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Natural Resource Stewardship and Science

Monitoring Water Quality of Inland Lakes, Great Lakes Network, 2012

Data Summary Report

Natural Resource Data Series NPS/GLKN/NRDS—2014/629

ON THE COVER
Jessica Ruuti, biological technician, and Rick Damstra, aquatic ecologist, on Sargent Lake, Isle Royale National Park.
Photo by Heather Johnson, U.S. Geological Survey.

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Natural Resource Data Series NPS/GLKN/NRDS—2014/629

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

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Contents

Contents (continued)

Figures

Page

Figures (continued)

Page

Figures (continued)

Page

Tables

Page

Appendices

Page

Abstract

The Great Lakes Inventory and Monitoring Network (GLKN or Network) monitored inland lake water quality at six national park units in 2012: Voyageurs National Park (VOYA), Apostle Islands National Lakeshore (APIS), Isle Royale National Park (ISRO), Pictured Rocks National Lakeshore (PIRO), Indiana Dunes National Lakeshore (INDU), and Sleeping Bear Dunes National Lakeshore (SLBE). The primary objective of this monitoring program is to monitor water quality in order to describe the current status and to detect trends of common limnological parameters within sampled lakes. The Network will provide early warnings of change, work with researchers to understand the causes of change, and provide interpretation of results to park staff.

Routine water quality monitoring was conducted at thirty-eight index lakes during the open water season in 2012. Field measurements included depth profiles of temperature, pH, specific conductance, and dissolved oxygen; water clarity; and water level relative to a benchmark. Water samples were collected for laboratory analyses of total phosphorus, total nitrogen, nitrate+nitrite-nitrogen, ammonium-nitrogen, dissolved silica, calcium, sodium, magnesium, potassium, sulfate, chloride, dissolved organic carbon, alkalinity, and chlorophyll-*a*.

Additional water quality monitoring in 2012 included collection of 1) total and methyl-mercury samples from five lakes at VOYA, 2) total suspended solids samples from four lakes each at ISRO and VOYA, 3) sediment samples at nine lakes at ISRO for analysis of diatom communities, and 4) baseline cyanobacteria toxin samples at 16 lake sites and four Lake Michigan sites across three parks (SLBE, PIRO, and ISRO) in collaboration with U.S. Geological Survey.

Additional lakes were sampled at ISRO, PIRO, and INDU one-to-three times each during the season. Field measurements were conducted at all of the lakes, and laboratory analyses of water samples were conducted on some of the lakes.

Results show that many lakes exceed the U.S. Environmental Protection Agency (USEPA) reference criteria for Secchi depth, pH, chlorophyll-*a*, total phosphorus, total nitrogen, and nitrate+nitrite-nitrogen for their respective ecoregion. Calculations of trophic state indices show most index lakes to be mesotrophic.

Graphs of several parameters over time show hints of trends occurring for some parameters at some parks. The Network will continue monitoring in 2013 at most index lakes, with some shallow, wetland-like lakes being dropped from the lake program. Three of the four lagoons at APIS are periodically connected to -and flushed by- Lake Superior, confounding analysis of long-term trends. Long Lake at INDU has experienced lowering water levels in the last few years, is now < 1m deep, choked with emergent vegetation, and functionally is a freshwater marsh instead of a lake. Additional sites, visits, and parameters will be included as funding permits.

Acknowledgments

We depend on park staff and park support for the successful implementation of the water quality monitoring program each year. The assistance we receive varies by park, but examples include boat maintenance, lab space, use of sampling equipment, boat transportation, vehicles, gasoline, housing, and more. Personnel from several divisions, including maintenance, interpretation, law enforcement, and especially natural resources have lent a hand. Special thanks to the primary field staff: Lora Loope, Leah Kainulainen, Chris Otto, Jaime LeDuc, Ted Gostomski, Jessica Ruuti, and Joshua Dickey. Thanks also to the many other people who assisted with field sampling in 2012 (if we try to name them all we are sure to accidentally omit someone). Ryan Bart assisted with creation of tables and graphs. Lora Loope, Leah Kainulainen, Ryan Maki, and, Ted Gostomski reviewed an earlier version of this report and provided helpful suggestions. We are especially grateful to Brenda Moraska Lafrancois, Lora Loope, Ryan Maki, and Chris Otto for discussions surrounding the interpretation of our results.

Introduction

The Great Lakes Inventory and Monitoring Network (hereafter the Network or GLKN) conducted water quality monitoring on inland lakes at six parks in 2012: Voyageurs National Park (VOYA), Apostle Island National Lakeshore (APIS), Isle Royale National Park (ISRO), Pictured Rocks National Lakeshore (PIRO), Indiana Dunes National Lakeshore (INDU), and Sleeping Bear Dunes National Lakeshore (SLBE). The protocol for monitoring water quality of inland lakes, a *vital sign* for GLKN, (Elias et al. 2008) encompasses the following:

- core suite (temperature, dissolved oxygen, conductivity, pH, water clarity)
- water level
- advanced suite (alkalinity, dissolved organic carbon, silica, chloride, sulfate, calcium, sodium, potassium, magnesium, chlorophyll-*a*, total phosphorus, total nitrogen, ammonium-nitrogen, nitrate+nitrite-nitrogen)
- primary productivity (as estimated by chlorophyll-*a* measurements)
- nutrient dynamics (as measured by the phosphorus and nitrogen species)

The Network also monitors diatoms (an additional *vital sign*) under a cooperative agreement with the St. Croix Watershed Research Station (SCWRS). The preserved remains of diatoms are collected from lake bottom sediments approximately every five years at each park on a rotating schedule (Ramstack et al. 2008). Diatom monitoring is closely tied to water quality monitoring and aids in the interpretation of water quality results. Monitoring a lake's diatom community is used as biological proxy for several water quality parameters, including hindcasting lake conditions before monitoring began.

In collaboration with the U.S. Geological Survey (USGS), Network and park staff collected water samples from five lakes at VOYA for analysis of total and methyl-mercury (bioaccumulative contaminants *vital sign*).

Also with USGS, Network and park staff began collecting samples to assess baseline levels of cyanobacteria toxins found within selected lakes at ISRO, PIRO, and SLBE in 2012. Increasing levels of cyanobacteria in lakes could be related to early ice-off (longer growing season, increased lake mixing) and increased summer water temperatures (weather and climate Vital Sign). Because USGS is the lead agency on these two projects, details will not be reported here, but findings will be published in peer-reviewed journals.

Network and park staff also collected continuous lake temperature profile data at one-meter intervals in one lake each at VOYA, ISRO, and PIRO. Collection of these data will provide insight on timing of ice on/out, timing and depth of thermal stratification, and habitat suitability for select fish species.

The Network's intent in monitoring inland lakes water quality is to contribute to an understanding of aquatic ecosystem health and to provide insight on water quality issues in the parks. The Network's primary objective is to describe the current status of lake water quality and to detect trends in common limnological parameters within sampled lakes. Many years of data collection will be needed before trends can be determined for most parameters; however, we hope to be able to provide early detection of change that may then lead to increased monitoring, research, or management action. Now that six years of data have been collected (seven years at INDU and VOYA), the natural variability that occurs in a given lake both within and between years is becoming more evident. This understanding is crucial to distinguish true change from the 'noise' inherent in the system, as well as that which occurs due to sampling equipment, laboratory analyses, and individual bias.

This report provides brief updates on the water quality monitoring program for inland lakes, including results from the 2012 field season and graphs of select parameters over time since monitoring began in 2006. Results from previous years (Elias 2007, 2009; Elias and VanderMeulen 2008; Elias and Damstra 2011; and Damstra and Elias 2012) can be found on the GLKN website (http://science.nature.nps.gov/im/units/glkn/index.cfm).

Methods

Study Sites

In developing the protocol for monitoring inland lakes water quality, the Network and the parks selected index lakes for annual monitoring. These lakes span gradients of chemical and physical parameters, visitor use, watershed size, and spatial distribution within each park (Elias et al. 2008). We sampled all 33 index lakes (Table 1) in 2012. At SLBE, a change in index lakes was made where North Bar Lake (SLBE_09) was added and Round Lake (SLBE_11) was dropped. More park visitors recreate at North Bar Lake than any other in the park, and park resource managers place high importance on long term water quality monitoring there. Additional lakes were sampled at least once at ISRO (N=2), PIRO (N=2), and INDU (N=1).

Table 1. Lakes/lagoons sampled for water quality in 2012 and types of data collected. The parks are listed in order from west to east. Index lakes are shown in **bold font**.

Park	Lake or Lagoon	Core Suite	Advanced Suite	Diatoms	Continuous Temperature Array	Mercury	Cyanobacteria
VOYA							
	Locator	x	x				
	Shoepack	x	x			x	
	Ek	x	x			x	
	Brown	x	x			x	
	Peary	x	x			x	
	Cruiser	x	x				
	Ryan	x	x			x	
	Little Trout	x	x		x		
APIS							
	Michigan Is.	x	x				
	Outer Is.	x	x				
	Stockton Is.	x	x				
	Little Sand Bay	x	x				
ISRO							
	Ahmik	x	x	x			
	Sargent	x	x	x			x
	Richie	x	x	x	x		x
	Beaver	x	x	x			
	Harvey	x	x	x			x
	George	x	x	x			
	Siskiwit	x	x	x	U of Maine		
	Desor	x	x	x	U of Maine		x
	Feldtmann	x	x	x			

Table 1 (continued). Lakes/lagoons sampled for water quality in 2012 and types of data collected. The parks are listed in order from west to east. Index lakes are shown in **bold font**.

Park	Lake or Lagoon	Core Suite	Advanced Suite	Diatoms	Continuous Temperature Array	Mercury	Cyanobacteria
	LeSage	x		x			x
	Chickenbone	x					x
PIRO							
	Grand Sable	x	x		x		x
	Trappers	x	x				x
	Legion	x	x				
	Beaver	x	x				x
	Little Beaver	x					
	Chapel	x	x				
	Miners	x	x				x
INDU							
	Long	x	x	x			
	Middle Lagoon	x	x	x			
SLBE							
	Manitou	x	x				x
	Florence	x	x				x
	Shell	x	x				x
	Bass (North)	x	x				x
	North Bar	x	x				x
	Loon	x	x				x

Water Quality Sampling

Field Methods

In accordance with the protocol (Elias et al. 2008), Network and park staff conducted field sampling at the deepest part of each index lake three times during the open water season (Table 2). Each lake is sampled at approximately the same location on each site visit; use of a GPS, bathymetric map, depth sounder, and detailed directions aided field personnel in returning to the same location each time.

Table 2. Dates (m/dd) of water quality sampling at index lakes, 2012.

Park	Round 1	Round 2	Round 3
VOYA	6/04 - 6/14	7/16 - 7/27	8/22 - 8/31
APIS	6/18 - 6/22	7/23 - 7/24	8/27 - 8/28
ISRO	6/13 - 6/25	7/13 - 7/26	8/14 - 8/28
PIRO	6/13 - 6/22	7/20 - 7/31	8/27 - 9/07
INDU	5/03	7/02	9/06
SLBE	6/15 - 6/21	7/24 - 7/31	9/13 - 9/26

Multi-probe sondes were used to collect profile data on temperature, dissolved oxygen, specific conductance, and pH. Different manufacturers' sondes were used at different parks: YSI (Model 6820) at PIRO, Eureka Manta (units 774 and 526) at APIS, Eureka Manta Sub 2 (units 178 and 526) and YSI Quattro (borrowed from Michigan Technological University) at ISRO, Eureka Manta (unit 775) at VOYA, Hydrolab (Model DSX5) at SLBE, and a Hydrolab (Model MS5.0) and a YSI Pro-Plus at INDU. At each site, water clarity was measured with a Secchi disk and/or transparency tube, a GPS reading was collected, environmental conditions (e.g., wind speed and direction, wave height, sky cover, air temperature) were recorded, water level relative to a benchmark was measured using a hand-held eye level and a light-weight stadia rod, and field personnel and instruments were noted.

Integrated (0-2 m) surface water samples for laboratory analyses were collected using an integrated tube sampler (MPCA 2004a, 2004b; WDNR 2004). On lakes that were less than 2 m deep, the tube sampler was angled to collect a sample from the full water column, or a grab sample was collected at approximately elbow depth. Sample water was composited in a high density polyethylene container. See Elias et al. (2008) and Elias and VanderMeulen (2008) for details on collection and handling of water samples.

At index lakes, water samples were collected and analyzed for nutrients and chlorophyll-*a* (chl-*a*) during each visit; samples for the remaining parameters (Table 3) were collected only during the second round of sampling. During sampling round 2, near-bottom water samples were collected with a Van Dorn sampler at thermally stratified lakes and analyzed for analysis of total phosphorus and total nitrogen. Field measurements (core suite) and water samples for laboratory analysis (advanced suite) were collected at some non-index lakes, while at others only field variables were measured (see Table 1).

Table 3. Parameters measured and abbreviations used in text. **Bold font** indicates parameters measured three times per season at index lakes (one-to-three times at non-index lakes); remaining parameters were measured once during mid-season.

Parameter	Abbreviation	Parameter	Abbreviation
Alkalinity	Alk	**Total Nitrogen**	**TN**
Calcium	Ca^{+2}	**Ammonium-Nitrogen**	**NH_4-N**
Chloride	Cl^{-}	**Nitrate+Nitrite-Nitrogen**	**NO_3+NO_2-N** or **NO_x**
Chlorophyll-*a*	**chl-*a***	Total Mercury (VOYA only)	THg
Dissolved Organic Carbon	DOC	Methyl-mercury (VOYA only)	MHg
Magnesium	Mg^{+2}	**Specific Conductance**	**SC25**
Potassium	K^{+}	**Dissolved Oxygen**	**DO**
Silica	SiO_2	**pH**	**pH**
Sodium	Na^{+}	**Temperature**	**Temp**
Sulfate	SO_4^{-2}	**Secchi Disk Depth**	**Secchi**
Total Phosphorus	**TP**	**Transparency Tube**	**T-tube**

At VOYA, samples for total and methyl-mercury were collected at five lakes (Brown, Ek, Peary, Ryan, and Shoepack) following U.S. Geological Survey (USGS) procedures (M. Brigham, USGS, personal communication). As in previous years, this was a collaborative effort with USGS—Network and park staff collected the samples and sent them to the USGS laboratory in Middleton, Wisconsin; the lab analyzed the samples; M. Brigham managed the data for USGS, and Network staff managed the data for GLKN.

In conjunction with USGS, cyanobacteria samples were collected three times in inland lakes at ISRO (n=6), PIRO (n=4), and at SLBE (n=6). Four additional sites were sampled on Lake Michigan at SLBE. The purpose of this research was to establish baseline levels of cyanobacteria-derived toxins in inland lakes. All samples were collected following USGS procedures (H. Johnson, USGS, personal communication). The samples were sent to the USGS Organic Geochemistry Research Laboratory for processing. USGS staff are managing all algal toxin data for this project; GLKN is managing all other field data.

Analytical Laboratories

White Water Associates (WWA) was contracted for analysis of major ions (Ca^{+2}, Cl^{-}, Mg^{+2}, K^{+}, Na^{+}, and SO_4^{-2}), alkalinity, dissolved organic carbon (DOC), and dissolved silica (SiO_2). WWA has conducted these analyses since the beginning of the Network's water quality monitoring program in 2006. The St. Croix Watershed Research Station (SCWRS) analyzed samples for nutrients (TP, TN, NO_3+NO_2-N, and NH_4-N) and chlorophyll-*a* (chl-*a*). They have done these same analyses for us since 2009. As in prior years, mercury samples from VOYA were analyzed by the USGS lab in Middleton, Wisconsin. Cyanobacteria samples were analyzed at the USGS Organic Geochemistry Research Laboratory in Lawrence, Kansas.

All samples were processed and handled according to standard operating procedures (Axler et al. 2008) and as required by the respective laboratories.

Sediment Sampling

Network staff collected lake bottom sediment samples in late summer from ten lakes at ISRO (see Table 1). This was the second time that sediment samples were collected at ISRO in conjunction with this project. Samples were collected with a drop corer and were handled and processed according to standard operating procedures (Ramstack et al. 2008). The bottom sediment samples were analyzed for diatom community assemblages by researchers at SCWRS. When living, the diatoms were in the water column or attached to submerged plants or rocks but settled onto the lake bottom after dying. Results from this project will facilitate the Network's understanding of changes in water quality, as diatom communities reflect the water quality conditions that exist over a few weeks or months rather than at a single moment in time (as with water samples). Diatom community assemblages serve as indicators of water quality because the species composition changes as environmental conditions change. Analysis of diatom communities complements the Network's discreet water quality sampling and provides a way to compare current conditions with those of the past, even before Europeans settled the region, by examining deeper sections of a sediment core.

Bathymetric Mapping

Hard-copy bathymetric maps exist for many of the index lakes, though electronic maps for these lakes are often not available. Network staff began constructing bathymetry maps at ISRO in 2007 using a combination GPS chart plotter and sonar depth finder, and continued the process in subsequent years. Depth and location data were collected along transects, crossing each lake. Data were then downloaded into GIS and processed. Final maps for ISRO have been completed and uploaded to the NPS Integrated Resource Management Applications (IRMA) Portal (https://irma.nps.gov/App/Reference/Profile/2193087).

Bathymetric mapping at PIRO was begun in 2012 and will continue until all lakes of interest to park and Network staff have been completed. Draft maps for some lakes have been created. Final maps will be completed and uploaded to IRMA in 2014.

Data Handling

Methods for using laboratory data below detection limit and reporting limit (method detection limit [MDL] and method quantitation limit [MQL], respectively; i.e., censored data) in statistical analyses are numerous and diverse (e.g., Helsel 1990, Helsel and Cohn 1988). Because data were summarized but not analyzed statistically for this report, values below MQL, including '0' were used. 'ND' (non-detect) is indicated when the laboratory reported it as such. Results of 'ND' were reported 59 times, all of which were for single measurements that did not require calculation of a mean.

Quality Assurance and Quality Control

Steps to ensure quality assurance and quality control (QA/QC) were undertaken routinely, according to standard operating procedures (Ledder and Elias 2008), as part of monitoring water quality. The following steps were taken in 2012:

- measurement sensitivities of each sonde were calculated under laboratory conditions prior to the field season and under field conditions during the season
- sondes were calibrated daily, adhering to acceptance criteria
- calibration logs were maintained with each instrument
- measurements taken in the field with the sondes were saved electronically and backed-up on paper data sheets
- duplicate field measurements were taken at the rate of approximately 10%
- duplicate water samples were collected at the rate of approximately 10%
- equipment blanks were conducted prior to and during the field season

In addition, contract laboratories conducted their own QA/QC that included blanks, duplicates, and spikes, and generated QA/QC reports that accompanied water sample results.

Network quality assurance criteria stipulate that results for water sample duplicates should be within 10% of each other for all parameters except nutrients and chl-*a*, which should be within 30% of each other (Ledder and Elias 2008). Most duplicates fell within the acceptable criteria. Those that did not meet quality assurance criteria were usually very close to laboratory detection or reporting limits. In such cases, actual small differences can result in large relative percent differences (e.g., the actual difference between 1 and 2 µg/L is small, but the relative difference is 67%). All values were included in this report unless specifically noted otherwise; however, duplicates were not used when calculating means. Values that do not meet the Network's quality assurance criteria are flagged as such in the National Park Service database, NPSTORET, and in the EPA database, STORET.

Results and Discussion

Data relative to USEPA reference criteria and trophic status are presented below for all parks so that comparisons across parks can be easily observed. Water level data and explorations of change over time for select parameters are presented for individual parks in the "Park-Specific Comments and Additional Results" section below. Appendices A–F contain all 2012 data for the six parks with the exception of profile data measured with multiprobe sondes; only data from 1.0 m (0.5 m in shallow lakes) are included. All data, including all profile data, are posted in EPA's STORET database and can be accessed at http://www.epa.gov/storet/dw_home.html. Graphs of temperature and oxygen profiles are not included in this report, but are available upon request.

EPA Reference Criteria

National park units are often considered to be relatively pristine and are commonly referred to as representative of reference conditions. However, the Network's data show that many of GLKN's index lakes do not meet the EPA reference criteria for Secchi depth, pH, chlorophyll-*a* (chl-*a*), total phosphorus (TP), total nitrogen (TN), and nitrate+nitrite-nitrogen (NO_3+NO_2-N) for their ecoregions (USEPA 2000a, 2000b, 2000c).

Secchi Depth

Many lakes at VOYA, ISRO, PIRO, INDU, and SLBE do not meet the EPA reference criteria for Secchi depth (Figure 1; USEPA 2000a, 2000b). Reasons for shallow Secchi measurements (i.e., lower than expected water clarity) vary by lake, but are primarily due to algae and naturally occurring tannin-stained water. Changes in Secchi depth over time may indicate a change in trophic status, but confounding factors such as changes in personnel, field conditions (e.g., rough water), and timing of sampling must be taken into consideration.

Water transparency at APIS and INDU was sometimes measured with a transparency tube because the shallow depths of the lakes/lagoons allowed the Secchi disk to be seen on the bottom. Lakes are included in Figure 1 only when at least two Secchi measurements were available. Data in Figure 1 for APIS are from lagoons at Stockton and Outer islands and Little Sand Bay (LSB), none of which meet EPA reference criteria. The Outer and Stockton lagoons are heavily stained with tannic acid, and the LSB lagoon is often turbid from suspended sediment. Long Lake (INDU) had shallow Secchi measurements due to suspended sediments.

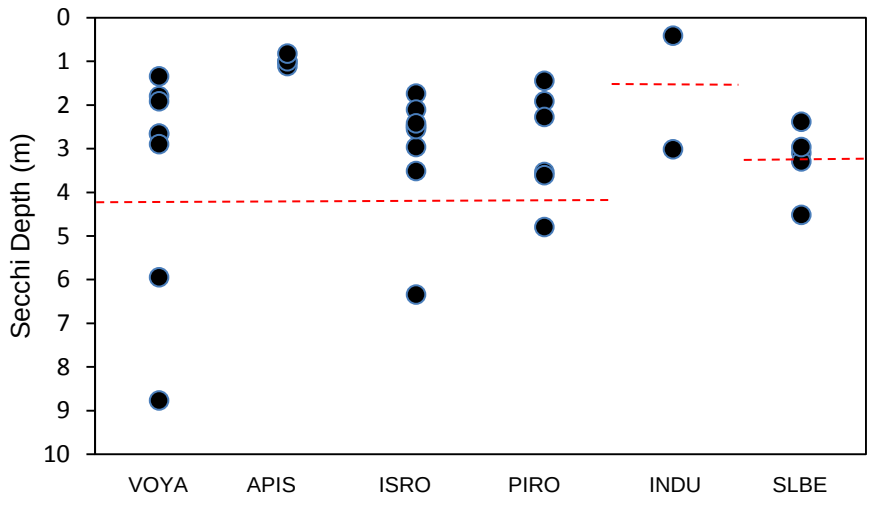

Figure 1. Mean Secchi disk measurements in lakes across five park units in the Great Lakes I&M Network, 2012. The dotted lines indicate the EPA reference criteria for the appropriate ecoregion. Measurements above the dotted lines do not meet the reference criteria. Park codes as in text.

pH

Most lakes had pH values within the USEPA reference criteria, though exceptions occurred at INDU (Middle Lagoon) and APIS (Outer, Stockton, and Little Sand Bay lagoons) (Figure 2; USEPA 2000a, 2000b, 2000c). Lakes on the low end of the pH scale are likely naturally acidic; aquatic communities of acidic lakes can be distinctly different from others with more neutral water. For example, acidic lakes may have few or no fish species, so the top predators may be invertebrates, amphibians, or reptiles.

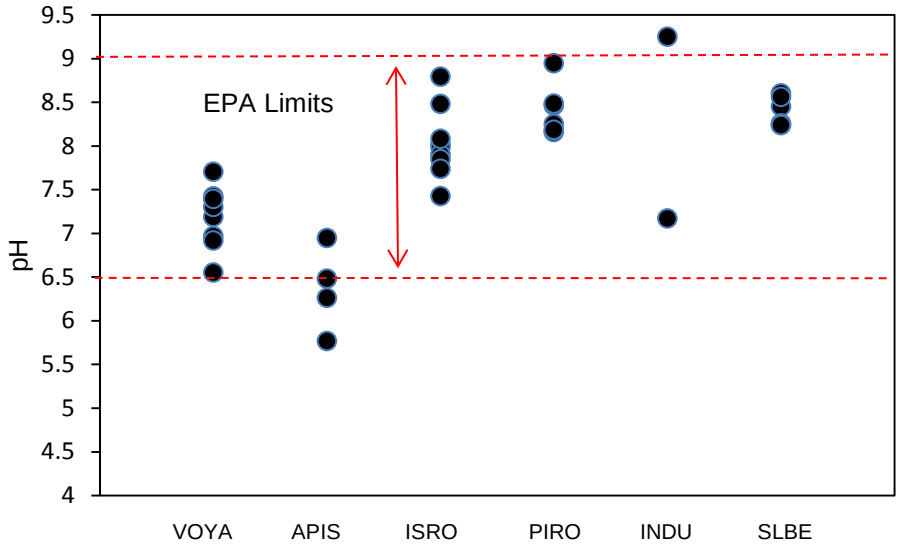

Figure 2. Mean near-surface pH values (1.0 m at VOYA, ISRO, PIRO, and SLBE; 0.5 m at APIS and INDU) of lakes across six park units in the Great Lakes I&M Network, 2012. The dotted lines indicate the lower (6.5) and upper (9.0) USEPA reference criteria (USEPA 2000a, 2000b, 2000c). Park codes as in text.

Chlorophyll-a

At INDU, Middle Lagoon met the EPA reference criterion for chl-*a* (3.66 µg/L), and half of the lakes at SLBE fell below the EPA criterion of 2.02 µg/L (Figure 3). All of the lagoons at APIS and most of the lakes at VOYA, ISRO, and PIRO had mean chl-*a* concentrations above the criterion of 1.38 µg/L for their ecoregion. The criteria are stringent and for some ecoregions the number of lakes sampled to develop the criteria was inadequate, which could bias the criteria. Specifically, the chl-*a* criterion using the fluorometric method of analysis for the ecoregion encompassing VOYA, APIS, ISRO, and PIRO was derived from only two samples (USEPA 2000a). At this time, it is more important to heed the status and trends in the trophic state of the lakes (see below) than to be concerned about exceeding EPA reference criteria for chl-*a*.

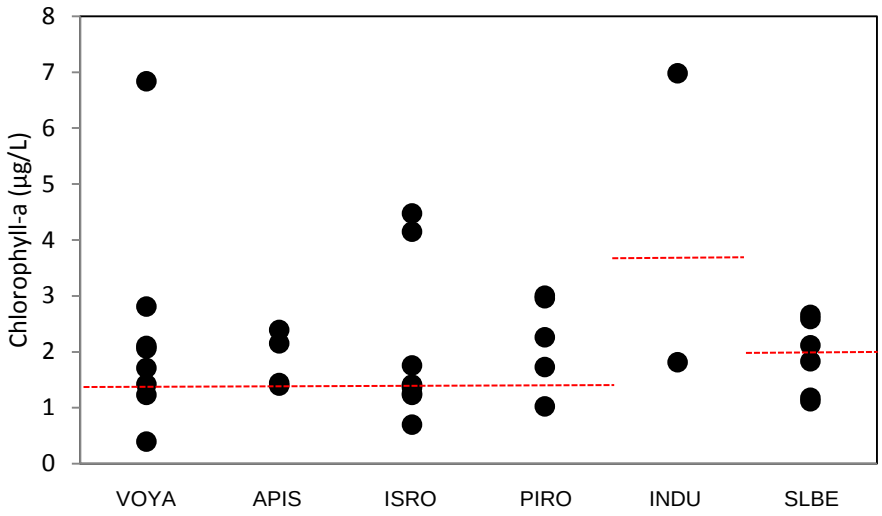

Figure 3. Mean chlorophyll-*a* values of lakes across six park units in the Great Lakes I&M Network, 2012. The dotted lines indicate the EPA reference criteria for the appropriate ecoregions. Measurements above the dotted lines do not meet the reference criteria. The reference criterion for INDU was calculated via regression so the laboratory method of analysis was consistent across parks (i.e., fluorometric rather than spectrophotometric). Park codes as in text.

Nutrients

Nutrient concentrations are very low in many lakes, and are often below method quantitation limits and near method detection limits for TP and NO_3+NO_2-N. However, because the reference criteria are also very low, many lakes at VOYA, APIS, ISRO, and PIRO exceeded the reference criteria for TP, TN, and NO_3+NO_2-N (Figures 4, 5, and 6). The majority of lakes in these parks do not receive direct anthropogenic inputs (e.g., fertilizer runoff, failing septic systems, sewage treatment plant effluent), so sources of phosphorus and nitrogen likely involve inputs from a) nutrient rich wetlands and beaver ponds in the watershed, b) atmospheric deposition (both direct and watershed-mediated), and c) re-suspension from lake sediment during mixing. Little Sand Bay Lagoon at APIS is an exception, as it receives runoff from a watershed that lies mostly outside of park borders. Mean TP concentration for the lagoon in 2012 was 21.9 µg/L, which was higher than any of the other lakes sampled at any park. However, the lagoons at APIS differ from lakes, and probably should not be held to the same standards. The lagoons are better classified as wetlands with open water areas. Nutrient criteria have not been developed for wetlands in Wisconsin.

With the greater amount of surrounding agricultural and developed land at INDU and SLBE, some lakes in these parks are subject to direct anthropogenic inputs. Yet the majority of lakes in these two parks have mean TP and TN concentrations below the reference criteria (Figures 4 and 5). As in the other four parks, mean concentrations of NO_3+NO_2-N in Middle Lagoon at INDU and in all SLBE lakes except for Bass Lake (north) exceed the reference criteria.

Miners Lake (PIRO) and North Bar and Shell lakes (SLBE) have particularly high mean concentrations of NO_3+NO_2-N (152, 277, and 156 µg/L, respectively). While not reaching levels that threaten human health (the drinking water standard for nitrate is 10,000 µg/L), the consistently high levels in these lakes are of interest and warrant further study. The most likely source of higher than expected NO_3+NO_2-N in these lakes is through groundwater inputs (unpublished data). The Network's and PIRO's attempts to get funding for groundwater studies have been unsuccessful to date; additional sources of funding should be sought. If the sources of NO_3+NO_2-N are anthropogenic, appropriate management actions can be initiated.

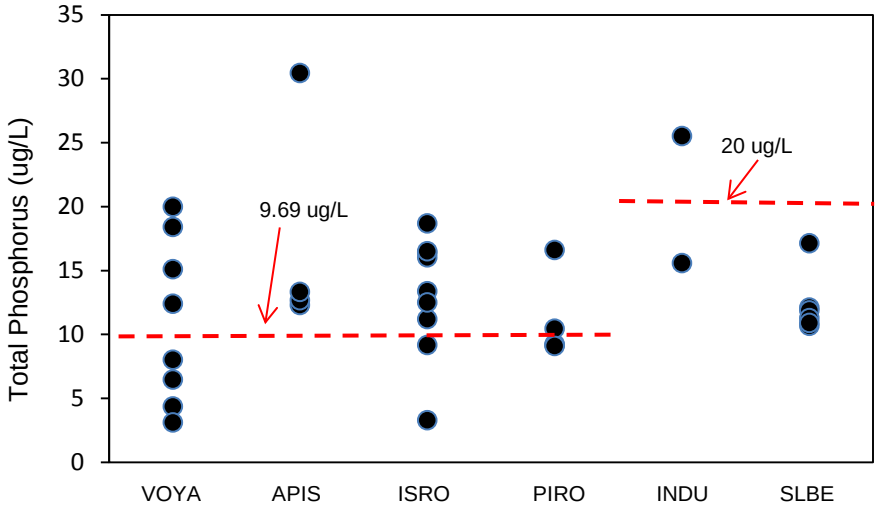

Figure 4. Mean total phosphorus (TP) levels for lakes across six parks in the Great Lakes I&M Network, 2012. The dotted lines indicate the USEPA reference criteria for the appropriate ecoregions. Park codes as in text.

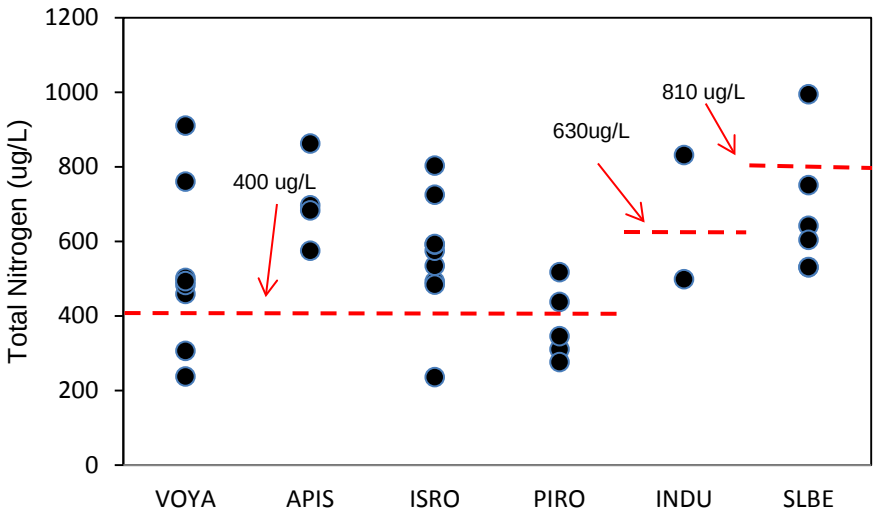

Figure 5. Mean total nitrogen (TN) levels for lakes across six parks in the Great Lakes I&M Network, 2012. The dotted lines indicate the USEPA reference criteria for the appropriate ecoregions. Park codes as in text.

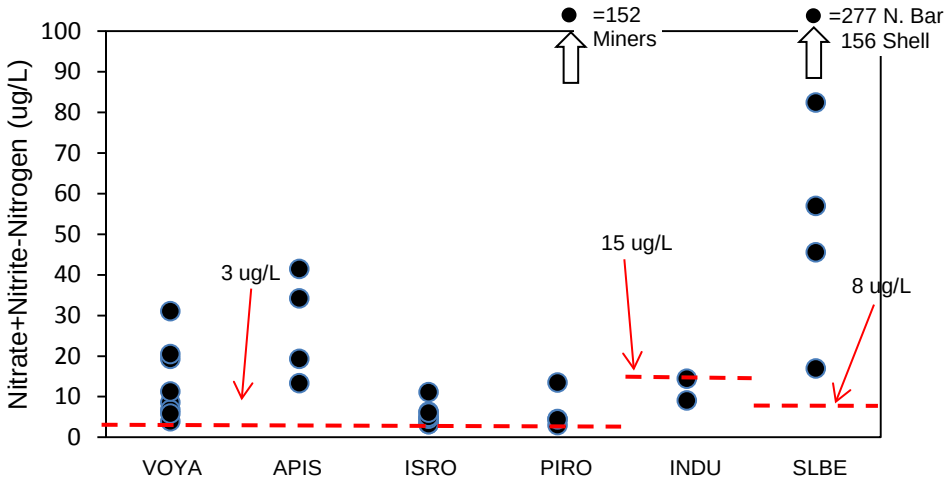

Figure 6. Mean nitrate+nitrite-nitrogen (NO_3+NO_2-N) levels for lakes across six parks in the Great Lakes I&M Network, 2012. The dotted lines indicate the USEPA reference criteria for the appropriate ecoregions. Note the break in the scale for lakes at PIRO and SLBE. Park codes as in text.

Trophic State

Carlson and Simpson (1996) define trophic state as the total phytoplankton biomass in a water body at a given time and location. A lake's Carlson trophic state index (TSI; Carlson 1977) can be calculated using values of Secchi disk depth, chl-*a* concentration, or TP concentration. The Network used chl-*a* concentration, which is the preferred method, to calculate TSI for lakes in 2012. Most GLKN index lakes are mesotrophic (Figure 7), with TSI values between 30 and 50. Generally, lakes

with a TSI <30 are considered oligotrophic and usually have clear water and low phosphorus levels, while lakes with TSI values >50 are considered eutrophic and usually have limited transparency and high phosphorus concentrations (Wetzel 2001). No lakes in 2012 were in the eutrophic range for chl-*a* TSI; only three were in the oligotrophic range.

Because the Carlson trophic state index is used to define the total phytoplankton biomass of a lake, it is not applicable under certain circumstances, such as shallow lakes that are dominated by macrophytes throughout the photic zone. For example, Middle Lagoon at INDU is very shallow and has high nutrient concentrations that exceed EPA reference criteria. Yet, because this lagoon is dominated by macrophytes and not planktonic (free-floating) algae (see Fig. 33), it has relatively low TSI values based on chl-*a* levels. Therefore, the true productivity of Middle Lagoon is not captured in the TSI metric.

See Appendices A–F for calculations of TSI in 2012 based on Secchi, TP, and chl-*a*.

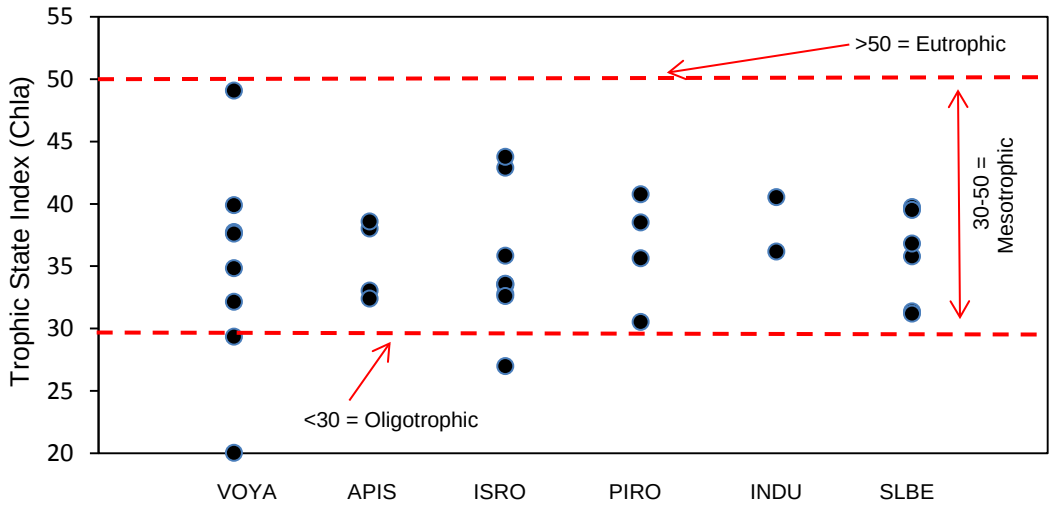

Figure 7. Trophic state indices calculated from mean chlorophyll-*a* measurements of lakes across Great Lakes I&M Network parks, 2012. Park codes as in text.

Summary

The EPA's criteria for defining a reference condition are rigorous, based on the lower 25th percentile of all lakes sampled in each EPA-defined ecoregion. By utilizing this standard, 75% of lakes within an ecoregion will not meet the criteria, regardless of the historical condition of a lake, with no consideration of whether a given lake's water quality has been affected negatively by exogenous factors, such as anthropogenic eutrophication, climate, or other local, regional, and global changes. This standard appears to be overly stringent, especially in an ecoregion with many low-productivity, oligotrophic lakes, and may not accurately reflect historical conditions for many lakes, particularly

shallow, productive lakes. The higher nutrient and chl-*a* concentrations and shallower Secchi measurements of many of the park lakes that are monitored are likely due to naturally occurring conditions (e.g., tannic acid, soil type, geology, landscape position) rather than degradation (Lafrancois et al. 2009).

Diatom-inferred TP levels, obtained from sediment cores in lakes at VOYA and ISRO and dating back to the mid-18th century, are not different from modern measurements. Based on TP levels inferred from diatom analyses of lake sediment cores, many of these lakes would not have met modern EPA reference criteria prior to European settlement of the area (Edlund et al. 2011; Mark Edlund, St. Croix Watershed Research Station, personal communication). Herlihy et al. (2013) suggests that use of nutrient reference criteria derived through a paleolimnological approach (i.e., diatom-inferred TP and TN), at least for natural lakes, is most appropriate, as it is a direct measure of nutrient condition before large-scale human disturbance. In future reports, Network staff will compare the diatom-inferred nutrient reference criteria proposed by Herlihy et al. (2013) to modern water quality data collected at index lake sites. Lake-specific, pre-European settlement, diatom-inferred nutrient conditions have been derived for a subset of parks' index lakes, and have been used to make an even more refined assessment of changes in lake water quality conditions (Edlund et al. 2011, Edlund et al. 2012, Edlund et al. 2013).

Park-Specific Comments and Additional Results

In the following sections preliminary explorations of select parameters at individual parks using the entire period of record for the Network's water quality monitoring effort are discussed. Additional sampling conducted in each park is also discussed, along with comments on logistics and plans for future monitoring.

While statistical analyses of trends are possible with the amount of current data, Network staff have not conducted such analyses because monitoring inconsistencies in the first few years of protocol implementation may confound any trends. However, some hints of trends are emerging, so a larger dataset will make future trend analyses more robust.

Voyageurs National Park

Additional Data Collected and Exploration of Trends

Network staff collected continuous (year-round) temperature data at Little Trout Lake in 2012, using a moored temperature array. An array consists of probes placed along a weighted line at approximately 1m intervals between the surface and 16 m depth, then at 20 m, 25 m, and near the lake bottom (approximately 28 m). Coupled with the profile data collected during sampling visits, the timing and depth of mixing will become more evident, as well as the suitability of conditions for coldwater fish species. In May 2012 Network staff visited Little Trout Lake with park staff to assist in array recovery. VOYA staff downloaded the summer data in mid-September 2012 and re-set the array for winter conditions under the ice.

Mixing events are visible in the summer 2012 data (Figure 8). Cooler water rose to the surface for several days in mid-to-late June and again in mid-August, prior to the fall turnover; during the mid-summer months, temperatures >20 °C extended to 5 m or more only from mid-August onward. Damstra and Elias (2012) showed adequate habitat existed throughout the summer for both lake trout (*Salvelinus namaycush*) and cisco (*Coregonus artedii*) in 2011, and apparently this trend continued in 2012.

When the Network's monitoring program began in 2006 drought conditions were prevalent at VOYA and caused low lake levels, especially as the summer progressed. In subsequent years, the amount of precipitation increased and lake levels generally responded accordingly. All of the index lakes except Locator have seen increases in mean summer water levels since 2006 (Figure 9). The failure of a beaver dam downstream of Locator Lake in late 2008 likely caused the lowering of lake levels. Acquiring more information on beaver activity upstream and downstream of each lake will greatly increase the Network's understanding of water level changes in the index lakes.

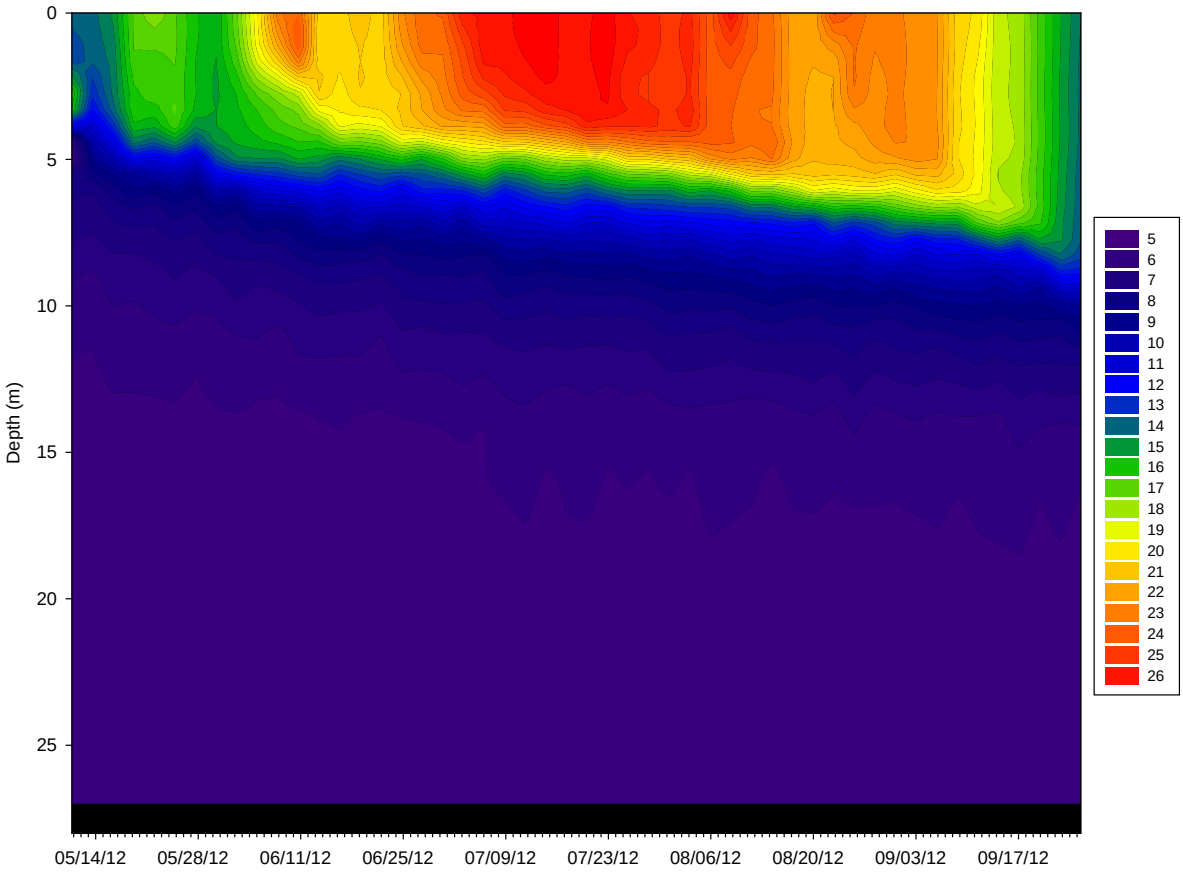

Figure 8. Hourly temperature data (in °C) collected throughout the water column in Little Trout Lake, Voyageurs National Park, 10 May–25 September 2012.

If changes are occurring in the field parameters the Network measures (specific conductance, pH, and water clarity as measured by Secchi disk depth), they are not obvious (Figures 10a, b, and c). Some lakes may be experiencing a slight decrease in specific conductance (e.g., Peary, Ryan). Cruiser and Ek lakes may be exhibiting a slight increase in pH, but in general, pH measurements are surprisingly variable from year to year. The mean TSI for all index lakes at VOYA seems to be trending downward (i.e., becoming less eutrophic, or nutrient-rich) (Figure 10d), and may reflect differences in weather (e.g., cooler, wet years may lead to lower algal production). Shoepack, Ek, and Peary lakes, which are relatively shallow, were eutrophic (TSI >50) in 2006 and 2008 (2007 chl-*a* data are not available), but dropped into the mesotrophic range thereafter (TSI between 30 and 50).

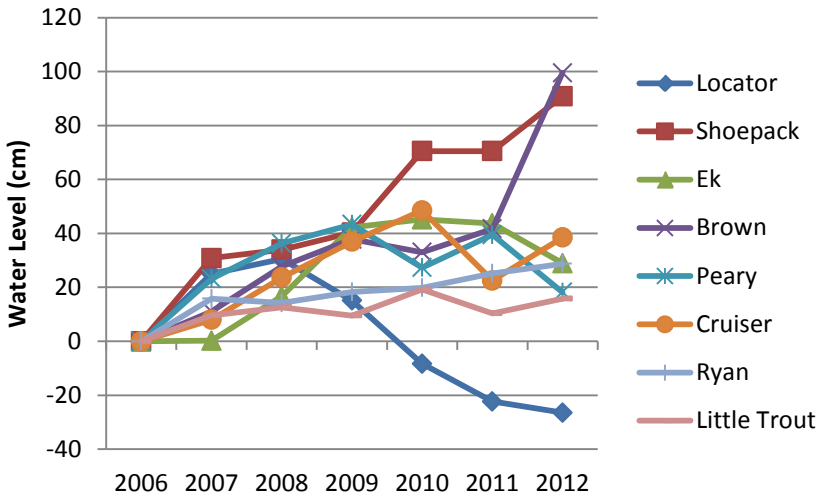

Figure 9. Mean summer lake levels, Voyageurs National Park, 2006-2012. Water level is measured relative to a permanent benchmark at each lake. All lake water levels are relative to the 2006 mean, which is set to zero.

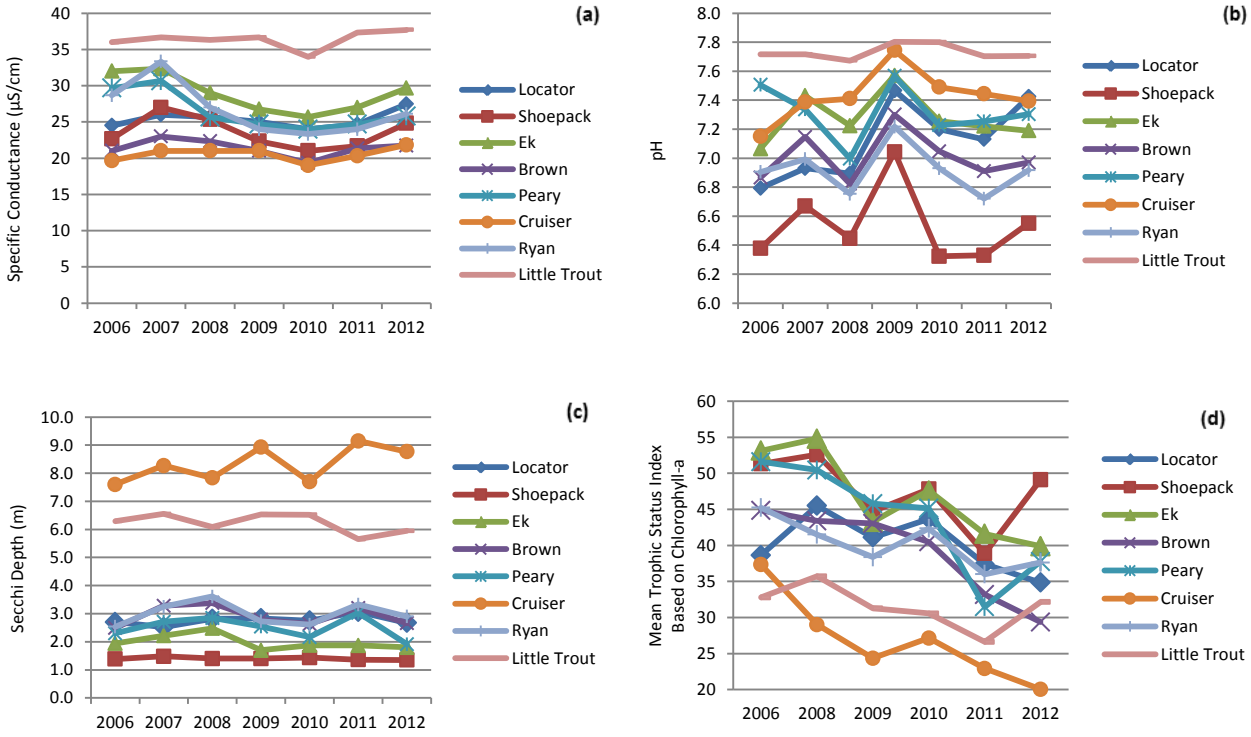

Figure 10. Mean measurements of specific conductance and pH at 1 m depth (**a** and **b**, respectively), water clarity as measured by Secchi disk depth (**c**), and trophic state index as calculated from chlorophyll-*a* measurements (**d**) for index lakes at Voyageurs National Park, 2006–2012. Chlorophyll-*a* data are not available for 2007.

With the exceptions of TP in Shoepack and Ek Lakes (decreasing, and perhaps increasing slightly, respectively), mean concentrations of TP and TN have not changed appreciably since 2006 (Figures 11a, 11b). Cruiser and Little Trout lakes have consistently been below EPA reference criteria; Shoepack, Ek, and Peary lakes have been above EPA reference criteria. Locator, Brown, and Ryan lakes have shown minor variations above and below the EPA reference criterion for TP, but have been slightly greater than the TN criterion.

Even though several of the index lakes exceed the EPA reference criterion for TP, none of the lakes exceed Minnesota's eutrophication criterion (30 µg/L) for lakes designated as Aquatic Recreation Use (Class 2B) for the Northern Lakes and Forest Ecoregion (Heiskary and Wilson 2008). Minnesota has also established eutrophication criteria for the response variables chl-*a* (9 µg/L) and Secchi depth (2.0 m). Several lakes have occasionally exceeded the chl-*a* criterion (none did in 2012) and/or had Secchi depth measurements that were shallower than the criterion (three in 2012: Shoepack, Ek, and Peary). Cruiser and Little Trout lakes are subject to stricter state criteria (TP = 12 µg/L, chl-*a* = 3 µg/L, and Secchi depth = 4.80 m) because they are designated as lake trout lakes. They have met these criteria.

Variations in the concentrations of NO_3+NO_2-N and NH_4-N are generally consistent across lakes; that is, lakes experienced increases and decreases in the same years (Figures 11c, 11d). Exceptions are Ryan Lake for NO_3+NO_2-N and Shoepack Lake for NH_4-N. Causes for these exceptions are unknown at this time. The unusually high NO_3+NO_2-N value for Locator Lake in 2006 was due to a single sample collected in July (102 µg/L) that may have been contaminated, as levels have been consistently low since then.

Silica is also a nutrient required by plants (e.g., diatoms) and animals (e.g., freshwater sponges). Concentrations of dissolved silica have varied little since 2006, with the exception of Brown Lake in 2008 (Figure 11e). Silica is incorporated into the cell walls of diatoms and the skeletal structure of freshwater sponges, and a portion of it is released when the diatoms and sponges die. The relatively high concentration of dissolved silica in Brown Lake in 2008 may have been due to the timing of a seasonal, sharp decline in certain diatom species followed by a pulse of other types of algae.

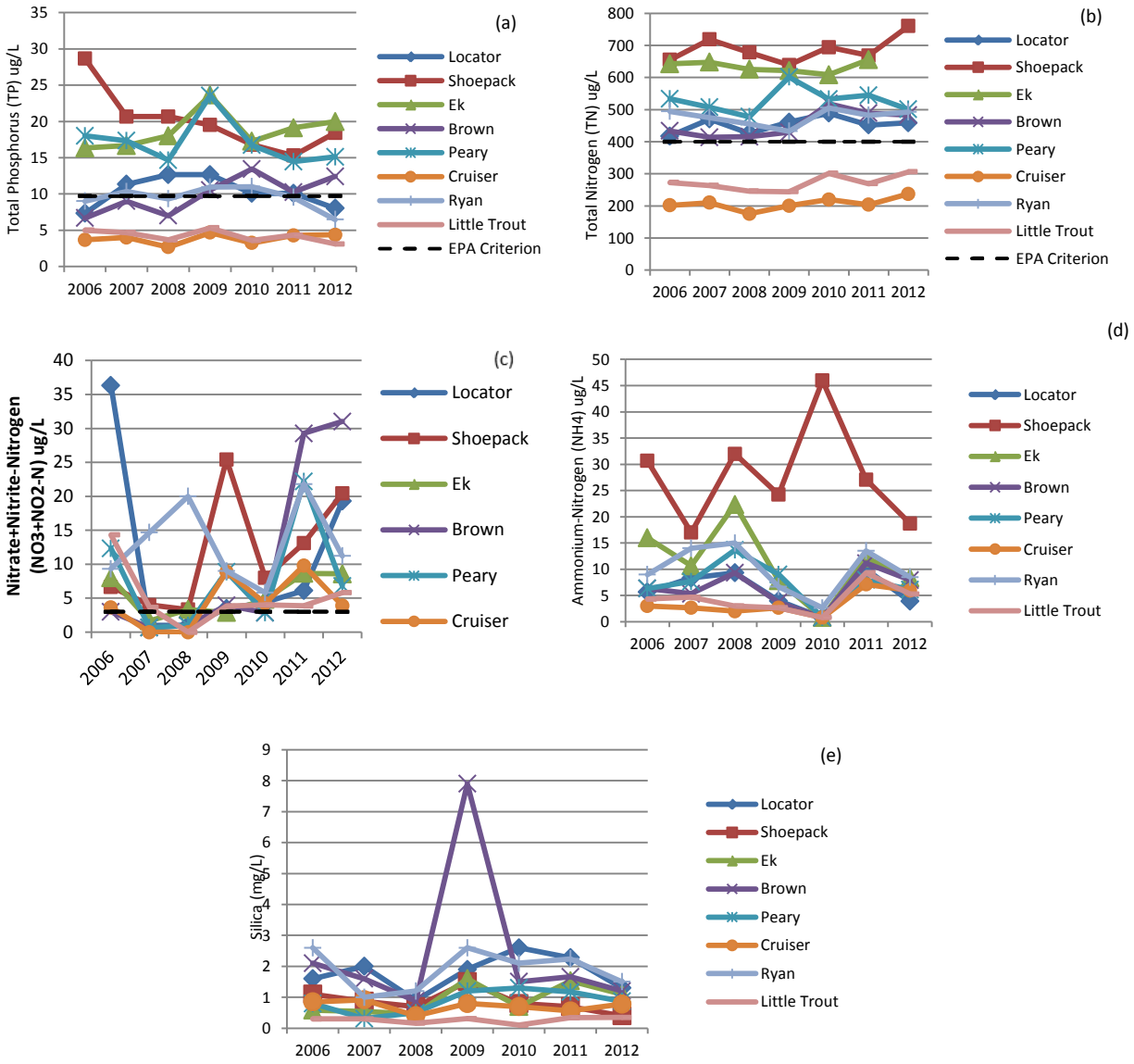

Figure 11. Mean concentration of nutrients in lakes at Voyageurs National Park, 2006–2012: total phosphorus (**a**), total nitrogen (**b**), nitrate+nitrite-nitrogen (**c**), ammonium-nitrogen (**d**), and silica (**e**).

Network and park staff collaborated with USGS on mercury sampling in five lakes (Ek, Shoepack, Brown, Ryan, and Peary) again in 2012. Such collaboration is beneficial to both agencies, as it reduces costs yet continues the flow of data for lakes susceptible to high levels of mercury methylation. Total mercury concentrations (THg) generally increased slightly between 2006 and 2009, then decreased slightly after 2009 (Figure 12a). Concentrations of methylmercury, the compound of mercury that bioaccumulates, did not follow a similar pattern (Figure 12b). The characteristics of individual watersheds play an important role in the methylation process (e.g., size of watershed, amount of wetland area, vegetation cover type) and, therefore, in determining the concentrations of methylmercury observed in the water and biota of these lakes.

A proposal submitted to the NPS/USGS Water Quality Partnership Program was funded in 2012 (Brigham et al. 2012). The purpose of the project is to analyze recent (2000–2012) trends in total mercury and methylmercury in select lakes and atmospheric deposition at VOYA. Data analysis was begun after final sample collection and lab analyses in 2012, and we expect it will provide examples of how concentrations of a key contaminant in lakes may be changing in response to changes in pollutant loads.

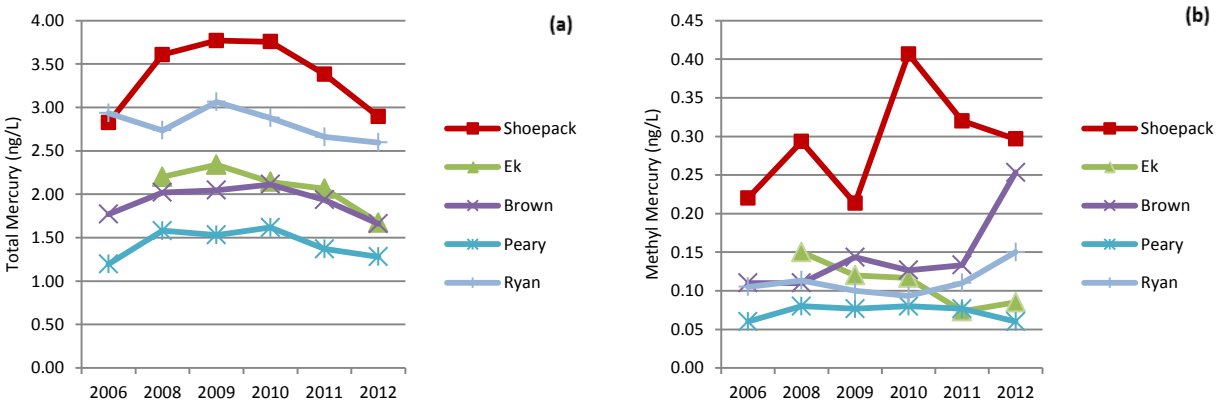

Figure 12. Mean total mercury (**a**) and methyl-mercury (**b**) concentrations in five inland lakes at Voyageurs National Park, 2006-2012 (samples were not collected in 2007).

Of the other parameters we measure annually, alkalinity, DOC, Cl^-, and SO_4^{-2} showed no clear trends (Figures 13a, b, c, and d). Chloride levels showed the same general rise-and-fall pattern across lakes, with minor exceptions. Sulfate concentrations were a bit more variable over time, both within and across lakes. Cations are not included here, as they are strongly correlated with specific conductance, discussed above. See Appendix A for all data.

Water samples were collected and analyzed for total suspended solids at four lakes (Ek, Peary, Cruiser, and Little Trout). Results (reported in Appendix A) are being used by Network collaborators at the St. Croix Watershed Research Station in a climate change modeling project.

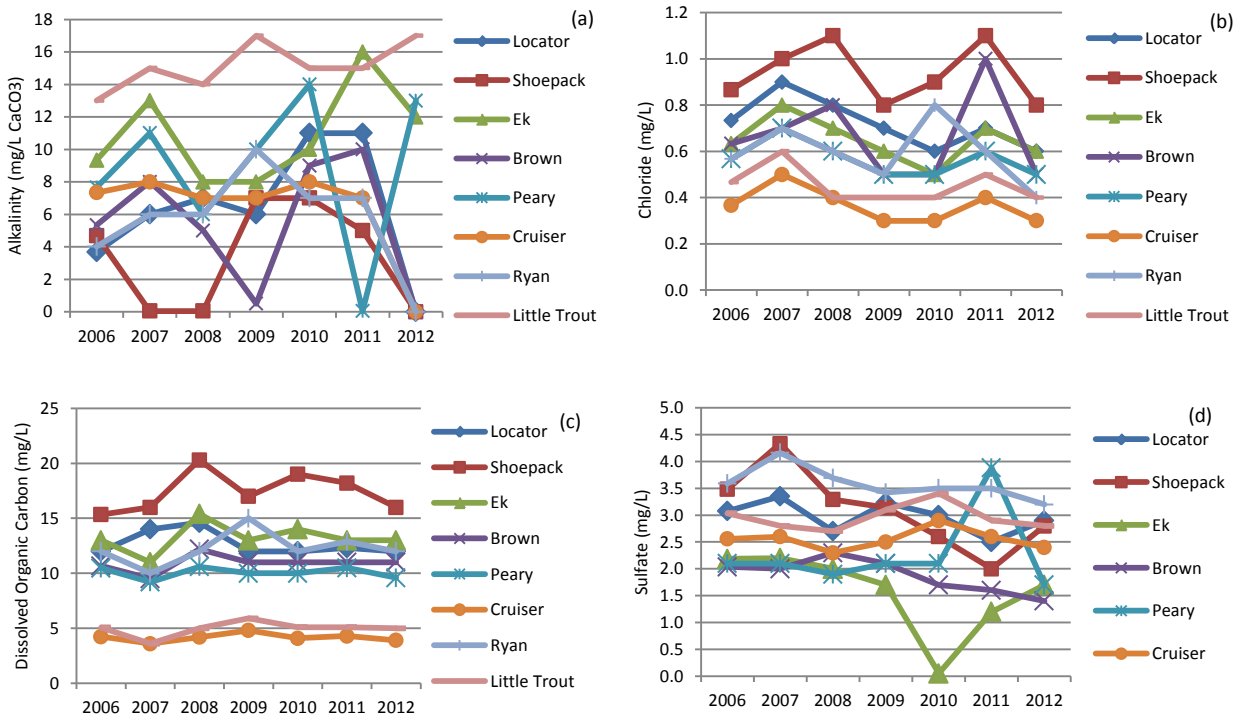

Figure 13. Concentrations of alkalinity (**a**), chloride (**b**), dissolved organic carbon (**c**), and sulfate (**d**) in index lakes at Voyageurs National Park, 2006–2012.

Apostle Islands National Lakeshore

Additional Data Collected and Exploration of Trends

In the late summer of 2008 Network staff installed permanent benchmarks at Stockton Island and Little Sand Bay (LSB) lagoons and temporary benchmarks at Michigan and Outer Island lagoons (these two lagoons are in designated wilderness areas where permanent benchmarks are not allowed). At the time, it was thought that if all the lagoons behaved similarly, then perhaps Stockton and Little Sand Bay could serve as proxies for Michigan and Outer. We found that water levels in all the lagoons, except Outer Island, are driven by Lake Superior water levels, and consequently, they behave more like coastal wetland lagoons, than lakes (Damstra and Elias 2012). Outlets from some of these lagoons to Lake Superior will open occasionally, and water from the lake was observed flowing in. Water level in Outer Island Lagoon fluctuates independently of Lake Superior levels, so it generally behaves more like an inland lake than a coastal wetland lagoon.

Generally, water levels in 2012 were up from 2011 (Figure 14). In 2012, water levels in Outer Island Lagoon were their highest since 2009. All other lagoons were below the initial 2009 water level.

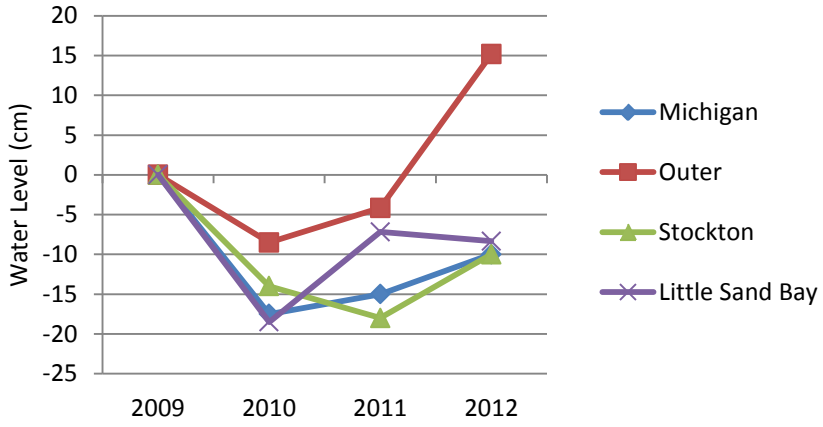

Figure 14. Mean summer water levels of lagoons at Apostle Islands National Lakeshore relative to 2009, which is set to zero.

There was no clear trend in mean specific conductance values in Michigan, Outer, and LSB lagoons (Figure 15a). Mean pH at Stockton and LSB lagoons showed a large amount of interannual variation, which was likely explained by the influence of Lake Superior water. When the outlet to the lake was open, the lagoon water closely matched lake water; when the outlet was closed, lagoon water was influenced by watershed characteristics. The trophic state of all four lagoons, calculated using chl-*a* concentration, has declined since 2008, though all lagoons remained in the mesotrophic category (TSI between 30 and 50; Figure 15c). TSI calculated using TP concentrations showed a very different pattern over the same time period (Figure 15d). Higher TP concentrations either have not led to increased phytoplankton biomass, perhaps due to the dark tannin-staining of the water, or zooplankton may have reduced the algae biomass through grazing.

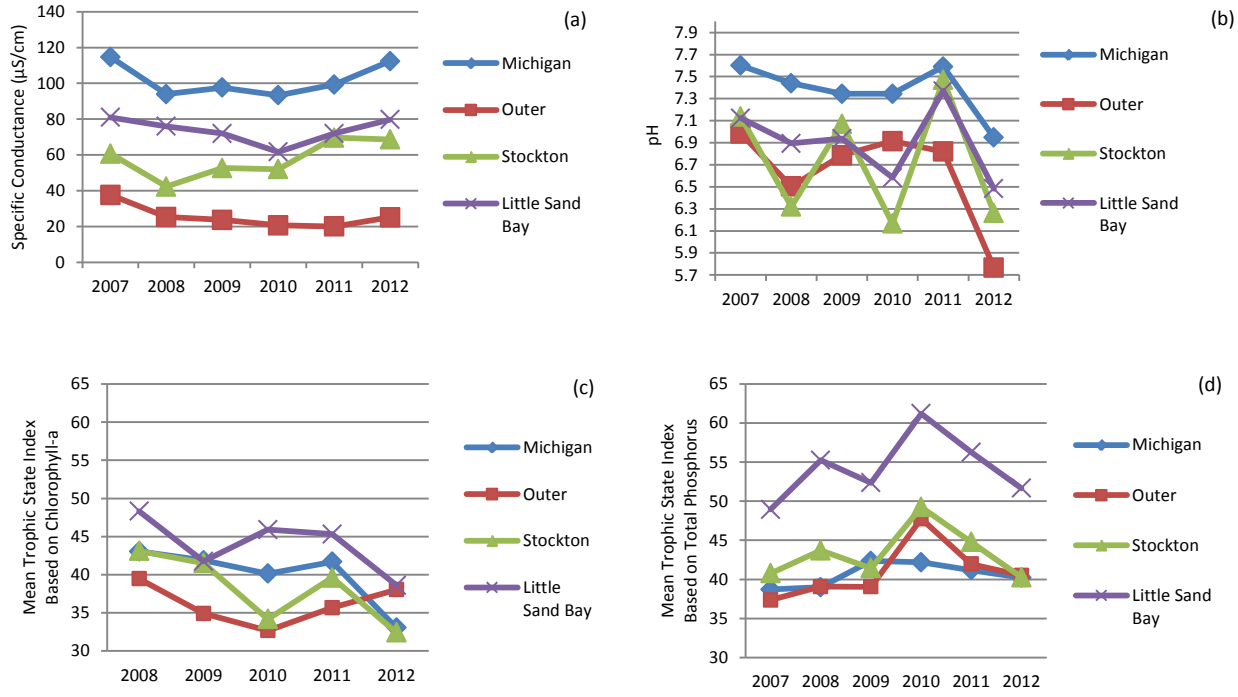

Figure 15. Mean measurements of specific conductance and pH at 0.5 m depth (**a** and **b**, respectively), trophic state index values calculated using chlorophyll-*a* concentration (**c**), and total phosphorus concentration (**d**) for lagoons at Apostle Islands National Lakeshore, 2007–2012. Chlorophyll-*a* data are not available for 2007.

Any potential trends in nutrient concentrations between 2007 and 2012 were masked by high variability (Figures 16a–16e). This is likely due in part to the relatively rapid rates of nitrification that occur in these lagoons, which function more like wetlands than like lakes, or because organic material is being re-suspended from the bottom back into the water column through frequent mixing. TP and TN concentrations at LSB and Stockton Island lagoons are affected by the exchange of water with Lake Superior, and in the case of LSB, runoff from the entire watershed is received via the Little Sand River. This watershed differs from those of the other lagoons in land use and ownership, as agriculture occurs on privately held parcels upstream of the park. Fluctuating silica levels (Figure 16e) were similarly influenced by Lake Superior water and the timing of the growth and demise of diatoms and freshwater sponges (uptake of silica during periods of growth and release of silica upon death).

Of the other parameters measured annually, the only other notable finding is that Outer Island lagoon may have experienced a decline in sulfate concentration, or the level in 2007 may have been abnormally high (Figure 17d). No other potential trends were evident (Figures 17a–17d). Interpretation of the chemistry of Stockton Island and LSB lagoons was confounded by their intermittent connection to Lake Superior. All data are listed in Appendix B.

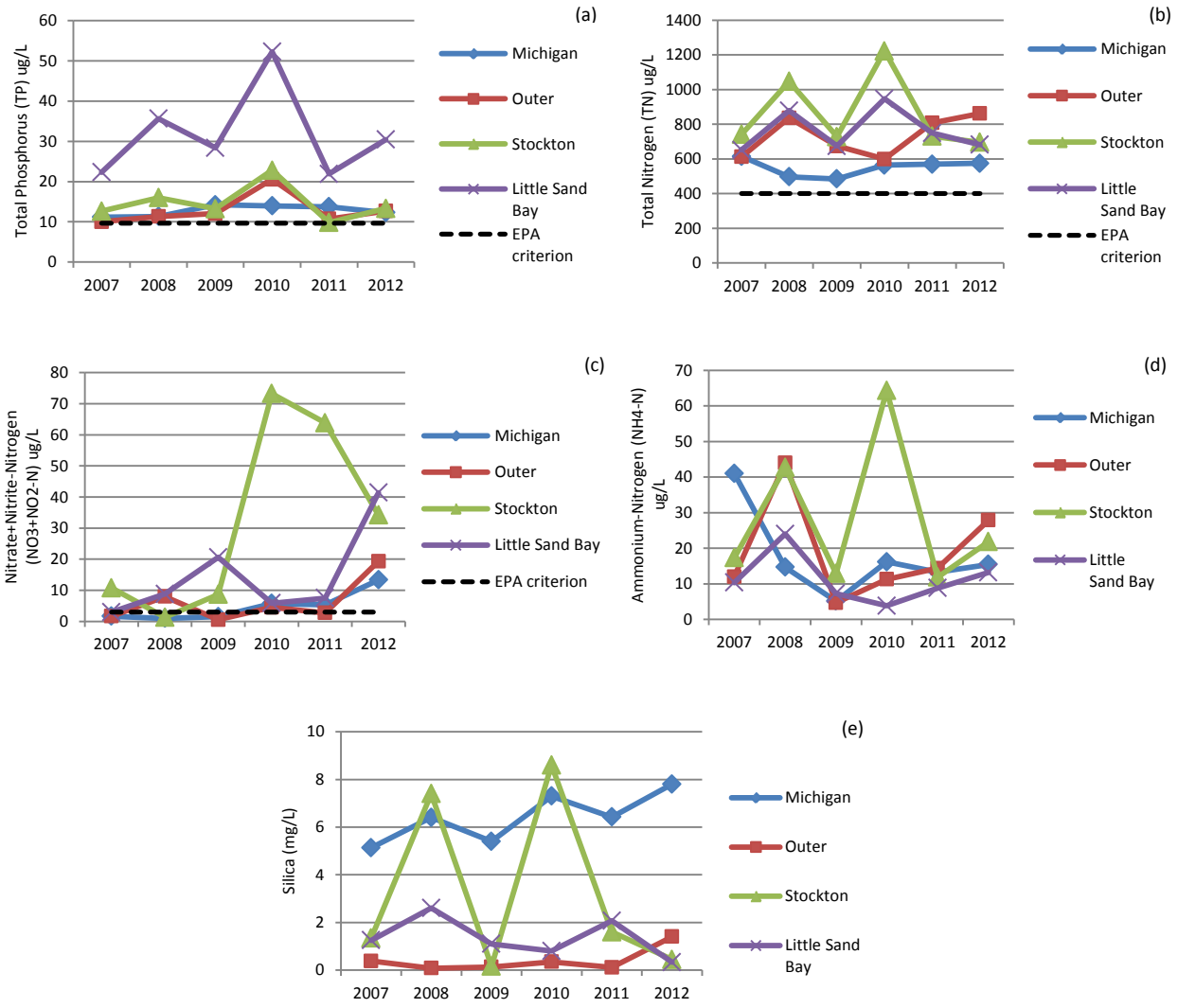

Figure 16. Mean concentration of nutrients in lagoons at Apostle Islands National Lakeshore, 2007–2012: total phosphorus (**a**), total nitrogen (**b**), nitrate+nitrite-nitrogen (**c**), ammonium-nitrogen (**d**), and silica (**e**).

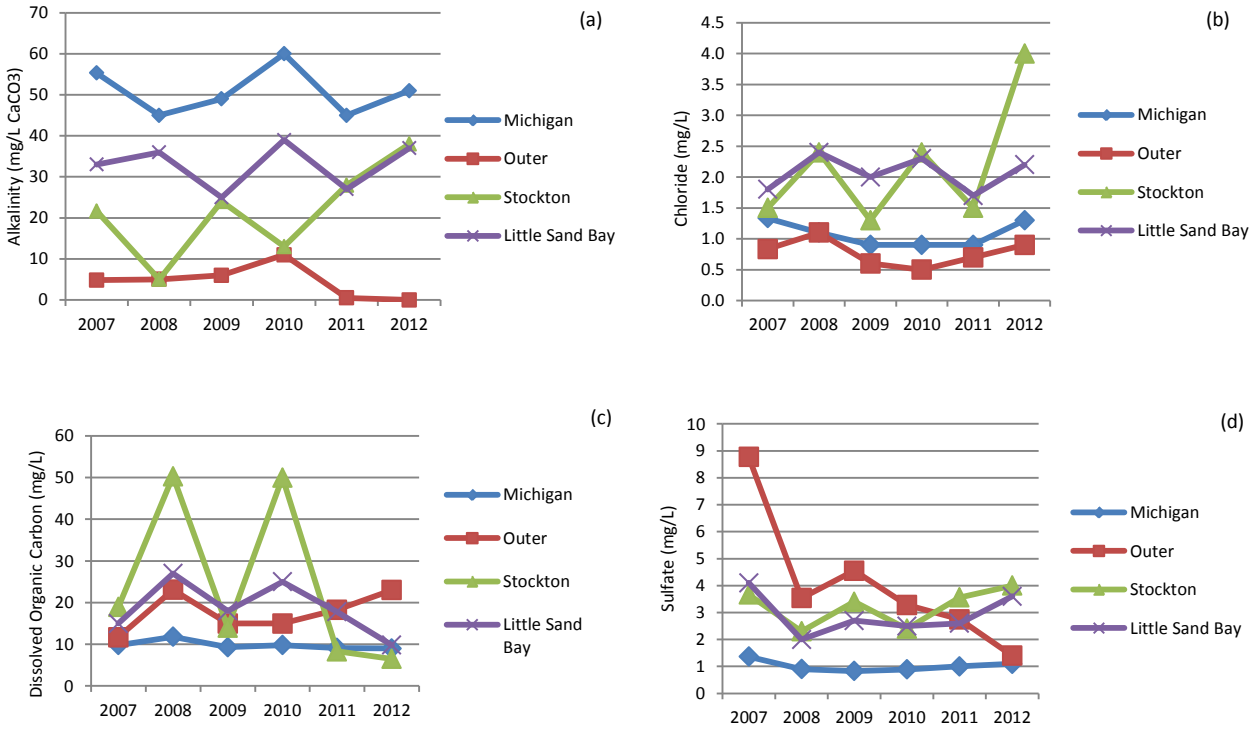

Figure 17. Concentrations of alkalinity (**a**), chloride (**b**), dissolved organic carbon (**c**), and sulfate (**d**) in lagoons at Apostle Islands National Lakeshore, 2007–2012.

Logistics and Recommendations

Due to the influence of Lake Superior on the water chemistry of the LSB, Stockton Island, and Michigan Island lagoons, and because they function as coastal wetlands instead of lakes, sampling will continue only at Outer Island Lagoon.

Recommendations for future monitoring are to:

1. Continue monitoring all parameters at Outer Island lagoon, as there is no surface water connection with Lake Superior and this lagoon is the most lacustrine (lake-like) of the four lagoons currently monitored at APIS.

2. Suspend monitoring at Michigan Island, Stockton Island, and LSB lagoons. Some basic monitoring at these lagoons may be initiated in the near future through a wetland monitoring standard operating procedure that will be a component of a larger amphibian monitoring effort at the park.

The understanding of lagoon water level fluctuations would benefit greatly from a study of groundwater connection to the lagoons. The Network's data suggest the lagoons do not respond uniformly to precipitation or changes in the water level of Lake Superior. Identifying the groundwater influences and the differences among the lagoons will better enable park managers to prepare for different climate change scenarios.

Isle Royale National Park

Additional Data Collected and Exploration of Trends

A minor cyanobacteria bloom occurred on Lake Richie in June 2012 and lasted into September. The bloom was less severe than those that occurred in 2007 and 2010, and required no advisories to avoid using water from the lake. Preliminary testing of water samples from Lake Richie and all other lakes sampled revealed no production of cyanobacteria toxins (H. Johnson, USGS, personal communication), but the final project report from USGS is pending. An early spring, with unseasonably warm temperatures in March and April, led to a long growing season. Warmer temperatures, longer growing seasons, and increased frequency of mixing in the water column (which re-suspends nutrients) likely contributed to the blooms. To better understand these processes, GLKN deployed an array of temperature sensors near the deepest part of Lake Richie in the spring of 2010. Except for cleaning the temperature sensors and downloading data, the array has been collecting hourly temperature data since then, year-round, throughout the water column. In addition to the temperature sensors, a pressure transducer used to measure depth is suspended at approximately 2 m deep on the array. The purpose of the depth measurement is to help control for possible differences in depth caused when the array is serviced—it is extremely difficult to place the array back into the exact same location where it was before servicing, and slight differences in instrument depth can occur following redeployment. The depth measurements can also be used to discern large runoff events and may have utility in determining ice-off dates on remote lakes.

Data from June through September 2012 show surface temperatures approached 28 °C in mid-July, which is quite warm for a lake of this depth (11 m) and latitude (Figure 18). Near complete mixing of the water column occurred in mid-to-late June during a storm event. Partial mixing events occurred in June and in late July due to separate rain and sustained wind events. Beginning in early August, temperatures ≥20 °C extended to depths greater than 6 m, which is more than half of the water column.

Koelz (1929) and Hubbs and Lagler (1949) found cisco (*Coregonus artedii*) inhabiting Lake Richie in 1929 and 1945, respectively. This species was not observed in sampling by Kallemeyn (2000) in the mid-1990s, nor by assessments performed by park staff in 2011 or 2012 (unpublished data). Thus, park resource managers are concerned about the possible extirpation of cisco from the lake. Through analysis of the data collected via the temperature array and the Network's synoptic profile data, we have been able to determine that suitable summer habitat, with the temperature and oxygen levels required by cisco, no longer exists in Lake Richie on a consistent basis during the hottest part of summer (Figure 19; Damstra and Elias 2012). Because cisco populations are declining and limited summer habitat exists in Lake Richie and other lakes at ISRO, park managers have established a policy of catch-and-release only for cisco in all of the park's inland lakes.

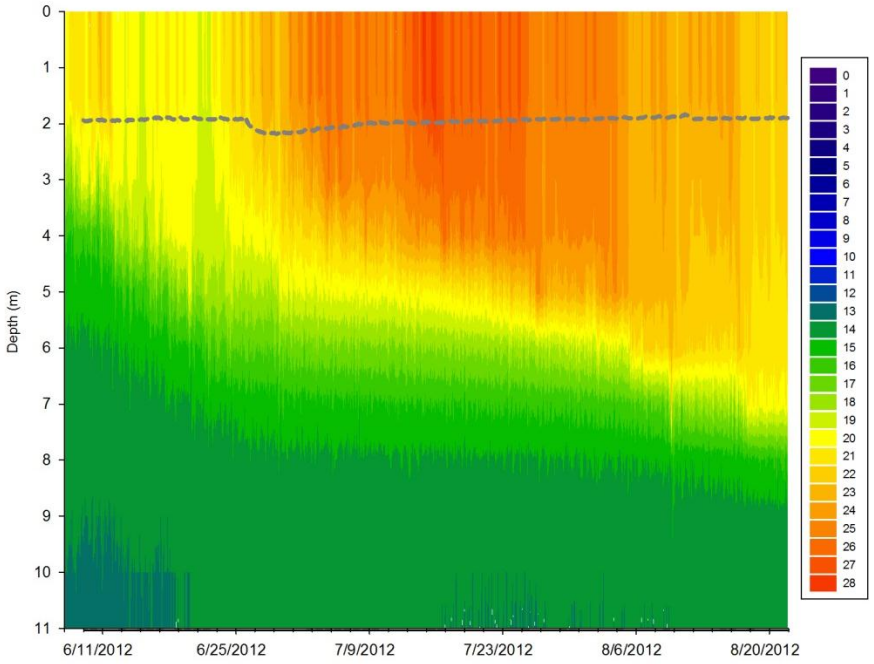

Figure 18. Hourly temperature (°C) data collected throughout the water column in Lake Richie, Isle Royale National Park, 8 June–22 August 2012. The grey dashed line represents water depth at about 2 m inferred from a pressure transducer attached to the vertical line at about 2 m.

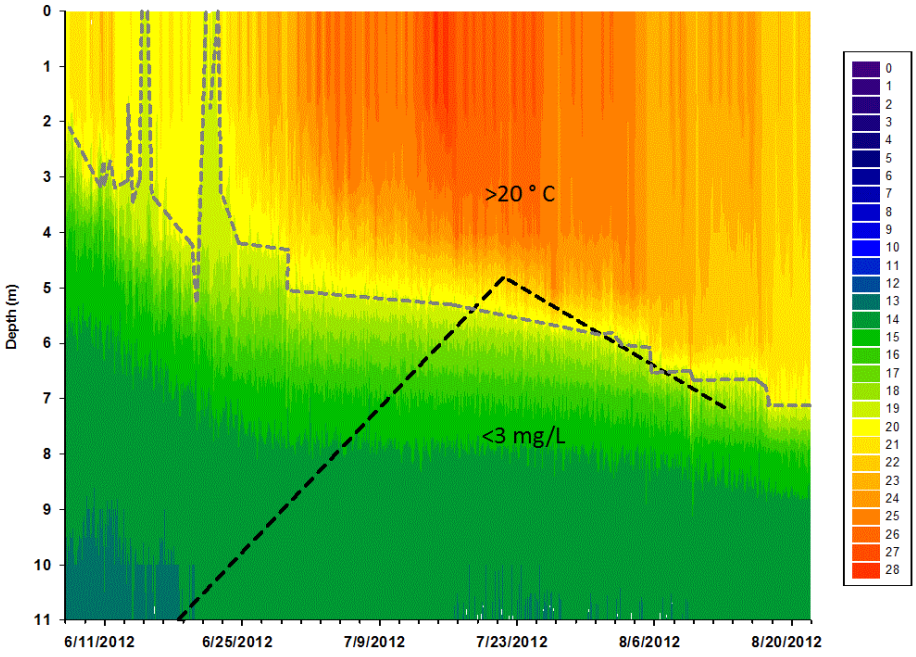

Figure 19. Hourly temperature (°C) data in Lake Richie, Isle Royale National Park, 8 June–22 August 2012. Above the grey dashed line, water temperature is greater than 20°C; below the black line, dissolved oxygen falls below 3 mg/L. Suitable habitat for cisco no longer exists after mid-July, which is depicted by the intersection of the two lines.

Water levels of index lakes generally have been highest during the first sampling round and gradually declined throughout the season. In 2012 several lakes experienced their highest mean summer level since monitoring began in 2007 (Figure 20). Beaver Lake is the exception, with water levels lower than at the start of the project. Large changes have occurred in several lakes, sometimes from one year to the next (e.g., difference of 38 cm at Feldtmann between 2009 and 2010, and a difference of >25 cm at Richie and Sargent between 2010 and 2011). Watershed size, basin morphometry, and beaver activity upstream or downstream of the lake are important influences on each lake's water level. More information is needed on beaver activity in the watersheds of all index lakes to distinguish their effects on water levels from the effects of weather or climate.

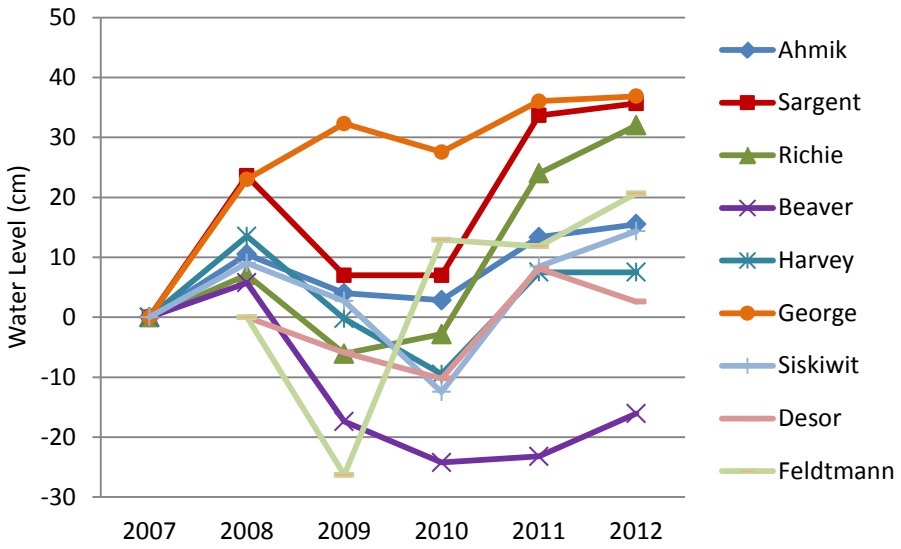

Figure 20. Mean summer water levels of index lakes at Isle Royale National Park, 2007–2012. Water level is measured relative to a permanent benchmark at each lake. All lake water levels are relative to the mean of the first season (i.e., 2007 or 2008 set to zero).

Trends in specific conductance and Secchi depth are not evident for any of the index lakes (Figures 21a and c). Mean pH values are surprisingly variable from year to year (Figure 21b), with Lake Harvey showing a slight increase, and Lake George showing a surprising decrease since monitoring began in 2007.

The mean trophic state indices as calculated by chl-*a* concentration indicate most lakes have been in the mesotrophic range (TSI values between 30 and 50) since monitoring began (Figure 21d). Siskiwit Lake tends to be oligotrophic (TSI <30), while Lake Richie is typically mesotrophic (TSI=30-50), but has been eutrophic (TSI >50) some years. Some lakes (e.g., Sargent, Harvey, George, Feldtmann) seem to be showing a slight decrease in trophic state.

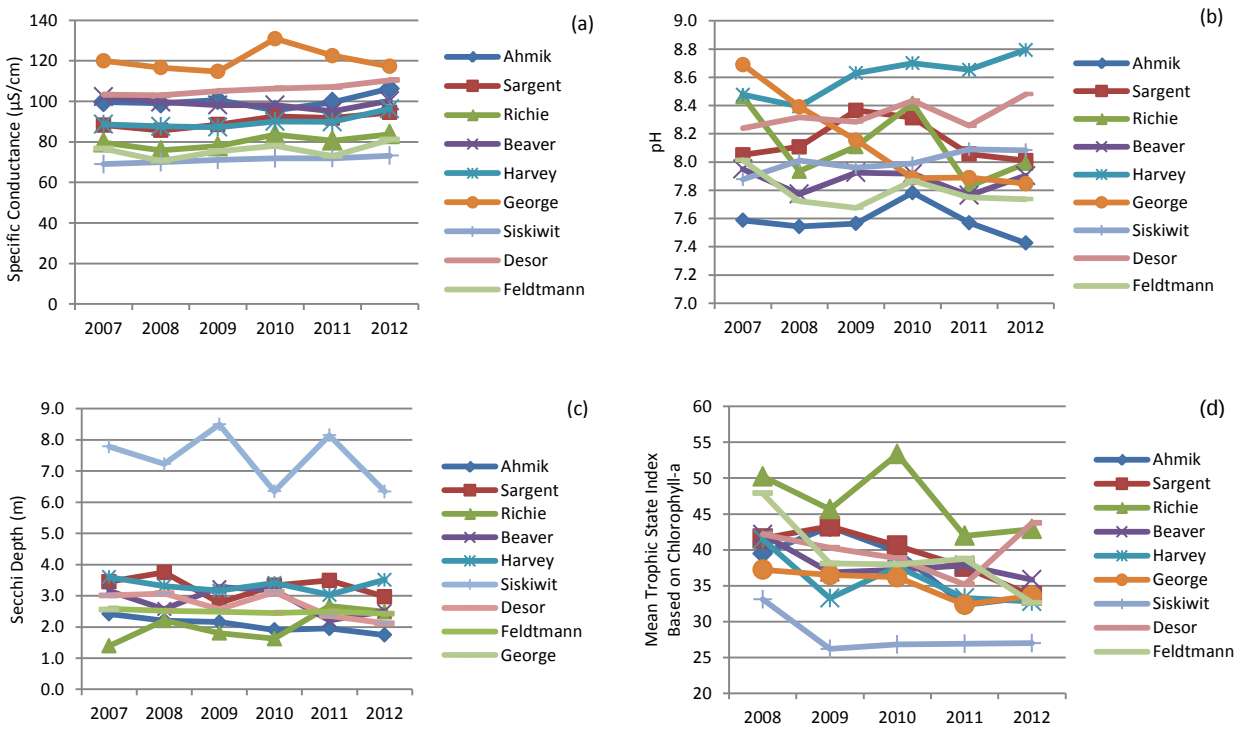

Figure 21. Mean measurements of specific conductance and pH at 1 m depth (**a** and **b**, respectively), water clarity as measured by Secchi disk depth (**c**), and trophic state index as calculated from chlorophyll-*a* measurements (**d**) for index lakes in Isle Royale National Park, 2007–2012. Chlorophyll-*a* data are not available for 2007.

Siskiwit Lake is the only lake with mean TP and TN concentrations consistently below EPA reference criteria (Figures 22a and b). Interannual variations in TP and TN have been relatively large in some lakes (notably Ahmik and Richie), but no trends are evident. With the exception of Siskiwit Lake, all lakes showed a remarkably consistent pattern of mean NO_3+NO_2-N concentrations increasing and decreasing together (Figure 22c). Relatively consistent patterns in NH_4-N concentrations also occurred, with Lake Ahmik exhibiting an exaggerated version of the variations (Figure 22d). Mean silica concentrations have seen little variation over the monitoring period, and no trends are evident (Figure 22e).

Of the other parameters measured annually, the lakes generally showed patterns similar to one another, rising and falling in unison, for alkalinity, Cl^-, DOC, and SO_4^{-2} (Figure 23a–23d). Hints of trends in these parameters are weak at best, with interannual variations overriding potential trends. All data are listed in Appendix C.

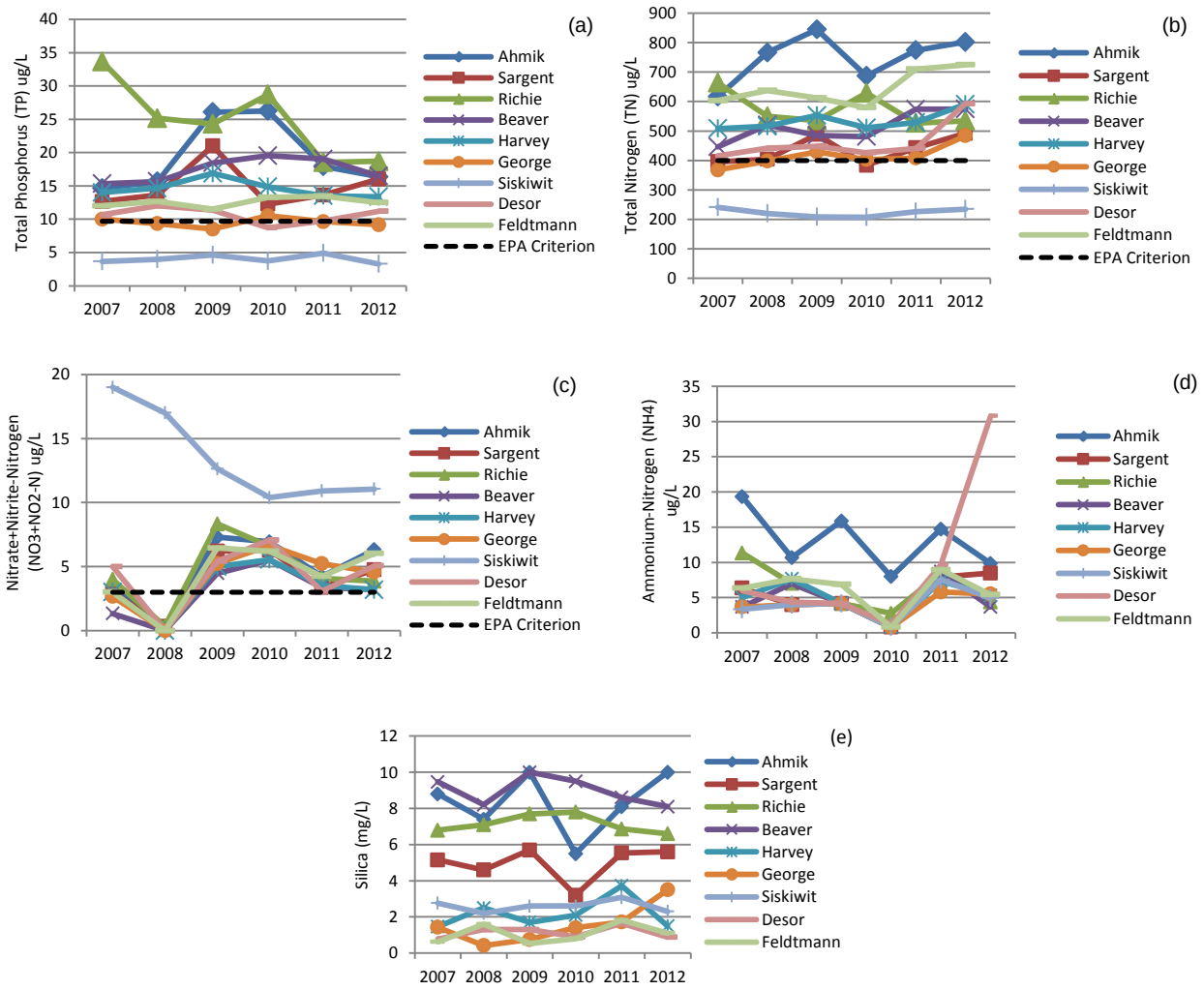

Figure 22. Mean concentration of nutrients in index lakes at Isle Royale National Park, 2007–2012: total phosphorus (**a**), total nitrogen (**b**), nitrate+nitrite-nitrogen (**c**), ammonium-nitrogen (**d**), and silica (**e**).

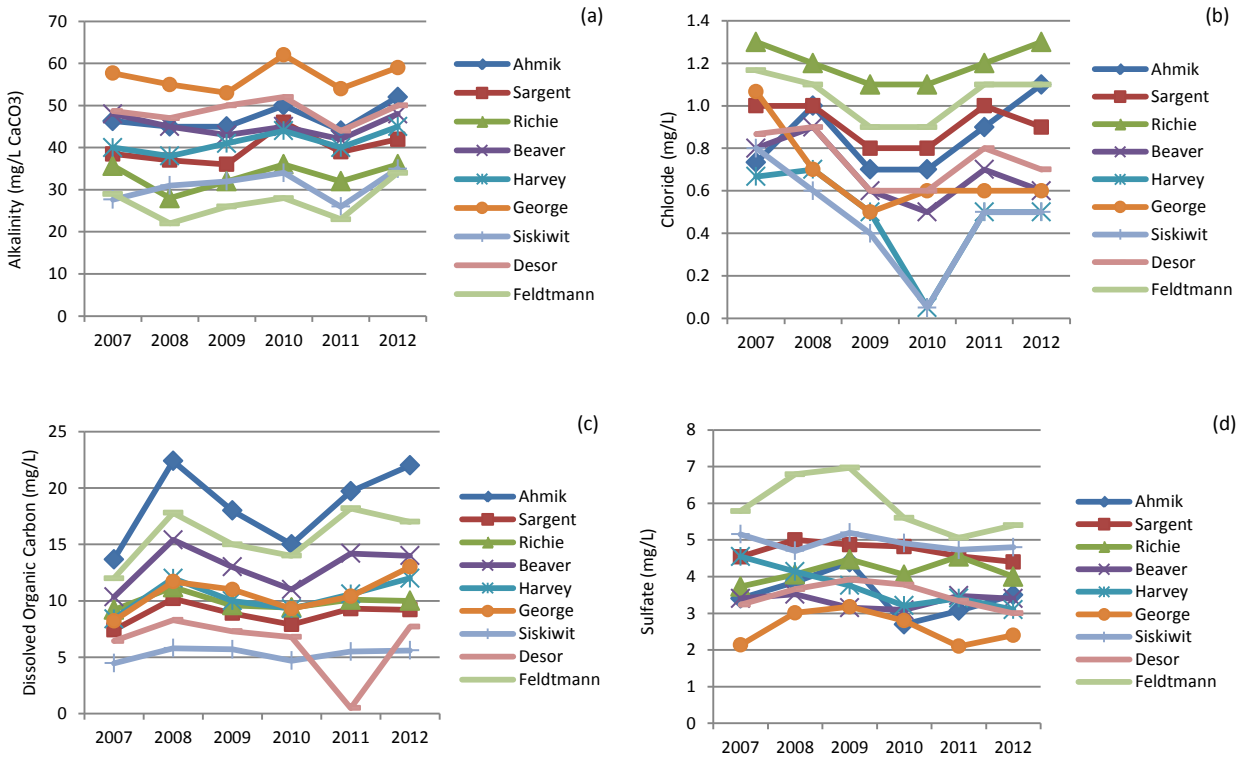

Figure 23. Concentrations of alkalinity (**a**), chloride (**b**), dissolved organic carbon (**c**), and sulfate (**d**) in index lakes at Isle Royale National Park, 2007–2012.

Other work completed at ISRO in 2012 included sampling at Chickenbone Lake and Lake LeSage in conjunction with USGS cyanobacteria sampling (see Appendix C for the data); stream temperature monitoring at two sites each on Benson and Washington creeks; depth monitoring in Washington Creek; deploying and retrieving a temperature arrays in Siskiwit Lake and Lake Desor for University of Maine researchers, and assisting them in other aspects of their project; providing logistical and field support for park, USGS, U.S. Fish and Wildlife Service, and outside research projects. Rationale for the stream monitoring work is discussed in the Network's protocol for monitoring water quality of wadeable streams, which is in development.

Logistics

Sampling was conducted by GLKN and through an exchange of assistance with ISRO staff and Michigan Technological University researchers. Whenever possible, GLKN staff shared boat operations with park staff to save fuel and boating hours.

Network staff will continue to collaborate with USGS to collect samples for analysis of algal toxins at Ahmik, Sargent, Richie, Harvey, Desor, and Chickenbone lakes, pursuant to NPS PMIS project #169376: Determination of Algal Toxin Concentrations in Surface Waters at Isle Royale National Park, Sleeping Bear Dunes National Lakeshore, and Pictured Rocks National Lakeshore. Though Chickenbone is not an index lake, field measurements will be conducted and water samples will be

collected for analyses of nutrients and chl-*a* during all three sampling rounds. The Network has proposed that Lake LeSage be dropped from the algal toxins project due to logistical concerns.

The temperature array in Lake Richie continued collecting hourly data throughout 2013, and it was re-set for under-ice conditions during the winter of 2013–2014. Data collection will be limited on Benson and Washington creeks to one site each, continuing with only the downstream sites established in 2011.

Pictured Rocks National Lakeshore

Additional Data Collected and Exploration of Trends

In early October 2011, GLKN and park staff deployed an array of temperature probes in Grand Sable Lake. The array was set for under-ice conditions, with a sub-surface float at approximately 2 m depth and probes extending from 2 m down to the bottom. The array collected hourly data throughout the winter and then was re-set in April 2012 to collect data through the rest of the year. Thus far, the array data show water temperature as high as 26 °C (Figure 24). The warmest time period in 2012 was between early July and early August. The lake appears to have been thermally stratified from the surface to approximately 10 m depth.

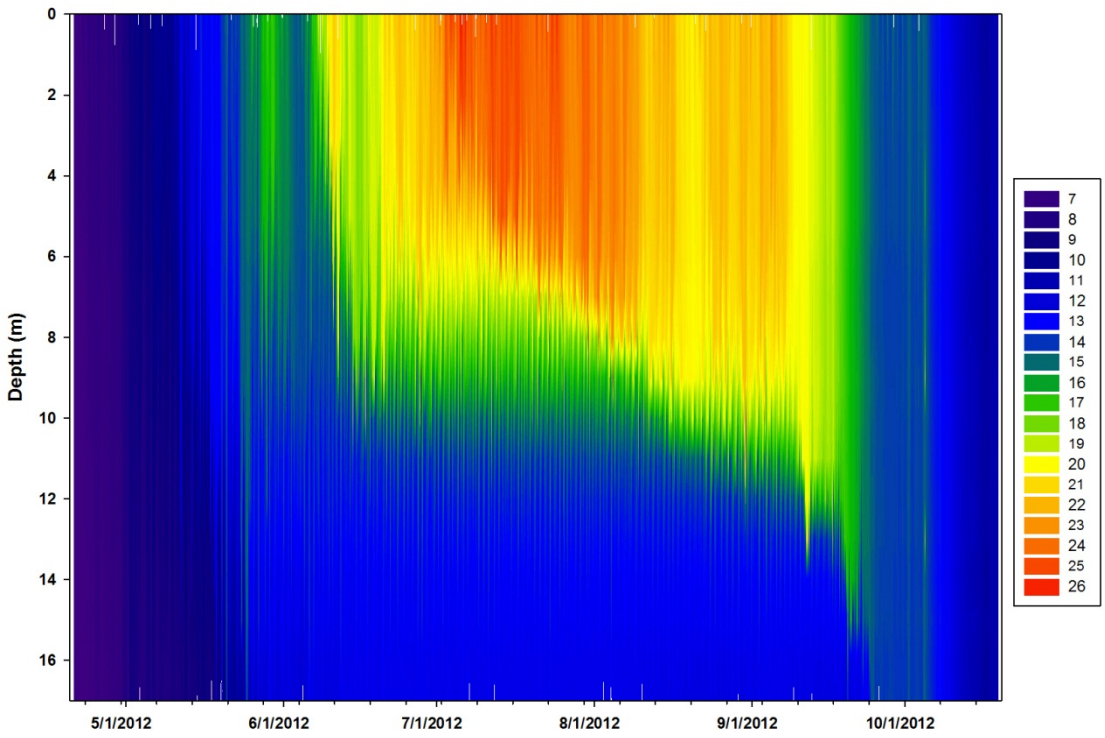

Figure 24. Hourly temperature (°C) data throughout the water column in Grand Sable Lake, Pictured Rocks National Lakeshore, 20 April–19 October 2012. The lake stratified in mid-June and turned over in mid-September.

Mean summer water levels have dropped substantially at Chapel Lake since 2008 (Figure 25). Beaver activity at the outlet of Chapel Lake likely impacts water levels. Legion Lake has experienced the most variable water levels since monitoring began. It is a seepage lake that is largely influenced by precipitation and evaporation. Changes in all other lakes have generally mirrored one another and shown little inter-annual variation.

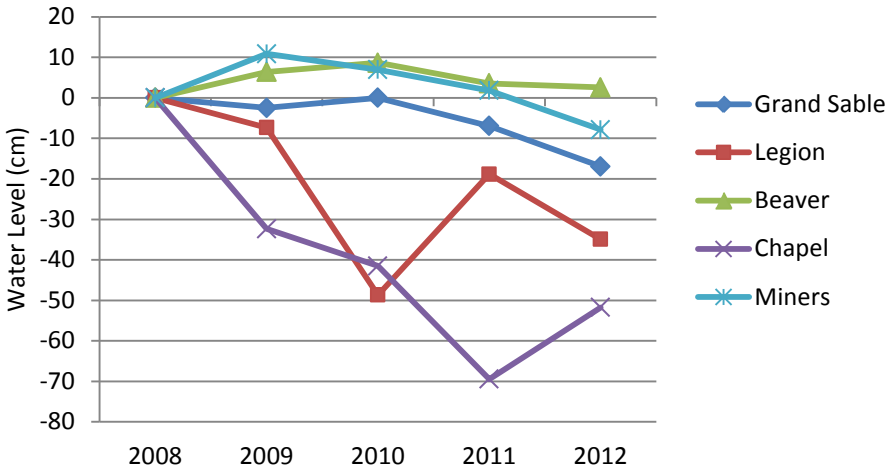

Figure 25. Mean summer lake levels, Pictured Rocks National Lakeshore, 2008–2012. Water level is measured relative to a permanent benchmark at each lake. All lake water levels are relative to the 2008 mean, which is set to zero.

No clear trends are evident in the field-measured parameters (Figures 26a–26c), with the possible exception of specific conductance at Miners Lake. If wind speed or the frequency of high wind events has increased over time, the specific conductance in a shallow lake like Miners could increase due to increased mixing. Index lakes at PIRO have generally been mesotrophic throughout the Network's monitoring tenure, with TSI values between 30 and 50 (Figure 26d). Annual variation in TSI values may reflect differences in weather (e.g., hot, dry years may lead to greater algal production). See Appendix D for TSI calculations based on Secchi disk data.

While some variation in mean nutrient levels occurred in all lakes since monitoring began in 2007, no clear trends are evident (Figures 27a–27e). Miners Lake, which showed the greatest amount of interannual variation, is a shallow, flow-through lake that is frequently mixed during the growing season. Such mixing brings nutrients that have settled into bottom sediments into suspension. Miners Lake also receives substantial groundwater inputs along the east side of the lake (L. Loope, PIRO aquatic ecologist, personal communication). The source of the relatively high NO_x levels in Miners Lake is of interest to park and GLKN staff. Network collaborative efforts to procure funding to study this have not been successful to date; we will pursue additional funding opportunities as they arise.

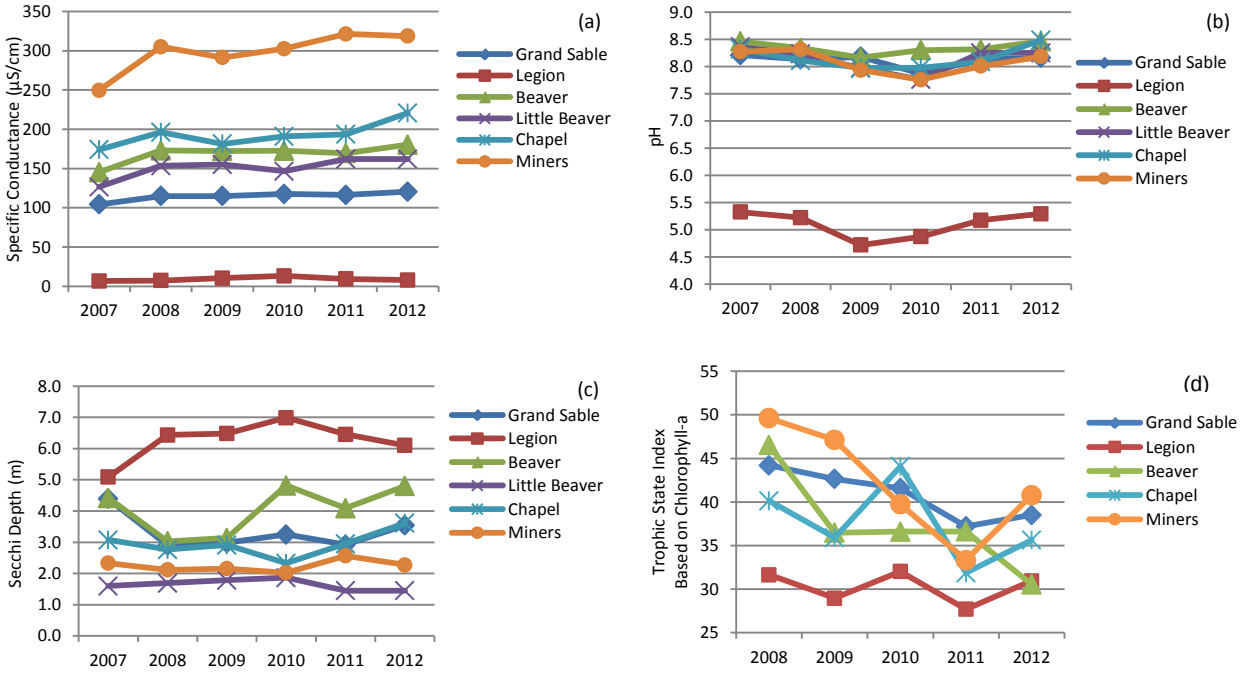

Figure 26. Mean measurements of specific conductance and pH at 1 m depth (**a** and **b**, respectively), water clarity as measured by Secchi disk depth (**c**), and trophic state index as calculated from chlorophyll-*a* measurements (**d**) for index lakes at Pictured Rocks National Lakeshore, 2007–2012. Chlorophyll-*a* data are not available for 2007.

Silica levels were extremely low in Legion Lake, indicating a lack of connection to the groundwater because of its position near the watershed divide and it's small (~72 ha) catchment area (Kenoyer and Anderson 1989). In Chapel and Beaver lakes, silica could be increasing slightly, but the concentration measured at any given time is influenced by the timing of growth and seasonal die-back of diatoms and freshwater sponges; dissolved silica is removed from the water during periods of growth and released when the organisms die.

No trends are obvious among the other parameters measured annually (alkalinity, DOC, and anions (Figure 28a–28d; cations are not included here as they are strongly correlated with specific conductance, discussed above). See Appendix D for all data. The deepest and shallowest lakes (Chapel and Miners, respectively) showed patterns similar to one another for Cl^- and DOC; likewise, Grand Sable, Legion, and Beaver lakes showed similar patterns to one another. All five index lakes showed little variation in alkalinity since monitoring began in 2007.

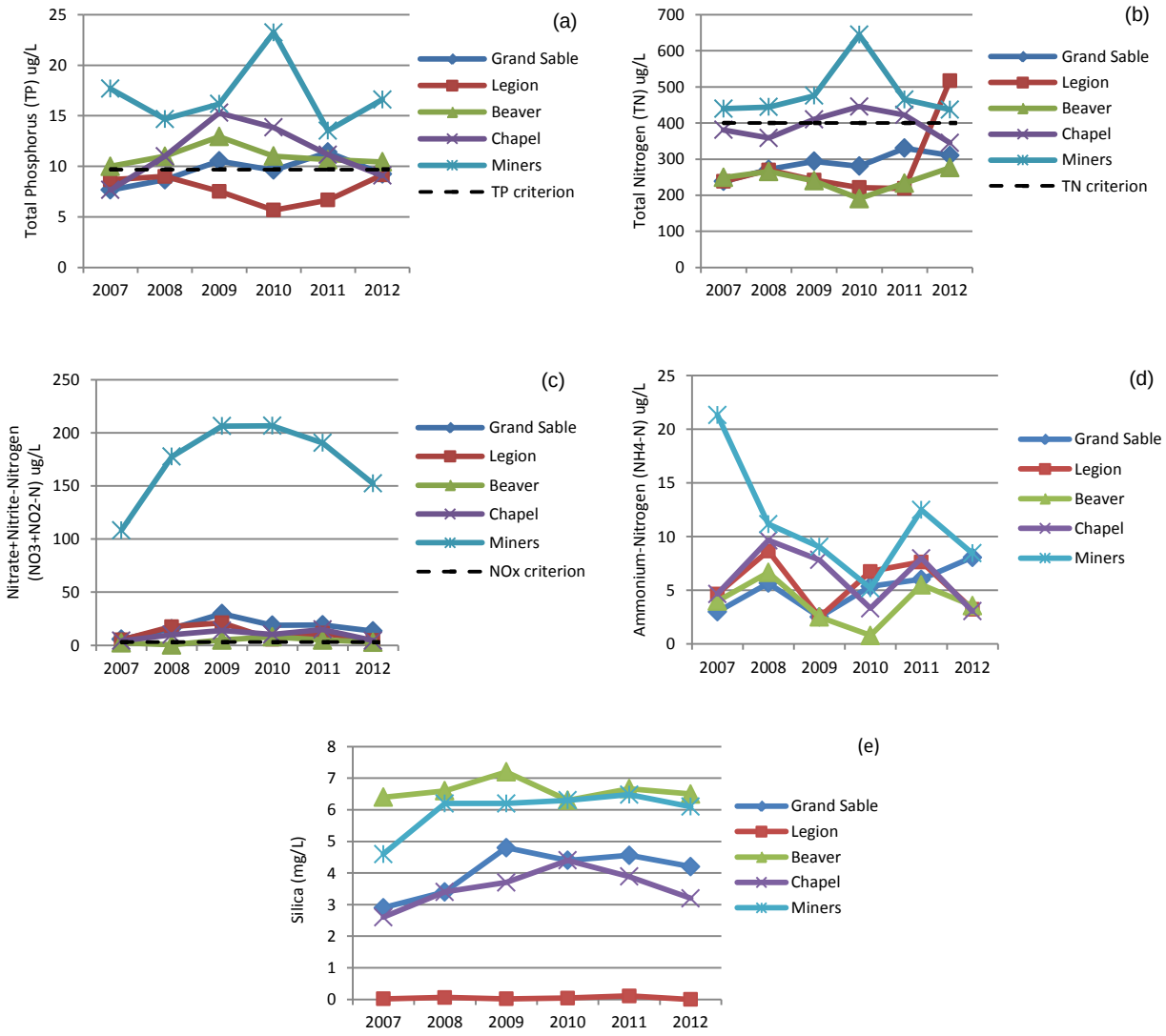

Figure 27. Mean concentration of nutrients in index lakes at Pictured Rocks National Lakeshore, 2007–2012; total phosphorus (**a**), total nitrogen (**b**), nitrate+nitrite-nitrogen (**c**), ammonium-nitrogen (**d**), and silica (**e**).

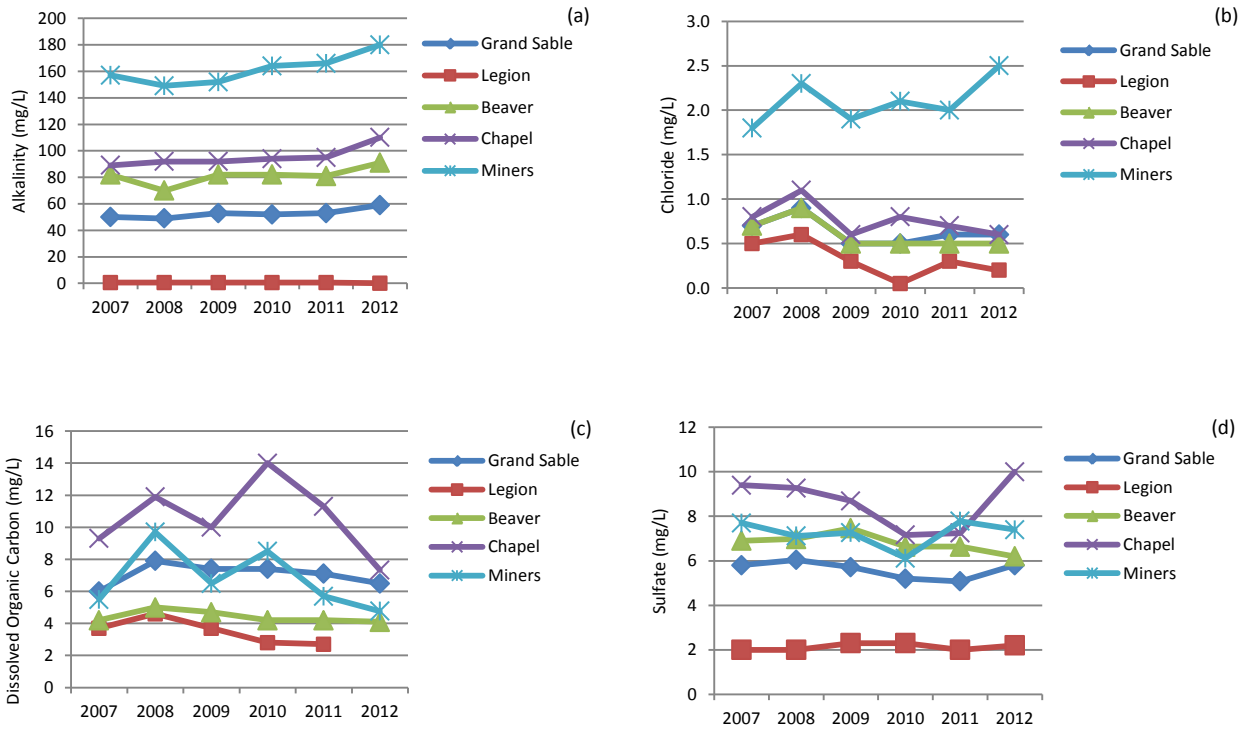

Figure 28. Concentrations of alkalinity (**a**), chloride (**b**), dissolved organic carbon (**c**), and sulfate (**d**) in index lakes at Pictured Rocks National Lakeshore, 2007–2012.

Logistics

In addition to the index lakes field measurements were collected at Little Beaver Lake and Trappers Lake. Data for these non-index lakes are reported alongside the index lakes in Appendix D.

The Network will continue working with USGS to collect samples for analysis of algal toxins at Beaver, Miners, Trappers, and Grand Sable lakes in 2013, pursuant to PMIS project # 169376, entitled "Determination of Algal Toxin Concentrations in Surface Waters at Isle Royale National Park, Sleeping Bear Dunes National Lakeshore, and Pictured Rocks National Lakeshore". Although Trappers is not an index lake, field measurements will be taken and water will be collected for analyses of nutrients and chl-*a* during all three regularly scheduled sampling rounds.

Indiana Dunes National Lakeshore

Additional Data Collected and Exploration of Trends

The Network has been measuring water levels at Long Lake relative to a USGS groundwater well cap since 2006. In 2010, the USGS replaced the well, and we converted Network measurements to values that corresponded to the height of the new well. As a back-up, water level has also been measured from a fixed point on the boardwalk since 2010. Unfortunately, in 2011 USGS personnel discovered that the old well had heaved 0.55 m (1.82 feet) sometime between when it was installed

(2002) and when it was replaced (2010). Because the date when this change in elevation occurred is unknown, the Network cannot use the water level data collected between 2006 and 2010.

The water level of Middle Lagoon has been measured from the bridge. Since 2008, water levels rose approximately 20 cm, before dropping back to near the starting point in 2012 (Figure 29a). Typically, the lowest water levels have occurred early in the season, but in 2012 water levels approached the all-time high, then declined throughout the season and dropped to the lowest measurement collected during the project (Figure 29b).

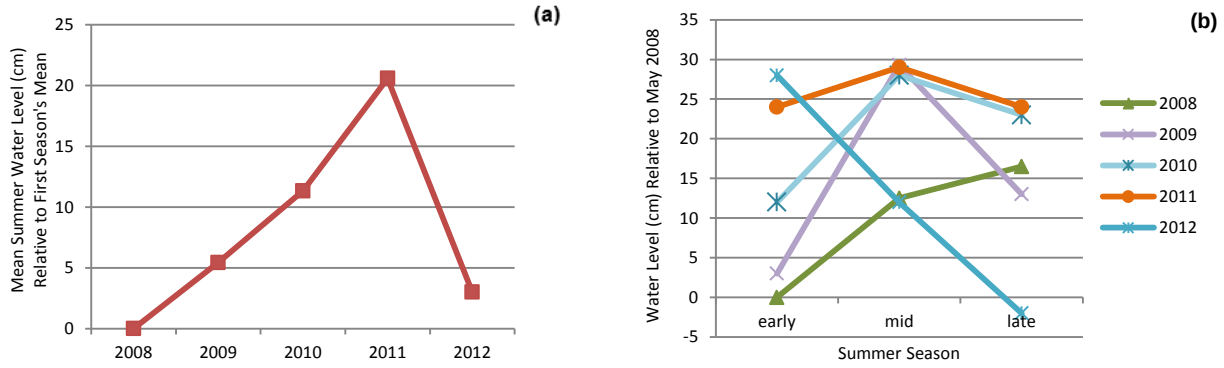

Figure 29. Mean summer water levels at Middle Lagoon, Indiana Dunes National Lakeshore, relative to the 2008 mean, which is set to zero (**a**). Water levels throughout the summer in Middle Lagoon, 2008–2012 (**b**).

Due to the amount of interannual variability and the short-term record, it is difficult to determine whether trends in the field-measured parameters can be observed in Middle Lagoon (Figures 30a and b). Mean specific conductance decreased in Middle Lagoon following the high levels in 2008, and in 2012 is nearly the same as it was in 2007. Mean pH levels have decreased in Middle Lagoon since 2007, but because of the short record, pH was prior to 2007is unknown. If it was similar to that of 2007, a trend may be emerging, but if pH prior to 2007 was lower, then 2007 may have been an anomaly. Specific conductance may be trending upwards in Long Lake, but no change in pH is evident.

Trophic state indices (TSIs), as calculated by chlorophyll-*a* concentration, for Long Lake and Middle Lagoon have been variable since monitoring began but track closely together (Figure 30c). However, both lakes remained within the mesotrophic category (TSI between 30 and 50). Conversely, when TSI is calculated using TP concentration, both water bodies have been in the eutrophic range (TSI >50) some years (Figure 30d). The likely explanation for the difference in the two calculations of TSI is that both lakes are dominated by macrophytes, and the available phosphorus is used by the macrophytes rather than resulting in increased phytoplankton biomass. The apparent decrease in TSI since 2009 could be the result of increased macrophyte growth, although this is not something the Network measures.

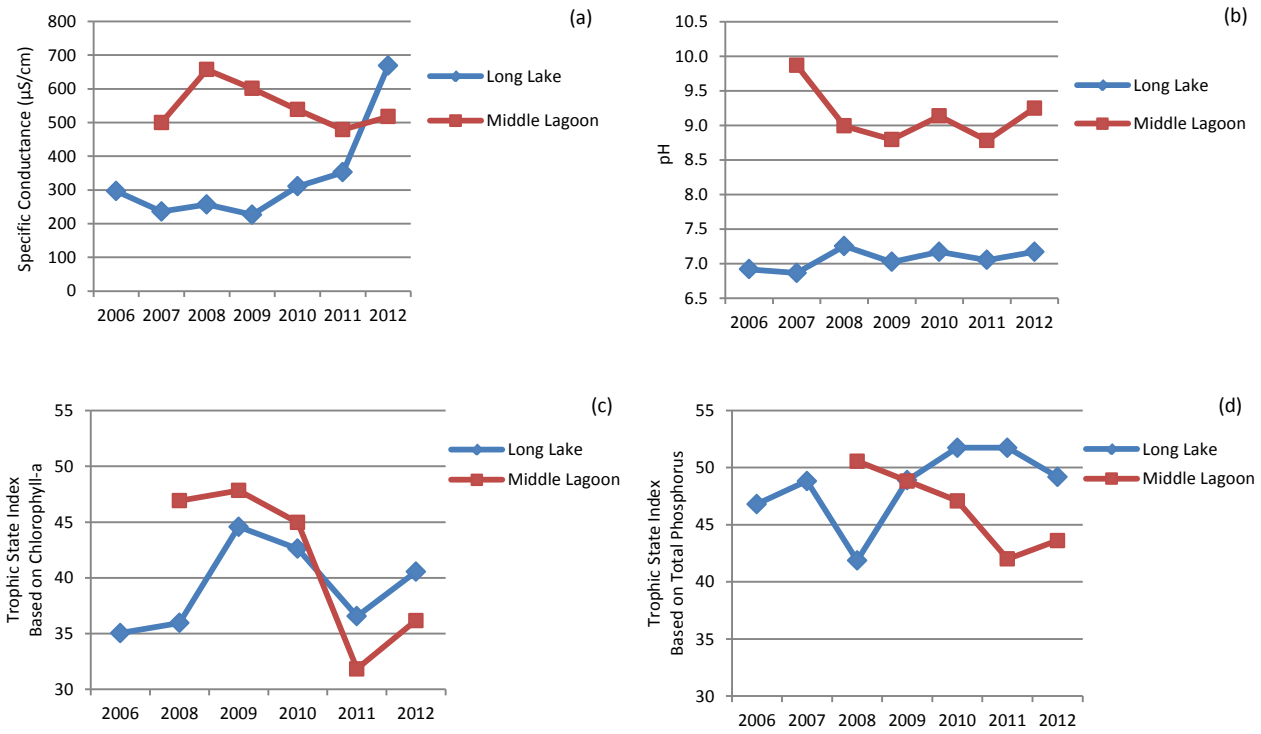

Figure 30. Mean measurements of specific conductance and pH at 0.5 m depth (**a** and **b**, respectively), trophic state index values calculated using chlorophyll-*a* concentration (**c**), and total phosphorus concentration (**d**) for Long Lake (2006–2012) and Middle Lagoon (2007–2012) at Indiana Dunes National Lakeshore. Chlorophyll-*a* data are not available for 2007.

Mean TP and TN concentrations have fluctuated around the levels of the EPA reference criteria (Figures 31a and b). Both TP and TN seem to have decreased in Middle Lagoon since 2008. Concentrations of NO_3+NO_2-N and NH_4-N appear to have changed dramatically since monitoring began (Figured 31c and d), but the values are actually quite low and the changes do not represent large ecological shifts. Silica concentrations have also been variable (Figure 31e), and are influenced by the uptake and release by diatoms and freshwater sponges. Dissolved silica is removed from the water during periods of growth and released when the organisms die.

Of the other parameters we measure annually, alkalinity shows little interannual fluctuation and no clear trend (Figure 32a). Chloride levels are high in both water bodies, especially Middle Lagoon (Figure 32b), and likely indicate contamination. Dissolved organic carbon concentration may be increasing in Long Lake and declining slightly in Middle Lagoon (Figure 32c). Sulfate concentration seems to have declined in both Long Lake and Middle Lagoon (Figure 32d). Cations are not included here, as they are strongly correlated with specific conductance, discussed above. See Appendix E for all of the data.

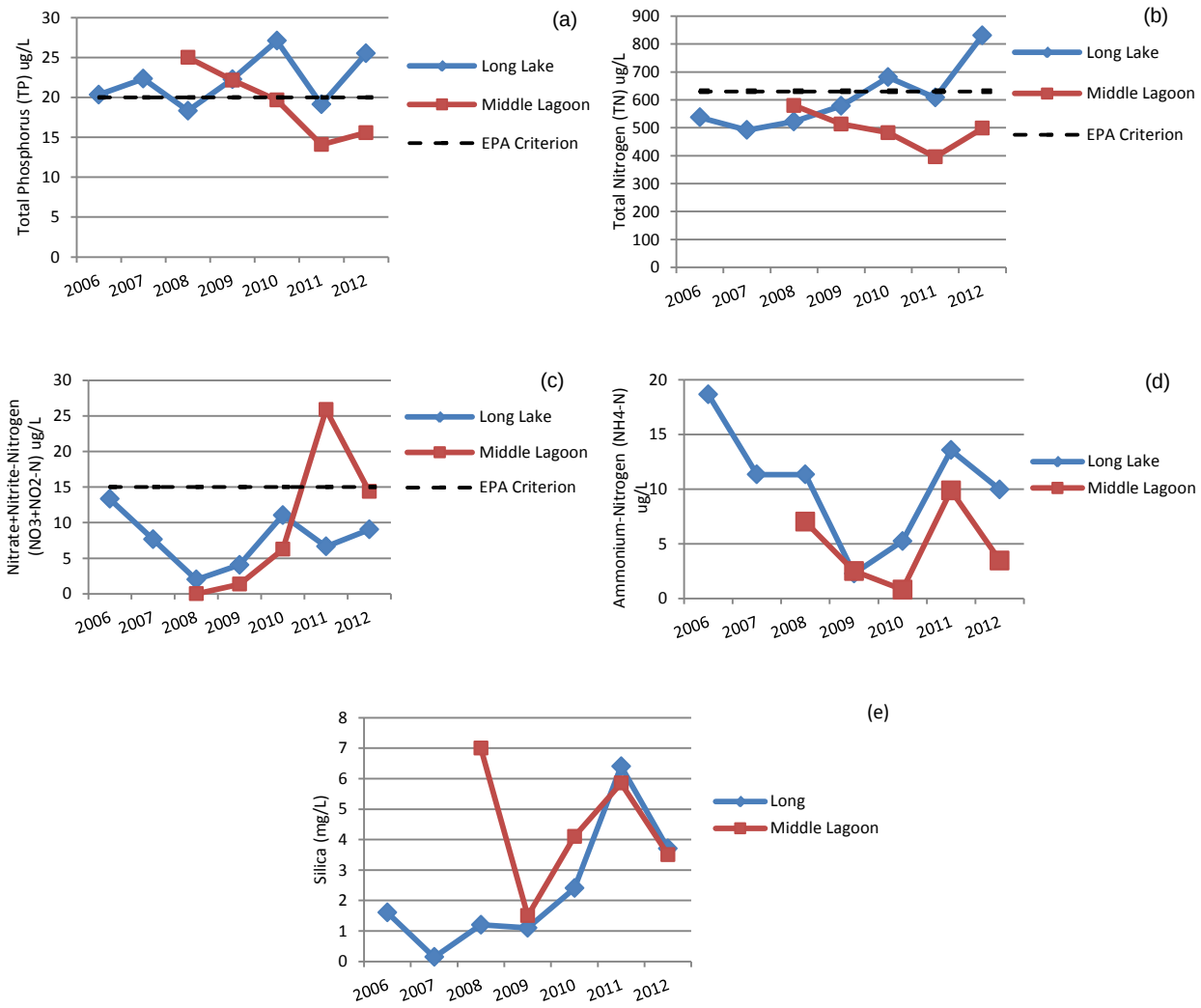

Figure 31. Mean concentration of nutrients in lakes at Indiana Dunes National Lakeshore, 2007–2012: total phosphorus (**a**), total nitrogen (**b**), nitrate+nitrite-nitrogen (**c**), ammonium-nitrogen (**d**), and silica (**e**).

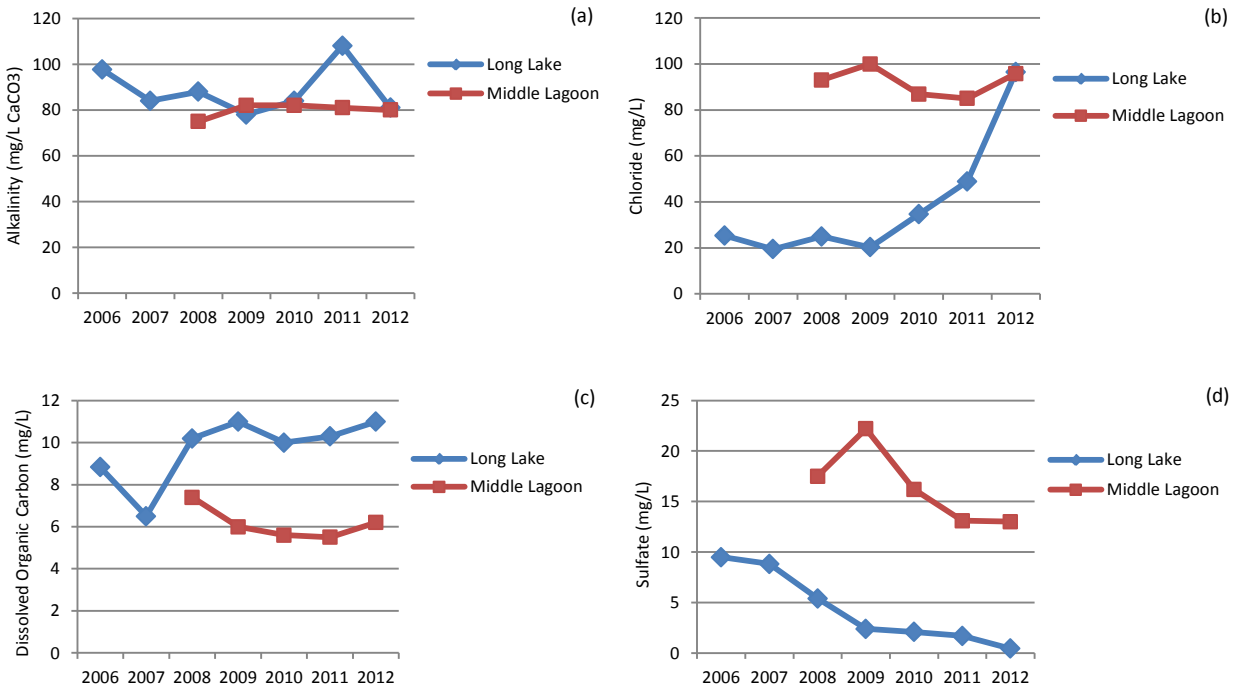

Figure 32. Concentrations of alkalinity (**a**), chloride (**b**), dissolved organic carbon (**c**), and sulfate (**d**) in lakes at Indiana Dunes National Lakeshore, 2006–2012.

Logistics

Water quality monitoring will continue at Middle Lagoon. However, after consultation with park staff the Network decided to stop monitoring Long Lake as an index lake. Long Lake has become more wetland-like, and has filled in with vegetation since 2009 when the nearby water treatment plant stopped using an adjacent impoundment for storage of excess treated water. Water from the impoundment seeped through a porous berm and kept water levels artificially high in Long Lake. However, since 2009 lake levels have progressively declined until very little open water exists (Figure 33).

Figure 33. Long Lake at Indiana Dunes National Lakeshore, 21 June 2012. Photo by Josh Dickey.

Sleeping Bear Dunes National Lakeshore

Additional Data Collected and Exploration of Trends

Water levels in Shell and Loon lakes have changed little since monitoring began (Figure 34). Bass Lake has fluctuated, greatly, dropping approximately 35 cm between 2008 and 2009, rising nearly the same amount in 2011, and dropping again in 2012. Bass Lake's water level may rise and fall as the result of the changing nature of a beaver dam at its connection to School Lake, which may explain the large fluctuations. Water levels of Manitou and North Bar lakes have declined since monitoring began. Investigations of the inlets to Manitou Lake may reveal whether the lake is being influenced by beaver activity or is responding to changes in weather and climate.

North Bar has an intermittent connection to Lake Michigan and its water level can change dramatically depending on whether the connection is open or closed. The water chemistry of Florence Lake suggests isolation from groundwater (low alkalinity and specific conductance compared to the other lakes in the park), and the lake is more strongly influenced by precipitation and evaporation than the other lakes.

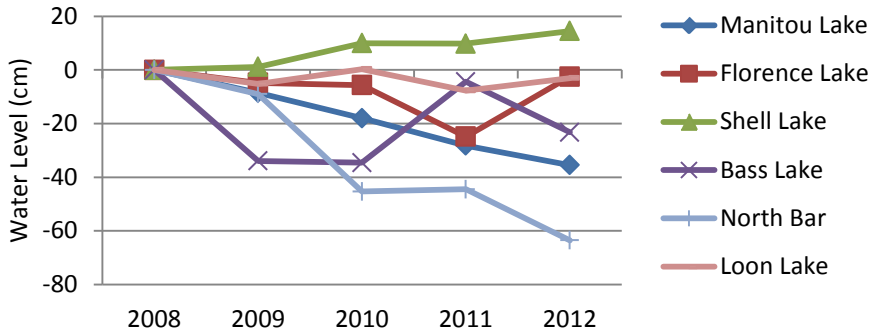

Figure 34. Mean summer water levels of lakes at Sleeping Bear Dunes National Lakeshore, 2008–2011. Water level is measured relative to a permanent benchmark at each lake. All lake water levels are relative to the 2008 mean, which is set to zero.

No clear trends in specific conductance, pH, or Secchi depth are apparent (Figures 35a–35c). While the pH data look 'noisy,' the variations are only approximately 0.2 standard units in most cases. The mean trophic state index, as calculated from chlorophyll-*a* concentration, resulted in almost all of the lakes being categorized as mesotrophic (TSI between 30 and 50; Figure 35d). The TSI of several lakes seems to have declined between 2008 and 2012 (e.g., Florence and Manitou). Additional years of data will help determine whether this is part of a long-term trend or shorter-term variations.

With the exception of TN in Shell Lake, mean TP and TN concentrations have generally remained below EPA reference criteria since monitoring began (Figures 36a and b). However, mean concentrations of NO_3+NO_2-N have often been above the EPA criterion (Figure 36c). Especially noteworthy are the high levels of NO_x at Otter and North Bar lakes (Figure 36c). Park and Network staff collaborated on a proposal in 2010 to determine the source of the high NO_x concentrations but did not receive funding. Additional funding opportunities will be pursued as they arise. Mean NH_4-N concentrations showed much variability among lakes and within some lakes across years (Figure 36d), obscuring any potential trends. Silica concentrations seem to be increasing in Round and Shell lakes; however, the timing of the growth and seasonal decline of diatoms and freshwater sponges influences silica levels at any given time. Silica is incorporated into the cell walls of diatoms and the skeletal structure of freshwater sponges, and a portion of it is released when the organisms die. The very low silica levels in Florence Lake are further evidence of its isolation from groundwater (Kenoyer and Anderson 1989).

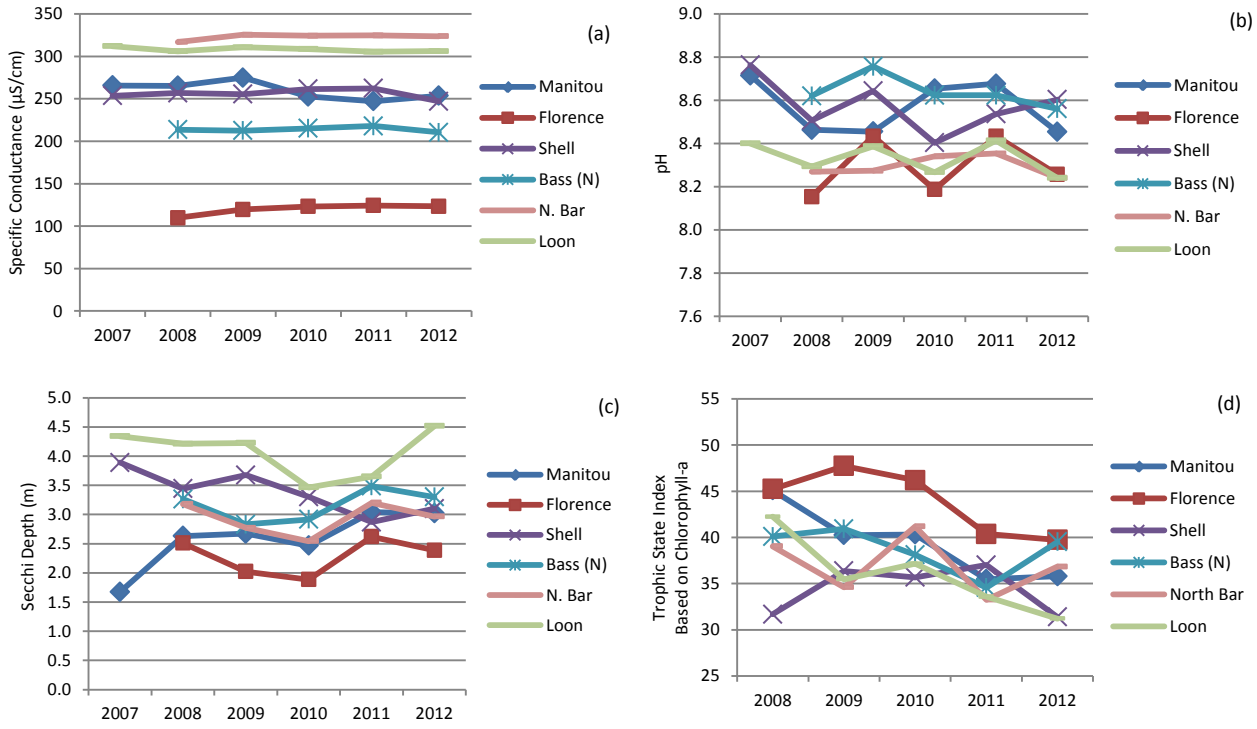

Figure 35. Mean measurements of specific conductance and pH at 1 m depth (**a** and **b**, respectively), water clarity as measured by Secchi disk depth (**c**), and trophic state index as calculated from chlorophyll-*a* measurements (**d**) for lakes at Sleeping Bear Dunes National Lakeshore—Manitou, Shell, and Loon, 2007–2012; Florence, Bass (N), and N. Bar, 2008–2012. Chlorophyll-*a* data are not available for 2007.

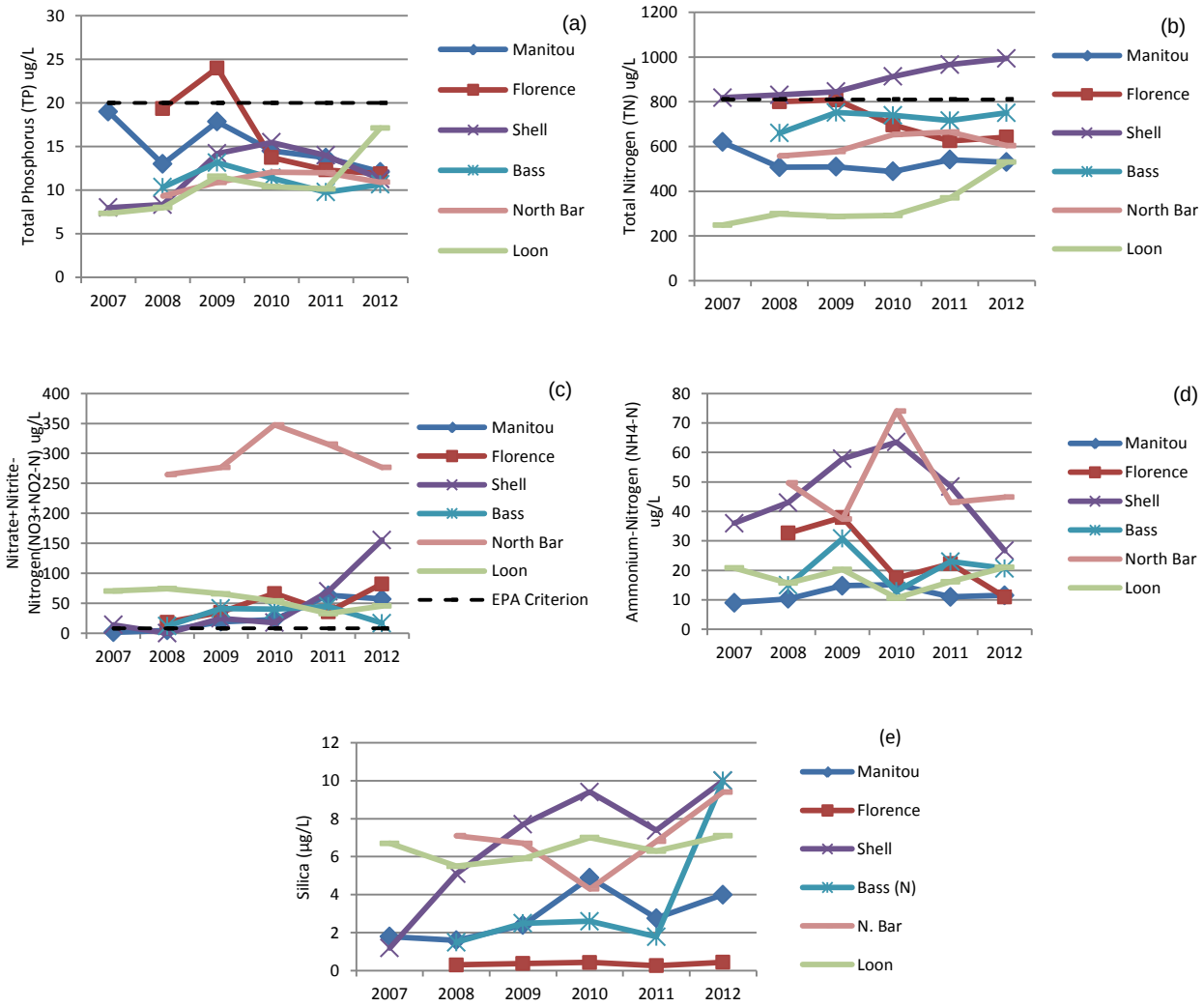

Figure 36. Mean concentration of nutrients in lakes at Sleeping Bear Dunes National Lakeshore—Manitou, Shell, and Loon, 2007–2012; Florence, Bass (N), and North Bar, 2008–2012. Total phosphorus (**a**), total nitrogen (**b**), nitrate+nitrite-nitrogen (**c**), ammonium-nitrogen (**d**), and silica (**e**).

No obvious trends are evident among the other parameters measured annually—alkalinity, DOC, and anions (Figures 37a–37d). Cations are not included here, as they are strongly correlated with specific conductance, discussed above. See Appendix F for all data. No noticeable trends in Cl^- were present in any of the lakes sampled in 2012. The relatively high SO_4^{2} levels in Shell Lake probably occur naturally.

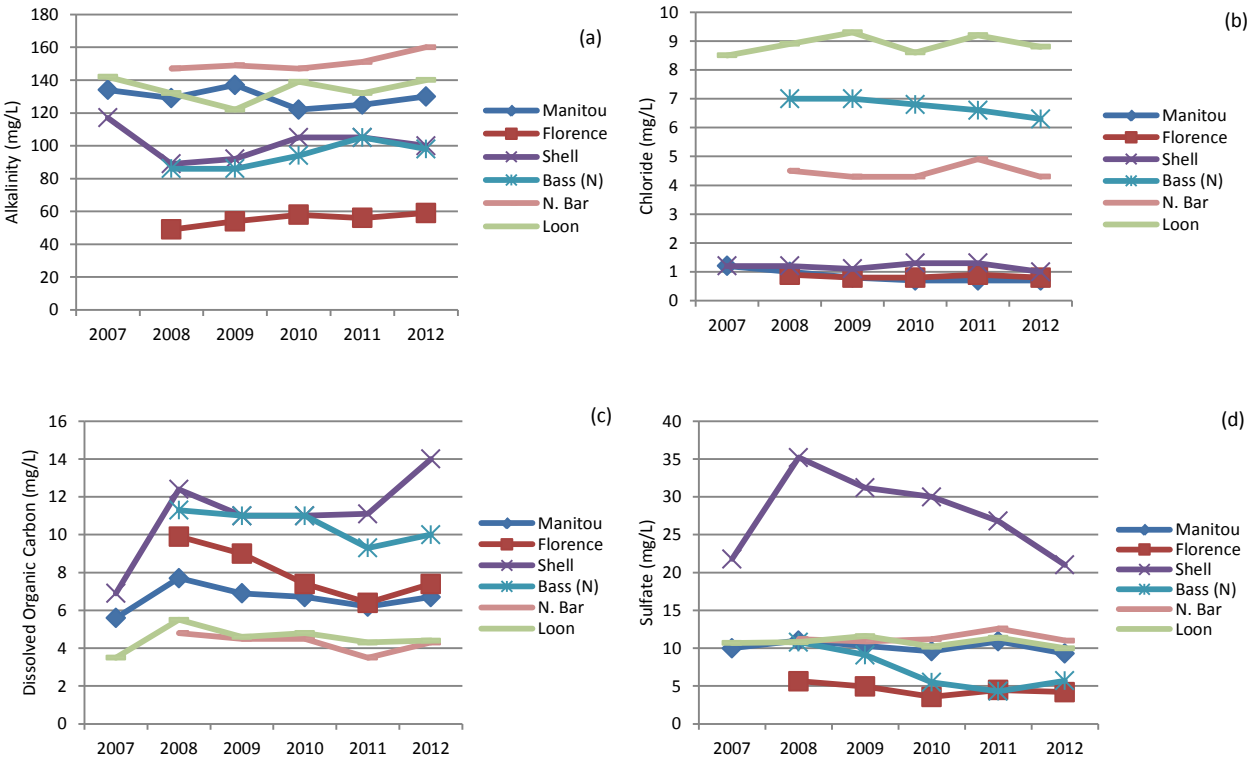

Figure 37. Concentrations of alkalinity (**a**), chloride (**b**), dissolved organic carbon (**c**), and sulfate (**d**) in lakes at Sleeping Bear Dunes National Lakeshore, 2007–2012.

Logistics

Four lakes (North Bar, Otter, Narada, and Tucker) in addition to the index lakes were sampled in 2012. We expect to continue monitoring Manitou, Florence, Shell, Bass [North], North Bar, and Loon lakes. We will also work with USGS to collect samples for analysis of algal toxins in these lakes in 2013, pursuant to PMIS project # 169376, entitled "Determination of Algal Toxin Concentrations in Surface Waters at Isle Royale National Park, Sleeping Bear Dunes National Lakeshore, and Pictured Rocks National Lakeshore". An array of vertical temperature probes will be placed in Manitou Lake in 2013 that will collect hourly data year-round.

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Appendix A. Field and laboratory results for Voyageurs National Park, 2012.

Abbreviations used in the following data tables (units of measurement are in parentheses):

Alk	Alkalinity (mg/L $CaCO_3$)	T Hg	Total Mercury (ng/L)
Ca^{+2}	Calcium (mg/L)	TSI (chl-*a*)	Trophic State Index calculated from chlorophyll-*a* concentration
Cl^{-}	Chloride (mg/L)	TSI (TP)	Trophic State Index calculated from TP concentration
DOC	Dissolved Organic Carbon (mg/L)	TSI (Secchi)	Trophic State Index calculated from Secchi depth
Mg^{+2}	Magnesium (mg/L)		
K^{+}	Potassium (mg/L)		
SiO_2	Silicate (mg/L)		
Na^{+}	Sodium (mg/L)		
SO_4^{-2}	Sulfate (mg/L)		
NH_4-N	Ammonium-Nitrogen (µg/L)		
NO_3+NO_2-N	Nitrate+Nitrite (µg/L)		
TN	Total Nitrogen (µg/L)		
TP	Total Phosphorus (µg/L)		
TN-Hypolimnion	Bottom TN (µg/L)		
TP - Hypolimnion	Bottom TP (µg/L)		
chl-*a*	Chlorophyll-*a* (µg/L)		
TSS	Total Suspended Solids (mg/L)		
DO	Dissolved Oxygen (mg/L)		
SC25	Specific Conductance (µS/cm)		
pH	pH (standard units)		
Temp	Temperature (°C)		
Secchi	Secchi Depth (m)		
Water Level	Water Level (m)		
M Hg	Methyl-mercury (ng/L)		

Table A1. Voyageurs National Park, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit, or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Locator	Shoepack	Ek	Brown	Peary	Cruiser	Ryan	Little Trout*	Duplicate	Duplicate Location
Alk	7/12	**ND**	**ND**	**12.0**	**ND**	**13.0**	**ND**	**ND**	**17.0**	**13.0**	Ek
Ca^{+2}	7/12	2.6	2.3	2.9	2.2	2.2	1.8	2.3	3.5	2.6	Ek
Cl^{-}	7/12	0.6	0.8	0.6	0.5	0.5	0.3	0.4	0.4	0.6	Ek
DOC	7/12	12.0	16.0	13.0	11.0	9.6	3.9	12.0	5.0	13.0	Ek
Mg^{+2}	7/12	1.0	0.9	1.2	0.9	1.0	0.6	0.9	1.5	1.1	Ek
K^{+}	7/12	0.5	0.5	0.7	0.4	0.4	**0.4**	**0.3**	**0.4**	0.5	Ek
SiO_2	7/12	1.3	0.4	1.1	1.2	0.9	0.8	1.5	0.4	1.1	Ek
Na^{+}	7/12	1.2	1.1	1.2	1.0	1.0	0.7	1.1	1.0	1.2	Ek
SO_4^{-2}	7/12	2.9	2.8	1.7	1.4	1.7	2.4	3.2	2.8	1.6	Ek
NH_4-N	6/12	**2.2**	30.8	**3.7**	**6.9**	**ND**	**ND**	**4.6**	**ND**	**ND**	Peary
NH_4-N	7/12	**4.0**	12.1	14.3	**7.0**	**4.0**	**ND**	13.5	**3.0**	12.3	Ek
NH_4-N	8/12	**5.6**	13.2	**7.0**	9.9	8.3	**6.0**	**7.4**	**7.6**	**5.7**	Locator
NH_4-N	average	3.9	18.7	8.4	7.9	6.1	6.0	8.5	5.3		
NO_3+NO_2-N	6/12	**2.9**	44.4	**5.7**	11.4	**4.6**	**ND**	16.9	**ND**	**2.8**	Peary
NO_3+NO_2-N	7/12	49.2	8.1	11.7	74.7	8.6	**3.9**	11.5	**7.3**	8.5	Ek
NO_3+NO_2-N	8/12	**5.8**	8.8	8.4	**6.9**	**7.2**	**4.0**	**5.2**	**4.3**	**7.7**	Locator
NO_3+NO_2-N	average	19.3	20.4	8.6	31.0	6.8	3.9	11.2	5.8		
TN	6/12	415.9	772.2	653.9	480.3	452.9	240.1	489.1	283.1	448.4	Peary
TN	7/12	459.6	768.7	1100.8	506.7	504.4	222.3	489.9	307.2	1070.5	Ek
TN	8/12	501.2	739.3	975.0	461.3	545.8	249.9	498.5	328.4	451.1	Locator
TN	average	458.9	760.1	909.9	482.8	501.0	237.4	492.5	306.2		
TP	6/12	8.6	17.2	15.1	9.9	9.5	**2.8**	7.3	**ND**	9.2	Peary
TP	7/12	5.3	16.9	13.3	11.6	14.3	**2.3**	3.6	**2.3**	75.3	Ek
TP	8/12	10.2	21.1	31.5	15.8	21.5	8.0	8.4	4.0	9.3	Locator

Table A1 (continued). Voyageurs National Park, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit, or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Locator	Shoepack	Ek	Brown	Peary	Cruiser	Ryan	Little Trout*	Duplicate	Duplicate Location
TP	average	8.0	18.4	20.0	12.4	15.1	4.4	6.5	3.1		
TN - Hypolimnion	7/12	629.9	1099.9	937.3	965.4	574.2	629.9	N/A	419.1	966.5	Ek
TP - Hypolimnion	7/12	25.2	33.2	30.1	29.3	36.7	57.5	N/A	17.7	30.2	Ek
chl-*a*	6/12	2.8	4.5	4.3	2.2	2.2	0.7	2.0	1.7	2.3	Peary
chl-*a*	7/12	1.2	8.9	1.6	**0.2**	1.6	**0.2**	2.3	0.8	1.1	Ek
chl-*a*	8/12	1.0	7.1	2.6	1.9	2.5	**0.3**	1.8	1.1	1.4	Locator
chl-*a*	average	1.7	6.8	2.8	1.4	2.1	0.4	2.1	1.2		
DO	6/12	10.2	7.8	8.8	9.2	9.0	9.6	9.9	8.8		
DO	7/12	8.0	8.0	7.5	7.7	8.1	7.9	7.7	7.9		
DO	8/12	9.1	8.1	8.3	8.3	9.0	8.5	8.5	8.5		
DO	average	7.4	6.6	7.2	7.0	8.7	8.7	8.7	8.4		
SC25	6/12	26.3	23.8	27.9	20.9	24.8	20.9	25.3	37.7		
SC25	7/12	28.6	24.5	31.0	21.7	27.8	22.2	25.8	37.7		
SC25	8/12	27.5	26.1	30.1	22.6	24.8	22.4	27.2	37.7		
SC25	average	27.5	24.8	29.7	21.7	25.8	21.8	26.1	37.7		
pH	6/12	7.5	6.4	7.3	7.0	7.3	7.4	6.7	7.7		
pH	7/12	7.5	6.5	7.2	7.0	7.4	7.2	7.0	3.59		
pH	8/12	7.3	6.7	7.1	6.9	7.3	7.6	7.0	7.7		
pH	average	7.4	6.6	7.2	7.0	7.3	7.4	6.9	7.7		
Temp	6/12	19.5	19.1	20.8	20.3	22.1	19.5	25.3	20.0		
Temp	7/12	25.7	25.8	25.9	25.0	25.9	25.4	25.8	26.0		
Temp	8/12	22.2	22.3	21.4	23.3	22.1	22.1	27.2	22.6		
Temp	average	22.4	22.4	22.7	22.9	23.3	22.3	26.1	22.8		
Secchi	6/12	2.1	1.2	1.4	2.8	2.4	8.8	3.1	5.7		
Secchi	7/12	2.9	1.7	2.1	2.6	1.7	9.1	2.8	5.8		
Secchi	8/12	3.1	1.2	2.0	2.6	1.7	8.5	2.8	6.4		

Table A1 (continued). Voyageurs National Park, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit, or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Locator	Shoepack	Ek	Brown	Peary	Cruiser	Ryan	Little Trout*	Duplicate	Duplicate Location
Secchi	average	2.7	1.4	1.8	2.7	1.9	8.8	2.9	6.0		
Water Level	6/12	-1.6	-1.3	-0.8	-0.5	-1.4	-0.7	-0.8	-1.1		
Water Level	7/12	-1.7	-1.3	-0.9	-0.6	-1.5	-0.7	-0.9	-1.1		
Water Level	8/12	-1.7	-1.4	-1.0	-0.7	-1.6	-0.9	-1.0	-1.1		
Water Level	average	-1.6	-1.3	-0.9	-0.6	-1.5	-0.8	-0.9	-1.1		
M Hg	6/12		0.2	**ND**	0.1	**ND**		0.1		**ND**	Peary
M Hg	7/12		0.3	0.1	0.2	0.1		0.2			
M Hg	8/12		0.4	0.1	0.5	0.1		0.2			
M Hg	average		0.3	0.1	0.3	0.1		0.2			
T Hg	6/12		3.4	2.0	2.0	1.6		3.2		1.6	Peary
T Hg	7/12		3.1	1.6	1.7	1.3		2.7			
T Hg	8/12		2.2	1.3	1.3	0.9		1.9			
T Hg	average		2.9	1.7	1.7	1.3		2.6			
TSI (chl-*a*)	6/12	40.9	45.4	44.9	38.5	38.2	27.0	37.6	36.0		
TSI (chl-*a*)	7/12	32.8	52.0	34.9	13.0	35.4	15.1	39.0	28.4		
TSI (chl-*a*)	8/12	30.9	49.8	39.9	36.6	39.6	18.1	36.3	32.0		
TSI (chl-*a*)	average	34.8	49.1	39.9	29.4	37.7	20.1	37.6	32.1		
TSI (TP)	6/12	35.2	45.2	43.3	37.2	36.6	19.1	32.9			
TSI (TP)	7/12	28.1	44.9	41.5	39.5	42.5	15.9	22.7	15.9		
TSI (TP)	8/12	37.7	48.1	53.9	43.9	48.4	34.2	34.9	24.0		
TSI (TP)	average	33.6	46.1	46.2	40.2	42.5	23.0	30.2	20.0		
TSI (Secchi)	6/12	49.2	57.4	55.7	45.0	47.7	28.7	43.7	34.9		
TSI (Secchi)	7/12	44.9	52.4	49.7	46.2	52.4	28.2	45.2	34.8		
TSI (Secchi)	8/12	43.9	58.0	50.0	46.5	52.4	29.2	45.2	33.3		
TSI (Secchi)	average	46.0	55.9	51.8	45.9	50.8	28.7	44.7	34.3		

Appendix B. Field and laboratory results for Apostle Islands National Lakeshore, 2012.

Abbreviations used in the following data tables (units of measurement are in parentheses):

Alk	Alkalinity (mg/L $CaCO_3$)
Ca^{+2}	Calcium (mg/L)
Cl^{-}	Chloride (mg/L)
DOC	Dissolved Organic Carbon (mg/L)
Mg^{+2}	Magnesium (mg/L)
K^{+}	Potassium (mg/L)
SiO_2	Silicate (mg/L)
Na^{+}	Sodium (mg/L)
SO_4^{-2}	Sulfate (mg/L)
NH_4-N	Ammonium-Nitrogen (µg/L)
NO_3+NO_2-N	Nitrate+Nitrite (µg/L)
TN	Total Nitrogen (µg/L)
TP	Total Phosphorus (µg/L)
chl-*a*	Chlorophyll-*a* (µg/L)
DO	Dissolved Oxygen (mg/L)
SC25	Specific Conductance (µS/cm)
pH	pH (standard units)
Temp	Temperature (°C)
Secchi	Secchi Depth (m)
T-tube	Transparency Tube (cm)
Water Level	Water Level (m)
TSI (chl-*a*)	Trophic State Index calculated from chlorophyll-*a* concentration
TSI (TP)	Trophic State Index calculated from TP concentration
TSI (Secchi)	Trophic State Index calculated from Secchi depth

Table B1. Apostle Island National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit, or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Michigan Island	Outer Island	Stockton Island	Little Sand Bay	Duplicate	Duplicate Location
Alk	7/12	51.0	**ND**	38.0	37.0	38.0	Little Sand Bay
Ca^{+2}	7/12	15.0	3.0	13.0	12.0	12.0	Little Sand Bay
Cl^{-}	7/12	1.3	0.9	4.0	2.2	2.2	Little Sand Bay
DOC	7/12	9.0	23.0	6.5	9.8	n/a	Little Sand Bay
Mg^{+2}	7/12	4.3	1.0	3.1	3.4	3.4	Little Sand Bay
K^{+}	7/12	**0.4**	0.7	0.6	0.9	0.8	Little Sand Bay
SiO_2	7/12	7.8	1.4	0.4	0.3	0.3	Little Sand Bay
Na^{+}	7/12	0.9	0.9	1.7	2.2	2.2	Little Sand Bay
SO_4^{-2}	7/12	1.1	1.4	4.0	3.6	3.6	Little Sand Bay
NH_4-N	6/12	18.9	48.7	10.1	13.2	14.4	Little Sand Bay
NH_4-N	7/12	12.0	24.3	19.6	**1.823**	**2.086**	Little Sand Bay
NH_4-N	8/12	**4.893**	10.6	35.9	**4.944**	**4.949**	Little Sand Bay
NH_4-N	average	15.4	27.9	21.8	14.4		
NO_3+NO_2-N	6/12	13.3	19.3	11.2	41.4	41.7	Little Sand Bay
NO_3+NO_2-N	7/12	**ND**	**6.601**	57.2	**4.473**	**3.004**	Little Sand Bay
NO_3+NO_2-N	8/12	**ND**	**ND**	**2.715**	**1.723**	**1.648**	Little Sand Bay
NO_3+NO_2-N	average	13.3	19.3	34.2	41.4		
TN	6/12	579.5	758.2	937.2	867.7	877.1	Little Sand Bay
TN	7/12	593.8	910.3	442.0	488.7	483.2	Little Sand Bay
TN	8/12	551.1	917.5	710.0	690.4	676.6	Little Sand Bay
TN	average	574.8	862.0	696.4	682.3		

Table B1 (continued). Apostle Island National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit, or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Michigan Island	Outer Island	Stockton Island	Little Sand Bay	Duplicate	Duplicate Location
TP	6/12	10.2	16.3	21.3	51.7	52.5	Little Sand Bay
TP	7/12	13.1	10.5	8.3	16.1	14.8	Little Sand Bay
TP	8/12	13.7	11.2	10.4	23.5	23.9	Little Sand Bay
TP	average	12.3	12.7	13.3	30.4		
chl-*a*	6/12	0.7	1.9	0.7	2.9	3.0	Little Sand Bay
chl-*a*	7/12	1.4	2.5	1.0	1.4	1.1	Little Sand Bay
chl-*a*	8/12	2.0	2.1	2.7	2.8	2.8	Little Sand Bay
chl-*a*	average	1.4	2.2	1.4	2.4		
DO	6/12	8.0	n/a	n/a	n/a	n/a	Little Sand Bay
DO	7/12	5.3	7.0	7.4	7.6	7.6	Little Sand Bay
DO	8/12	5.6	7.6	6.6	5.9	5.8	Little Sand Bay
DO	average	6.3	7.3	7.0	6.7		
SC25	6/12	91.0	22.1	23.5	61.5	61.6	Little Sand Bay
SC25	7/12	119.2	27.3	99.1	97.0	97.0	Little Sand Bay
SC25	8/12	126.9	26.1	83.3	80.7	80.7	Little Sand Bay
SC25	average	112.4	25.2	68.6	79.7		
pH	6/12	7.2	5.4	4.6	6.0	6.1	Little Sand Bay
pH	7/12	6.7	5.8	7.3	6.9	7.0	Little Sand Bay
pH	8/12	6.9	6.0	6.9	6.6	6.6	Little Sand Bay
pH	average	6.9	5.8	6.3	6.5		
Temp	6/12	20.9	18.2	18.4	16.9	16.9	Little Sand Bay
Temp	7/12	25.9	26.4	27.0	26.6	26.6	Little Sand Bay

Table B1 (continued). Apostle Island National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit, or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Michigan Island	Outer Island	Stockton Island	Little Sand Bay	Duplicate	Duplicate Location
Temp	8/12	22.3	24.2	23.5	23.2	23.2	Little Sand Bay
Temp	average	23.0	22.9	23.0	22.2		
Secchi	6/12	Bottom	1.4	1.0	0.4		
Secchi	7/12	1.1	0.8	Bottom	Bottom		
Secchi	8/12	1.0	Bottom	Bottom	1.2		
Secchi	average	1.0	1.1	1.0	0.8		
T-tube	6/12	**>QL**	n/a	n/a	n/a		
T-tube	7/12	n/a	n/a	n/a	n/a		
T-tube	8/12	n/a	n/a	n/a	n/a		
T-tube	average						
Water Level	6/12	-1.6	-1.2	-1.1	-1.1		
Water Level	7/12	-1.7	-1.6	-1.0	-1.0		
Water Level	8/12	-1.7	-1.7	-1.1	-0.9		
Water level	average	-1.7	-1.5	-1.1	-1.0		
TSI (chl-*a*)	6/12	27.5	36.6	26.7	41.2		
TSI (chl-*a*)	7/12	34.2	39.7	30.3	33.8		
TSI (chl-*a*)	8/12	37.4	37.7	40.3	40.8		
TSI (chl-a)	average	33.0	38.0	32.4	38.6		
TSI (TP)	6/12	37.6	44.4	48.3	61.1		
TSI (TP)	7/12	41.2	38.1	34.6	44.2		
TSI (TP)	8/12	41.9	39.0	37.9	49.7		
TSI (TP)	average	40.2	40.5	40.3	51.6		

Table B1 (continued). Apostle Island National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit, or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Michigan Island	Outer Island	Stockton Island	Little Sand Bay	Duplicate	Duplicate Location
TSI (Secchi)	6/12		55.2	60.0	72.2		
TSI (Secchi)	7/12	59.3	62.7				
TSI (Secchi)	8/12	60.3			57.0		
TSI (Secchi)	average	59.8	58.9	60.0	64.6		

Appendix C. Field and laboratory results for Isle Royale National Park, 2012.

Abbreviations used in the following data tables (units of measurement are in parentheses):

Alk	Alkalinity (mg/L $CaCO_3$)
Ca^{+2}	Calcium (mg/L)
Cl^{-}	Chloride (mg/L)
DOC	Dissolved Organic Carbon (mg/L)
Mg^{+2}	Magnesium (mg/L)
K^{+}	Potassium (mg/L)
SiO_2	Silicate (mg/L)
Na^{+}	Sodium (mg/L)
SO_4^{-2}	Sulfate (mg/L)
NH_4-N	Ammonium-Nitrogen (µg/L)
NO_3+NO_2-N	Nitrate+Nitrite (µg/L)
TN	Total Nitrogen (µg/L)
TP	Total Phosphorus (µg/L)
TN - Hypolimnion	Bottom TN (µg/L)
TP - Hypolimnion	Bottom TP (µg/L)
chl-*a*	Chlorophyll-*a* (µg/L)
TSS	Total Suspended Solids (mg/L)
DO	Dissolved Oxygen (mg/L)
SC25	Specific Conductance (µS/cm)
pH	pH (standard units)
Temp	Temperature (°C)
Secchi	Secchi Depth (m)
Water Level	Water Level (m)
TSI (chl-*a*)	Trophic State Index calculated from chlorophyll-*a* concentration
TSI (TP)	Trophic State Index calculated from TP concentration
TSI (Secchi)	Trophic State Index calculated from Secchi depth

Table C1. Isle Royale National Park (index lakes), 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Ahmik	Sargent	Richie	Beaver	Harvey	George	Siskiwit	Desor	Feldtmann	Duplicate	Duplicate Location
Alk	7/2012	52.0	42.0	36.0	48.0	45.0	59.0	35.0	50.0	34.0	53.0	Ahmik
Ca^{+2}	7/2012	17.0	11.0	10.0	11.0	12.0	21.0	9.3	14.0	12.0	14.0	Ahmik
Cl^{-}	7/2012	1.1	0.9	1.3	0.6	0.5	0.6	0.5	0.7	1.1	1.1	Ahmik
DOC	7/2012	22.0	9.2	10.0	14.0	12.0	13.0	5.6	7.7	17.0	22	Ahmik
Mg^{+2}	7/2012	5.9	4.2	3.3	5.4	4.6	1.9	2.6	4.6	2.5	5.9	Ahmik
K^{+}	7/2012	**ND**	**0.2**	**0.3**	**0.2**	**ND**	**0.1**	**0.3**	0.5	0.5	**ND**	Ahmik
SiO_2	7/2012	10.0	5.6	6.6	8.1	1.5	3.5	2.3	0.9	1.1	11.0	Ahmik
Na^{+}	7/2012	2.2	2.4	1.7	2.9	2.0	1.0	1.2	1.9	1.4	2.1	Ahmik
SO_4^{-2}	7/2012	3.5	4.4	4.0	3.4	3.1	2.4	4.8	3.0	5.4	3.4	Ahmik
NH_4-N	6/2012	**7.2**	**3.1**	**ND**	**ND**	**6.4**	**ND**	**ND**	**ND**	**ND**	**6.4**	Harvey
NH_4-N	7/2012	11.4	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**ND**	**6.1**	12.0	Ahmik
NH_4-N	8/2012	10.9	13.8	**4.4**	**3.7**	**4.2**	**5.5**	**4.9**	30.8	**4.8**	**3.6**	Harvey
NH_4-N	average	9.8	8.5	4.4	3.7	5.3	5.5	4.9	30.8	5.4		
NO_3+NO_2-N	6/2012	**5.8**	**3.3**	**4.4**	**2.0**	**2.5**	**5.9**	17.5	**3.3**	**6.2**	**3.1**	Harvey
NO_3+NO_2-N	7/2012	**6.8**	**6.2**	**5.1**	**4.4**	**3.9**	**5.5**	**4.6**	**6.5**	**5.9**	10.7	Ahmik
NO_3+NO_2-N	8/2012	**ND**	**ND**	**2.1**	**ND**	**ND**	**2.3**	**ND**	**5.3**	**ND**	**ND**	Harvey
NO_3+NO_2-N	average	6.3	4.8	3.9	3.2	3.2	4.6	11.1	5.1	6.0		
TN	6/2012	730.0	534.9	509.2	548.9	563.0	472.9	253.5	552.6	698.1	599.5	Harvey
TN	7/2012	873.1	474.2	521.0	599.1	602.5	477.2	228.7	648.6	749.4	861.0	Ahmik
TN	8/2012	803.8	466.9	572.8	574.9	606.5	501.5	223.0	577.4	726.5	631.2	Harvey
TN	average	802.3	492.0	534.3	574.3	590.7	483.9	235.1	592.8	724.7		
TP	6/2012	13.0	20.1	15.0	16.0	12.0	7.5	**2.8**	11.6	11.8	12.0	Harvey

Table C1 (continued). Isle Royale National Park (index lakes), 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Ahmik	Sargent	Richie	Beaver	Harvey	George	Siskiwit	Desor	Feldtmann	Duplicate	Duplicate Location
TP	7/2012	17.4	15.1	17.5	15.8	14.8	12.4	3.1	11.6	14.3	20.6	Ahmik
TP	8/2012	18.7	12.9	23.6	17.7	13.3	7.6	4.0	10.4	11.4	12.0	Harvey
TP	average	16.4	16.0	18.7	16.5	13.4	9.2	3.3	11.2	12.5		
TN-Hypolimnion	7/2012	n/a	548.0	588.6	599.5	811.4	n/a	286.5	1186.4	n/a	n/a	n/a
TP-Hypolimnion	7/2012	n/a	18.5	33.1	28.2	49.0	n/a	7.7	31.6	n/a	n/a	n/a
chl-*a*	6/2012	1.8	1.2	1.6	2.3	1.3	1.4	0.7	3.0	1.2	1.2	Harvey
chl-*a*	7/2012	1.5	1.5	3.0	1.7	1.3	1.9	0.7	6.6	1.2	1.5	Ahmik
chl-*a*	8/2012	0.9	1.4	8.8	1.3	1.2	0.9	0.7	2.8	1.3	1.5	Harvey
chl-*a*	average	1.4	1.4	4.5	1.8	1.3	1.4	0.7	4.1	1.2		
TSS	6/2012	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Harvey
TSS	7/2012	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Ahmik
TSS	8/2012	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Harvey
TSS	average	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		
DO	6/2012	7.8	9.0	9.1	8.7	8.8	8.5	9.6	9.3	8.5		
DO	7/2012	6.5	8.3	8.3	7.7	8.0	8.4	8.3	9.1	7.9		
DO	8/2012	8.6	8.7	9.1	8.2	10.0	8.1	8.7	8.8	8.6		
DO	average	7.6	8.6	8.8	8.2	9.0	8.3	8.9	9.0	8.3		
SC25	6/2012	94.5	92.6	81.5	96.6	93.2	112.7	71.4	107.8	77.5		
SC25	7/2012	112.0	95.2	84.1	98.1	99.3	120.0	73.6	112.0	82.7		
SC25	8/2012	112.3	95.9	85.8	106.1	96.6	119.1	74.6	111.7	83.2		
SC25	average	106.3	94.6	83.8	100.3	96.4	117.3	73.2	110.5	81.1		
pH	6/2012	7.4	8.2	8.1	8.1	8.5	7.7	8.2	8.5	7.8		
pH	7/2012	7.5	8.0	8.0	8.1	8.9	8.1	8.1	8.8	7.6		
pH	8/2012	7.4	7.8	7.9	7.6	9.0	7.7	8.0	8.1	7.8		
pH	average	7.4	8.0	8.0	7.9	8.8	7.8	8.1	8.5	7.7		

Table C1 (continued). Isle Royale National Park (index lakes), 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Ahmik	Sargent	Richie	Beaver	Harvey	George	Siskiwit	Desor	Feldtmann	Duplicate	Duplicate Location
Temp	6/2012	19.1	20.4	19.2	20.7	20.1	18.6	17.4	20.5	19.2		
Temp	7/2012	25.8	24.6	25.2	25.1	26.3	25.6	24.2	25.1	25.3		
Temp	8/2012	20.6	21.8	21.8	21.5	23.4	22.5	21.1	20.9	22.8		
Temp	average	21.8	22.3	22.1	22.5	23.3	22.2	20.9	22.2	22.4		
Secchi	Early 6/2012	n/a	n/a	2.2	n/a	n/a	n/a	n/a	n/a	n/a		
Secchi	6/2012	1.6	2.9	2.9	2.6	3.4	3.0	4.8	2.1	2.4		
Secchi	7/2012	1.2	2.8	2.4	2.3	3.2	2.1	6.1	1.7	2.7		
Secchi	8/2012	2.3	3.3	2.1	2.7	4.0	bottom	8.2	2.5	2.3		
Secchi	average	1.7	3.0	2.5	2.5	3.5	2.6	6.3	2.1	2.4		
Water Level	Early 6/2013	n/a	n/a	-0.6	n/a	n/a	n/a	n/a	n/a	n/a		
Water Level	6/2012	-0.3	-1.2	-0.7	-1.3	n/a	-0.4	-0.5	-0.7	-0.3		
Water Level	7/2012	-0.4	-1.2	-0.7	-1.4	-1.0	-0.5	-0.6	-0.9	-0.5		
Water Level	8/2012	-0.5	-1.2	-0.7	-1.4	-1.2	-0.5	-0.8	-0.9	-0.5		
Water Level	average	-0.4	-1.2	-0.7	-1.4	-1.1	-0.4	-0.6	-0.8	-0.5		
TSI (chl-a)	6/2012	36.3	32.6	35.5	38.8	33.2	33.8	27.5	41.4	32.1		
TSI (chl-a)	7/2012	34.6	34.5	41.2	35.7	32.8	36.9	26.4	49.1	32.5		
TSI (chl-a)	8/2012	29.5	33.6	52.0	33.1	32.4	30.0	27.1	40.8	33.2		
TSI (chl-a)	average	33.5	33.6	42.9	35.9	32.8	33.6	27.0	43.8	32.6		
TSI (TP)	6/2012	41.2	47.4	43.2	44.1	40.0	33.2	18.9	39.5	39.8		
TSI (TP)	7/2012	45.4	43.3	45.4	43.9	43.0	40.5	20.4	39.5	42.5		
TSI (TP)	8/2012	46.4	41.0	49.7	45.6	41.4	33.4	24.2	37.9	39.2		
TSI (TP)	average	44.3	43.9	46.1	44.6	41.5	35.7	21.2	39.0	40.5		
TSI (Secchi)	6/2012	57.0	44.9	44.6	46.2	42.4	44.2	37.5	49.4	47.6		
TSI (Secchi)	7/2012	48.3	45.4	47.2	48.3	43.4	49.2	33.9	52.0	46.0		
TSI (Secchi)	8/2012	48.3	42.8	49.2	45.9	40.1	n/a	29.8	46.7	48.3		

Table C1 (continued). Isle Royale National Park (index lakes), 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Ahmik	Sargent	Richie	Beaver	Harvey	George	Siskiwit	Desor	Feldtmann	Duplicate	Duplicate Location
TSI (Secchi)	average	51.2	44.4	47.0	46.8	42.0	46.7	33.7	49.4	47.3		

Table C2. Isle Royale National Park (non-index lakes), 2012.

Parameter	Month/Yr	LeSage	Chickenbone
NH_4-N	6/2012	13.7	**3.3**
NH_4-N	7/2012	**4.1**	**ND**
NH_4-N	8/2012	**7.3**	9.5
NH_4-N	average	8.3	6.4
NO_3+NO_2-N	6/2012	24.5	**6.2**
NO_3+NO_2-N	7/2012	**4.8**	**3.6**
NO_3+NO_2-N	8/2012	**ND**	**ND**
NO_3+NO_2-N	average	14.7	4.9
TN	6/2012	587.8	526.4
TN	7/2012	614.8	547.2
TN	8/2012	621.8	611.2
TN	average	608.1	561.6
TP	6/2012	11.8	16.6
TP	7/2012	16.3	25.2
TP	8/2012	15.9	29.8
TP	average	14.7	23.9
chl-*a*	6/2012	1.5	2.3

Table C2 (continued). Isle Royale National Park (non-index lakes), 2012.

Parameter	Month/Yr	LeSage	Chickenbone
chl-*a*	7/2012	2.1	1.6
chl-*a*	8/2012	3.6	2.3
chl-*a*	average	2.4	2.0
DO	6/2012	8.0	8.0
DO	7/2012	7.7	8.2
DO	8/2012	8.2	8.5
DO	average	8.0	8.3
SC25	6/2012	61.6	97.5
SC25	7/2012	69.5	104.1
SC25	8/2012	69.3	105.6
SC25	average	66.8	102.4
pH	6/2012	7.4	7.8
pH	7/2012	7.6	7.9
pH	8/2012	7.5	7.9
pH	average	7.5	7.9
Temp	6/2012	19.9	20.1
Temp	7/2012	26.5	27.3
Temp	8/2012	23.0	23.1
Temp	average	23.1	23.5
Secchi	6/2012	2.1	2.1
Secchi	7/2012	1.4	1.9
Secchi	8/2012	1.8	2.3
Secchi	average	1.8	2.1
TSI (chl-*a*)	6/2012	34.2	38.6
TSI (chl-*a*)	7/2012	37.9	35.0
TSI (chl-*a*)	8/2012	43.2	38.7
TSI (chl-*a*)	average	38.5	37.5

Table C2 (continued). Isle Royale National Park (non-index lakes), 2012.

Parameter	Month/Yr	LeSage	Chickenbone
TSI (TP)	6/2012	39.7	44.6
TSI (TP)	7/2012	44.4	50.7
TSI (TP)	8/2012	44.0	53.1
TSI (TP)	average	42.7	49.5
TSI (Secchi)	6/2012	55.0	49.1
TSI (Secchi)	7/2012	51.3	50.8
TSI (Secchi)	8/2012	51.3	48.3
TSI (Secchi)	average	52.5	49.4

Appendix D. Field and Laboratory Results for Pictured Rocks National Lakeshore, 2012.

Abbreviations used in the following data tables (units of measurement are in parentheses):

Alk	Alkalinity (mg/L $CaCO_3$)
Ca^{+2}	Calcium (mg/L)
Cl^{-}	Chloride (mg/L)
DOC	Dissolved Organic Carbon (mg/L)
Mg^{+2}	Magnesium (mg/L)
K^{+}	Potassium (mg/L)
SiO_2	Silicate (mg/L)
Na^{+}	Sodium (mg/L)
SO_4^{-2}	Sulfate (mg/L)
NH_4-N	Ammonium-Nitrogen (µg/L)
NO_3+NO_2-N	Nitrate+Nitrite (µg/L)
TN	Total Nitrogen (µg/L)
TP	Total Phosphorus (µg/L)
TN - Hypolimnion	Bottom TN (µg/L)
TP - Hypolimnion	Bottom TP (µg/L)
chl-*a*	Chlorophyll-a (µg/L)
DO	Dissolved Oxygen (mg/L)
SC25	Specific Conductance (µS/cm)
pH	pH (standard units)
Temp	Temperature (°C)
Secchi	Secchi Depth (m)
Water Level	Water Level (m)
TSI (chl-*a*)	Trophic State Index calculated from chlorophyll-*a* concentration
TSI (TP)	Trophic State Index calculated from TP concentration
TSI (Secchi)	Trophic State Index calculated from Secchi depth

Table D1. Pictured Rocks National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Grand Sable	Trappers	Legion	Beaver	Little Beaver	Chapel	Miners	Duplicate	Duplicate Location
Alk	7/2012	59.0		**ND**	91.0		110.0	180.0	89.0	Beaver
Ca^{+2}	7/2012	15.0		0.5	26.0		26.0	39.0	27.0	Beaver
Cl^{-}	7/2012	0.6		0.2	0.5		0.6	2.5	0.6	Beaver
Mg^{+2}	7/2012	5.6		0.1	5.7		13.0	20.0	5.7	Beaver
K^{+}	7/2012	0.9		**0.2**	0.6		0.8	0.8	0.6	Beaver
SiO_2	7/2012	4.2		**ND**	6.5		3.2	6.1	6.4	Beaver
SO_4^{-2}	7/2012	5.8		2.2	6.2		10.0	7.4	6.5	Beaver
Na^{+}	7/2012	0.9		**ND**	0.9		0.7	1.8	0.9	Beaver
DOC	5/2012	6.9		2.8	4.1		7.9	5.2	3.9	Beaver
DOC	7/2012	6.5	12.0	3.4	4.5		7.4	5.0	4.5	Beaver
DOC	8-9/2012	6.1	11.0	3.0	3.7		6.7	4.1		
DOC	average	6.5		3.1	4.1		7.3	4.8		
NH_4-N	6/2012	8.1		**0.0**	**ND**		**ND**	9.4	**ND**	Beaver
NH_4-N	7/2012	**ND**	**0.3**	**2.0**	**ND**		**ND**	**5.7**	**ND**	Beaver
NH_4-N	8-9/2012	**ND**	**ND**	**7.7**	**3.6**		**3.1**	10.3	**ND**	Legion
NH_4-N	average	8.1		3.2	3.6		3.1	8.5		
NO_3+NO_2-N	6/2012	23.2		**2.5**	**2.5**		**6.4**	191.3	**5.7**	Beaver
NO_3+NO_2-N	7/2012	**3.8**	**3.5**	**6.4**	**3.2**		**3.5**	114.7	**3.5**	Beaver
NO_3+NO_2-N	8-9/2012	**ND**	**ND**	**4.6**	**3.2**		**3.2**	151.2	**ND**	Legion
NO_3+NO_2-N	average	13.5		4.5	3.0		4.4	152.4		
TN	6/2012	326.3		256.2	247.6		368.1	511.2	225.5	Beaver
TN	7/2012	309.2	998.2	241.1	208.9		358.4	411.8	220.5	Beaver
TN	8-9/2012	295.6	283.8	1053.4	371.7		308.7	388.2	219.2	Legion

Table D1 (continued). Pictured Rocks National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Grand Sable	Trappers	Legion	Beaver	Little Beaver	Chapel	Miners	Duplicate	Duplicate Location
TN	average	310.4		516.9	276.1		345.1	437.1		
TP	6/2012	8.5		6.5	8.9		7.6	12.8	9.5	Beaver
TP	7/2012	7.9	13.9	7.1	8.2		11.7	19.3	7.7	Beaver
TP	8-9/2012	11.4	15.4	13.9	14.3		8.0	17.7	8.1	Legion
TP	average	9.2		9.2	10.4		9.1	16.6		
TN-Hypolimnion	7/2012	365.7		290.6	182.3		3538.7	n/a	235.6	Beaver
TP-Hypolimnion	7/2012	12.2		13.4	12.2		20.9	n/a	14.0	Beaver
chl-*a*	6/2012	1.9		0.5	1.3		1.2	1.7	1.6	Beaver
chl-*a*	7/2012	2.6	4.3	0.5	1.1		1.9	3.2	1.2	Beaver
chl-*a*	8-9/2012	2.2	1.6	4.4	0.7		2.1	4.1	0.6	Legion
chl-*a*	average	2.3		1.8	1.0		1.7	3.0		
DO	6/2012	9.1	9.1	9.1	8.4	9.8	9.4	9.9		
DO	7/2012	8.7	8.7	8.7	7.6	7.6	8.1	9.5		
DO	8-9/2012	8.4	9.5	9.5	9.1	9.7	9.0	8.9		
DO	average	8.7		9.1	8.4	9.1	8.8	9.4		
SC25	6/2012	115.0	162.0	162.0	182.0	151.0	202.0	299.0		
SC25	7/2012	123.0	140.0	140.0	178.0	169.0	226.0	334.0		
SC25	8-9/2012	123.0	143.0	143.0	181.0	177.0	234.0	323.0		
SC25	average	120.3		148.3	180.3	162.0	220.7	318.7		
pH	6/2012	8.1	8.8	5.1	8.5	8.3	8.4	8.3		
pH	7/2012	8.3	9.1	5.4	8.5	8.4	8.4	8.3		
pH	8-9/2012	8.1	9.0	5.4	8.5	8.6	8.6	8.0		
pH	average	8.2		5.3	8.5	8.3	8.5	8.2		
Temp	6/2012	19.2	24.7	24.7	21.2	19.1	20.0	14.6		

Table D1 (continued). Pictured Rocks National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 1.0 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Grand Sable	Trappers	Legion	Beaver	Little Beaver	Chapel	Miners	Duplicate	Duplicate Location
Temp	7/2012	23.2	24.4	24.4	24.0	24.0	24.1	18.4		
Temp	8-9/2012	21.5	21.7	21.7	21.9	21.6	21.8	16.7		
Temp	average	21.3		23.6	22.3	21.3	22.0	16.6		
Secchi	4/2012	2.7								
Secchi	6/2012	3.3		6.6	3.7	1.6	3.1	1.9		
Secchi	7/2012	3.8	2.3	5.6	5.6	2.5	3.5	2.6		
Secchi	8-9/2012	3.5	1.6	6.2	4.0	1.8	3.7	2.0		
Secchi	10/2012	3.4								
Secchi	average	3.5	1.9	6.1	4.8	1.5	3.6	2.3		
Water Level	6/2012	-1.5		-1.4	-1.0		-2.0	-1.1		
Water Level	7/2012	-1.6		-1.5	-1.0		-2.0	-1.2		
Water Level	8-9/2012	-1.6		-1.6	-1.1		-2.0	-1.2		
TSI (chl-*a*)	6/2012	37.1		24.4	32.9		32.1	35.9		
TSI (chl-*a*)	7/2012	40.1	44.9	23.4	31.2		37.1	41.9		
TSI (chl-*a*)	8-9/2012	38.4	35.3	45.0	27.5		37.7	44.5		
TSI (chl-*a*)	average	38.5	40.1	30.9	30.5		35.6	40.8		
TSI (TP)	6/2012	34.9		31.1	35.6		33.3	40.9		
TSI (TP)	7/2012	33.9	42.1	32.5	34.4		39.7	46.8		
TSI (TP)	8-9/2012	39.3	43.6	42.1	42.5		34.0	45.6		
TSI (TP)	average	36.0	42.8	35.2	37.5		35.7	44.4		
TSI (Secchi)	6/2012	42.8			41.3		43.9	51.1		
TSI (Secchi)	7/2012	41.0	48.3	35.2	35.2		41.8	46.5		
TSI (Secchi)	8-9/2012	41.9	53.3	33.8	40.0	51.8	41.1	50.0		
TSI (Secchi)	average	41.9	50.8	34.5	38.8	51.8	42.3	49.2		

Appendix E. Field and laboratory results for Indiana Dunes National Lakeshore, 2012.

Abbreviations used in the following data tables (units of measurement are in parentheses):

Alk	Alkalinity (mg/L $CaCO_3$)
Ca^{+2}	Calcium (mg/L)
Cl^{-}	Chloride (mg/L)
DOC	Dissolved Organic Carbon (mg/L)
Mg^{+2}	Magnesium (mg/L)
K^{+}	Potassium (mg/L)
SiO_2	Silicate (mg/L)
Na^{+}	Sodium (mg/L)
SO_4^{-2}	Sulfate (mg/L)
TSS	Total Suspended Solids
NH_4-N	Ammonium-Nitrogen (µg/L)
NO_3+NO_2-N	Nitrate+Nitrite (µg/L)
TN	Total Nitrogen (µg/L)
TP	Total Phosphorus (µg/L)
chl-*a*	Chlorophyll-*a* (µg/L)
DO	Dissolved Oxygen (mg/L)
SC25	Specific Conductance (µS/cm)
pH	pH (standard units)
Temp	Temperature (°C)
Secchi	Secchi Depth (m)
T-tube	Transparency Tube (cm)
Water Level	Water Level (m)
TSI (chl-*a*)	Trophic State Index calculated from chlorophyll-*a* concentration
TSI (TP)	Trophic State Index calculated from TP concentration
TSI (Secchi)	Trophic State Index calculated from Secchi depth

Table E1. Indiana Dunes National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Long	Middle Lagoon	Duplicate	Duplicate Location
Alk	07/12	81.0	80.0	120.0	Long
Ca^{+2}	07/12	35.0	15.0	35.0	Long
Cl^{-}	07/12	96.4	95.8	97.5	Long
DOC	07/12	11.0	6.2	11.0	Long
Mg^{+2}	07/12	13.0	15.0	12.0	Long
K^{+}	07/12	1.6	1.5	1.4	Long
SiO_2	07/12	3.7	3.5	3.5	Long
Na^{+}	07/12	53.0	56.0	51.0	Long
SO_4^{-2}	07/12	0.5	13.0	0.6	Long
NH_4-N	05/12	9.1	**2.9**	**2.4**	Middle Lagoon
NH_4-N	07/12	10.2	**3.1**	9.0	Long
NH_4-N	09/12	10.6	**4.4**	**4.9**	Middle Lagoon
NH_4-N	average	10.0	3.5		
NO_3+NO_2-N	05/12	**6.6**	**5.9**	**6.2**	Middle Lagoon
NO_3+NO_2-N	07/12	16.2	33.1	13.5	Long
NO_3+NO_2-N	09/12	**4.3**	**4.2**	**3.8**	Middle Lagoon
NO_3+NO_2-N	average	9.0	14.4		
TN	05/12	676.5	426.3	415.5	Middle Lagoon
TN	07/12	774.4	503.6	778.8	Long
TN	09/12	1042.0	564.7	571.8	Middle Lagoon
TN	average	831.0	498.2		
TP	05/12	15.1	16.5	11.0	Middle Lagoon

Table E1 (continued). Indiana Dunes National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Long	Middle Lagoon	Duplicate	Duplicate Location
TP	07/12	17.9	12.8	18.1	Long
TP	09/12	43.6	17.4	18.4	Middle Lagoon
TP	average	25.5	15.6		
chl-*a*	05/12	**0.4**	2.1	2.2	Middle Lagoon
chl-*a*	07/12	3.0	1.3	3.0	Long
chl-*a*	09/12	17.6	2.0	2.7	Middle Lagoon
chl-*a*	average	7.0	1.8		
DO	05/12	7.6	10.5		
DO	07/12	0.7	13.8		
DO	09/12	0.2	11.2		
DO	average	2.8	11.8		
SC25	05/12	494.4	542.0		
SC25	07/12	572.0	523.0		
SC25	09/12	939.9	486.2		
SC25	average	668.8	517.1		
pH	05/12	8.5	9.3		
pH	07/12	6.5	9.5		
pH	09/12	6.5	9.0		
pH	average	7.2	9.3		
Temp	05/12	19.7	17.9		
Temp	07/12	24.8	28.3		
Temp	09/12	22.3	26.0		

Table E1 (continued). Indiana Dunes National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Long	Middle Lagoon	Duplicate	Duplicate Location
Temp	average	22.3	24.1		
chl-*a*	05/12	**0.4**	2.1	2.2	Middle Lagoon
chl-*a*	07/12	3.0	1.3	3.0	Long
chl-*a*	09/12	17.6	2.0	2.7	Middle Lagoon
chl-*a*	average	7.0	1.8		
Secchi	05/12				
Secchi	07/12	0.45			
Secchi	09/12	0.39	0.85		
Secchi	average	0.42			
T-tube	05/12		**>QL**		
T-tube	07/12	54.4	**>QL**		
T-tube	09/12	33.45	**>QL**		
T-tube	average	76.00	>120		
Water Level	05/12	-1.54	-5.59		
Water Level	07/12	-1.95	-5.75		
Water Level	09/12	-1.78	-5.89		
Water Level	average	-1.76	-5.74		
TSI (chl-*a*)	05/12	21.6	38.0		
TSI (chl-*a*)	07/12	41.3	32.9		
TSI (chl-*a*)	09/12	58.7	37.5		
TSI (chl-*a*)	average	40.5	36.2		
TSI (TP)	05/12	43.3	44.6		
TSI (TP)	07/12	45.7	40.9		

Table E1 (continued). Indiana Dunes National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in **bold font** indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Long	Middle Lagoon	Duplicate	Duplicate Location
TSI (TP)	09/12	58.6	45.3		
TSI (TP)	average	49.2	43.6		
TSI (Secchi)	05/12				
TSI (Secchi)	07/12	71.5			
TSI (Secchi)	09/12	73.6	62.3		
TSI (Secchi)	average	72.5	62.3		
Secchi	05/12				
Secchi	07/12	0.45			
Secchi	09/12	0.39	0.85		

Appendix F. Field and laboratory results for Sleeping Bear Dunes National Lakeshore, 2012.

Abbreviations used in the following data tables (units of measurement are in parentheses):

Alk	Alkalinity (mg/L CaCO3)
Ca^{+2}	Calcium (mg/L)
Cl^{-}	Chloride (mg/L)
DOC	Dissolved Organic Carbon (mg/L)
Mg^{+2}	Magnesium (mg/L)
K^{+}	Potassium (mg/L)
SiO_2	Silicate (mg/L)
Na^{+}	Sodium (mg/L)
SO_4^{-2}	Sulfate (mg/L)
NH_4-N	Ammonium-Nitrogen (µg/L)
NO_3+NO_2-N	Nitrate+Nitrite (µg/L)
TN	Total Nitrogen (µg/L)
TP	Total Phosphorus (µg/L)
TN - Hypolimnion	Bottom TN (µg/L)
TP - Hypolimnion	Bottom TP (µg/L)
chl-*a*	Chlorophyll-*a* (µg/L)
DO	Dissolved Oxygen (mg/L)
SC25	Specific Conductance (µS/cm)
pH	pH (standard units)
Temp	Temperature (°C)
Secchi	Secchi Depth (m)
Water Level	Water Level (m)
TSI (chl-*a*)	Trophic State Index calculated from chlorophyll-*a* concentration
TSI (TP)	Trophic State Index calculated from TP concentration
TSI (Secchi)	Trophic State Index calculated from Secchi depth

Table F1. Sleeping Bear Dunes National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in bold font indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Manitou	Florence	Shell	Bass (N)	North Bar	Loon	Duplicate	Duplicate Location
Alk	7/2012	130	59	100	98	160	140	160	North Bar
Ca^{+2}	7/2012	26	14	23	24	39	34	38	North Bar
Cl^{-}	7/2012	0.7	0.8	1	6.3	4.3	34	4.4	North Bar
DOC	7/2012	6.7	7.4	14	10	4.3	4.4	4.1	North Bar
Mg^{+2}	7/2012	15	5.8	13	8.9	14	12	14	North Bar
K^{+}	7/2012	**0.37**	0.5	**0.37**	0.76	0.57	0.65	0.58	North Bar
SiO_2	7/2012	4	0.45	10	10	9.4	7.1	9.3	North Bar
Na^{+}	7/2012	1.3	0.64	1.6	3.3	1.9	6.6	1.9	North Bar
SO_4^{-2}	7/2012	9.3	4.2	21	5.7	11	10	11	North Bar
NH_4-N	7/2012	15.67	16.38	45.09	34.26	24.46	32.84	34.03	Bass (N)
NH_4-N	7/2012	10.03	12.45	27.09	10.3	20.24	8.2	19.41	North Bar
NH_4-N	9/2012	8.94	**3.996**	**7.975**	17.45	89.81	22.12	91.52	Loon
NH_4-N	average	11.5	10.9	26.7	20.7	44.8	21.1		
NO_3+NO_2-N	6/2012	10.44	13.2	8.45	16.32	307.07	65.61	15.69	Bass (N)
NO_3+NO_2-N	7/2012	154.71	223.1	447.81	25.63	274.77	60.31	272.29	North Bar
NO_3+NO_2-N	9/2012	**5.687**	11	10.66	8.75	248.12	10.69	11.36	Loon
NO_3+NO_2-N	average	56.9	82.4	155.6	16.9	277	45.5		
TN	6/2012	515.09	606.23	969.48	675.52	589.53	368.16	694.28	Bass (N)
TN	7/2012	535.73	639.68	939.32	751.6	541.97	954.67	590.82	North Bar
TN	9/2012	538.32	678.79	1072.5	824.06	678.36	269.21	296.98	Loon
TN	average	530	642	994	750	603	531		
TP	6/2012	10.43	12.05	10.49	6.1	7.46	7.14	7.93	Bass (N)
TP	7/2012	10.67	10.59	12.17	11.55	9.59	33.83	10.51	North Bar

Table F1 (continued). Sleeping Bear Dunes National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in bold font indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Manitou	Florence	Shell	Bass (N)	North Bar	Loon	Duplicate	Duplicate Location
TP	9/2012	15.19	13.01	11.13	14.33	15.64	10.4	11.16	Loon
TP	average	12.1	11.9	11.3	10.7	10.9	17.1		
TN - Hypolimnion	7/2012	51.74	662.02	n/a	1388.6	1004.2	823.44	999.67	North Bar
TP - Hypolimnion	7/2012	1301.71	10.51	n/a	18.78	27.71	20.46	27.6	North Bar
chl-*a*	6/2012	1.63	2.98	0.84	1.7	1.34	0.54	1.54	Bass (N)
chl-*a*	7/2012	1.08	3.36	1.47	2.62	1.39	1.59	1.43	North Bar
chl-*a*	9/2012	2.78	1.63	1.03	3.44	3.61	1.4	1.52	Loon
chl-*a*	average	1.8	2.7	1.1	2.6	2.1	1.2		
DO	6/2012	8.8	8.04	10.15	8.7	9.35	9.16		
DO	7/2012	8.61	8.37	9.17	9	8.52	8.61		
DO	9/2012	8.2	8.61	9.41	9.54	10.84	8.49		
DO	average	8.5	8.3	9.6	9.1	9.6	8.8		
SC25	6/2012	259.8	119.7	258.5	217.7	325.5	317.7		
SC25	7/2012	250.9	125.5	231.2	210	321.6	299.7		
SC25	9/2012	250.2	124.6	251.4	203.6	324	301.1		
SC25	average	254	123	247	210	324	306		
pH	6/2012	8.43	7.93	8.62	8.4	8.17	8.26		
pH	7/2012	8.51	8.35	8.73	8.75	8.09	8.34		
pH	9/2012	8.42	8.49	8.46	8.53	8.46	8.12		
pH	average	8.5	8.3	8.6	8.6	8.2	8.2		
Temp	6/2012	22.69	22.65	22.57	23.51	24.04	22.75		
Temp	7/2012	25.23	25.24	27.63	27.9	25.12	25.5		
Temp	9/2012	20.97	21.02	18.99	19.11	14.66	17.22		
Temp	average	23	23	23.1	23.5	21.3	21.8		
Secchi	6/2012	3.3	2.63	n/a	4.25	3.5	6.55		
Secchi	7/2012	2.88	2.33	3.45	3	2.1	2.75		

Table F1 (continued). Sleeping Bear Dunes National Lakeshore, 2012. Multiprobe measurements for pH, specific conductance (SC25), dissolved oxygen (DO), and temperature are reported from 0.5 m depth. Results in bold font indicate values less than the laboratory reporting limit (also known as the method quantitation limit or MQL). Blank cells indicate that no results are available.

Parameter	Month/Yr	Manitou	Florence	Shell	Bass (N)	North Bar	Loon	Duplicate	Duplicate Location
Secchi	9/2012	2.88	2.2	2.75	2.65	3.3	4.25		
Secchi	average	3.02	2.39	3.1	3.3	2.97	4.52		
Water Level	6/2012	-0.95	-0.67	-0.34	-0.62	-1.35	-0.57		
Water Level	7/2012	-1.11	-0.79	-0.53	-1.08	-1.6	-0.68		
Water Level	9/2012	-1.28	-0.93	-0.73	-1.55	-1.33	-0.64		
Water Level	average	-1.11	-0.8	-0.53	-1.08	-1.43	-0.63		
TSI (chl-*a*)	6/2012	35	41	29	36	33	25		
TSI (chl-*a*)	7/2012	31	42	34	40	34	35		
TSI (chl-*a*)	9/2012	41	35	31	43	43	34		
TSI (chl-*a*)	average	36	40	31	40	37	31		
TSI (TP)	6/2012	38	40	38	30	33	32		
TSI (TP)	7/2012	38	38	40	39	37	55		
TSI (TP)	9/2012	43	41	39	43	44	38		
TSI (TP)	average	40	40	39	37	38	42		
TSI (Secchi)	6/2012	43	46		39	42	33		
TSI (Secchi)	7/2012	45	48	42	44	49	45		
TSI (Secchi)	9/2012	45	49	45	46	43	39		
TSI (Secchi)	average	44	48	44	43	45	39		

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