Great Lakes

Inventory and Monitoring Network

National Park Service

U.S. Department of the Interior

A Decade of Science and Stewardship

2006-2016

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Pages 8–9: eaglets in nest (Jim Campbell-Spickler), climbers with landowner (Eli Nichols); pages 10–11: ovenbird (Dick Daniels, carolinabirds.org/Wikimedia Commons); pages 12–13: aerial photos (National Agriculture Imagery Program), prescribed fire (Grand Portage Band of Lake Superior Chippewa Trust Lands and Natural Resources Management Program); page 16: diatoms (St. Croix Watershed Research Station/Mark Edlund); page 18: aerial photo of river confluence (Metropolitan Council Environmental Services); pages 24–25: USGS scientist with lupine (University of Notre Dame), Karner blue butterfly–top view (A.E. Cole), Karner blue butterfly–side view (USFWS/Joel Trick); pages 28–29: family picnic (Wikimedia Commons/Carole Robertson), triclosan label (Jack Black's Stunt Double/Flickr, CC BY-NC 4.0), child's hand with berry (Wikimedia Commons/Raphaël Quinet); pages 30–31: northern goshawk (Wikimedia Commons/Norbert Kenntner), aerial photo (National Agriculture Imagery Program, datagateway.nrcs.usda.gov); page 34: Higgins eye mussels (USFWS); pages 36–37: girl holding northern pike (Dave Larsen), fishing from a canoe (University of Wisconsin–La Crosse/Kris Rolfhus); page 38–39: cricket frog (Minnesota DNR, http://bit.ly/1jRxgHR), Ellie Hoopman at science fair and Sophie Howk in lab (Rick Erickson), dragonfly larvae and UW-L students dip-netting (University of Wisconsin–La Crosse/Roger Haro).

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A Timeline of Great Lakes Network History

1916
National Park Service created.

1929
George M. Wright conducts the first wildlife survey in the national parks.

1931
Isle Royale National Park established.

1951
Grand Portage National Historic Site established.

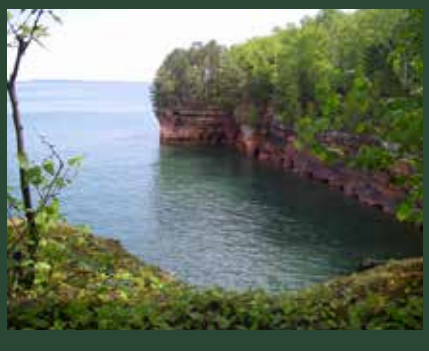
1958
Grand Portage NHS re-designated as a National Monument.

1966
Pictured Rocks and Indiana Dunes National Lakeshores established.

1968
St. Croix National Scenic Riverway established.

1970
Sleeping Bear Dunes and Apostle Islands National Lakeshores established.

1910 1930 1950 1960 1970



2000
Great Lakes I&M Network established.

2006
Network's *Long-term Ecological Monitoring Plan* is approved. **Annual field work begins.**

2004
Gaylord Nelson Wilderness established at Apostle Islands.

2009
Beaver Basin Wilderness designated at Pictured Rocks.

1988
Mississippi National River and Recreation Area established.

1980 1990 2000 2010

1975
Voyageurs National Park established.

1976
98% of Isle Royale designated as wilderness.

1999
Inventory and Monitoring Program created as part of the NPS's Natural Resource Challenge.

2014
Sleeping Bear Dunes Wilderness designated.

2016
Ten years of monitoring in the Great Lakes Network parks.

Celebrating 10 Years of Partnership in Natural Resource Monitoring

Under the Organic Act that established the National Park Service in 1916, national park managers are charged with conserving park resources and providing for public use and enjoyment "in such a manner and by such means as will leave them unimpaired for future generations."

But, park managers are faced with many challenges, including invasive species, environmental contamination, a changing climate, and increased visitation. To meet these challenges, managers must rely on their own intimate knowledge of these places and they must engage the assistance of a variety of partners, cooperators, and researchers. Nine national parks in the upper Midwest are connected to one another through a collegial partnership with a shared vision and need to monitor and assess the natural resources they protect. Collectively, the nine parks are part of the Great Lakes Inventory and Monitoring Network. Together, managers and scientists at the parks and at the Network conduct long-term monitoring of critical park resources—"vital signs"—to assess the health of park ecosystems and provide a scientific basis for management actions. This report summarizes our first decade of field work in collaboration with the parks, and it is our way of acknowledging the National Park Service's Centennial year.

Bill Route is the Great Lakes Network Program Manager, a position he has held since the Network's creation in 2000.

Fresh water is critical for all life on Earth, and it is a defining feature in these nine national parks. Apostle Islands National Lakeshore, Isle Royale National Park, Pictured Rocks National Lakeshore, Sleeping Bear Dunes National Lakeshore, and Indiana Dunes National Lakeshore are all on one of the Great Lakes—the world's largest interconnected system of fresh water. Grand Portage National Monument (also on Lake Superior) and Voyageurs National Park help preserve significant portions of the waterways that were so important in the early fur trade, exploration, and settlement of the upper Midwest. The St. Croix National Scenic Riverway was also an important historical waterway and was one of this nation's first designated Wild and Scenic Rivers. The Mississippi National River and Recreation Area is a NPS-led, multi-partner effort to protect green space along the nation's largest working river. But these parks are about more than the water. Visitors come to these parks to fish, hike, boat, swim, canoe, and view wildlife, and the upper Midwest is fortunate to have these areas that set aside sand dunes and beaches, bogs and wetlands, northern temperate and southern boreal forests, and all the requisite fish, amphibians, birds, mammals, and other plants and animals.

To present a full accounting of the efforts required to assess and manage natural resources in these parks would take many volumes. What we offer in the following stories are examples that illustrate the spectrum of issues park managers and scientists are facing. Our stories reveal how bald eagles, freshwater mussels, and tiny diatoms can act as sentinels to help us monitor the health of lakes and rivers, while Karner blue butterflies, songbirds, and forest plant communities help us understand

National parks of the Great Lakes Inventory and Monitoring Network.

the direct effects of change on sensitive resources. In addition, the weather, human population growth, and land use outside the parks are major drivers of change inside parks, and we must understand these forces to put change in perspective. These larger, regional issues are where Network scientists play their most important role—helping put individual park resource issues in a larger context. By contrast, park scientists are best positioned to assess specific park resource issues such as locally threatened species. Together, Network and park professionals work collaboratively to monitor and manage natural resources in these protected areas.

Through these stories, we hope to convey a sense of the passion, dedication, and in some cases, urgency, that goes into assessing and managing natural resources in our national parks. They are written by the professionals who work each day to find solutions that allow visitor use while fulfilling the mandate of leaving the parks unimpaired for future generations. We focus on nine national parks in the upper Midwest, but these stories have importance beyond their boundaries because understanding what is happening to the natural world within them sheds light on what is happening to nature that surrounds us every day.

National parks are important places for people to visit and experience the natural world. They are also important for science, learning, and understanding. We hope these stories help you to understand some of the challenges facing our parks and what we are doing to better understand and protect them.

—Bill Route

Iconic Shifts

Above: A remote automated weather station (RAWS) is installed in the Apostle Islands.

Opposite page (bottom): Low lake levels create inconveniences and safety concerns for boats moored at park docks.

Cooler by the lake! "Lake-effect snow." We often hear how the Great Lakes influence local weather, but how climate might influence the Great Lakes region is an increasingly relevant question.

The dictionary defines climate as "the average course or condition of the weather at a place, usually over a period of years." Climate is what makes people think "warm and dry" when they think of the southwestern deserts or "hot and humid" for the Gulf Coast bayous. It is also what makes the Great Lakes region "northern temperate." We have a moderate climate that is not excessive in one way or the other. Climate is what makes each part of the country distinct, and climate change is likely to cause a fundamental shift in the overall character of each region's prevailing weather.

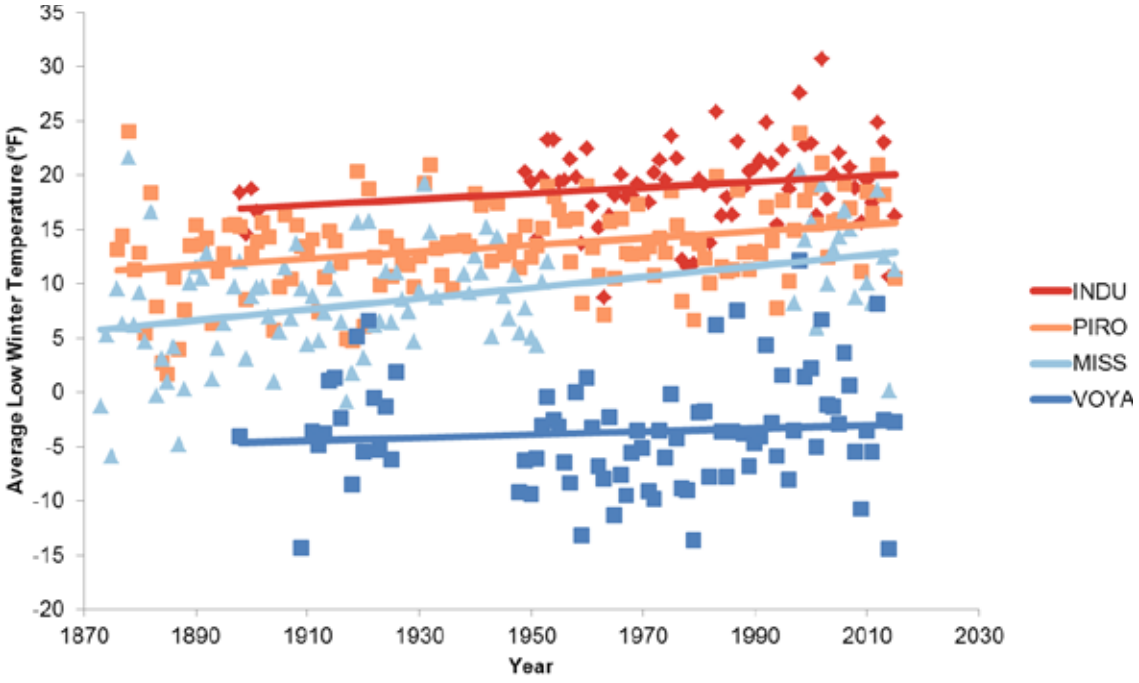
Climate change predictions for the Great Lakes region include higher average temperatures, more rainfall than snow during the winter, less rain in the summer, and more evaporation, creating drier and hotter summers (Saunders et al. 2011).

In places like Isle Royale or the Apostle Islands, the current lake-influenced temperate climate makes it possible for arctic disjunct plants to survive. Separated from their typical home range in far northern Canada and Alaska by the glaciers thousands of years ago, these plants persist today because of the cold, wet climate maintained along the Lake Superior shoreline (*see page 26*). As we shift toward a generally warmer and drier climate, those Arctic disjunct plants could literally dry up and disappear. The predicted reduction in winter ice cover is expected to cause greater evaporation of water from the open lakes, increasing lake-effect snow in some parts of the region, but also lowering summer lake levels and leaving some docks and harbors difficult or impossible to reach. Lake Superior, Lake Michigan, and the large lakes at Voyageurs National Park will all bear witness to those changes.

For the river parks, the amount of precipitation that falls each year, both as snow and rain, determines if the Mississippi will overflow its banks in the spring (*see page 18*), or if the upper St. Croix and Namekagon rivers will have enough water to be passable by canoe during the busy visitor season. In both rivers and lakes, warmer temperatures combined with other factors have already created outbreaks of toxic algal blooms that make the water unsafe for people to swim in or drink (GLKN 2013, Edlund et al. 2014) and fatal to fish and the waterbirds such as loons that eat them (Lafrancois et al. 2011).

Across all of our parks, the shifting climate means that the plant communities and animals they support will also change (Saunders et al. 2011, NPCA 2009, Prasad et al. 2007) (*see page 22*). Some species such as balsam fir and paper birch are predicted to

disappear from the southern portion of their range across the Lake States, leaving only those trees that thrive in warmer, drier conditions. Worse, though, are the predicted increases in incidents of exotic species invasions and disease and insect outbreaks, both of which will create inhospitable conditions for native plant communities (Saunders et al. 2011, Fisichelli et al. 2014b). Loss of ice cover on Lake Superior has also decreased the chances of wolves naturally crossing over to Isle Royale (*see page 26*).



Average low winter temperatures (up to 2015) at the "four corners" of the Great Lakes Network—Indiana Dunes National Lakeshore in the southeast (starting in 1898), Mississippi National River and Recreation Area in the southwest (starting in 1873), Voyageurs National Park in the northwest (starting in 1898), and Pictured Rocks National Lakeshore in the northeast (starting in 1876). Mississippi River shows the sharpest rise, perhaps resulting from the growth of the city, while Voyageurs shows the least amount of change. Data compiled from the National Oceanic and Atmospheric Administration and made available at www.climateanalyzer.org.

Our climate monitoring efforts rely in part on weather stations maintained by other agencies, but we have worked to fill gaps in coverage. We have installed new Remote Automated Weather Stations (RAWS) that use solar panels and satellite transmission to provide hourly weather data from the most remote locations in the parks. For example, North Manitou Island (part of Sleeping Bear Dunes) is a popular destination that now has a RAWS providing valuable weather information for island visitors and boaters. The Network makes this near-real-time weather data, along with other current and historic records from a variety of stations, available to park staff and the public online at (www.climateanalyzer.org).

The warmer winters and extended periods of drought predicted in climate change models will have consequences for the natural treasures of our parks. Our monitoring efforts are intended to help park managers understand and prepare for those changes.

—Mark Hart and Ted Gostomski

Noteworthy:

- Weather and climate are two of the main drivers of the Great Lakes system, both in the water and on land.
- The icons of some Great Lakes parks may be in jeopardy as our climate becomes warmer and drier. Plants and animals and how they interact will be affected.
- How park managers prepare for and respond to climate change will influence what the parks look like and how they biologically function in the coming decades.

Cool Little Birds Reveal a Human Story

Above: A pair of eaglets watch as a climber approaches their nest. After a few minutes, the climber will enter the nest, gently place the eaglets in bags, then take them down to the ground for sample collection and measurements.

Opposite page (bottom): Climbers Jim Campbell-Spickler (*left*) and Giacomo Renzulo (*right*) with a landowner and eaglets from the nest on his property.

When it comes to chemicals, industry can provide useful products, but we must understand and weigh the consequences to the environment and human health.

For example, the group of industrial chemicals known as polychlorinated biphenyls (PCBs) was banned in the U.S. in 1979 because they affected the health of humans and wildlife (USEPA 2016). A mere decade later tens of thousands of tons of polybrominated diphenyl ethers (PBDEs) were being dumped into the environment each year. These PBDEs were used as flame retardants on furniture and other fabrics, but were they safe? Maybe not; their chemical structure is so similar to the banned PCBs that they have many of the same effects on humans and wildlife (Zota et al. 2013). Laboratory studies in humans and other animals show that PBDEs can be transferred from mother to infant, interfere with immune and thyroid function, and alter human infant behavior (Talsness 2008). Similarly, perfluorinated compounds (PFCs) that make our clothing water- and stain-resistant are slowly breaking down, rubbing off, and adding to the mixture of chemicals in our lakes and rivers.

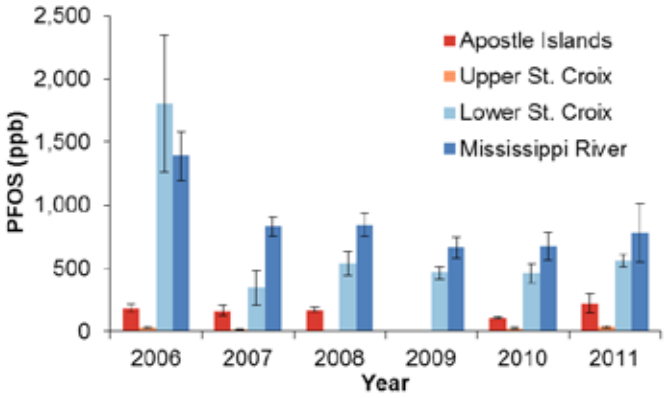
A National Symbol, A National Indicator

For more than 30 years, scientists have monitored bald eagles, collected and tested nonviable eggs, and collected blood and feathers from eagle nestlings to assess the levels and impacts of chemicals they ingest as predators atop the aquatic food web. Nestling eagles are used, not only because they are easier to catch than adults, but because they have not yet been exposed to the variety of food sources that adults use throughout the year. An eaglet's food comes from the area immediately surrounding the nest, so chemical levels in the eaglet's blood are indicative of what is in the immediate environment.

A great deal of this work has been done in national parks of the upper Midwest, including Voyageurs National Park (*see page 36*). Work done there has advanced our understanding of mercury in aquatic systems and alerted park managers to other chemicals of concern (Bowerman et al. 1995). From the 1980s through 2002, the Wisconsin Department of Natural Resources monitored eagles along the southern shore of Lake Superior, including the Apostle Islands. Our program built off their efforts by including eaglets from the St. Croix Riverway and the upper Mississippi River, and by testing for additional chemicals (Dykstra et al. 2010).

All You Need is Blood...and Feathers

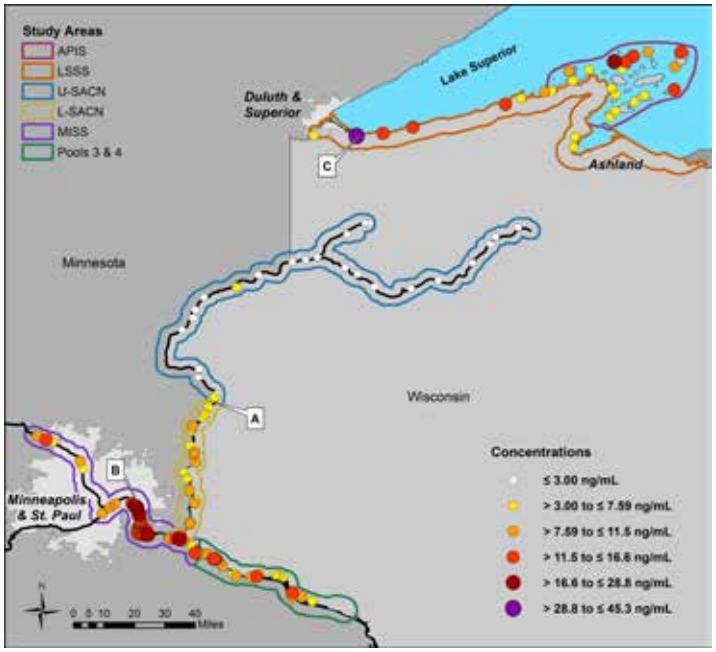
To monitor contaminants in eaglets, we collect a small amount of blood and a few breast feathers from 5- to 9-week-old birds.



One of the primary PFCs we monitor is PFOS (perfluorooctane sulfonate), a fabric stain- and water-repellent. The amount of PFOS in eaglet blood is declining at most of our study sites. "ppb" = parts per billion.

Two groups of chemicals that eagles have helped us track are the PBDEs and PFCs. These chemicals end up in our municipal wastewater treatment plants through industrial and household waste streams, they do not break down in the environment, and they have been found in wildlife and humans around the world. High levels of PBDEs are found in house dust and laundry lint from normal wear and washing of clothes, carpets, and furniture that are coated with these chemicals.

We have found both PBDEs (Route et al. 2014a) and PFCs (Route et al. 2014b) at higher levels in eaglets that live near large population centers. In particular, eaglets that live near or downstream from municipal wastewater treatment plants, or near industrial waste release sites, have the highest levels. In fact, some eaglets along the Mississippi River are carrying the highest PFC levels ever reported for bald eagle nestlings.



Distribution of PBDEs in bald eagle nestlings at Apostle Islands National Lakeshore (APIS), the Lake Superior South Shore (LSSS), upper and lower St. Croix National Scenic Riverway (U- and L-SACN), Mississippi National River and Recreation Area (MISS), and Pools 3 and 4 of the Mississippi River. (A) and (B) indicate municipal wastewater treatment plants. (C) indicates a municipal landfill.

And Now For Some Good News

Numerous studies link high levels of these chemicals to potential human health risks (USEPA 2015). As a result, some countries (e.g., Canada, Europe) and states (e.g., California, Oregon) have banned or restricted their use. This led to the major chemical manufacturers reducing production and pledging to remove them from the market. In the case of PBDEs and PFCs, these positive steps have resulted in lower levels of these chemicals in bald eagle nestlings from parks of the upper Midwest.

—Bill Route

Noteworthy:

- Flame retardants and stain-resistant chemicals break down slowly and add to the mixture of chemicals in lakes and streams.
- These chemicals are known to have dangerous effects on the health of both humans and wildlife and are found in the blood of bald eagle nestlings.
- Bald eagle nestlings are showing us that levels of some of these chemicals have started to decline as major manufacturers reduce or cease production.

Keeping the Common Species Common

When talking about wildlife conservation, attention often narrows to focus only on the high priority, high visibility species listed under the Endangered Species Act.

Of course, we must protect them, but we cannot forget the common species such as robins, woodpeckers, and chickadees. These are the ones visitors are most likely to see or hear in the national parks, so changes in these populations might be more readily noticed.

The Migratory Bird Treaty Act (MBTA) of 1918 charged federal land managers, including the National Park Service, with protecting the songbirds that use our parks either as rest stops during migration, for nesting during the breeding season, or as a year-round home. The MBTA ensures that we work to "keep the common species common."

Above: Conducting point counts on the St. Croix Riverway (*left*). A male ovenbird (*right*).

Opposite page (bottom): A cedar waxwing with a wintergreen berry.

Trends—A Mixed Bag

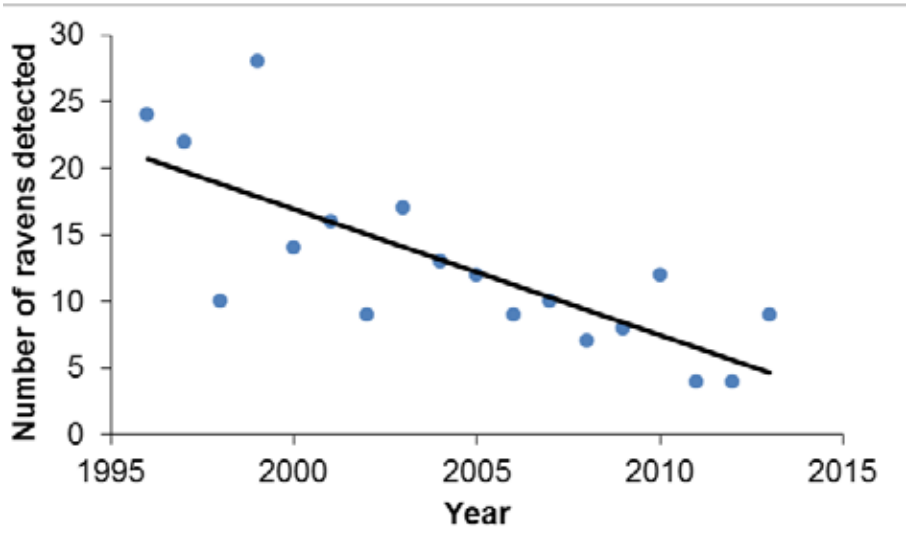
Seven of the nine Network parks have conducted surveys for five or more years, giving us a sufficient amount of data for analysis. In those seven parks, among 21 of the most common bird species, just five species show increasing population trends in all seven parks: the American robin, the red-bellied woodpecker, the red-breasted nuthatch, the red-winged blackbird, and the song sparrow. Others are increasing in one park but decreasing in another. Tree swallows, for example, are significantly increasing on the upper St. Croix Riverway, but are exhibiting a significant decline in the Apostle Islands. Meanwhile, four common species are showing significant trends in three or more of the parks: the ovenbird and chipping sparrow are increasing, while chestnut-sided warbler and American crow are decreasing.

Mixed results are expected across a large area. The trick is in finding patterns. One set of interesting patterns are those species whose trends in the parks are contrary to what is happening elsewhere in the state or region. For example, cedar waxwings at Indiana Dunes and American crows at Voyageurs are declining, but both are generally increasing elsewhere. Conversely, the meadowlark, veery, and wood thrush at Sleeping Bear Dunes are doing better in the parks than most other places in the Great Lakes region.

Conditions We Cannot Control

What does this mean for songbirds in the Great Lakes parks? If the future brings warmer temperatures and generally drier conditions, then northern species will have to move further north to find the appropriate habitats or temperatures. Matthews et al. (2004) predict ovenbirds will decrease substantially in abundance as climate changes force them to move further north. Nashville

warblers are predicted to disappear from the eastern United States as summer temperatures become warmer and balsam fir—a primary component of its preferred nesting habitat—disappears (Matthews et al. 2004). Filling in behind these could be the blue-gray gnatcatchers and northern cardinals that are predicted to expand northward as winter temperatures become more moderate (Matthews et al. 2004).



Common ravens are declining on Isle Royale, yet outside the park they are thriving, with some of the strongest increases in Michigan and Minnesota (Sauer et al. 2014). What's different for ravens on Isle Royale?

Fluctuating weather patterns could also force birds to shift the timing of their northward migration to better match the arrival of spring and the emergence of insects. Because Nashville warblers rely on insects for their food year-round, they are more vulnerable to population declines if they are unable to adapt to climate change effects on the timing of insect emergence (Marra et al. 2014).

What can the national parks do for birds when the changing conditions are beyond our control? What the national parks have always offered for the birds is a relatively safe place to nest and raise young. The majority of U.S. breeding habitat for at least 39 bird species is found in national parks (NABCI 2011). In the Great Lakes region, that means forest habitats. Only 2% of forest bird species show high vulnerability to climate change (NABCI 2010), but we cannot rest on that statistic. Recommended actions include maintaining natural processes in our parks such as fire to regenerate trees (*see page 14*) and water flow to maintain river-side forests. We should also manage forests in a way that assists in the transition rather than trying to block it. This means working to connect our parks with the surrounding landscapes in a way that provides forest corridors that plants and animals will need to successfully move north.

A New Normal

Our next ten years (and more) are sure to bring some interesting observations. Perhaps there will be more questions than answers, but long-term monitoring is a finger on the pulse of the natural world. It provides information to help us in our conservation responsibilities and to adjust to a "new normal" for birds in our parks. Either way, we are working to keep the common species common and our parks wild.

—Ted Gostomski

Noteworthy:

- Among 21 of the most common bird species, only five are increasing in all seven parks.
- There are no clear patterns in species trends across parks, but there are species trends in parks that run opposite of those in the larger state or region.
- Warmer, drier weather and the loss of habitat-specific requirements will cause shifts in what bird species future visitors will see and hear in the parks.

Changing From the Outside In

Landscape dynamics describes the ever-changing nature of the land. Some of these changes are important and necessary to the health of forests, prairies, lakes, and rivers.

Some disturbances—such as windstorms that blow down trees, or fires that kill non-native plants and open the resin-heavy cones of jack pines—are part of a natural cycle that creates a mosaic of habitats. Plants and animals can benefit from these disturbances. On the other hand, some human-caused changes have the opposite effect: the development of a subdivision or a parking lot eliminates natural habitats and puts obstacles in the migratory path of plant seeds and animals.

Above: A former Bureau of Mines building complex along the Mississippi River (2008, *left*) is being restored to an oak savanna at the Coldwater Spring property (2013, *right*).

Opposite page (bottom): A prescribed fire at Grand Portage.

A Broader View

We monitor the land area inside the parks and large areas along their borders using satellite imagery and aerial photography, looking for changes affecting two acres or more. We have seen how natural events and human activities can change the landscape, and not surprisingly, changes inside the parks often differ from those outside their borders. This broad view also helps us to identify changes outside the parks that may influence the movement of plants and animals or affect other park resources.

Changes Occurring Inside and Out

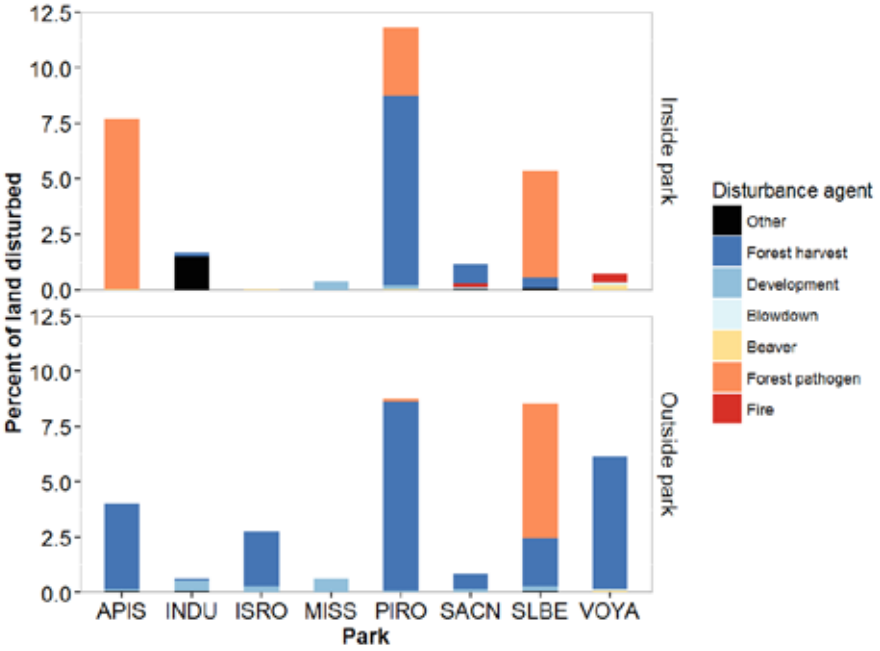
We typically find a healthy, natural disturbance regime inside the parks, with change usually caused by windstorms, insects and diseases, beaver activity, and fire. Some examples of natural disturbance regimes are seen at Voyageurs National Park where we have found disturbances due to fire, beaver, and blowdown in a short six-year period.

Insect activity at Apostle Islands (caused by an outbreak of the "saddled prominent" caterpillar) and Sleeping Bear Dunes (gypsy moths) resulted in large numbers of trees being defoliated. But defoliated trees do not die; the leaves return the next year.

The largest exception to the rule of natural disturbance in the parks is Pictured Rocks National Lakeshore. Logging is allowed within a portion of the park, so forest harvest is the main disturbance both inside and out. We also see a large amount of tree mortality due to beech bark disease spreading from east to west within the park. It is the second most common form of disturbance on both

sides of the park boundary.

As you might expect, human-related activities are the primary disturbance agents outside the parks. This is most notable on lands adjacent to northern parks such as Voyageurs, Apostle Islands, and Pictured Rocks, where logging is the dominant influence. Between 2006 and 2011, nearly 12,000 acres were harvested in a contiguous block on the eastern edge of Pictured Rocks. Large-scale disturbances such as this create unique and sometimes beneficial habitats, but they also fragment the landscape and create the potential for invasive species to enter. In addition, some activities can affect water quality. Heavy logging doesn't just remove trees; it also tramples and strips shrubs and low-growing plants from the soil, plants that normally slow the flow of water over the ground. If they are removed, increased rates of runoff and higher amounts of sediment in that runoff can ruin fish spawning beds and smother developing fish eggs.



The proportion of land disturbed inside (*top*) and outside (*bottom*) of park boundaries, by disturbance agent.

Finally, some disturbances cause permanent changes in the underlying habitat type. A forest harvest has a short-term effect because trees regrow and the land continues to function as a forest. But in urban areas, such as those around the Mississippi River, Indiana Dunes, and parts of the St. Croix River and Sleeping Bear Dunes, more permanent changes occur when forests are replaced by buildings and parking lots, leaving almost no habitat for native plants and animals.

Functioning in Isolation

The Great Lakes Network parks are part of a landscape that spans a wide range of cover types and land uses. The land around the more northern and rural parks is sparsely populated and densely forested. Forest harvest is the primary disturbance agent, fragmenting the landscape and affecting water quality and quantity. The parks in and near urban areas are true islands of natural habitat in a sea of human-dominated land use. Though the amount of disturbance around these parks is small, development continues to engulf what little natural area exists, further isolating the parks and limiting opportunities for animal migration and plant seed dispersal.

—Ulf Gafvert and Al Kirschbaum

Noteworthy:

- We monitor landscape changes as small as two acres in and around the parks using satellite imagery and aerial photography.
- Disturbances inside the parks are dominated by natural causes (windstorms, insects and diseases), while human activities, especially logging, are the primary disturbance agents outside the parks.
- Development is one of the few disturbances that causes permanent changes in the underlying habitat type.

Simplification Is Not Healthy For a Forest

Forests can change very slowly, gradually attaining a mature composition and structure, or they can change in an instant when fire, severe windstorms, or insect outbreaks sweep through.

Our vegetation monitoring program tells us something about the threats and challenges parks face in meeting the NPS mandate to protect scenery and wildlife. The three biggest threats to park forests are altered fire cycles, heavy deer browse pressure, and invasive species. Collectively, these processes contribute to an overall simplification of forest composition and processes.

Above: The difference between a forest with a healthy ground layer (*left*) and one that has been browsed by deer (*right*).

Opposite page (bottom): The mark of deer browse on a bluebead lily leaf.

Altered Fire Regimes

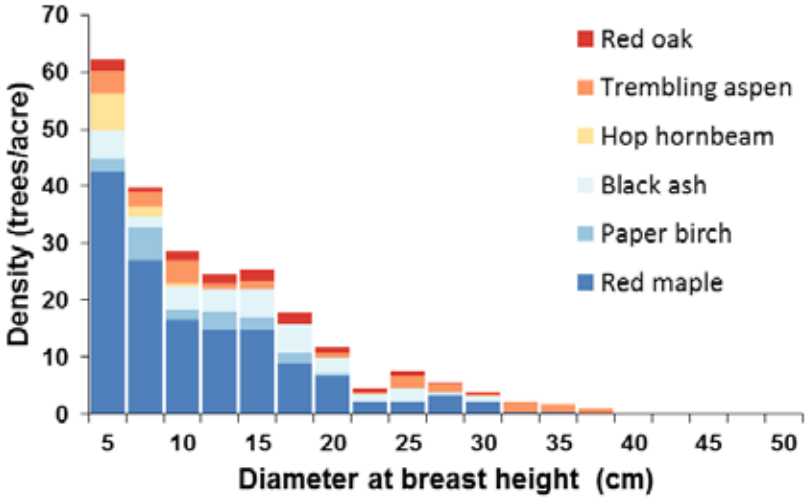
Fire suppression is widespread throughout our national parks and is contributing to a process known as mesophication—a gradual change from a drier, open habitat to one with moderately moist soils and a more shade-tolerant plant community. Without fire, fire-dependent tree species cannot release seeds and successfully regenerate, while fire-intolerant species become common. With this change in species composition, there is a reduction in the amount of sunlight that reaches the forest floor. Red maple is one species that is becoming more widespread as a result of mesophication. Its leafy canopy promotes greater shading, which reduces evaporation and increases soil moisture, further reducing the likelihood of fire. All this leads to a set of conditions that ultimately changes the way a forest functions.

Deer Herbivory

High deer densities are prohibiting the regeneration of some canopy tree species, like white cedar and hemlock, and shrubs such as Canada yew (*see page 20*). Hardwood species such as beech, trembling aspen, and sugar maple may fill the gaps, but the simpler species assemblage that results can have significant impacts. Both cedar and hemlock provide extensive wildlife habitat by sheltering the understory from large snowfalls and providing animals with den and burrow sites. Deer are also over-browsing the ground layer, reducing the number and diversity of herbaceous species including many wildflowers. These are being replaced by low diversity (i.e., simpler) stands of ferns, grasses, and sedges.

Invasive Species

Invasive species include non-native plants, as well as insects (e.g., emerald ash borer), fungi (e.g., Dutch elm disease), and earthworms. Once established, invasive species alter the forest community by limiting the amount of sunlight, water, and nutrients available to native species and can change the successional pathway. The biggest invasive species challenges for Network parks include the non-native beech scale insect, a cause of beech bark disease, which has claimed most of the beech trees at Pictured Rocks (*see page 30*); nonnative earthworms that devour the leaf litter on the forest floor, denying plants the nutrients they need to thrive; and invasive plants such as the exotic honeysuckles that outcompete native shrubs such as the dogwoods, reducing forest richness and the amount of good quality food and habitat available to wildlife.



Red maple is most common among the smaller (younger) trees in upland mixed conifer-hardwood forests along the St. Croix Riverway. Though it is a native species, it can outcompete other trees and dominate an area.

There Is Some Good News

All nine parks have large expanses of high-quality habitat. Many island parks are free from the threats facing mainland parks—deer populations are low or nonexistent (except for Sand and York Islands in the Apostles and North Manitou Island at Sleeping Bear Dunes) and invasive species are limited. As a result, the island forests more closely resemble the pre-Euro-American settlement period. A large number of tree species are regenerating, and the shrub and herb layers contain species not commonly found on the mainland, including a large number of orchids and Canada yew.

The abundant downed woody material and standing dead trees in the parks provide habitat for small mammals, serve as nursery beds for seed germination, and provide nutrients to the plant community. Standing dead trees, or snags, provide habitat for cavity-nesting birds, including woodpeckers, owls, nuthatches, and chickadees.

As climate change continues to affect the region, large blocks of native habitat in our northern parks, especially Isle Royale, will likely provide refuge for a number of boreal tree species, including paper birch, white spruce, and balsam fir. As the climate warms and the concentrations of these species move north, north-facing slopes and sheltered coves cooled by Lake Superior may provide niches where small populations can persist. Ensuring these pockets remain free of invasive species over the next 50–100 years will be a key management action.

—Suzanne Sanders and Jessica Kirschbaum

Noteworthy:

- Not enough fire, too many deer, and the introduction of invasive species are the most common threats to Great Lakes forests.
- Many forests are becoming overly simplified in both species composition and the processes that maintain quality habitat.
- All nine parks have large expanses of high quality habitat, some of which may play an important role as climate change continues to affect the region.

History Emerges From the Deep

The undeveloped lakeshores that are found in the national parks may cause you to stop and wonder what the lake looked like before the upper Midwest was settled by Europeans.

Of course, the tools to measure things like water clarity, nutrients, and algae were not available back then, but we commonly measure these things today and use that information to describe lake water quality. Fortunately, we now also have an indirect but powerful tool to help us develop a reasonable idea of what a lake's water quality conditions were like when European settlers arrived, and that tool is buried in the bottom of the lake.

Above (left to right): Short- and long-cores used to collect lake bottom sediments. Diatoms magnified 875–1,250 times.

The Small But Powerful Diatom

You are probably not thinking about algae when you try to imagine what a lake looked like in the past, but diatoms are a type of algae, or very small plants, that live in lakes and form the base of a lake's food chain.

What makes diatoms unique is that their cell walls are made of biologically produced glass, and when diatoms die, their cell walls are preserved in the lake bottom sediments.

Here's where the history comes in. We collect long cores of sediment from the lake bottoms, assign dates to different layers (similar to how tree rings are counted and aged), then identify the kinds of diatoms that were present in the different time periods. Then, using what we know about the water quality conditions that certain diatoms prefer, we can use the identities of the diatoms in the sediment core to reconstruct past water quality conditions, including water nutrient levels (e.g., phosphorus) and acidity (pH).

These reconstructions are important because we actually measure those same conditions in park lakes today using special sensors and electronic equipment, and by analyzing water samples collected from the lakes. So we can compare our current data with what the diatoms tell us conditions were like hundreds of years ago, before lakes were protected through the creation of national parks.

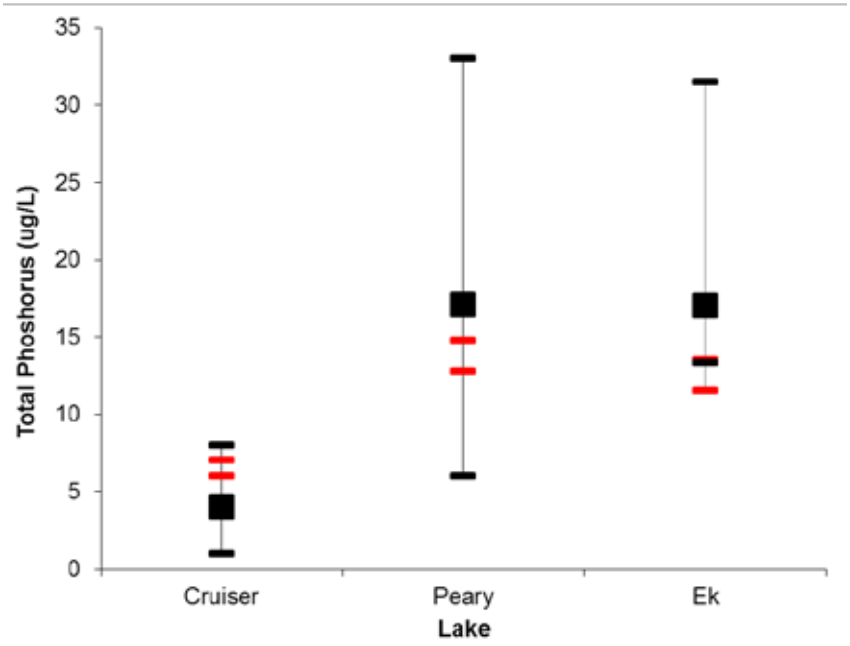
Still the Same...Mostly

When we compare current water quality conditions with our "diatom-inferred" reconstructions of historic water quality

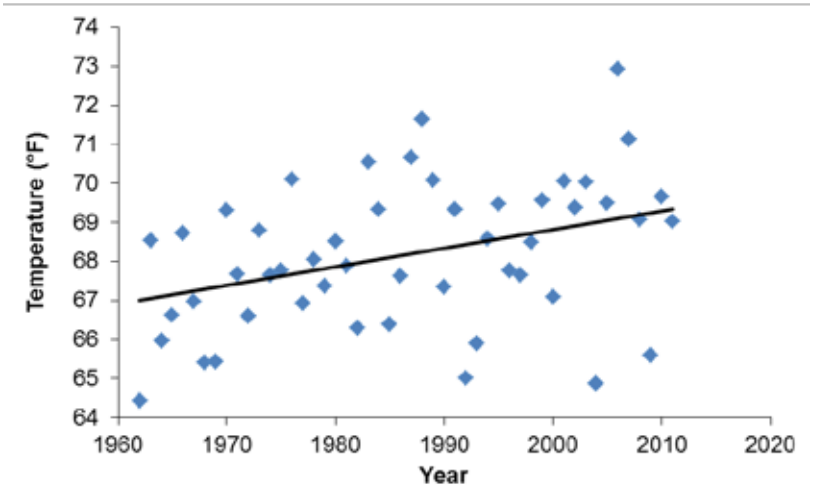
conditions, we can see periods where diatom communities were likely affected by events such as fires, logging, or agriculture. But we also see evidence that water quality in most lakes has not been significantly altered in the last 100 to 200 years (Edlund et al. 2011).

Of course, there is one small but important wrinkle in this story: many of the inland lakes where we monitor water quality have experienced notable changes in their diatom communities in the last 10 to 20 years (Edlund et al. 2011). This might be some sort of climate change signal that has the potential to alter our lakes in ways that we are just beginning to explore.

—David VanderMeulen and Mark Romanski



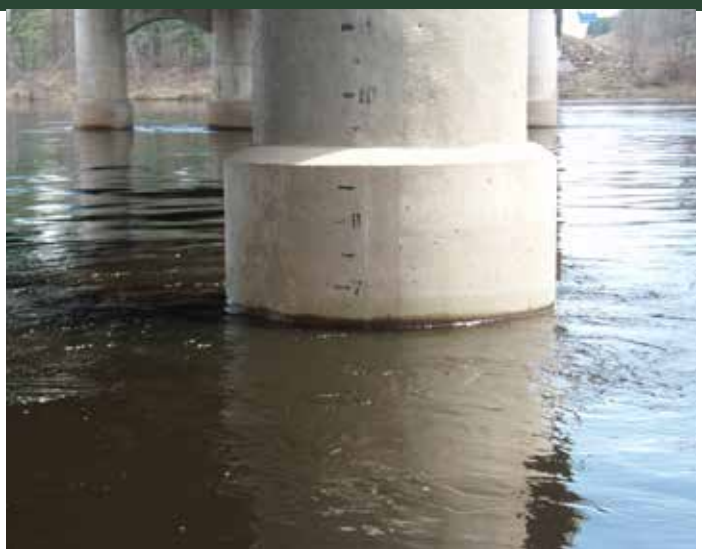
A comparison of total phosphorous levels in three lakes at Voyageurs National Park. Measurements for the years 1780–2000 (red lines) are inferred from the diatom record in lake bottom sediments. Their proximity to levels actually measured by Network staff between 2006 and 2012 (black square and vertical bars) indicates that water quality in these lakes has not changed much in the last 200 years.



Summer temperatures in the shallow waters of Lake Richie on Isle Royale have increased by nearly 2° Celsius since 1960. Similar increases have been seen in three other lakes on the island and at four lakes in Voyageurs National Park. Such changes could affect diatom communities in these lakes, which is something we will watch for in future years.

Noteworthy:

- The glass-like cell walls of diatoms are preserved in lake bottom sediments after the algae dies. Different species require different conditions to survive.
- By dating the layers of lake bottom sediments, then identifying the diatoms in each layer, we can reconstruct historic water quality conditions.
- Comparisons with current data show that water quality in most lakes has not been significantly altered in the last 100 to 200 years.



Going With the Flow

Understanding how rivers were abused in the past is key to appreciating just how much their water quality has improved since the middle of the 20th century.

Early problems were caused by logging and the increase of sediment that washed into the rivers as a result. The construction of dams and wingdams to facilitate logging and, later, locks and dams to aid in navigation altered the river flow, which also degraded conditions for aquatic life. Urbanization and increased wastewater, and a dramatic increase in the use of fertilizer on agricultural lands since the 1950s resulted in high nutrient levels (primarily phosphorous). Combined with increased sediment runoff, the water became a toxic brew, especially in the Mississippi River.

Along with the passage of key legislation such as the Clean Water Act of 1972, changes in land use practices and the technology used in wastewater treatment plants are helping to improve water quality, sustain the rivers, and in some cases bring life back to them.

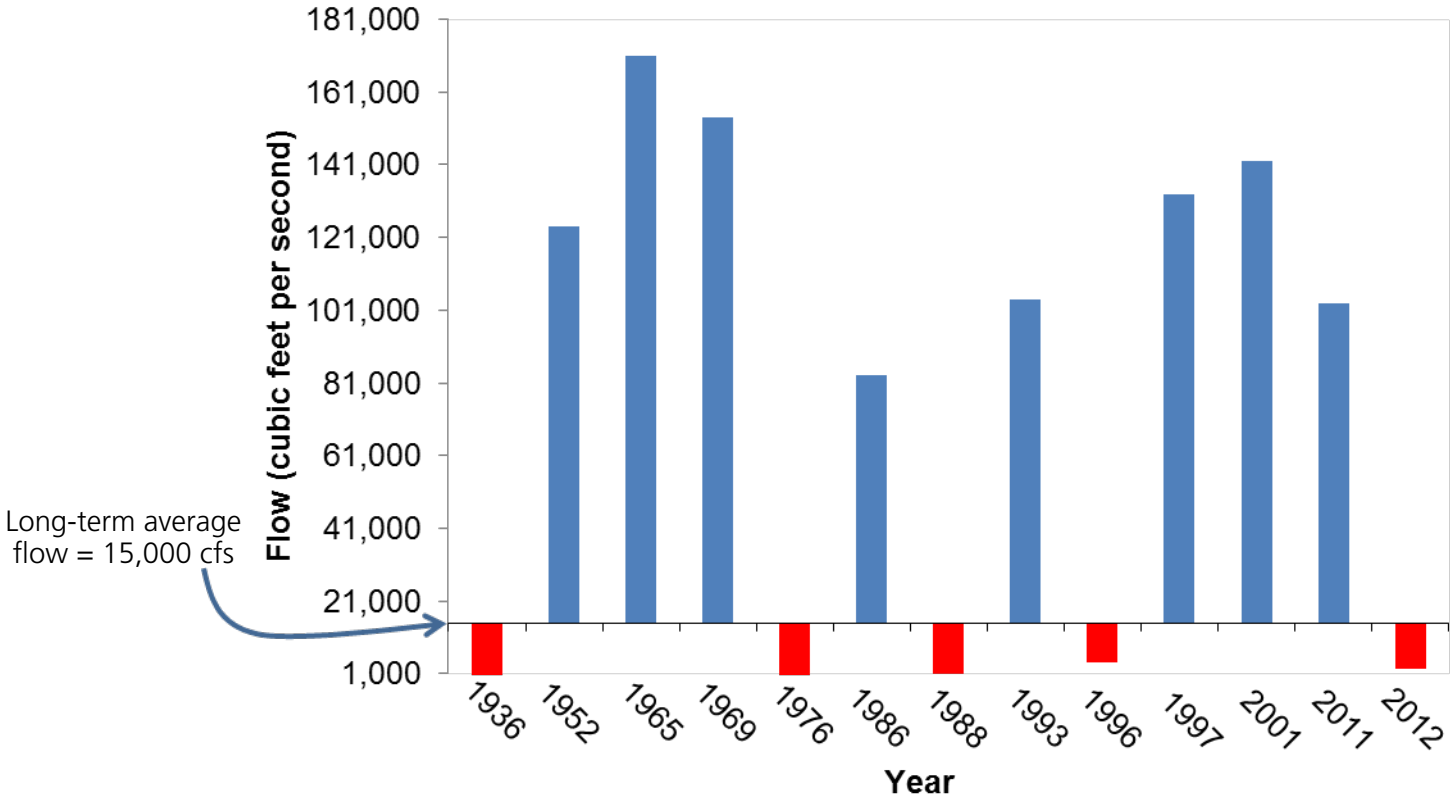
Our water quality monitoring efforts on the Namekagon/St. Croix Rivers and on the Mississippi River allow us to track both current conditions and long-term changes. In addition, the U.S. Geological Survey, U.S. Army Corps of Engineers, Minnesota and Wisconsin Departments of Natural Resources, Minnesota Pollution Control Agency, and Metropolitan Council of Environment Services all conduct long-term water quality monitoring at one or both river parks.

Our monitoring was designed to complement and add to existing efforts, but after comparing several years of data we collected with that collected by others, we found that our efforts on the Mississippi River were not contributing in any substantial way to a better understanding of water quality conditions. So we suspended our field work on the Mississippi River in 2013 and shifted our focus to tracking and periodically analyzing the data collected by the other agencies.

On the St. Croix we now primarily monitor water quality at previously underrepresented areas in the upper Riverway, including areas that the U.S. Environmental Protection Agency considers to be “the best of what is

Above: Differences in land use along the rivers become evident where the blue St. Croix meets the muddy Mississippi (*left*). A depth gauge on a bridge piling provides an indicator of river flow (*right*).

Opposite page: Spring flood on the Apple River, a tributary of the St. Croix



Select high and low flow events on the Mississippi River over the last 80 years, as measured by a gauge in St. Paul, Minnesota. We monitor river flow through the use of stream gauges operated by the U.S. Geological Survey and the U.S. Army Corps of Engineers.

left" for navigable rivers (USEPA 2008).

The constantly changing nature of rivers make trends difficult to verify, but annual monitoring helps us to understand what is happening in a given year. Sometimes that is enough, because, as Leonardo Da Vinci said, "In rivers, the water that you touch is the last of what has passed and the first of that which comes."

—David VanderMeulen and Rick Damstra

Noteworthy:

- Legislation, changes in land use practices, and advances in wastewater treatment technology are helping to improve water quality in the St. Croix and Mississippi Rivers.
- Many state and federal agencies and municipal organizations monitor water quality on the St. Croix and Mississippi Rivers.
- Our monitoring is focused on underrepresented areas of the St. Croix River, including "the best of what is left" for navigable rivers in the U.S.

Apostle Islands National Lakeshore (Wisconsin)

Preserving Windows Into the Past

You walk into the forest and are greeted by a sea of green. There are places where the shrubs grow so close together and the tangle of branches is so dense and tall that you swim, rather than walk, to make progress; at times your feet don't even touch the ground.

The shrub is Canada yew, and the place is York Island. This experience is a very rare one today, but Canada yew used to be very abundant in coastal areas and islands throughout the Great Lakes and the northeastern portion of the United States.

Above: There is a stark difference between healthy yew and yew that has been browsed by deer.

Opposite page (bottom): Deer are able to swim to the islands that are closest to the mainland and from one island to another.

"Deer Candy"

Canada yew is known as "deer candy" because deer so strongly prefer it over anything else. Consequently, Canada yew has declined in abundance in recent years, primarily due to over browsing by white-tailed deer. In the Apostles, large increases in the deer population during the 1950s and 1960s, combined with logging and fire, greatly reduced yew's abundance on many of the islands. Yet, some islands provided refuge to the plant, and on those islands, Canada yew continued to blanket the ground. This was the case for Sand and York Islands until the early 2000s.

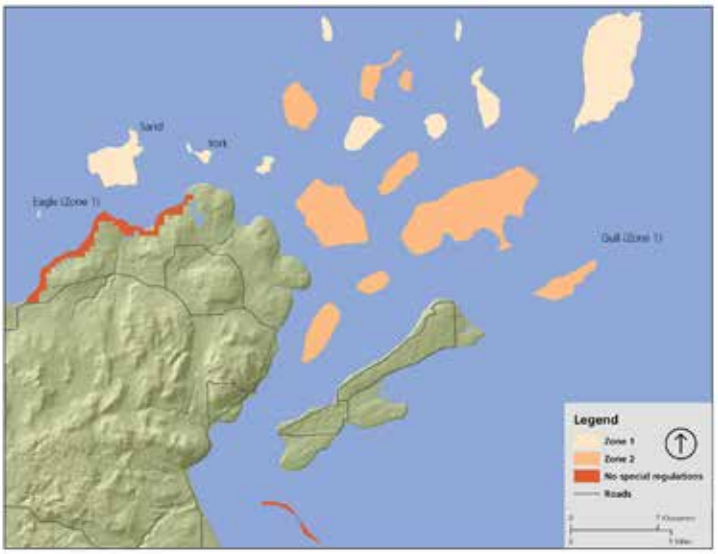
Deer became established on Sand and York Islands in the early 2000s and rapidly multiplied. In less than 10 years, the population on Sand Island grew from near zero to more the 50 deer/mi^2, and browse and pellet survey results revealed that deer were having a severe impact on Canada yew (Smith 2007). The situation was even more apparent on York Island, where the biomass of Canada yew dramatically declined in just a few years (Allison 2006).

The Appropriate Management Tool

In 2004 we began taking actions to reduce the deer population and save this rare plant and its associated forest community. We started by encouraging hunters to participate in an October muzzleloader hunting season on Sand and York Islands. At the same time, we requested the help of our tribal and state partners in developing a harvestable species plan (NPS 2007; updated in 2014), which established two deer management zones in the park. Zone 1 includes 11 islands that historically had few to no deer and has the management goal of keeping deer numbers

as low as possible. The remaining nine islands are within Zone 2. These islands have a history of deer presence and a management goal of keeping deer populations at or below estimated historic levels (<10 deer/mi^2). The park worked closely with the Wisconsin DNR on changes to State regulations needed to implement the plan.

Unfortunately, hunting alone was not enough. Deer numbers continued to increase. Even the addition of Park and volunteers cullers was not enough to stop a burgeoning deer population. Thanks to Great Lakes Restoration Initiative funding, the park was able to enter into an agreement with the U.S. Department of Agriculture's Wildlife Services that brought deer culling specialists to the islands from 2009 to 2012, resulting in a dramatic decline in deer numbers. (All venison acquired through these culling operations was donated to the local tribal food shelf.)



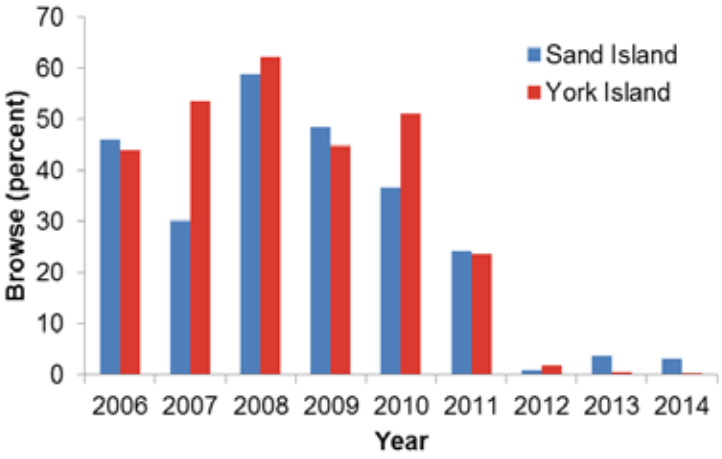
Special deer management zones were created in the Apostle Islands as part of the park's Harvestable Species Plan. The Mainland Unit and Long Island were not included in the park plan.

A Slow Return

Annual browse and pellet surveys, along with remote cameras, allow us to monitor the deer population and determine if we are reaching our management goal. There are hopeful signs. The number of deer pellet groups/acre on Sand Island decreased from a high of 240 in 2008 to 1 in 2014, and Canada yew is slowly showing signs of recovery (Sizer and Johnson 2014).

The story of deer impacts on rare and sensitive plants is a common one. Managing the issue means balancing a vibrant and diverse plant community with a highly visible and beloved animal. Many parks share similar concerns, and we are all striving to achieve that balance.

—Julie Van Stappen



Average percentage of Canada yew browsed by deer in monitoring plots on Sand and York Islands, 2006–2014. Intensive deer culling on the two islands began in 2009.

Noteworthy:

- Canada yew was once so abundant on York Island that it was one of the most difficult islands on which to hike.
- Canada yew has been nearly eliminated from the forest on Sand and York Islands due to deer browsing.
- Strategies to manage deer on the islands have successfully reduced the herd so that yew is now showing signs of recovery.

Above: White pine is a dominant tree on Lake Superior's north shore landscape, making it an integral part of what the Ojibwe call "home."

Regenerating a Cultural Landscape

The southern boreal forest plant community has always been an important part of the heritage and culture of the Grand Portage Ojibwe as well as a critical component of the natural scene along Lake Superior's north shore.

Because of our focus on the Ojibwe people as well as the fur trade, their cultural perspective is the starting point for forest management at Grand Portage National Monument.

There Goes the Neighborhood

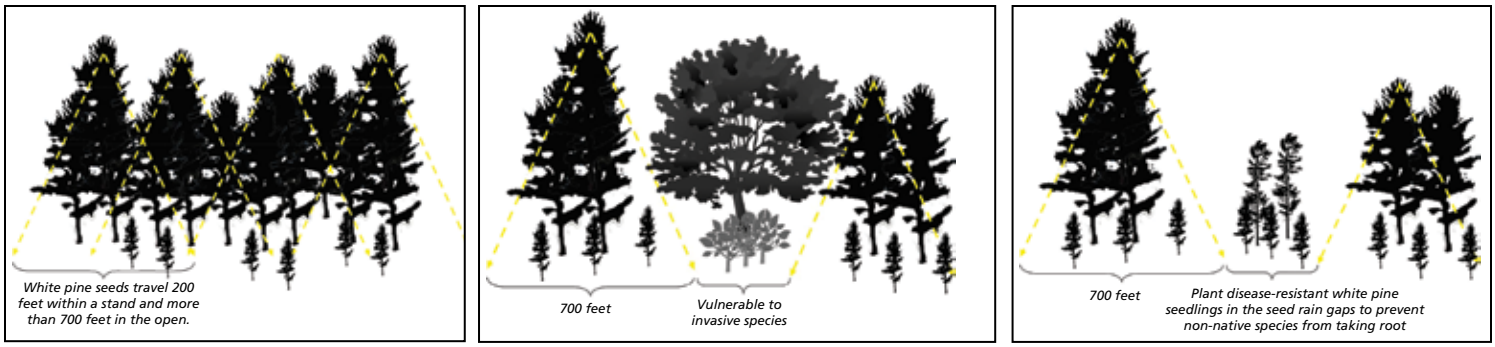
Climate change models predict that boreal forest tree species may disappear from the Great Lakes as the region becomes warmer and drier (Fisichelli et al. 2014a). White pine, black spruce, and tamarack—species native to the boreal forest and part of Grand Portage Ojibwe culture for the last 300–400 years—may vanish and be replaced by species such as black and white oak and black cherry. To lose white pine would be similar to waking up one day to find your entire neighborhood re-built around you; nothing is familiar and all the signs of "home" are gone.

Forest managers have several options for responding to these predicted changes. One is to embrace the potential new species as a novel environment and manage the "new forest" for maximum biodiversity regardless of impacts to cultural practices. A second option is to manage the forest as a historical garden in which we weed out the "exotic" migrants and deny the shift in forest habitat. A third option is to invest in an aggressive program to propagate, restore, and regenerate those native species that are predicted to persist in greater numbers than they do now, species such as black ash, balsam poplar, sugar maple, tamarack, red and white pine, and bigtooth aspen (Fisichelli 2014b). Nurturing this suite of species will create forests that are more resilient to climate-induced changes and maintain a reasonable amount of cultural integrity.

White pine has endured a number of challenges since Euro-American settlement: early 20th century logging, the white pine weevil, fire suppression, and the introduction of white pine blister rust. All of these combined to drastically reduce white pine abundance and genetic diversity in the Great Lakes region (White and Host 2003, Host 2011). White pine occupies a forest niche that could otherwise be filled by red maple, a native species that is considered to be the most aggressive climate change–induced invader of northern forests (Drake et al. 2011) (*see page 14*).

Selecting For Resilience

Cliff and Isabel Ahlgren—two champions of the white pine—sought to restore the tree to its former grandeur. To do this, they selectively bred white pines on the shores of Basswood Lake in northern Minnesota



When seeds fall from the cones of a white pine (called seed rain), they can travel 200 feet within a stand of trees and more than 700 feet in the open. But gaps between stands of white pine are also vulnerable to invasion by non-native or invasive species. By planting disease-resistant white pines in the gaps beyond the 700-foot seed rain buffers of adjacent white pine stands, pine forests have a chance to remain dominant and healthy.

to unravel the secrets of blister rust tolerance (Isabel Ahlgren, personal communication, 2011). After decades of work, they identified a wide diversity of traits that allowed white pine to tolerate blister rust in different ways. To combine these different traits, the Ahlgrens gathered seed from tens of thousands of the most promising trees in northeastern Minnesota and parts of northern Wisconsin, and planted them in U.S. Forest Service nurseries in Michigan and Minnesota. The progeny from these nurseries were then planted in some of the worst blister rust areas on the Minnesota north shore of Lake Superior. To make it even more challenging, every possible alternate host plant for white pine blister rust was planted between the rows of pines. Of course, many pines succumbed to blister rust, but several thousand trees survived unharmed. These remaining trees cross-pollinated each other and created the seed we are using for our restoration project.

Before we planted trees, we used the recently completed forest vegetation inventory (Hop et al. 2010), soils inventory (Gafvert 2009), and forest vegetation monitoring report (Sanders 2008) to identify suitable stands for white pine restoration as well as stands already containing white pine that needed some "regenerative assistance." Next, we mapped a "seed rain" buffer zone around each existing pine or groups of pines, representing the area where seed normally falls from a reproducing tree. Using this map, we planted 700 seedlings in the spaces between seed rain buffers. Additionally, in the pine stands that were already established, we removed vegetation from around the young pines so they had every advantage in reaching the canopy.

Tamarack Is Next

Our next step is to invest in tamarack restoration, but only three tamarack trees remain at Grand Portage, so we have far fewer options for restoration. Still, with a lot of hard work and a little luck, niches abandoned by climate-induced tree migrations will have a good chance of being filled by ecologically and culturally important white pine and tamarack.

—Brandon Seitz

Noteworthy:

- Climate change modeling predicts that some boreal forest tree species will disappear from the northern United States as warmer and drier conditions become the norm.
- Many boreal tree species hold a special place in the culture and history of the Ojibwe people. Losing the trees also means losing a piece of that culture and history.
- Park staff are working to regenerate and restore some boreal tree species including white pine and tamarack.

Saving a Spot of Blue

Above: Checking lupine for Karner blue eggs or caterpillars (*left*). An adult Karner blue butterfly (*right*).

Opposite page: Karner blue caterpillars were raised in individual plastic containers with fresh lupine leaves for food. Team members checked them every day, cleaning the containers and providing fresh leaves until the caterpillars transitioned to the chrysalis (pupal) stage.

In late spring and early to mid-summer, wildlife biologists at Indiana Dunes National Lakeshore are frequently found walking transects and counting Karner blue butterflies.

The Karner blue is a small butterfly whose range formerly extended across 12 states—from Minnesota to Maine—and the province of Ontario, Canada. Today it can only be found in seven states—Minnesota, Wisconsin, Michigan, Ohio, New York, New Hampshire, and Indiana (U.S. Fish and Wildlife Service 2003). The Karner blue is native to Indiana Dunes National Lakeshore, where it favors black oak savanna and the wild lupine that is found there. Wild lupine is the sole host plant for Karner blues during their larval (caterpillar) stage. Restoration of the oak savanna and carefully managed prescribed burns help ensure that populations of wild lupine remain plentiful.

A Slight Change of Plan

The Karner blue butterfly was listed as federally endangered in 1992, so we enlisted a butterfly expert to help design a monitoring protocol and train park staff in its implementation. Intensive monitoring began in 1994 and has continued over the last 21 years.

In the early 2000s, when population monitoring data began to show an alarming downward trend, we worked with multiple partners to develop and carry out a five-year propagation program that began in 2006. As a result of that program, 885 pupae were successfully reared. However, despite both habitat management and propagation efforts, the butterfly population continued to decline. Why?

To find out, we provided funding to the U.S. Geological Survey and the University of Notre Dame to investigate the impacts of climate change on the Karner blue. They raised eggs into multiple generations of butterflies in the laboratory and found that Karner blues produced additional broods in warmer temperatures. Unfortunately, each successive brood yielded lighter-weight butterflies, and lighter-weight females laid fewer eggs. Additional broods also develop later in the season, increasing the risk that wild lupine will die back before the butterflies have fully developed.

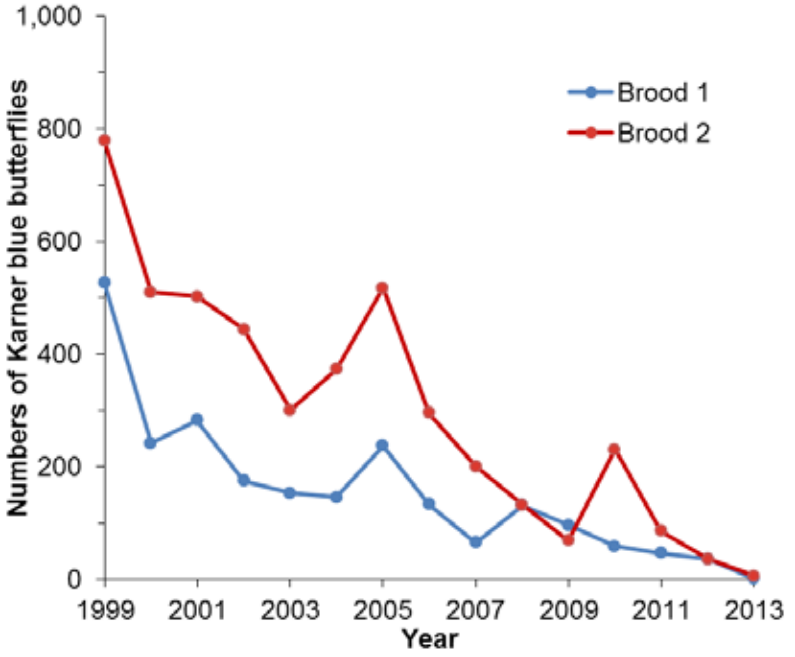
But in 2012, it wasn't late broods that were lost. Instead, hot weather came early to northwestern Indiana, with March temperatures reaching 86 degrees Fahrenheit—something that would normally not happen until April or May. Karner blue eggs hatched much earlier than normal, before many of their wild lupine host plants had emerged. With little to no food, we believe the majority of the Karner blue larva died.

Augmenting the Population

Monitoring data paint a grim picture of the Karner blue butterfly population at Indiana Dunes—only two butterflies were observed in 2014. The population here may be extirpated, or at the very least is extremely low. But we have not given up hope. Eggs from the Karner blues reared in the laboratory experiment are still alive. With the help of partners like the Peggy Notebaert Nature Museum (the educational arm of the Chicago Academy of Sciences), a small number of Karner blue butterflies from other locations will be brought in to augment the Indiana Dunes gene pool. Perhaps this population can be saved.

In the meantime, erratic shifts in weather like those in 2012 are predicted to become more frequent as our climate continues to change at an unprecedented rate. It is a new game, and resource managers must consider new strategies to protect our park resources.

—Wendy Smith



Numbers of Karner blue butterflies observed during surveys on six routes at Indiana Dunes. Surveys are conducted twice a year because Karner blues produce two broods of young each year.

Noteworthy:

- Indiana Dunes National Lakeshore has been managing for and monitoring the endangered Karner blue butterfly since 1992.
- Despite propagation and habitat management efforts, the Karner blue population at Indiana Dunes continues to decline.
- Climate shifts threaten the success of efforts to save this endangered species.

The Island as Refuge

Many people, when they hear the word "island," immediately envision a tropical landscape with palm trees and white sand beaches.

Indeed, many islands fit this stereotype, but islands in the boreal forest are quite different from this mental image. On Isle Royale, for example, the islands were created by ancient lava flows and are covered in shallow soils and dense forests. But, like islands found the world over, Isle Royale is a dynamic ecosystem, influenced by the size of the island and its distance from the mainland. It is this isolation that can significantly hinder some plant and animal populations from thriving—such as the inbreeding currently afflicting Isle Royale wolves (Räikkönen et al. 2009)—while others find a refuge from potential stressors. Those that thrive may even, over time, become genetically distinct from mainland populations of the same species (Howell 1936).

Above: Common loons (*left*) and a northern long-eared bat (*right*).

Opposite page (top): Butterwort is an arctic disjunct plant that grows in the rocky crevices of Isle Royale's Lake Superior shoreline.

At Isle Royale National Park we see many examples of flora and fauna that have taken refuge here. Numerous plant species in the park are disjuncts, cut off from their arctic and western origins. The island is also home to the federally threatened northern long-eared bat, and more than one-third of Michigan's breeding common loons and two-thirds of the state's moose.

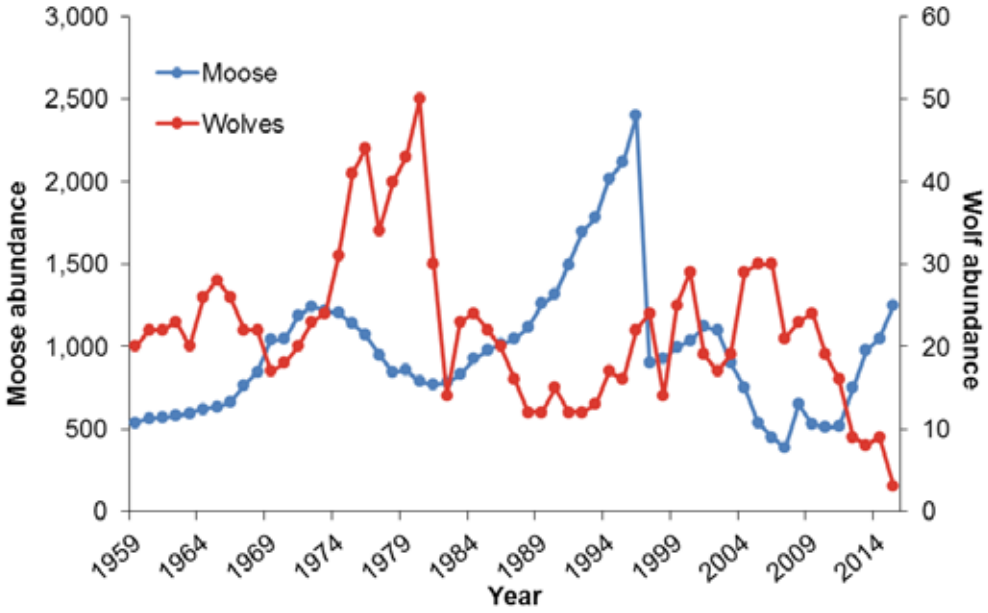
Arctic and Western Plants

The island's rocky shores and the cold waters of Lake Superior that surround it provide perfect ecological niches for nearly two dozen plant species that are western disjuncts or have arctic-alpine affinities (Slavick and Janke 1987). Disjunct species are those with unusually wide gaps in their overall geographic distribution. Most of the disjunct plants on Isle Royale found refuge here as the ice sheets receded from the Laurentian Great Lakes almost 10,000 years ago, so the next closest place to find them is in the Black Hills of South Dakota and further west to the coast of the U.S. and Canada.

Wildlife, From Small to Tall

Disjunct species on the island are not limited to the plants. A recent bee survey found over 30 species of native bees on the island (Rodman et al. 2015), many of which exhibit this disjunct distribution; two are being evaluated as potentially new, previously unknown species.

The federally threatened northern long-eared bat is one of the six species of bats known to spend summers on Isle Royale. Bats are fully protected within the park boundaries, and the island provides ample high-quality habitat and abundant food. What we do not have is good winter habitat, so the bats migrate off the island to find hibernation sites for the winter. As a result, even though Isle Royale can serve as a summer refuge, it cannot protect this species from its greatest threat: white-nose syndrome, a fungal infection



Isle Royale's wolf and moose populations have fluctuated through time in response to winter ticks and harsh winters (for moose) and disease and genetic issues (for wolves). Data from the Wolves and Moose of Isle Royale web page (www.isleroyalewolf.org/)

that affects this bat and others during their long winter hibernation.

For moose, the island serves as a refuge from a multitude of stressors (including warming temperatures and brainworm) that are causing populations to decline across much of the Great Lakes region (Dybas 2009). So while mainland moose have been steadily declining in recent years, Isle Royale moose have been steadily increasing.

Sometimes Isolation Isn't Enough

In our increasingly connected world, even islands may not continue to be effective refuges. We do what we can to protect the plant and animal species that reside in the national parks, but we have little control over what happens to these species once they leave our boundaries.

—Paul Brown

Noteworthy:

- Islands are dynamic ecosystems that are influenced by the size of the island and its distance from the mainland.
- This isolation can significantly hinder the success of some plant and animal populations while helping others.
- Isle Royale is a refuge for unique plants and animals, but the specter of climate change may affect what species are found there in the future.

The Cleaner That Isn't So Clean

Your family has enjoyed a wonderful day at the park. There is no running water, but you brought along a large bottle of antibacterial handwash.

It's come in handy for the kids, especially the one that grabbed a frog and then wanted to grab a hamburger! But did you read the label on that handwash? Are you familiar with triclosan, a common ingredient in some antibacterial products?

Triclosan is an antibacterial product developed in the 1960s and introduced for use in health care facilities in 1972; it has since been added to a wide variety of household products. It is most commonly found in liquid antibacterial hand and dish soaps, but is also used in toothpaste, deodorant, fabric, kitchenware, and cosmetics. An estimated 96% of triclosan from consumer products goes down the drain, much of it eventually reaching wastewater treatment plants (*see page 9*). Treatment plants are not designed to remove triclosan, so it remains in treated water that is discharged into the environment (Buth et al. 2010).

What Are the Risks?

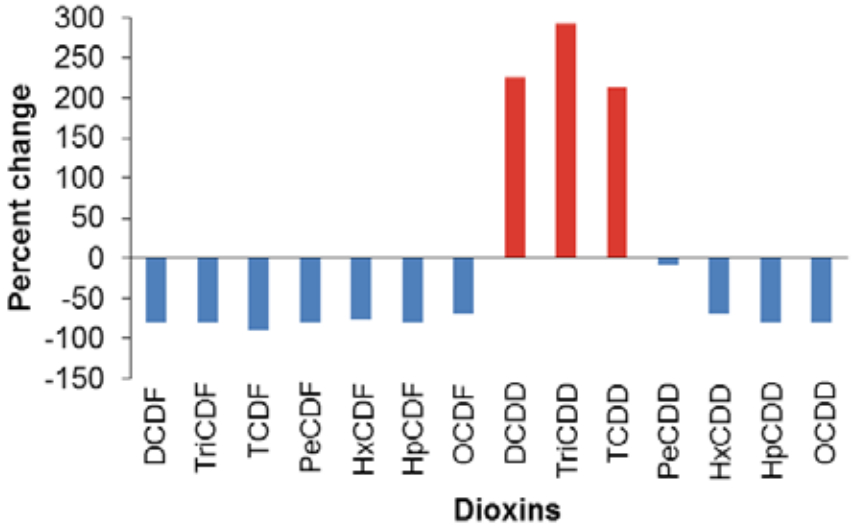
You might think, "it's a hand-cleaner; what could be so bad about it?" First, as triclosan moves through the wastewater treatment process, it is exposed to sunlight and chlorine, which can transform it into potentially harmful dioxins and other carcinogens, some of which can persist in our environment (Buth et al. 2010). Once in the environment, triclosan can directly impact aquatic organisms by interfering with thyroid and reproductive systems, disrupting endocrine function, and affecting neural development (Chalew and Halden 2009, Martin 2011). It has also been shown to disrupt muscle function in mice (Cherednichenko et al. 2012) and interfere with fetal development in sheep (James et al. 2010).

Humans can be exposed to triclosan through skin contact, ingestion of contaminated drinking water, or inhalation (Food and Water Watch 2009, Minnesota Department of Health 2010). It has been found in the urine of 75% of Americans over the age of five (Calafat et al. 2008, Martin 2011), breast milk (Allmyr et al. 2006), and blood (Allmyr et al. 2008). Higher overall levels are found in the bodies of people who use triclosan products.

Triclosan's effects on humans are unclear, but triclosan exposure can lead to allergy susceptibility in humans (Savage et al. 2012) and present risks to healthy fetal development in pregnant women (Woodruff et al. 2011). In addition, the Minnesota Department of Health (2010) recommends against using antibacterial products in most home applications because they may contribute to the emergence of resistant strains of bacteria.

Status and Trends

In the bottom sediments of Lake Pepin—a naturally occurring lake approximately 60 miles downstream from Saint Paul, Minnesota—the amount of triclosan-derived dioxins has increased by 200% to 300% since 1963. Dioxins are highly toxic, and this increase is consistent with the increased use of triclosan since its introduction into household products. Levels of all other dioxins have decreased by 73% to 90% (Buth et al. 2010). Triclosan-derived dioxins represent as much as 31% of the total mass of dioxins in Lake Pepin sediment (Buth et al. 2010).



The amount of triclosan-derived dioxins (red bars) in sediments at the bottom of Lake Pepin has increased by 200% to 300% since 1963, while all other dioxins (blue bars) have decreased (Buth et al. 2010).

The U.S. Geological Survey found that 58% of U.S. streams contain triclosan, including the metro Mississippi River (Kolpin et al. 2002). Amounts are also increasing in several Minnesota lakes (Anger et al. 2013).

What You Can Do

Consumers who are concerned about the potential impacts of triclosan can: (1) follow the recommendations of both the Minnesota Department of Health and the American Medical Association by avoiding triclosan products for personal or household use; (2) look for triclosan in the ingredients list or "Drug Facts" box of over-the-counter drugs or personal care products; and (3) wash hands with soap and warm water, which the Centers for Disease Control and Prevention (2012) suggest is the best way to remove germs. If soap and water are unavailable, clean your hands with a hand sanitizer that contains at least 60% alcohol. Alcohol-based hand sanitizers do not contain triclosan.

The Future

In 2014, partially in response to attention brought to this issue by Russell and Weller (2013), Minnesota passed legislation banning the sale of triclosan-containing consumer products. The law goes into effect on January 1, 2017, but some manufacturers have already announced plans to phaseout the use of triclosan in their consumer products (Thomas 2012). Until similar actions are taken elsewhere, consumers need to be diligent in watching what they buy and what they send down the drain.

—Lark Weller and Trevor Russell

Noteworthy:

- Triclosan is an antibacterial product used in a wide variety of household items.
- Triclosan is present in 75% of Americans over the age of five.
- Minnesota has passed the nation's first legislation to ban triclosan in consumer products.

Beech Bark Disease Affects More Than Just Trees

The northern hardwood forest is home to the red-shouldered hawk and northern goshawk, both of whom are nest specialists that need the interior of mature northern hardwood forests with a closed canopy for nest sites.

Above: A beech tree infected with beech bark disease (*left*). An adult northern goshawk (*right*).

Opposite page (bottom): A red-shouldered hawk nest is exposed to extreme heat after beech bark disease kills the tree and the leafy canopy is lost.

Beech bark disease—a two-part "disease complex" involving a beech scale insect followed by two species of fungi (Ehrlich 1934)—is killing beech trees across the Northeast and Midwest, and at Pictured Rocks National Lakeshore. The loss of nest trees, increased competition from other hawks and owls exploiting the open forest, and a loss of prey species can all lead to declining populations of red-shouldered hawks (a State threatened species) and northern goshawks (a species of Special Concern in Michigan).

Nesting

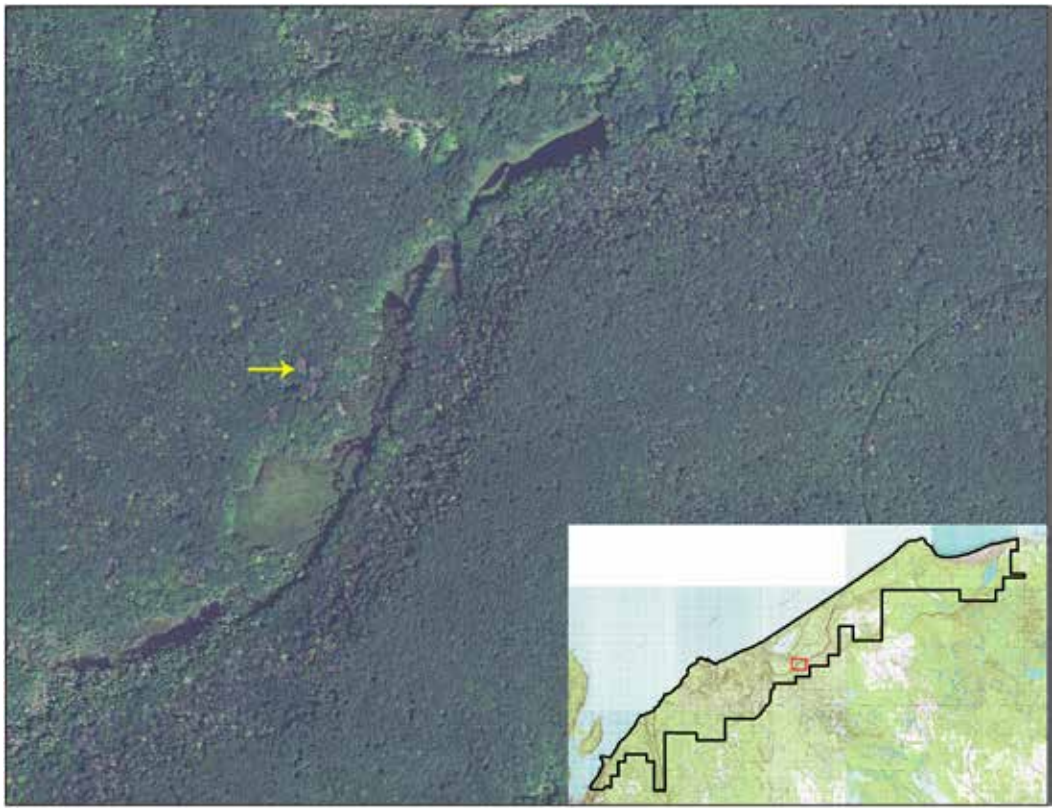
One way beech bark disease affects red-shouldered hawks and northern goshawks is by killing nest trees. Like other raptors, both red-shoulders and goshawks require a sturdy tree with appropriate branching that will support their large nests. They typically nest near the bottom of the high leafy canopy, which provides protection from wind, rain, and late season snows. Due to past logging practices, American beech are sometimes the only suitable trees available to nesting hawks. An infected tree loses its protective leafy cover as it slowly dies. This loss of cover exposes incubating adults, eggs, and then chicks to sun, wind, rain, and cold temperatures, all of which introduce unnecessary stress to the birds and can ultimately kill the developing embryos or the hatched chicks.

Competition and Predation

As beech trees die, gaps form where beech trees once stood and the closed canopy forest becomes more open. As the forests open up, red-tailed hawks can move deeper into the forest and, if given the chance, will kill the smaller red-shouldered hawks or push them out by taking over nest sites (Craighead and Craighead 1969). This happened once before, in Michigan's Lower Peninsula as it was cleared for farming in the 19th century (Craighead and Craighead 1969). Now, due to beech bark disease, history may repeat itself, as we are seeing more red-tailed hawks and fewer red-shouldered hawks in the park.

Though it is unclear if northern goshawks are increasing or if our ability to find their nests has improved, this larger forest raptor is also susceptible to predation. Like red-tailed hawks, great horned owls will infiltrate farther into an open forest and prey on both nestling and adult goshawks and red-shouldered hawks (Craighead and Craighead 1969, Curnutt 2009). An owl is suspected

to have killed an adult northern goshawk and preyed on its nest in 2014—the first such incident documented in the park.



Seen from the air (2012), a dark brown, S-shaped line of dead beech trees along the southern edge of the Beaver Basin Wilderness gives a sense of the devastation beech bark disease is inflicting in the park's forests. The purplish-brown dots north and east of the ridgeline (left side of the photo; group of three largest indicated by yellow arrow) are also dead beech trees. Inset map shows the location of this ridge in the park.

Food Production

The death of beech trees also causes a significant decline in the production of beech nuts, or mast. Beech nuts are an extremely important food for many animals including chipmunks, red squirrels, ruffed grouse, and blue jays—animals that also happen to be some of the preferred prey of red-shouldered hawks and goshawks. One study in central Appalachia found that survival of the ruffed grouse population depends strongly on mast crops, particularly beech and oak (Tirpak et al. 2006). Another (Rosemier and Storer 2010) found that the abundance of white-footed mice and deer mice in Michigan's Upper Peninsula was related to the production of beech seeds the previous autumn. They also found a correlation between eastern chipmunk abundance and the presence of beech, and that small mammals (deer mice, eastern chipmunk, and red-backed voles) preferred American beech seeds over those from sugar maples.

Losing beech trees will have a profound effect on seed-eating birds and small mammals, and those effects will ripple throughout the food web, all the way to the woodland raptors.

—Cindy Heyd

Noteworthy:

- Beech bark disease—a two-part "disease complex" involving a beech scale insect followed by two species of fungi—is killing beech trees throughout Pictured Rocks National Lakeshore.
- Interior forest hawks are especially vulnerable because suitable nest sites are lost, there is increased competition with and predation by other raptors, and the small mammals they prey on are affected.
- The loss of beech nuts reduces the amount of food available for small mammals.

Sharing the Beach With Piping Plovers

A high-pitched *peep-lo* called out over the beach announces the return of piping plovers each spring.

Piping plovers are small migratory shorebirds with three distinct breeding populations in the United States, one of which is found on beaches in the Great Lakes region. Great Lakes piping plovers nest on wide, sparsely vegetated beaches with a fair amount of cobble and gravel. They were once considered common around the Great Lakes, but increasing development and recreational use of coastal beaches greatly reduced their available habitat, resulting in significant population declines (Cuthbert et al. 2014). Only 17 nesting pairs remained in the region by the 1980s, all of them in Michigan. Subsequently, the piping plover was listed as federally endangered in 1986.

Above: Once nests are located, park staff close sections of beach during the plover nesting season (*left*). A newly-hatched piping plover wears colored leg bands (*right*).

Opposite page (bottom): Plover nests are well-camouflaged among the sand and gravel.

Taking Action in a Variety of Ways

One-third of the Great Lakes piping plover population nests at Sleeping Bear Dunes, so we have an important role in a multi-faceted species recovery program that includes monitoring, protection, education, and research. We work with the U.S. Fish and Wildlife Service and other agencies, universities, private institutions, and a network of citizen volunteers to help the piping plover reach the primary recovery goal of 150 nesting pairs in the Great Lakes region, with 100 of them in Michigan.

Sharing the Beach

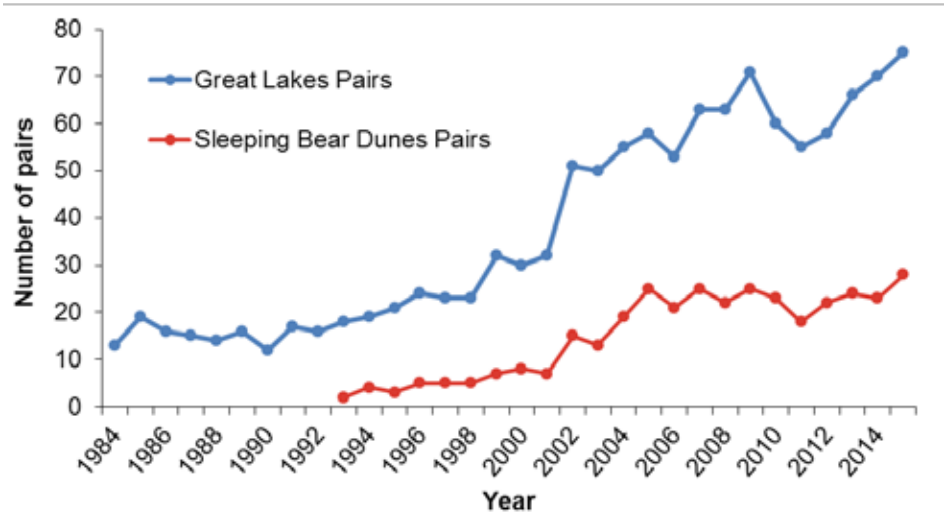
Our work begins each year with a search for nests along park beaches. Where nests are found, those beaches are closed to limit the potential for disturbance by humans and their pets. Adult plovers that are frequently scared off their nests will abandon that nest, or the unprotected eggs will fail to hatch because of frequent exposure to heat, cold, or rain.

We use displays, media, and on-site programming to provide beach users, school groups, and the general public with information about piping plovers. These efforts go a long way in helping visitors to understand why some park beaches are closed in early summer. Plovers begin migrating south in mid-July, so beaches are reopened once nesting and chick-rearing is completed.

Nests are monitored throughout the breeding season. When eggs are laid, we place a small cage, or nest exclosure, over each nest to protect the birds and their eggs from predators. The mesh size of these exclosures is large enough for plovers to move through, but it prevents predators from taking adults, eggs, or chicks. Foxes, gulls, and crows are often attracted to areas where beach-goers have left behind food and garbage, but they also find their prey by watching the movements of adult plovers that have been scared off their nests. Additionally, the

merlin (a small falcon) is thought to be responsible for the loss of approximately 30 adult piping plovers since 2005, along with an unknown number of chick deaths (Cuthbert et al. 2014).

After eggs hatch and young leave the nest, we capture adult plovers and their young and place color-coded bands on their legs. These bands allow us to identify individual birds from year to year so that we can track its age, measure its nesting success, and determine what migration routes and wintering sites it uses. This information guides our management strategies. For example, we now know that consistent use of exclosures increases hatching success and that chicks who hatch earlier are more likely to survive to fledging (Saunders et al. 2014).



Recovery efforts have lifted the Great Lakes piping plover population from 14 pairs in 1984 to 75 in 2015. One-third of the Great Lakes piping plover population nests at Sleeping Bear Dunes National Lakeshore.

One exciting component of our species recovery efforts is a captive rearing program in partnership with the Detroit Zoo. When a nesting adult is preyed upon or otherwise abandons a nest, the abandoned eggs are collected and sent to any one of a network of zoo keepers across the country. The eggs are incubated and hatched, and the young are fed and carefully monitored until they are ready for release back into the wild. Seven chicks were captive-reared and released in 2015.

What the Future Holds

Our combined efforts have contributed to a steady increase in the Great Lakes region from 13 pairs in 1984 to 75 breeding pairs in in 2015. Yet, the population remains well below the recovery goal. The potential loss of beach habitat due to climate change-induced fluctuations in lake level is one threat, but a bigger concern is the unforeseen random event such as a severe storm or disease outbreak. Such events are especially threatening to sites like Sleeping Bear Dunes, where plovers are abundant and nest density is high, because a catastrophic event would affect a larger proportion of the population at one time.

Until the population is large enough to sustain natural losses and hazards, intensive monitoring and conservation strategies will be necessary to ensure every spring is accompanied by a high-pitched *peep-lo*.

—Sue Jennings and Kevin Skerl

Noteworthy:

- There were 17 pairs of piping plovers nesting in the Great Lakes region—all of them in Michigan—when the shorebird was first listed as endangered in 1986.
- The primary recovery goal for the Great Lakes population is to have 150 nesting pairs in the Great Lakes region, with 100 of them in Michigan.
- In 2015, there were 75 breeding pairs in the region, one-third of which nested on beaches at Sleeping Bear Dunes National Lakeshore.

It Takes a Fish to Grow a Mussel

If you are an animal that can live for 80 years or more, if you only move 10 feet during your lifetime, and if you gather food by filtering water, you do not respond very well to the loss of your home or the declining quality of water from which you feed.

Such is the case for many of the mussels that are native to our country's rivers. The St. Croix National Scenic Riverway boasts over 40 species of native freshwater mussels (more than any other river outside the southeastern United States), among which are five federally endangered species with colorful names like the Higgins eye, winged mapleleaf, snuffbox, sheepnose, and spectaclecase.

Above: Higgins eye mussels.

Opposite page (bottom): A winged mapleleaf displays her glochidia-filled lure to attract a host fish.

An Incredible Find

In the mid-1980s, a park naturalist asked a private mussel researcher to identify a shell for him. The researcher was thrilled to report that it was a winged mapleleaf—the first evidence that the species was in the St. Croix River! A number of surveys ensued to determine how many mussels there were and where they were living (Doolittle 1988). Regular population monitoring followed, and NPS biologists continue to assist the U.S. Army Corps of Engineers in their assessments of mussel communities at two locations in the river.

Simply monitoring was not enough, so in the late 1990s, the Upper Mississippi Basin Mussel Coordination Team began working to improve conditions for the survival of these important river dwellers. One of our projects was to develop rearing techniques for several of the threatened, endangered, or special concern species.

It Takes a Fish...And a Matchmaker

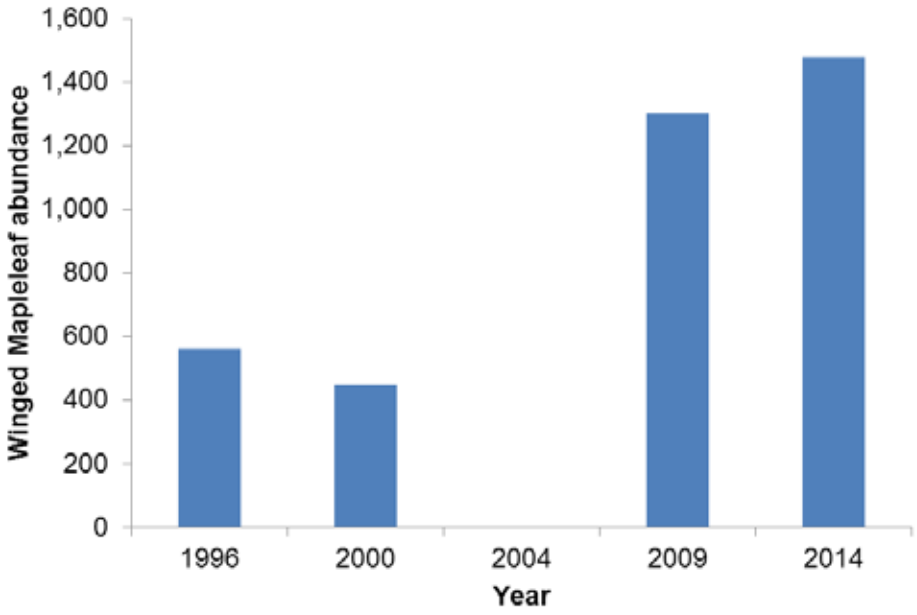
There is an important connection between mussels and fish. For mussels to reproduce, they use fish as a host for their developing larvae (called glochidia). Some mussels use more than one host fish species. Winged mapleleaf mussels in the St. Croix River use only one—the channel catfish. So our first step was to identify and then raise the host fish.

When an adult mussel is ready to release her glochidia, she uses different types of lures to attract the host. Some produce small glochidia-filled packets that look like tasty insects a fish might want to eat. Others produce flaps that look like minnows, complete with eye spots, tails, and fins. Several species troll "lures" behind them that wave in the current like fish bait. Using her lure, a female mussel attracts a fish in close, then transfers the glochidia to it by inducing a bite from the fish or simply squirting the glochidia onto it. The glochidia latch onto the gills or fins of the unsuspecting host and stay there for a period of weeks or months, drawing nutrients from the fish's blood to

develop their own internal organs.

Our second step, once we raised the fish, was to find female mussels at the right time to donate their young, and to put the two together so that the mussels could transfer their glochidia to the appropriate host fish.

The fish are not harmed by this semi-parasitic relationship, and in addition to being a "mussel nursery," they help young mussels to disperse by giving them rides to different parts of the river. Once the mussels are old enough, they drop off the fish and begin living as adults on the river bottom, but only if they land on a suitable area. To ensure successful dispersal, we placed the glochidia-laden fish in cages in appropriate reaches of the river, then monitored the growth of the newly free–living mussels for several months.



Estimated number of winged mapleleaf mussels in the Interstate Study Area, St. Croix River, derived from number of mussels observed in square-meter quadrats. Data from multiple sources and summarized by U.S. Fish and Wildlife Service (2015).

Success and Challenges

Using these methods, we have helped raise thousands of Higgins eye mussels in the last 10 years. Winged mapleleaf mussels have proven more challenging; we have only been able to raise and recover a few dozen over this same period. But in 2014, we found hundreds of winged mapleleaf mussels that were released during our first propagation effort in 2005, suggesting we might indeed be able to raise these animals in the wild.

Our propagation efforts are especially important to mussel populations in the St. Croix River because their survival is threatened by non-native zebra mussels and Asian carp as well as habitat loss. But even worse is that survival and reproduction of native mussels are hampered by chemicals and microplastics from personal care products (*see pages 8 and 28*), caffeine, and pharmaceuticals that pass through wastewater treatment plants. Mussels can continue to thrive if we are diligent in keeping the invasive species out, and if we are mindful of what we wash down the drain. We can grow mussels, but it takes a clean river to keep them alive, and that is something everyone can help to achieve.

—Byron Karns

Noteworthy:

- The St. Croix River is home to more than 40 species of native mussels—more than any other river outside the southeastern United States.
- The NPS is involved in monitoring, propagation, restoration, and research of native mussels. Successes include a colony of hundreds of endangered winged mapleleaf mussels thriving in the river.
- Threats to native mussels include the invasions of nonnative zebra mussels and black carp, the loss of habitat, and the decline of water quality.

Mercury Contamination: Improvements on the Horizon?

Voyageurs National Park, like most of the upper Midwest, lies in a mercury-sensitive landscape where mercury deposited from the atmosphere is transformed to methylmercury that accumulates to dangerously high levels in fish and wildlife.

Above and opposite page (bottom): Fishing for northern pike is a popular activity at Voyageurs, but people need to be aware of the health risks posed by eating fish contaminated with mercury.

Many of the lakes in Voyageurs are listed as impaired by the U.S. Environmental Protection Agency and are subject to Minnesota Department of Health fish consumption advisories. Anglers spend over 700,000 hours per year fishing in the park, with walleye and northern pike being the most frequently harvested species (Kallemeyn et al. 2003). Considering that these predatory fish are known to accumulate high levels of mercury and are frequently eaten by humans, mercury contamination of park lakes is a public health concern in addition to being an ecosystem health issue.

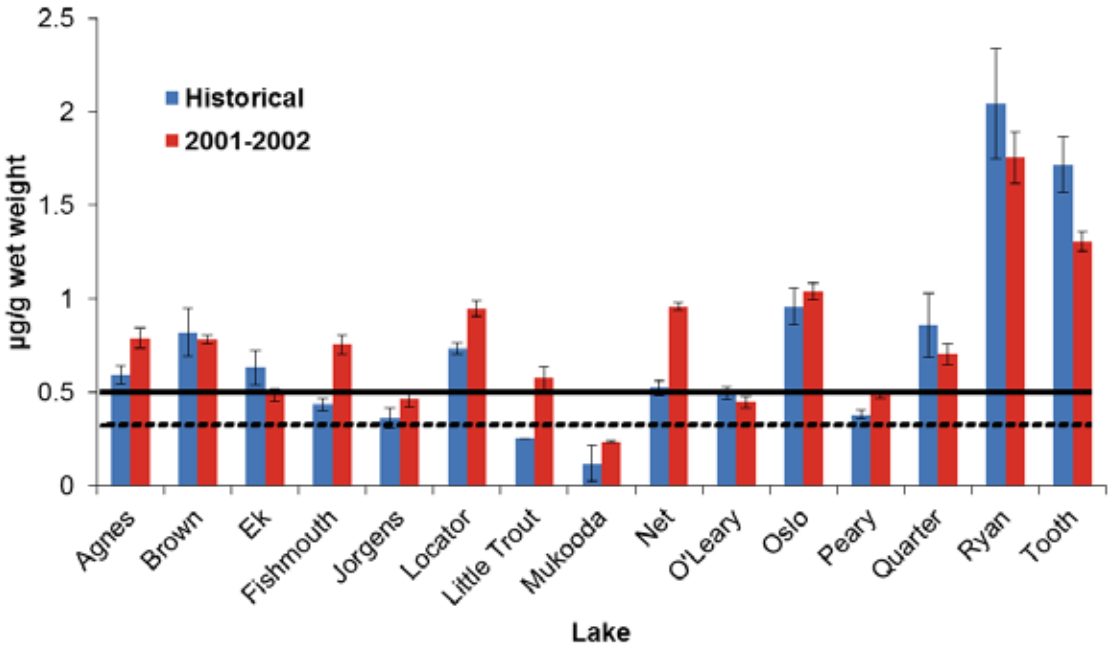
Scientists at Voyageurs National Park have been monitoring mercury in the park's lakes for over a decade, working with the Great Lakes Inventory and Monitoring Network, the U.S. Geological Survey, the University of Wisconsin–La Crosse, the University of Minnesota–Duluth, the Minnesota Pollution Control Agency, the Science Museum of Minnesota, and others to determine where the mercury comes from and how it moves through the food web. This work has revealed that the majority of mercury contamination in this region comes from human sources such as coal fired power plants and industrial boilers (Evers et al. 2011), and that natural chemical processes that occur in wetlands play a role in changing this mercury to methylmercury.

Methylmercury is the most toxic form of mercury and the cause of our concern for fish and other aquatic organisms (Wiener et al. 2006). Inorganic mercury falls into lake water as rain, snow, or dust, where sulfate-reducing bacteria living in the bottom of the lake transform it into organic and highly toxic methylmercury—a process known as methylation. We have found that methylmercury has contaminated all levels of the aquatic food web including invertebrates, fish, fish-eating birds such as common loons and bald eagles, and even terrestrial songbirds that eat aquatic insects.

Dams artificially control water levels in Rainy Lake and the Namakan Reservoir. Studies have established a link between annual water level fluctuations and the pulse of methylmercury that enters the aquatic food web in these two lakes (Sorensen et al. 2005, Larson et al. 2014). Large fluctuations in water levels release methylmercury when the bottom sediments and associated wetlands are exposed and re-flooded.

Reasons for Optimism

A recent publication (Brigham et al. 2014) shows that mercury contamination of some interior lakes at Voyageurs is decreasing in concert with decreasing amounts of mercury being deposited in northern Minnesota from the atmosphere. We believe this is related to better controls on emissions from coal-fired power plants and waste incinerators. A similar decline in mercury levels was documented in bald eagles nesting in and around Wisconsin's Apostle Islands National Lakeshore (Dykstra et al. 2010).



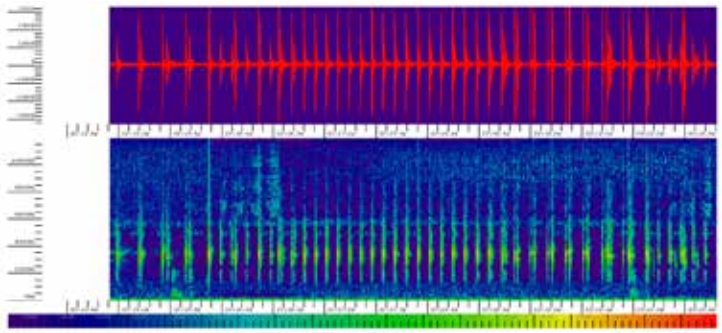
Mercury levels in northern pike from 15 lakes at Voyageurs National Park, 1986–1999 (historical) and 2001–2002. Dashed line shows the level at which the U.S. Environmental Protection Agency considers a fish to be unsafe for human consumption (0.3 micrograms/g). Solid line shows the level at which mercury begins to affect a fish's ability to reproduce. Data from Knights et al. (2005).

Through our monitoring and future work, we aim to provide dam operators with water level management options that would decrease mercury contamination in these large lakes that are popular fishing destinations. Moreover, continued efforts to control emissions through cleaner energy sources, regulation, and improved technologies can slowly decrease the levels of mercury in the aquatic systems, which will benefit fish, wildlife, and people.

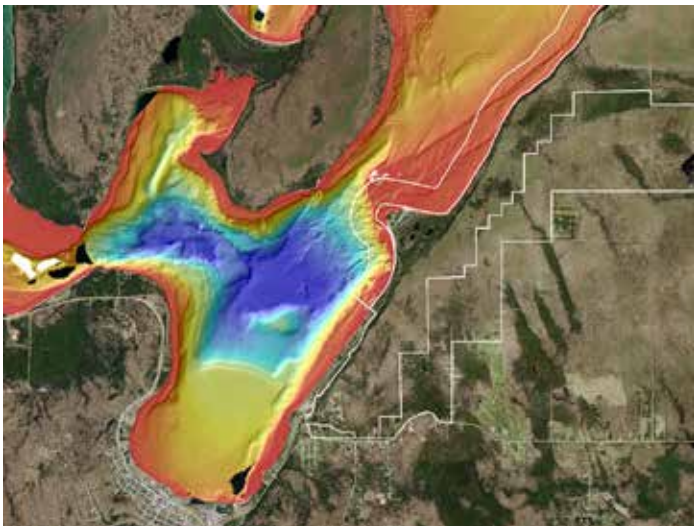
—Ryan Maki and Bill Route

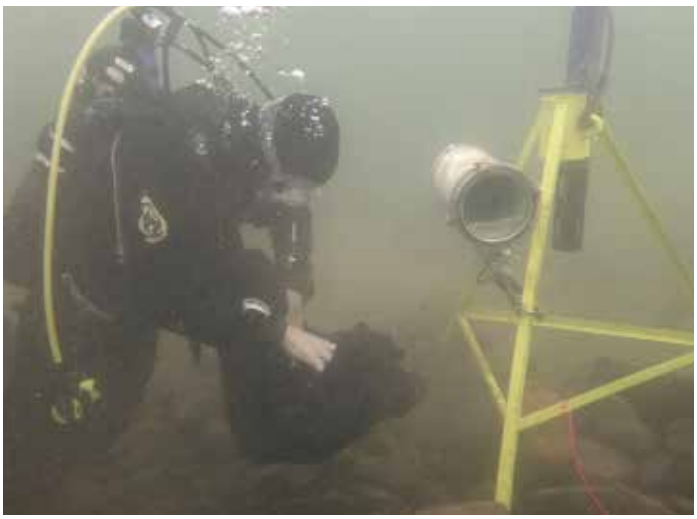
Noteworthy:

- Mercury contamination in park lakes is high enough to harm fish and wildlife and require fish consumption advisories for people.
- Monitoring results show that mercury contamination is decreasing, which may be related to regional emission controls.
- It may be possible to further reduce contamination of the aquatic food web by modifying the way dams artificially control water levels in park lakes.



Using remote recording units ("frog loggers"; *top left*) we are monitoring **amphibians** in all nine Network parks. In 2015, one of the recorders along the Mississippi River detected calling cricket frogs, an endangered species in Minnesota (*cricket frog sonogram at left, frog above right*).

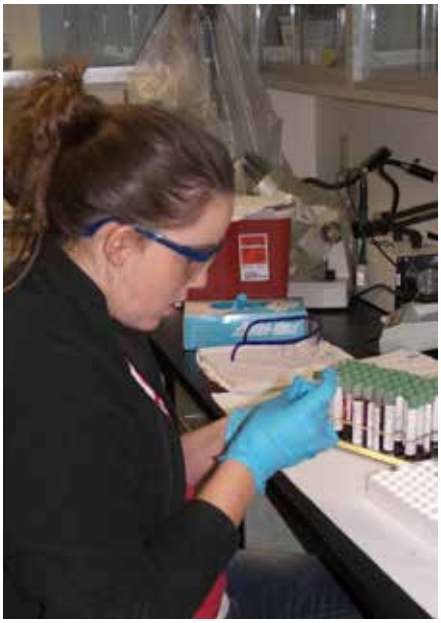




Great Lakes RESTORATION

Network and Midwest Region staff are collaborating on projects funded by the Great Lakes Restoration Initiative to **map the bottom of Lakes Superior and Michigan** within park boundaries at Apostle Islands, Isle Royale, Pictured Rocks, and Sleeping Bear Dunes. Imagery from Munising Bay and the southern part of Pictured Rocks (*top right*) show that the lake is not just a flat blue feature on the map. This information is being used to help locate historical artifacts (mostly shipwrecks), understand sand movement along nearshore areas, and identify important fish habitat. We are also collaborating on a **study of lake currents and water chemistry** in Lake Michigan near Sleeping Bear Dunes and in Lake Superior near the Apostle Islands using monitoring stations that are anchored to the lake bottom (*bottom right*).

In concert with our contaminants monitoring program, Bayfield High School students studied water chemistry, isotopes in eagle blood (*far right*), and, with a Northland College professor, different parts of the Lake Superior food web. For the food web study, students collected water, **zooplankton** (*near right*), and fish near eagle nests in the Apostle Islands. These studies help us understand how contaminants move through the food web up to bald eagles. Students developed their own research questions and presented the data at regional and national student science competitions.



Monitoring **contaminants in fish and dragonflies** at Grand Portage, Indiana Dunes, Isle Royale, Pictured Rocks, Sleeping Bear Dunes, and Voyageurs was carried out by scientists from the University of Wisconsin–La Crosse. Dragonfly larvae were collected with dip nets (*left*). These fascinating insects (*below*) proved to be an ideal sentinel because the average concentration of methylmercury found in dragonflies that burrow in lake bottom sediments was positively correlated with average methylmercury concentrations in unfiltered lake water and, in some cases, with average mercury concentrations in prey fish and game fishes from the same lakes (Haro et al. 2013). Thus, data from dragonflies can be extrapolated to tell us something about the larger environment. Plus, they are easier to collect than fish, allow us to study lakes that have no fish, and collection and identification is easily taught, so they are well-suited to citizen volunteer monitoring programs. As a result, in 2012, eleven national parks across the country participated in a pilot study of mercury in dragonflies. More than 300 dragonfly larvae samples were collected from 25 sites by about 200 citizen scientists (Nelson et al. 2015). For more information, visit www.nature.nps.gov/air/Studies/air_toxics/dragonfly/

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A view from the Empire Bluff Trail, Sleeping Bear Dunes National Lakeshore.

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