ROCR_PYBR	8/23/11	7.47	7.05	20.90	2088	729.50	1.40	0.137
NCRN_ROCR_PYBR	9/26/11	7.84	8.95	21.35	2040	739.50	3.00	0.117
NCRN_ROCR_ROC3	10/3/07	7.63	6.45	19.80	1864	469.70	2.10	0.130
NCRN_ROCR_ROC3	11/1/07	7.73	8.25	11.70	1472	390.10	1.90	0.098
NCRN_ROCR_ROC3	11/26/07	7.80	9.30	7.80	1872	437.80	2.30	0.114
NCRN_ROCR_ROC3	1/8/08	7.59	12.40	5.30	1448	502.00	1.90	0.104
NCRN_ROCR_ROC3	2/4/08	7.54	10.78	4.80	1136	460.30	1.80	0.082
NCRN_ROCR_ROC3	3/4/08	8.43	11.46	9.06	1384	1002.25	2.10	0.085
NCRN_ROCR_ROC3	4/1/08	7.77	9.24	9.65	1504	535.00	2.10	0.153
NCRN_ROCR_ROC3	4/29/08	7.78	10.09	14.00	1272	214.35	2.80	0.062
NCRN_ROCR_ROC3	6/17/08	7.71	9.22	21.80	1360	267.80	1.60	0.085
NCRN_ROCR_ROC3	7/15/08	7.44	7.15	22.79	1240	235.08	1.00	0.111
NCRN_ROCR_ROC3	8/20/08	8.05	7.86	21.83	2000	568.50	1.50	0.059
NCRN_ROCR_ROC3	9/10/08	7.93	7.54	21.45	1040	226.98	1.00	0.065
NCRN_ROCR_ROC3	10/8/08	8.02	10.20	14.60	1424	407.67	1.50	0.059
NCRN_ROCR_ROC3	10/28/08	7.68	10.20	10.48	1320	292.81	1.10	0.101
NCRN_ROCR_ROC3	11/24/08	7.87	13.10	3.16	1512	445.89	3.70	0.065
NCRN_ROCR_ROC3	1/13/09	7.81	13.45	2.33	1064	376.87	2.00	0.059
NCRN_ROCR_ROC3	2/9/09	7.91	14.10	3.26	1176	953.00	2.80	0.108
NCRN_ROCR_ROC3	5/20/09	8.06	9.50	17.98	1560	449.28	1.70	0.101
NCRN_ROCR_ROC3	6/29/09	8.01	8.57	22.19	1656	402.29	1.40	0.101
NCRN_ROCR_ROC3	8/5/09	8.02	8.48	23.94	1664	429.60	2.10	0.091
NCRN_ROCR_ROC3	9/1/09	8.08	8.97	20.68	1032	309.33	1.70	0.130
NCRN_ROCR_ROC3	9/29/09	8.02	9.73	16.98	1384	299.33	1.00	0.316
NCRN_ROCR_ROC3	10/27/09	7.47	10.20	13.20	808	177.40	0.60	0.248
NCRN_ROCR_ROC3	11/24/09	7.61	10.70	10.60	992	152.70	1.00	
NCRN_ROCR_ROC3	12/22/09						0.00	0.095
NCRN_ROCR_ROC3	1/26/10	8.00	12.20	7.90	1192	679.70	1.50	
NCRN_ROCR_ROC3	2/23/10						0.00	0.166
NCRN_ROCR_ROC3	3/30/10	8.44	12.35	11.90	2016	497.95	1.60	0.020
NCRN_ROCR_ROC3	4/22/10	8.24	11.04	15.34	1640	506.33	0.70	0.205

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_ROC3	5/18/10	7.90	9.20	15.40	1288	410.30	2.20	0.228
NCRN_ROCR_ROC3	6/22/10	7.97	7.87	24.73	1176	560.17	2.70	0.098
NCRN_ROCR_ROC3	7/27/10	7.76	7.54	25.20	1104	300.09	1.60	0.088
NCRN_ROCR_ROC3	8/25/10	7.95	7.73	22.30	1368	396.57	1.70	0.219
NCRN_ROCR_ROC3	9/27/10	7.75	7.93	20.55	1464	429.48	1.60	0.082
NCRN_ROCR_ROC3	10/26/10	7.08	8.49	15.50	1432	468.40	4.00	0.166
NCRN_ROCR_ROC3	11/22/10	8.00	11.40	10.22	1224	432.70	2.00	0.075
NCRN_ROCR_ROC3	12/15/10	7.77	14.70	5.30	1296	394.40	2.20	
NCRN_ROCR_ROC3	1/24/11						0.00	0.072
NCRN_ROCR_ROC3	2/16/11	8.51	16.12	4.77	1280	757.15	1.50	0.144
NCRN_ROCR_ROC3	3/21/11	7.90	11.20	11.20	1040	422.80	2.30	0.098
NCRN_ROCR_ROC3	4/18/11	7.78	9.50	14.00	1144	335.00	1.20	0.277
NCRN_ROCR_ROC3	5/16/11	7.56	6.80	19.60	1040	272.50	1.60	0.088
NCRN_ROCR_ROC3	6/27/11	7.83	6.96	22.74	1832	602.00	1.30	0.108
NCRN_ROCR_ROC3	7/25/11	7.59	6.40	27.20	1928	567.00	1.80	0.121
NCRN_ROCR_ROC3	8/23/11	7.65	7.48	22.20	1160	276.56	1.00	0.075
NCRN_ROCR_ROC3	9/26/11	7.93	8.58	21.30	1336	376.25	1.60	0.463
NCRN_ROCR_SVPS	11/3/05	7.41	7.64	11.20	1340	706.00	3.10	
NCRN_ROCR_SVPS	12/8/05	8.07	13.71	2.05	2150	1580.00	1.70	
NCRN_ROCR_SVPS	1/3/06	7.78	4.99	8.10	1240	456.90	3.60	
NCRN_ROCR_SVPS	2/14/06	8.14	13.38	4.90	1744	2171.00	1.70	
NCRN_ROCR_SVPS	3/8/06	8.88	10.72	5.50	2080	736.00	1.70	
NCRN_ROCR_SVPS	4/4/06	8.95	5.59	13.65	1584	550.00	2.00	
NCRN_ROCR_SVPS	5/4/06	8.19	2.58	16.70	2288	701.00	4.60	
NCRN_ROCR_SVPS	6/1/06	7.84	3.28	21.70	2552	722.00	3.40	
NCRN_ROCR_SVPS	7/20/06	7.97	7.21	23.50	2336	757.00	4.70	
NCRN_ROCR_SVPS	8/3/06	7.97	6.13	24.90	2544	776.00	4.10	
NCRN_ROCR_SVPS	9/12/06	7.58	8.41	18.00	2320	711.00	2.40	
NCRN_ROCR_SVPS	10/11/06	7.88	8.72	16.50	2376	603.00	4.20	
NCRN_ROCR_SVPS	11/21/06	8.19	11.10	7.50	1960	774.00	4.30	
NCRN_ROCR_SVPS	12/21/06	8.35	9.71	6.50	1544	782.50	0.00	
NCRN_ROCR_SVPS	1/30/07		13.55	0.85	2320	879.61	1.31	0.036
NCRN_ROCR_SVPS	3/19/07	8.19	11.95	4.30	1952	775.50	1.96	0.075
NCRN_ROCR_SVPS	4/18/07	8.55	13.88	9.60	1968	714.67	1.75	0.323
NCRN_ROCR_SVPS	5/22/07	7.87	7.12	15.20	2408	845.75	2.34	0.356
NCRN_ROCR_SVPS	6/25/07	7.94	7.37	20.30	1808	771.00	1.70	0.205
NCRN_ROCR_SVPS	7/30/07	7.94	6.82	23.10	2168	569.00	1.10	0.333
NCRN_ROCR_SVPS	9/4/07	8.12	6.73	20.70	2352	831.00	2.40	0.323
NCRN_ROCR_SVPS	10/11/07	8.06	6.59	17.50	3128	847.00	3.00	0.294
NCRN_ROCR_SVPS	11/5/07	8.09	9.12	9.70	2736	774.00	3.70	0.287
NCRN_ROCR_SVPS	12/3/07	7.76	9.21	8.20	1560	326.90	1.90	0.157
NCRN_ROCR_SVPS	1/24/08		13.60	0.85	2448	1118.00	4.30	0.153
NCRN_ROCR_SVPS	2/20/08	8.07	11.96	3.40	2568	927.00	3.40	0.095
NCRN_ROCR_SVPS	3/18/08	8.28	11.29	8.02	2480	831.00	3.40	0.078
NCRN_ROCR_SVPS	4/8/08	8.16	12.24	9.62	2472	748.50	2.90	0.104

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
NCRN_ROCR_SVPS	6/16/08	7.91	8.26	19.90	2056	865.00	1.80	0.147
NCRN_ROCR_SVPS	7/14/08	7.76	7.86	22.50	1240	245.08	2.10	0.241
NCRN_ROCR_SVPS	8/21/08	8.09	5.62	19.05	2344	903.75	4.10	0.277
NCRN_ROCR_SVPS	9/11/08	8.12	6.68	19.80	2256	732.25	3.00	0.212
NCRN_ROCR_SVPS	10/8/08	7.86	8.07	12.82	2048	858.75	3.50	0.147
NCRN_ROCR_SVPS	10/28/08	7.73	9.33	11.40	1520	364.93	1.80	0.183
NCRN_ROCR_SVPS	11/24/08	8.00	11.35	2.77	1968	905.00	2.60	0.117
NCRN_ROCR_SVPS	1/13/09	8.01	12.22	3.20	2392	833.75	2.90	0.121
NCRN_ROCR_SVPS	2/9/09	7.90	13.90	3.53	2568	1121.75	3.90	0.091
NCRN_ROCR_SVPS	4/8/09	8.78	11.78	8.22	2512	870.25	2.60	0.192
NCRN_ROCR_SVPS	5/20/09	8.06	9.60	14.10	2488	791.50	2.80	0.137
NCRN_ROCR_SVPS	6/29/09	7.97	8.00	19.37	3112	827.00	2.70	0.245
NCRN_ROCR_SVPS	8/5/09	8.03	6.80	21.50	2432	855.33	3.10	0.202
NCRN_ROCR_SVPS	9/1/09	8.06	7.85	17.40	2544	880.00	3.80	0.209
NCRN_ROCR_SVPS	9/29/09	7.82	6.85	14.90	1712	759.00	2.40	0.166
NCRN_ROCR_SVPS	10/27/09	7.70	9.80	13.70	952	186.80	0.90	
NCRN_ROCR_SVPS	11/24/09	7.80	9.80	11.80	1296	260.55	0.90	
NCRN_ROCR_SVPS	12/22/09						0.00	0.101
NCRN_ROCR_SVPS	1/26/10	8.28	12.85	7.50	1864	843.00	2.00	
NCRN_ROCR_SVPS	2/23/10						0.00	0.215
NCRN_ROCR_SVPS	3/30/10	8.15	11.70	10.00	2088	870.50	1.90	0.176
NCRN_ROCR_SVPS	4/22/10	7.77	8.90	12.90	2040	749.00	2.20	0.280
NCRN_ROCR_SVPS	5/18/10	7.94	9.05	14.20	1712	597.70	2.40	0.290
NCRN_ROCR_SVPS	6/22/10	7.78	5.65	20.90	1696	913.50	3.70	0.245
NCRN_ROCR_SVPS	7/27/10	7.84	6.70	21.90	2424	881.00	2.80	0.248
NCRN_ROCR_SVPS	8/25/10	7.74	7.60	20.10	2096	1096.00	4.00	0.590
NCRN_ROCR_SVPS	9/27/10	7.74	7.90	19.80	1832	406.00	2.10	0.228
NCRN_ROCR_SVPS	10/26/10	7.28	8.47	15.70	2560	882.00	3.00	0.183
NCRN_ROCR_SVPS	11/22/10	8.00	10.40	10.30	2136	727.00	3.20	
NCRN_ROCR_SVPS	12/15/10						0.00	
NCRN_ROCR_SVPS	1/24/11						0.00	0.137
NCRN_ROCR_SVPS	2/16/11	8.23	15.80	2.60	2192	1109.00	1.80	0.134
NCRN_ROCR_SVPS	3/21/11	8.04	11.70	9.90	784	303.70	2.30	0.205
NCRN_ROCR_SVPS	4/18/11	8.25	11.40	12.80	1920	699.00	1.30	0.310
NCRN_ROCR_SVPS	5/16/11	7.65	7.60	17.70	1816	640.00	1.10	
NCRN_ROCR_SVPS	6/27/11						0.00	
NCRN_ROCR_SVPS	9/26/11						0.00	0.025
RCM0009	10/18/00	7.80	8.70	15.70		414.00	4.63	0.059
RCM0009	11/16/00	7.70	10.70	6.10		340.00	0.11	0.047
RCM0009	12/6/00	7.60	12.90	0.70		360.00	4.57	0.064
RCM0009	1/10/01	7.70	13.20	2.50		1465.00	8.56	0.045
RCM0009	2/7/01	7.60	12.90	3.40		919.00	5.22	0.140
RCM0009	3/21/01	7.50	11.40	7.50		360.00	4.09	0.053
RCM0009	4/18/01	7.70	10.40	9.40		317.00	4.24	0.036
RCM0009	5/16/01	7.70	8.60	15.10		433.00	4.19	0.049

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
RCM0009	6/20/01	7.60	7.90	22.60		319.00	3.44	0.032
RCM0009	7/25/01	7.70	7.00	24.70		437.00	3.65	0.039
RCM0009	8/8/01	7.80	6.90	25.00		440.00	3.56	0.043
RCM0009	9/19/01	7.70	8.30	18.50		457.00	4.55	0.035
RCM0009	10/18/01	7.70	9.70	10.50		315.00	1.47	0.050
RCM0009	11/7/01	7.70	10.30	9.60		507.00	1.90	0.036
RCM0009	12/19/01	7.80	10.00	7.50		346.00	3.78	0.031
RCM0009	1/24/02	7.60	11.90	5.30		3180.00	5.91	0.021
RCM0009	2/21/02	7.60	11.50	7.60		530.00	4.11	0.075
RCM0009	3/21/02	7.50	11.50	8.60		230.00	3.25	0.042
RCM0009	4/18/02	7.60	6.90	22.30		462.00	2.60	0.039
RCM0009	5/16/02	7.90	9.10	15.60		330.00	2.97	0.040
RCM0009	6/12/02	7.40	7.40	23.80		398.00	3.42	0.112
RCM0009	7/25/02	7.60	7.80	23.50		218.00	2.15	0.025
RCM0009	8/21/02	7.60	6.20	24.70		491.00	1.64	0.029
RCM0009	9/25/02	7.70	7.70	17.90		517.00	2.37	
RORO102	3/26/02	7.36						
RORO102	6/25/02	6.85						
RORO202	4/23/02	6.97						
RORO202	6/17/02	6.86						
RORO203	6/17/02	6.70						0.004
WIL0013	1/18/00	7.30	12.60	-1.80		470.00	2.81	0.426
WIL0013	2/14/00	7.20	14.30	1.60		494.00	5.50	0.006
WIL0013	3/6/00	7.70	10.50	8.30		302.00	3.59	0.006
WIL0013	4/10/00	8.10	11.60	10.00		322.00	2.73	0.012
WIL0013	5/8/00	7.80	9.20	16.50		485.00	1.30	0.017
WIL0013	6/12/00	7.70	8.80	19.70		376.00	2.37	0.009
WIL0013	7/10/00	7.80	8.40	20.20		683.00	0.56	0.076
WIL0013	8/7/00	7.60	9.10	17.70		329.00	4.74	0.020
WIL0013	9/11/00	7.80	8.20	20.10		627.00	0.95	0.010
WIL0013	10/8/02	7.90	8.70	12.50		459.00	0.36	0.006
WIL0013	10/15/02	8.60	10.40	10.70		647.00	1.30	0.028
WIL0013	10/17/02	8.10	9.60	11.80		224.00	3.14	0.008
WIL0013	10/21/02	7.70	10.20	9.60		280.00	3.00	0.007
WIL0013	10/23/02	7.70	9.40	9.70		301.00	1.89	0.013
WIL0013	11/7/02	7.40	11.20	6.70		149.00	5.18	0.004
WIL0013	11/12/02	7.60	10.60	9.80		171.00	4.29	0.026
WIL0013	11/13/02	7.60	10.90	8.90		148.00	4.50	0.014
WIL0013	11/15/02	7.30	10.80	7.30		144.00	5.22	0.006
WIL0013	11/18/02	8.00	11.10	6.40		143.00	5.93	0.003
WIL0013	11/20/02	7.30	11.30	5.00		137.00	4.23	0.003
WIL0013	12/2/02	8.40	13.20	0.60		183.00	4.34	0.008
WIL0013	12/9/02	8.60	13.90	-0.10		215.00	6.49	0.010
WIL0013	12/17/02	8.10	12.50	1.50		174.00	6.86	0.010
WIL0013	1/7/03	7.70	13.30	1.50		152.00	5.81	0.006

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WIL0013	2/3/03	8.00	12.80	0.60		242.00	4.42	0.033
WIL0013	3/18/03	7.20	10.10	7.20		95.00	5.93	0.007
WIL0013	4/1/03	7.80	12.60	3.90		179.00	3.92	0.013
WIL0013	4/15/03	7.80	11.50	10.10		139.00	4.09	0.011
WIL0013	4/21/03	7.70	10.40	10.90		181.00	3.09	0.012
WIL0013	4/28/03	8.10	10.40	12.30		205.00	2.39	0.011
WIL0013	5/5/03	7.80	9.90	12.50		221.00	1.90	0.016
WIL0013	5/19/03	7.50	10.80	10.40		121.00	4.19	0.015
WIL0013	6/2/03	7.60	11.00	11.10		124.00	3.78	0.010
WIL0013	6/16/03	7.80	9.80	15.40		171.00	3.05	0.007
WIL0013	7/7/03	8.10	8.50	22.90		318.00	1.48	0.006
WIL0013	7/21/03	8.20	8.60	22.30		386.00	0.95	0.028
WIL0013	8/4/03	7.90	8.00	22.40		246.00	2.28	0.005
WIL0013	8/18/03	8.30	9.00	23.20		407.00	0.40	0.004
WIL0013	9/8/03	8.40	8.50	19.80		241.00	0.26	0.015
WIL0013	9/22/03	7.70	8.80	16.70		141.00	4.00	0.007
WIL0013	10/7/03	7.70	10.60	9.80		188.00	2.65	0.008
WIL0013	10/21/03	7.80	10.50	11.70		167.00	1.96	0.004
WIL0013	12/8/03	7.60	13.50	0.50		163.00	4.44	0.017
WIL0013	2/9/04	7.40	13.60	-0.10		188.00	6.18	0.014
WIL0013	2/10/04	7.40	13.30	0.30		166.00	5.77	0.012
WIL0013	2/12/04	7.40	13.40	0.30		191.00	5.59	0.010
WIL0013	3/29/04	7.90	10.80	9.30		162.00	4.54	0.011
WQN0509	12/13/04	7.03	11.70	5.90			6.11	0.019
WQN0509	2/15/05	7.53	11.90	4.20		175.30		0.021
WQN0509	3/22/05	8.30	13.60	6.80		196.30		0.056
WQN0509	3/28/05	7.27	10.20	9.10		130.00		0.224
WQN0509	3/29/05	7.12	11.60	11.40		76.10		0.014
WQN0509	4/18/05	8.48	12.00	13.70		215.00		0.011
WQN0509	5/19/05	8.46	9.80	16.40		244.00		0.067
WQN0509	6/16/05	7.79	7.40	23.40		235.00		0.029
WQN0509	7/28/05	8.00	11.10	25.80		264.00		0.038
WQN0509	8/25/05	8.00	9.63	22.90				0.018
WQN0509	9/22/05	7.89	12.84	20.60		344.00		0.024
WQN0509	10/18/05	7.93	11.24	16.40		302.00		0.024
WQN0509	11/22/05	7.86	13.05	5.96		242.00		0.049
WQN0509	12/1/05	7.85	10.34	7.80				0.018
WQN0509	12/20/05	7.90	13.44	0.10		213.00		0.051
WQN0509	1/19/06	7.26		2.00		124.20		0.014
WQN0509	2/21/06	8.46	13.52	1.50		195.00		0.023
WQN0509	3/30/06	8.36	11.95	11.60		243.00		0.027
WQN0509	4/20/06	8.56	10.53	17.90		181.70		0.021
WQN0509	5/24/06	8.33	10.19	14.80		206.00		0.054
WQN0509	6/22/06	7.71	7.41	24.30		294.00		0.041
WQN0509	7/19/06	7.80	9.85	26.40		269.00		0.050

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WQN0509	8/22/06	8.09	13.23	24.60		350.00		0.049
WQN0509	9/14/06	7.58	9.17	17.30		259.00		0.056
WQN0509	10/18/06	7.34	9.31	20.50		245.00		0.018
WQN0509	12/4/06	8.31	39.30	3.83		225.00		0.015
WQN0509	12/19/06	7.33	18.26	4.83		298.60		0.022
WQN0509	1/30/07	7.91	17.50	0.20		228.00		0.025
WQN0509	2/28/07	7.82	20.00	0.23		222.00		0.017
WQN0509	3/20/07	7.11	15.00	4.40		176.40		0.035
WQN0509	3/21/07	7.51	5.60	5.60		156.50		0.020
WQN0509	4/19/07	6.87	8.20	8.90		146.00		0.017
WQN0509	5/10/07	7.82	11.00	20.10		240.00		0.036
WQN0509	6/11/07	8.80	7.40	23.40		619.00		0.052
WQN0509	7/3/07	2.52	2.00	20.70		251.00		0.035
WQN0509	7/25/07	8.09	2.57	20.90		279.00		0.153
WQN0509	8/21/07	7.49	5.90	18.20		211.00		0.086
WQN0509	8/28/07	7.34	7.50	21.00		199.90		0.042
WQN0509	9/18/07	8.30		20.00		269.00		0.043
WQN0509	9/27/07	8.30		21.00		331.00		0.068
WQN0509	10/10/07	8.20		20.00		361.00		0.018
WQN0509	10/17/07	8.30		15.00		369.00		0.056
WQN0509	10/24/07	8.20		18.00		336.00		0.098
WQN0509	11/13/07	8.20		17.60		459.00		0.036
WQN0509	12/3/07	8.00		4.80		250.00		0.027
WQN0509	1/14/08	5.95		4.50		130.90		0.023
WQN0509	2/6/08	8.00		6.40		143.60		0.015
WQN0509	3/4/08	8.54	115.00	6.30		181.00		0.044
WQN0509	3/20/08	7.80				162.10		0.016
WQN0509	4/14/08	9.00	13.00	12.20		180.20		0.072
WQN0509	4/29/08	8.04	11.11	12.06		96.50		0.026
WQN0509	5/6/08	8.55	10.30	14.65		131.70		0.064
WQN0509	6/4/08	8.30	8.46	19.00		214.00		0.062
WQN0509	7/23/08	7.93	6.61	24.10		320.00		0.055
WQN0509	8/5/08	8.40				300.00		0.066
WQN0509	9/3/08	8.15	8.22	21.10		272.00		0.040
WQN0509	10/6/08	8.42	11.76	14.20		313.00		0.037
WQN0509	11/5/08	7.96	6.00	11.63		367.50		0.086
WQN0509	12/1/08	8.56	12.00	2.65		31.00		0.075
WQN0509	12/29/08	8.27	12.12	3.90		145.00		0.021
WQN0509	1/13/09	7.59	12.80	1.10		210.30		0.048
WQN0509	2/3/09	7.29	11.09	3.30		315.10		0.028
WQN0509	2/26/09	8.21	12.56	1.93		250.30		0.012
WQN0509	3/3/09	7.60	8.71	0.90		521.50		0.045
WQN0509	4/2/09	7.80	32.29	10.10		142.80		0.055
WQN0509	4/22/09	6.60	19.20	10.30		131.40		0.197
WQN0509	5/5/09	6.70	9.34	12.00		111.80		0.028

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WQN0509	6/1/09	4.60	9.00	18.30		184.70		0.229
WQN0509	6/17/09	7.34	9.00	19.20		260.80		0.024
WQN0509	7/7/09	7.99	9.20			316.70		0.060
WQN0509	8/6/09	6.94	8.43	23.40		314.80		0.028
WQN0509	9/3/09	8.18	9.82	18.30		383.00		0.037
WQN0509	9/17/09	7.64	7.79	18.90		403.20		0.024
WQN0509	10/6/09	7.91	10.55	16.20		314.30		0.023
WQN0509	11/3/09	6.66	10.05	13.40		208.30		0.024
WQN0509	12/8/09	6.54	12.23	4.40		175.70		0.017
WQN0509	1/7/10	6.53	12.21	1.90		216.80		0.048
WQN0509	1/20/10	6.52	11.67	3.50		136.20		0.082
WQN0509	1/27/10	6.29	11.40	4.40		116.70		0.029
WQN0509	2/3/10	6.58	11.38	4.40		186.80		0.016
WQN0509	3/3/10	7.14	13.30	3.90		152.60		0.081
WQN0509	3/29/10	7.23	14.07	8.80		150.00		0.023
WQN0509	3/31/10	7.13	10.20	10.10		125.00		0.018
WQN0509	4/5/10	7.71	12.02	14.90		170.40		0.056
WQN0509	5/4/10	7.15	9.09	16.40		115.40		0.055
WQN0509	5/19/10	7.70	10.18	13.60		197.80		0.032
WQN0509	6/2/10	8.00						0.039
WQN0509	6/16/10	7.50	7.66	22.20		265.50		0.053
WQN0509	7/14/10	7.70	8.02	24.00		313.90		0.042
WQN0509	7/26/10	8.20	7.70	25.80		298.00		0.051
WQN0509	8/9/10	8.23	8.08	22.76		279.32		0.035
WQN0509	8/24/10	8.12	7.85	21.50		300.00		0.026
WQN0509	9/7/10	7.93	8.48	19.90		139.17		0.029
WQN0509	9/29/10	8.20	9.52	18.35		268.50		0.047
WQN0509	10/5/10	7.76	10.10	13.50		204.93		0.022
WQN0509	11/1/10	7.60	12.00	7.10		235.00		0.027
WQN0509	11/23/10	8.00	12.00	7.30		272.00		0.215
WQN0509	12/2/10	8.00	8.50	6.79		85.00		0.014
WQN0509	1/5/11	9.00	17.00	0.00		400.01		0.014
WQN0509	1/25/11	8.70	16.00	0.00		287.00		0.015
WQN0509	1/31/11	8.50	16.00	0.76		270.00		0.032
WQN0509	2/17/11	8.30	14.00	1.70		219.90		0.102
WQN0509	3/1/11	7.42	12.50	5.00		158.00		0.018
WQN0509	5/24/11	7.30				148.70		0.054
WQN0509	8/3/11	7.80	7.50	25.00		273.00		0.066
WQN0509	8/16/11	8.40	9.16	22.50		293.00		0.087
WQN0509	8/22/11	8.50	9.00	23.30		305.00		0.079
WQN0509	8/30/11	8.00	9.90	20.70		382.00		0.045
WQN0509	9/22/11	8.00	10.00	17.50		400.25		0.125
WQN0509	9/28/11	7.70	8.50	19.80		165.00		0.108
WQN0509	10/4/11	7.75	11.40	12.20		200.00		0.024
WQN0509	10/27/11	8.40	10.00	12.50		288.90		0.029

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WQN0509	11/2/11	7.78	15.00	6.90		257.00		0.058
WQN0509	11/30/11	7.76	11.50	10.10		200.00		0.034
WQN0509	12/6/11	6.70	14.20	8.10		271.00		0.045
WQN0509	12/21/11	7.79	13.62	6.10		377.00		0.010
WQN0512	11/17/04	6.66	10.60	4.50			2.12	0.010
WQN0512	12/13/04						3.45	0.010
WQN0512	1/11/05	6.29	11.60	4.40			3.45	0.012
WQN0512	2/15/05	6.69	12.20	1.80			2.92	0.010
WQN0512	3/22/05	6.60	12.60	4.90			1.99	0.010
WQN0512	4/21/05	6.96	9.00	15.60		89.80		0.013
WQN0512	6/1/05	7.48	9.00	18.30		123.30		0.015
WQN0512	6/13/05	7.61	7.80	26.10		133.00		0.011
WQN0512	8/25/05	7.75	11.00	25.80		189.50		0.010
WQN0512	9/22/05	7.10	9.35	20.80		280.00		0.012
WQN0512	10/18/05	7.29	9.86	16.60		189.80		0.010
WQN0512	12/20/05	7.30	14.16	0.00		142.50		0.011
WQN0512	1/17/06	6.83	12.12	5.90		74.70		0.010
WQN0512	2/21/06	6.74	14.77	0.20		87.50		0.010
WQN0512	3/30/06	6.64	11.76	8.00		90.50		0.013
WQN0512	4/25/06	6.75	8.48	14.00		66.10		0.010
WQN0512	5/24/06	6.87	9.03	16.20		84.80		0.010
WQN0512	6/22/06	6.73	6.44	22.40		104.80		0.012
WQN0512	7/19/06	6.65	7.50	24.80		111.40		0.011
WQN0512	8/23/06	6.92	7.33	21.00		184.10		0.010
WQN0512	9/26/06	6.99	16.10	15.90		184.00		0.010
WQN0512	10/19/06	6.77	9.66	14.90		274.00		0.019
WQN0512	11/2/06	7.80	10.10	7.30		165.30		0.013
WQN0512	11/14/06	6.00	9.50	5.00		125.20		0.010
WQN0512	11/27/06	6.43	15.07	4.23		106.70		0.010
WQN0512	12/13/06	7.25	10.73	1.25		141.00		0.022
WQN0512	12/26/06	3.72	11.80	5.50		193.30		0.010
WQN0512	1/30/07	7.26	16.83	0.33		119.50		0.010
WQN0512	2/28/07	7.20	20.00	0.10		151.63		0.015
WQN0512	3/26/07	7.02	6.00	9.10		95.20		0.010
WQN0512	4/11/07	6.91	9.00	5.40		107.00		0.015
WQN0512	5/9/07	7.62	8.00	17.20		106.70		0.015
WQN0512	6/4/07	7.30	9.00	20.30		144.40		0.012
WQN0512	6/13/07	8.92	8.50	18.90		153.60		0.022
WQN0512	6/20/07	6.61	7.50	21.40		143.20		0.010
WQN0512	7/12/07	7.29		25.10		196.70		0.021
WQN0512	7/19/07	7.14	1.00	23.30		181.00		0.022
WQN0512	8/8/07	7.81	3.20	26.90		202.00		0.024
WQN0512	8/28/07	7.40	8.50	21.00		83.60		0.012
WQN0512	9/17/07	7.80	8.50	16.00		182.60		0.010
WQN0512	10/1/07	7.70		19.00		159.90		0.010

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WQN0512	10/25/07					136.70		0.013
WQN0512	11/5/07	7.60		5.49		201.00		0.013
WQN0512	11/27/07	7.60		10.41		156.10		0.030
WQN0512	12/10/07	7.40		8.98		173.70		0.010
WQN0512	1/8/08	7.40		7.48		99.60		0.010
WQN0512	2/4/08	7.71		3.00		84.60		0.010
WQN0512	2/27/08	7.21		2.50		182.00		0.145
WQN0512	3/5/08	8.50	119.00	6.80		283.00		0.010
WQN0512	4/10/08	8.53	12.86	12.00		92.20		0.014
WQN0512	5/8/08	7.83	9.83	17.00		70.90		0.017
WQN0512	6/3/08	7.61	8.70	18.90		95.20		0.010
WQN0512	6/17/08	7.73	8.73	20.80		135.70		0.010
WQN0512	7/8/08	7.60	6.90	25.00		120.00		0.010
WQN0512	8/14/08	7.84	6.41	22.30		157.00		0.010
WQN0512	9/8/08	7.86	7.23	23.00		246.00		0.027
WQN0512	10/7/08	7.93	11.66	13.00		196.60		0.010
WQN0512	10/29/08	7.95	9.64	7.55		410.20		0.010
WQN0512	11/19/08	7.98	11.50	2.80		151.20		0.010
WQN0512	12/9/08	7.48	13.46	0.53		189.00		
WQN0512	1/17/09	7.30	14.27	9.80		174.90		0.010
WQN0512	1/22/09	6.98	12.02	2.50		163.20		0.016
WQN0512	2/10/09	6.52	12.09	0.90		138.00		0.010
WQN0512	3/9/09	6.97	10.88	8.80		120.00		0.037
WQN0512	4/16/09	7.00	29.86	9.30		104.40		0.025
WQN0512	5/13/09	6.70	9.79	14.10		72.01		0.030
WQN0512	6/8/09	6.73	8.64	22.20		157.00		0.012
WQN0512	7/6/09	6.23	7.32	23.50		153.30		0.013
WQN0512	7/23/09	6.13	8.35	23.40		147.20		0.010
WQN0512	8/11/09	7.94	8.43	23.20		314.80		0.012
WQN0512	9/10/09	7.37	8.15	19.60		251.00		0.011
WQN0512	10/19/09	6.31	7.69	10.50		138.60		0.010
WQN0512	11/17/09	7.30	14.27	9.80		174.90		0.021
WQN0512	12/14/09	6.28	13.10	3.80		94.52		0.010
WQN0512	1/11/10	6.00	12.37	0.30		116.50		0.010
WQN0512	2/22/10	6.73	14.11	1.00		152.60		0.017
WQN0512	3/4/10	6.67	13.54	4.60		108.20		0.025
WQN0512	3/17/10	6.59	10.00	8.50		76.00		0.024
WQN0512	3/30/10	6.87	13.70	9.35		83.23		0.010
WQN0512	4/14/10	6.50	12.67	11.60		91.20		0.010
WQN0512	5/11/10	6.88	10.02	11.50		86.02		0.014
WQN0512	5/25/10	6.80	8.19	18.80		83.81		0.013
WQN0512	5/27/10	7.19	8.59	21.70		102.90		0.012
WQN0512	6/8/10	7.36	8.40	19.50		121.50		0.012
WQN0512	6/17/10	7.10				122.60		0.010
WQN0512	7/19/10	7.55	5.35	28.50		137.00		0.014

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WQN0512	7/22/10	7.87	7.77	29.00		141.80		0.017
WQN0512	8/11/10	7.54	6.26	26.45		183.50		0.013
WQN0512	9/13/10	7.50	9.00	18.00		115.00		0.013
WQN0512	9/30/10	7.70	7.80	17.10		155.55		0.010
WQN0512	10/14/10	7.40	11.00	13.00		1778.00		0.010
WQN0512	11/9/10	7.73	13.34	4.70		260.00		0.010
WQN0512	12/7/10	7.80	15.50	0.15		126.70		0.010
WQN0512	12/20/10	7.85	16.00	0.00		122.70		0.010
WQN0512	1/13/11	7.65	15.14	0.00		251.70		0.010
WQN0512	1/31/11	7.50	14.50	0.00		263.00		0.011
WQN0512	2/7/11	8.06	15.40	0.50		128.90		0.012
WQN0512	3/9/11	7.00	14.00	5.80		225.00		0.010
WQN0512	5/9/11	7.40				75.90		0.010
WQN0512	5/24/11	7.00				77.70		0.010
WQN0512	8/8/11	7.50	9.00	26.70		213.00		0.151
WQN0512	9/7/11	7.40	10.50	17.00		110.00		0.107
WQN0512	9/15/11	7.40	9.40	18.70		81.00		0.012
WQN0512	10/12/11	7.70	10.50	15.00		89.77		0.010
WQN0512	11/8/11	8.00	15.00	5.00		122.00		0.010
WQN0512	11/29/11	7.30	11.00	11.00		92.90		0.012
WQN0512	12/12/11	8.84	15.00	1.80		100.00		0.010
WQN0512	12/15/11	7.90	13.60	3.70		96.00		0.010
WQN0513	10/23/06	8.09	10.53	9.30		250.00		0.011
WQN0513	12/5/06	7.02	18.66	0.80		172.50		0.019
WQN0513	12/26/06	7.73	15.93	5.00		155.60		0.020
WQN0513	1/29/07	7.76	16.00	0.43		219.00		0.028
WQN0513	2/27/07	7.56	15.00	0.15		200.00		0.014
WQN0513	3/14/07	8.04	25.00	8.00		140.90		0.010
WQN0513	4/4/07	7.89	5.40	15.30		145.80		0.010
WQN0513	4/26/07	7.78	8.00	13.60		163.10		0.012
WQN0513	5/17/07	8.59	5.80	17.60		181.30		0.011
WQN0513	6/5/07	7.99	8.00	21.20		222.00		0.012
WQN0513	6/18/07	8.11	3.50	23.70		199.90		0.014
WQN0513	7/18/07	7.74	3.50	24.57		194.00		0.012
WQN0513	8/7/07	7.86	3.50	24.90		204.00		0.037
WQN0513	8/27/07	4.53	7.00	21.00		120.00		0.025
WQN0513	9/11/07	8.10	5.00	24.00		233.00		0.010
WQN0513	10/2/07	8.10		19.00		279.00		0.024
WQN0513	11/6/07	8.10		6.80		273.00		0.012
WQN0513	11/15/07	8.10		10.06		243.00		0.010
WQN0513	12/19/07	7.60		0.72		137.80		0.026
WQN0513	1/2/08	7.70		0.74		134.40		0.010
WQN0513	1/30/08	7.90		0.10		150.90		0.012
WQN0513	2/19/08	6.96		3.60		130.90		0.045
WQN0513	3/6/08	7.65	110.00	5.50		108.00		0.012

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WQN0513	3/27/08	8.33	117.50	8.16		145.10		0.010
WQN0513	4/3/08	8.43	12.80	10.30		159.00		0.126
WQN0513	4/21/08	7.77	10.76	13.50		84.20		0.046
WQN0513	5/12/08	7.70	10.51	11.00		91.00		0.010
WQN0513	6/23/08	8.34	8.86	24.00		223.00		0.010
WQN0513	7/22/08	7.89	7.00	25.00		416.00		0.010
WQN0513	8/7/08	8.15	7.33	24.30		258.00		0.010
WQN0513	9/4/08	8.15	7.35	21.10		270.00		0.010
WQN0513	9/29/08	8.03	8.12	19.20		295.00		0.010
WQN0513	11/3/08	8.26	9.63	8.73		354.60		0.010
WQN0513	12/4/08	7.80	13.36	3.25		334.00		0.018
WQN0513	1/6/09	7.74	12.27	2.56		191.40		0.012
WQN0513	2/5/09	7.10	12.19	1.50		224.10		0.019
WQN0513	3/4/09	6.97	11.80	1.30		335.40		0.017
WQN0513	3/17/09	7.82	11.45	5.60		157.50		0.010
WQN0513	4/6/09	7.03	8.76	11.50		130.10		0.236
WQN0513	5/6/09	7.00	9.42	12.30		96.17		0.021
WQN0513	6/2/09	7.52	9.20	23.60		159.40		0.010
WQN0513	7/1/09	6.87	7.69	21.80		202.00		0.011
WQN0513	8/3/09	6.35	7.40	23.60		220.80		0.010
WQN0513	9/2/09	7.29	8.09	17.80		309.00		0.013
WQN0513	10/7/09	6.77	8.19	18.10		308.00		0.010
WQN0513	11/2/09	7.11	10.21	12.30		214.80		0.010
WQN0513	12/2/09	6.11	21.31	3.90		214.50		0.010
WQN0513	1/5/10	7.05	12.15	0.30		179.00		0.010
WQN0513	2/1/10	6.09	12.75	1.00		152.00		0.029
WQN0513	3/2/10	7.45	13.10	4.10		152.50		0.015
WQN0513	3/24/10	7.00	13.06	9.40		135.70		
WQN0513	4/6/10	7.05	9.81	16.70		145.80		0.043
WQN0513	5/3/10	6.80	8.00	17.70		107.90		0.011
WQN0513	6/1/10	8.04	7.96	22.80		186.00		0.017
WQN0513	7/12/10	8.08	6.79	23.60		236.80		0.011
WQN0513	8/2/10	8.00	8.00	23.45		251.50		0.014
WQN0513	8/17/10	8.00	6.65	24.50		271.90		0.010
WQN0513	9/1/10	7.54	6.98	22.90		164.90		0.036
WQN0513	10/4/10	7.56	9.41	13.95		225.20		0.010
WQN0513	11/4/10	7.70	13.00	7.70		300.00		0.013
WQN0513	11/29/10	8.24	14.50	0.20		193.00		0.010
WQN0513	11/30/10	8.00	17.00	3.40		269.00		0.010
WQN0513	1/3/11	8.50	16.50	1.50		174.00		0.064
WQN0513	2/16/11	8.00	14.50	0.65		122.87		0.013
WQN0513	3/2/11	7.50	14.00	4.90		120.00		0.010
WQN0513	5/9/11	7.70				150.00		0.010
WQN0513	5/23/11	7.70				145.70		0.010
WQN0513	8/2/11	8.00	6.50	26.00		226.50		0.010

Site	Date	pH	DO	Temp	ANC	Cond.	NO_3	TP
WQN0513	8/15/11	8.00	8.50	23.00		223.00		0.010
WQN0513	8/29/11	7.58	7.36	21.90		243.00		0.010
WQN0513	9/20/11	7.79	10.00	17.00		181.00		0.048
WQN0513	10/3/11	8.00	9.86	12.00		122.00		0.010
WQN0513	10/31/11	8.00	14.50	5.85		231.00		0.010
WQN0513	11/28/11	8.10	13.10	8.70		146.50		0.010
WQN0513	12/5/11	7.60	14.00	5.00		169.00		0.010
WQN0513	12/19/11	8.00	14.21	1.80		186.50		
Overall median		**7.8**	**9.3**	**12.9**	**1848**	**504.00**	**3.3**	**0.072**

Table A-3. Deer density (deer/km^2) in CHOH. Deer-counting routes are shown in Figure 4.39.

Year	Density
2001	47.26
2002	31.76
2003	39.90
2004	41.70
2005	45.60
2006	40.03
2007	55.97
2008	45.17
2009	49.23
2010	54.72
2011	36.57
Overall median	**45.17**

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