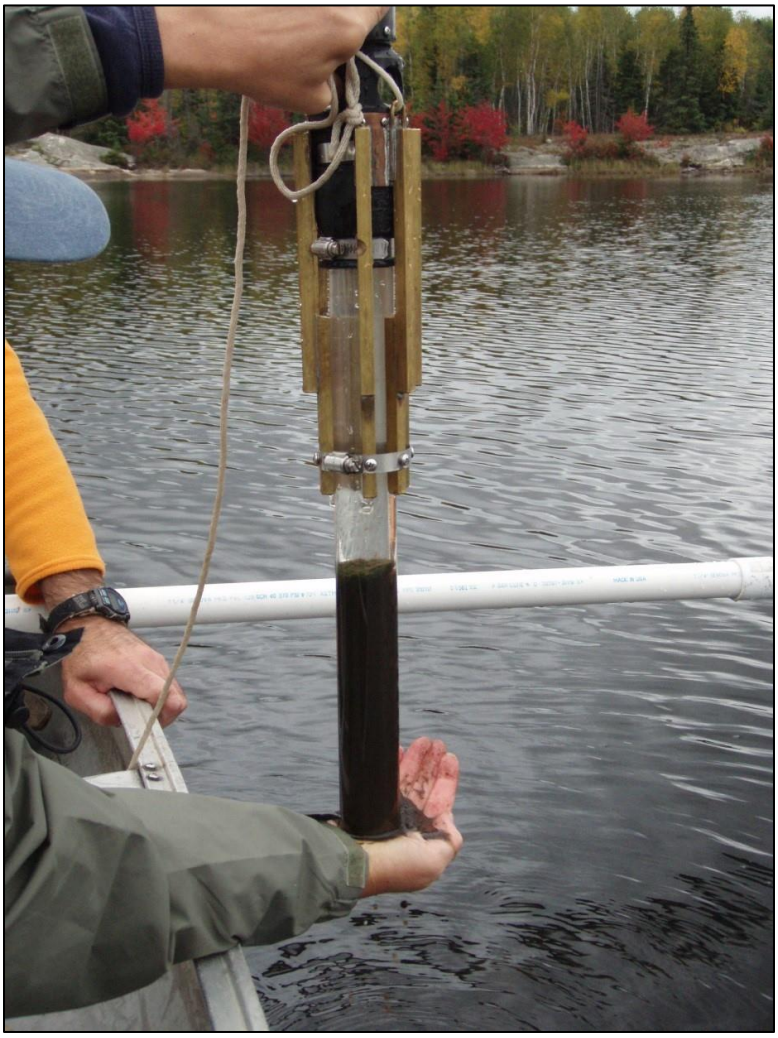
National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Diatom Monitoring Protocol for the Great Lakes Network

Version 1.1

Natural Resource Report NPS/GLKN/NRR—2019/1910



ON THE COVER
Surface sediment sample collected with a Wiegner corer at Voyageurs National Park.
Photograph © Ray Wise.

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Version 1.1

Natural Resource Report NPS/GLKN/NRR—2019/1910

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

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

Version 1.0 of this protocol received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

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Revision History Log

The following table lists all edits and amendments to this document since the original publication date. Information entered in the log must be complete and concise. Users of this protocol narrative will promptly notify the project manager and/or the Great Lakes Network (GLKN) data manager about recommended and required changes. The project manager must review and incorporate all changes, complete the revision history log, and change the date and version number on the title page and in the footer of the document file. For complete instructions, please refer to Revising the Protocol, SOP #13.

Revision log:

Previous Version #	**Revision Date**	**Author (with title and affiliation)**	**Location in Document and Concise Description of Revision**	**Reason for Change**	**New Version #**
1.0	3/21/2019	D. VanderMeulen, GLKN	Section 4.2 and throughout	Updated database used to manage and archive data; minor edits throughout rest of document	1.1
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Add rows as needed for each change or set of changes tied to an updated version number					

Abstract

The National Park Service's (NPS) Great Lakes Inventory and Monitoring Network (GLKN) has developed a prioritized list of indicators, termed "Vital Signs", for monitoring long-term ecosystem health in NPS units in the Great Lakes ecoregion. Diatoms, a group of algae with cell walls made of silica, are one of several Vital Sign monitored by GLKN. Diatom cells walls preserve well in lake and river sediment, and different species can be identified by unique patterns in their cell walls. Diatoms sensitively register environmental changes at the base of the food chain and are thus critical to all 'bottom-up' ecological processes. As primary producers, their relationship to environmental stressors is more direct and traceable than those at higher trophic levels (e.g., invertebrates, fish, and amphibians). Therefore, diatoms are useful bioindicators of lake and river ecological health and can be used to track changes in ecological health over time.

The nine national parks in GLKN encompass a variety of aquatic habitats and biota, including 129 named lakes, totaling nearly 41,000 ha. Diatom monitoring will occur at approximately 30-25 lake and 5-8 river sites that are co-located with sites monitored by GLKN for water quality through separate protocols. The lakes selected for monitoring span gradients of surface area, depth, visitor use, water chemistry, and spatial distribution within each park. The few river sites selected for diatom monitoring will be lake-like, where sediment deposition occurs. Diatom monitoring will be rotated across parks on an approximate 5 year cycle, with about ten sites monitored annually, typically in the fall.

Through analysis of diatoms in surficial sediment we will address the following questions:

1. What is the current ecosystem status of a particular lake in relation to other regional lakes?
2. Are similar ecological trends occurring across regional lakes (e.g., related to climate change or atmospheric deposition)?
3. What is the ecosystem status of this lake in relation to historical environmental change noted in regional sediment cores?
4. Has this lake changed since the last time it was sampled? If so, what are the magnitude and direction of that change?

Acknowledgments

The diatom monitoring project is closely tied to the water quality monitoring protocols for inland lakes and large rivers. See Elias et al. (2015) and Magdalene et al. (2016), respectively, for additional details on these projects

1.0. Background and Objectives

This protocol is designed to use diatoms as bioindicators to monitor lakes and large rivers within the National Park Service Great Lakes Inventory and Monitoring Network (Network or GLKN) park units. Network parks encompass a variety of aquatic habitats and biota, including 129 named lakes, totaling nearly 41,000 ha (101,000 acres) (Lafrancois and Glase 2005). Monitoring of diatoms will occur in the lakes selected for GLKN's monitoring of water quality in inland lakes (Elias et al. 2015) and at select sites that are part of monitoring in large rivers (Magdalene et al. 2016). The lakes selected for monitoring span gradients of surface area, depth, visitor use, water chemistry, and spatial distribution within each park. The few river sites selected for diatom monitoring will be lake-like, where sediment deposition occurs. Aquatic resources at each of the parks are described in Elias et al. (2015), Magdalene et al. (2016), and Route and Elias (2005). Throughout the remainder of this protocol we will refer only to the inland lakes protocol to simplify the description, although diatom monitoring also will occur at several sites that are part of the large rivers protocol.

Because diatom monitoring is conducted in close collaboration between GLKN staff and contracted cooperators, this protocol is intended to address the essential aspects required of the project partners.

1.1. Rationale for Selecting This Resource to Monitor

A variety of stressors such as climate change, environmental contaminants, exotic species, and land and resource uses including shoreline and urban development, recreation, water level management, logging, and agriculture in and near GLKN park units influence the parks' resources. Park managers seek information to make considered decisions in a future certain to bring change.

Bioindicators are critical to long-term monitoring of water quality because: (1) they provide an assessment of the actual ecological impact of environmental stressors, (2) it is not possible to measure directly all of the water quality parameters needed to detect unexpected environmental change, and (3) they serve as integrators of changes in water quality that may be missed during routine water chemistry sampling. Physical and chemical measures of water quality provide only a partial picture of ecological impact, and even the full suite of proposed water quality indicators (Elias et al. 2015) is likely to miss stressors that are not currently identified or anticipated.

Diatoms (Class Bacillariophyceae) are among the most powerful groups of biological indicators of environmental conditions in aquatic systems (lakes, rivers, wetlands, estuaries; Stoermer and Smol 1999). Diatoms make excellent bioindicators because they are generally abundant in aquatic systems and respond rapidly to changes in their environment. They form a cell wall made of silica, which preserves well in the sediments, and different species can be identified by unique patterns in this silica cell wall. Diatoms sensitively register environmental changes at the base of the food chain and are thus critical to all 'bottom-up' ecological processes. As primary producers, their relationship to environmental stressors is more direct and traceable than those at higher trophic levels (e.g., invertebrates, fish, amphibians). The recent discovery that increases in chloride concentration from road-salt application have had a pronounced effect on diatom assemblages in the Minneapolis/St. Paul metropolitan area as well as more rural parts of Minnesota (Ramstack et al. 2004) is a case in point. Today chloride concentrations in many of these lakes are 1–2 orders of magnitude greater than

those in pre-European times. What is unexpected about this finding is not the increase in chloride, although there was no way of assessing the magnitude of the increase without diatoms, but that a conservative anion had produced such a large impact on algal communities and that this change had gone unnoticed.

Analysis of diatoms in surficial lake sediments is a powerful tool to detect recent environmental change, or to place modern conditions in a regional or historical context (Cumming et al. 1992; Ramstack et al. 2003, 2004; Smol and Douglas 2007). We will integrate diatom monitoring in GLKN park units with paleolimnological efforts on a subset of the lakes. Paleolimnology offers unique opportunities for aquatic and terrestrial biomonitoring programs, primarily by providing historical data with which to contextualize modern monitoring in the absence of long-term monitoring data. Paleolimnology is often the only available or practical means for reconstructing ecosystem conditions, because historical water quality records are rarely available and if they are, records do not extend beyond the influence of European settlement. Many, if not most, modern lakes are significantly altered from their natural state; thus the use of reference lakes or computer models to simulate reference conditions may produce questionable results.

By coordinating the diatom monitoring and paleolimnology efforts, it will be possible to place the current lake conditions in a historical perspective. The results will provide a management foundation by determining the natural variability or reference condition of national park lakes and by reconstructing a detailed history of lake response to ecological changes that have occurred in and around the lakes during the last 150 years. Lake-sediment records integrate across both spatial and temporal scales; therefore, the results of the paleolimnological analyses can be used in conjunction with the biomonitoring efforts to quantify modern environmental conditions relative to historical conditions, to detect early ecological change and recent trends, and to evaluate success of management actions.

In the mid-2000s GLKN and the St. Croix Watershed Research Station (SCWRS) collaborated on a paleolimnological project that included several GLKN park units. As part of this project, a select subset of GLKN lakes was cored for diatom and geochemical analysis to determine the timing and magnitude of historical environmental change. Results from that project are now available (Edlund et al. 2011) and are useful in that they help us place into context data gathered through diatom monitoring in surficial sediments.

1.2. Measure Objectives

The analysis of diatoms in surficial lake sediments will address the following questions:

- What is the current ecosystem status of a particular lake in relation to other regional lakes?
- Are similar ecological trends occurring across regional lakes? (e.g., related to climate change or atmospheric deposition)
- What is the ecosystem status of this lake in relation to historical environmental change noted in regional sediment cores?

- Has this lake changed since the last time it was sampled? If so, what are the magnitude and direction of that change?

To answer these questions the following steps will be taken:

1. *Analyze diatom communities in surficial lake sediments to complement the routine physical and chemical water quality sampling and enhance the potential for detecting long-term changes in water quality.*

Rationale for using diatoms as bioindicators include:

- The sensitivity and tolerance of diatoms to environmental variables—including nutrients, organic pollutants, pesticides, heavy metals, salinity (and major ion chemistry), pH, alkalinity, light, temperature, substrate, and depth—are known to vary among species (Battarbee et al. 2001). These species-specific responses can be used to infer environmental conditions and to provide an early warning of the cumulative impacts of environmental change at the base of aquatic food webs. Early detection of change may facilitate park management decisions such that irreversible changes may be avoided.
- Diatoms occur in highly diverse assemblages, and species are relatively easily distinguished. The taxonomic diversity of diatom communities provides a high level of redundancy (confirmation by responses from multiple species) for robust tracking of environmental conditions.
- The combined cost of diatom sampling and analysis is relatively low when compared to other biological indicators (Stevenson and Pan 1999), and diatom samples are easily archived and preserved semi-indefinitely, allowing samples to be re-examined at future dates, if desirable.
- In lake environments, the deep-water sediments provide a highly integrated sample of diatom community structure for the lake as a whole. This means that only a single sample of surface sediment is needed to characterize the entire lake (Anderson 1990), as compared to the numerous samples required to overcome spatial heterogeneity for other bioindicators (e.g., benthic invertebrates).
- Diatoms have been used extensively to assess environmental conditions in freshwaters. Literally dozens of papers are published each year in peer-reviewed journals describing analytical and numerical (statistical) methods, taxonomic refinements, environmental requirements, paleo-environmental constructions, and applications in water-quality issues and policy development (Stoermer and Smol 1999). Diatoms are currently being used in both state (e.g., Minnesota, Montana) and nation-wide (Environmental Monitoring and Assessment Program [EMAP], National Water-Quality Assessment [NAQWA]) assessments of water quality.

2. *Analyze contemporary changes in the community composition of diatoms within the context of the range of natural variability, as determined by diatoms present in cores dating back to the time of European settlement.*

The question of natural variability is particularly important to environmental monitoring, which in the final analysis aims to distinguish significant human perturbations from background conditions. Ecological systems are often naturally variable (seasonally and inter-annually), and decades of careful water monitoring may be needed to detect significant trends. Even where long-term datasets are available, it is often difficult to know whether the observed trends are of concern or within the range of natural variation. Comparing the current community composition of diatoms to the species compositions dating back 150–200 years will allow us to determine whether the current conditions are outside of the range of natural variability of GLKN park lakes.

3. *Compare diatom species assemblages in surficial lake sediments with recent water chemistry measurements to continue to improve our understanding of diatom response to physical/chemical variables.*

Diatom communities are readily compared using multivariate techniques such as ordination because the assemblages are taxonomically diverse. Differences among samples (in space or time) are summarized by dissimilarity metrics such as chord distance or by arraying them along one or a few major axes in multivariate space (using principal components analysis [PCA], correspondence analysis [CA], or similar techniques). If independent water quality measurements have been taken (e.g., pH, total phosphorus, Secchi depth), the ordination can be constrained so that the major axes of diatom variability are aligned with the most explanatory environmental gradients (canonical correspondence analysis); the strength of these relationships can then be summarized statistically as an objective measure of explained variance (Battarbee et al. 2001).

2.0. Sampling Design

Analysis of diatoms in surficial sediments is used to augment and integrate water quality monitoring of inland lakes and large rivers, so the sampling design is based on these projects (Elias et al. 2015 and Magdalene et al. 2016, respectively) and known sedimentation rates. Approximately 30–35 lakes and 5–8 river sites will comprise the routine diatom monitoring sites.

2.1. Number and Location of Sampling Sites

The deep-water sediments of lakes provide a highly integrated sample of diatom community structure from the lake as a whole. Therefore, only a single sample of surface sediment is needed to characterize an entire lake (Anderson 1990). The diatom surface sediment sample at each lake will be collected at the deepest part of the lake, where routine water quality monitoring is conducted (Elias et al. 2015).

2.2. Frequency and Timing of Sampling

Sediment samples for diatom analysis will be collected from lakes selected for water quality monitoring approximately once every five years, depending primarily on sedimentation rate. Although lakes will be sampled annually as part of the water quality monitoring protocol, diatom analysis in surficial sediments will be rotated across parks on an approximate 5-year cycle in an attempt to spread the costs evenly. Additional lakes will be sampled for diatoms and routine water chemistry as funding permits (see Elias et al. 2015 for details).

Surface sediment samples will be collected during the final water quality monitoring event of the season, usually in September or October. Only one sediment sampling event at the end of the field season is necessary because that sample will represent the diatoms that have settled out of the water column over the previous approximately 3–5 years. At each site the top 0–1 cm and 1–2 cm of sediment will be collected, and kept as two separate samples. In most cases only the 0–1-cm sample will be analyzed; however, in lakes that are found to have a high sedimentation rate (this will be determined from the analysis of long cores), the 0–1- and 1–2-cm samples will be combined for analysis. This combined sample will then represent the previous 3–5 years.

2.3. Level of Change that Can Be Detected Given the Sampling Design

Sediment cores collected and analyzed for diatoms as part of the GLKN monitoring program will provide a historical framework for interpreting variability in the samples. Comparing the current community composition of diatoms to the species compositions dating back 150–200 years will demonstrate if the current conditions are outside of the range of natural variability of GLKN park lakes.

Change will be evaluated in two ways; first, the amount of floristic change in the diatom community composition will be measured using a chord distance dissimilarity measure. Second, the change in diatom-inferred water quality estimates will be evaluated using the root mean square error of prediction.

The chord distance dissimilarity measure will be used to quantify the floristic change in diatom community composition between subsequent sampling events. Meaningful change can be assessed using percentile cutoffs (Bennion et al. 2004), or by using the chord distance between samples from sediment cores as a framework (refer to SOP #9, Data Analysis and Management for more information on chord distance).

Methods for evaluating the certainty of inferred water quality estimates are well established. Generally error bars are reported as model error estimates, the jack-knifed or bootstrapped root mean square error of prediction ($RMSEP_{boot/jack}$) of the calibration model (Fritz et al. 1999, Ramstack et al. 2003, Köster et al. 2004) (refer to SOP #9, Data Analysis and Management, for more information on the diatom calibration model being used for this project). Variability or change in inferred water quality parameters greater than the $RMSEP_{boot/jack}$ represents a measure of significant change.

3.0. Field Methods

This section summarizes the information presented in greater detail in the standard operating procedures (SOPs) #1 (Pre-season Preparation), #4 (Field Methods and Surface Sediment Collection), #7 (Analysis of Diatoms on Microscope Slides), and #9 (Data Analysis and Management). Refer to these SOPs for more information.

3.1. Field Season Preparations and Equipment Setup

Prior to the field season, many preparations must be completed to ensure sampling can be undertaken according to schedule. The field season for collecting surface sediment samples for diatom analysis in GLKN park units is generally late summer/early fall. Because the surface sediment samples will be collected during the final water quality sampling event of the year it will be necessary to coordinate with personnel conducting water quality monitoring of inland lakes.

All details for the season need to be planned well in advance. Field preparations should begin in January to allow enough time for ordering new supplies and equipment and making repairs if necessary. Field equipment should be checked to ensure proper functioning; supplies should be inventoried and orders placed. Refer to SOP #1 (Pre-season Preparation) for a complete list of field season preparations.

For sampling stations located within park boundaries, a Scientific Research and Collecting Permit must be obtained before any work can be done. Refer to SOP #1 for details on renewing or obtaining new permits. Permanent diatom slides are considered U.S. government property, and as such, must be curated properly. Consult with the appropriate park representative for advice on compliance with government curation mandates.

Agreements for diatom analysis with cooperators should be reviewed and modified, if necessary. Both parties (NPS and cooperating organization) should agree on the number of samples to be collected in the year, annual timelines, and other expectations.

3.2. Sample Collection

A line-operated gravity corer will be used to collect the upper 0–1 cm and 1–2 cm of sediment for an integrated assessment of lake conditions during the previous approximately 3–5 years (see SOP #4 for details). Collection sites will be precisely located by GPS to allow re-sampling in the same location in subsequent years; sampling sites will target central depositional basins in each lake. Sediment samples can be collected by water quality monitoring personnel during the final round of water quality sampling of the season.

Surface sediment samples will be processed in the field according to SOP #4 and kept refrigerated until they are sent to the analytical laboratory for further processing and analysis. Upon receipt by the analytical laboratory, samples will be homogenized and subsampled for diatom analyses.

3.3. Post-Collection Processing of Samples

Diatom microscope slides will be prepared using standard oxidation and mounting techniques (see SOPs #5 and #6). A total of 400 diatom valves will be counted in each sample using a light

microscope fitted with full immersion optics capable of 875–1250× magnification and numerical aperture (N.A.) >1.30. Analyses will follow the enumeration criteria used in the Minnesota calibration set (Ramstack et al. 2003, Edlund and Kingston 2004, Edlund 2005).

Approximately 10% of the samples will be recounted by another analyst. Refer to SOP #12 for details on QA/QC.

Diatoms will be identified using floras and monographs by Hustedt (1927–1966, 1930), Patrick and Reimer (1966, 1975), Collins and Kalinsky (1977), Camburn et al. (1978, 1984–1986), Krammer and Lange-Bertalot (1986, 1988, 1991a, 1991b), Cumming et al. (1995), Reavie and Smol (1998), Camburn and Charles (2000), and Fallu et al. (2000), as well as all other pertinent literature.

3.4. End-of-Season Procedures

Before storing the gravity corer, be sure it is clean and dry and that all removable parts have been returned to the storage case. Inventory all field and laboratory supplies and replace as necessary as soon as possible. Refer to SOP #11 (Post-season Procedures) for a complete list of end-of-season procedures.

4.0. Data Handling, Analysis, and Reporting

4.1. Data Entry, Verification, and Editing

Each diatom species will be described by an 8-character species code; all of the codes used in the GLKN calibration set are listed in Appendix A of SOP #7 (Analysis of Slides). These codes follow the format used by the Great Lakes Environmental Indicators (GLEI) project (E. Reavie, Natural Resources Research Institute, University of Minnesota, Duluth). The GLEI list was used as a starting point; however, many taxa and codes continue to be added as the project progresses. A complete and up-to-date list of codes for this project will be maintained by GLKN and the cooperators. When uploading to the Neotoma online database, the taxa are harmonized with the Neotoma database, and their set of unique codes.

After each sediment sample has been processed and diatoms have been identified, the following information will be recorded:

- The full name, including authority(ies) of each diatom taxon identified
- The appropriate 8-character code for each taxon
- The number of valves of each taxon (refer to SOP #7 for details on counting)
- The percentage abundance (relative frequency) of each taxon (number of times a taxon is observed, divided by the total number of diatoms observed)

The cooperators, as subject experts, will verify the data prior to providing them to GLKN (refer to SOP #12 for details).

4.2. Overview of Database

All diatom species data collected as part of this project will be uploaded, stored, and made available to the public through the online Neotoma Paleoecology Database (https://www.neotomadb.org/). Neotoma is an online resource tailored for paleoecology projects where species data (including diatoms) have been collected. The Neotoma data upload process will be managed by the NPS partner analyzing the diatom slides (i.e., diatom subject matter experts; currently researchers from the St. Croix Watershed Research Station).

To upload to Neotoma, data are first organized in Excel, then transferred to a Tilia file template, and finally uploaded to Neotoma with the assistance and oversight of a certified Neotoma Data Steward. As a first step, a Neotoma Data Steward should be contacted; Data Stewards are analogous to editors, have experience with particular proxy types, and assist with the upload process. A list of Neotoma Data Stewards can be found at https://www.neotomadb.org/data/category/contribution.

Data Stewards will provide Excel templates that will assist with arranging data in the proper format. In general, Excel files should be arranged with a sheet consisting of diatom species names as rows, and samples as columns. Diatom valve counts need to be raw counts, not relative abundance, and samples should be labeled as depth in the sediment. Metadata will be listed in a separate Excel sheet; the Data Steward will provide the full list of metadata that can be associated with a given proxy type. The data in the Excel spreadsheet are migrated to a Tilia file, with the advice and guidance of the

Data Steward. A free version of Tilia can be downloaded at https://www.tiliait.com/. The completed Tilia file, containing species counts and associated metadata, is sent to the Data Steward, who will manage the upload to Neotoma.

Once data have been added to Neotoma, they can be located and retrieved in several ways. The online Neotoma Explorer (http://apps.neotomadb.org/explorer/) is an interactive portion of the website where the user can search for data using various parameters (e.g., taxon name, investigator, geographic place name). When a dataset is located on Neotoma Explorer's interactive map, the data can be viewed online and saved as a .csv file. However, the .csv file download will not contain all of the associated metadata. The full dataset, including metadata, can be retrieved through Tilia.

The Neotoma development team is currently developing additional ways to prepare, upload, and retrieve data. For example, with new features being implemented in NEOTOMA, data and metadata will be fully retrieveable in .json file format as a single download and upon retrieval each dataset can be assigned a DOI (digital object identifier) number; that DOI will bring you directly to the dataset at any future time. Neotoma is also interoperable with Microsoft Access, allowing migration of data to a different format if necessary in the future.

NPS partners shall provide copies of the original Excel document and the Tilia file to the NPS representative after the data have been finalized and uploaded to Neotoma. GLKN will maintain one master copy of the original Excel document and associated Tilia files for each park on a central server in the Ashland office. Data will also be stored on Neotoma servers, which are currently at Penn State University, and at a secondary off-site backup location.

4.3. Metadata Procedures

Metadata allows potential data users to evaluate the quality and usefulness of the data based on an understanding of the complete process under which it was collected and maintained. All of the protocol documentation, including standard operating procedures (SOPs), is part of a dataset's metadata for this reason. A reference to the appropriate version of these documents is part of the metadata for any particular element of a dataset. All data must have associated values for the dates and times they were collected.

The Geospatial Data Act of 2018 mandates federal agencies use metadata "consistent with international standards and protocols" using guidance of the Federal Geographic Data Committee. Bald eagle contaminants monitoring meets the definition of geospatial data and, thus, GLKN is responsible for documenting all public datasets using metadata that meets that standard. Consult the GLKN Data Management Plan (Hart and Gafvert 2005) for additional details about metadata procedures and requirements.

Although it is not required, we will make every effort to complete Biological Data Profiles (www.fgdc.gov/standards/status/sub5_2.html) for appropriate data sets and add associated metadata to the National Biological Information Infrastructure (NBII; www.nbii.gov/datainfo/metadata) Clearinghouse.

For more details on the Great Lakes Network's overall strategy for metadata generation, management, and distribution see Chapter 8, Data Documentation, of GLKN's Data Management Plan (Hart and Gafvert 2005) and the appendices of that document.

4.4. Routine Data Summaries and Statistical Analyses

Multivariate statistical analysis of the diatom data will occur regularly, following diatom enumeration and uploading into Neotoma. Comparisons of diatom species assemblages with water chemistry measurements will be used to derive an understanding of diatom response to physical/chemical variables. During the 2004–2009 diatom project (Task Agreement #J2105040028), surface sediment samples were collected from approximately 50–60 lakes within the Great Lakes Network parks and used as a diatom calibration set. Subsequent surface sediment samples that are analyzed for diatoms will be plotted passively on this calibration set to look for changes in the lakes.

Changes in the community composition of diatoms will be analyzed in relation to other lakes as well as within the context of the range of natural variability, as determined by diatoms present in sediment cores dating back before the time of European settlement. Refer to SOP #9 Data Analysis and Management, for a detailed discussion of the multivariate statistical methods that will be used to assess data collected under this protocol.

4.5. Reporting Schedule

One of GLKN's goals is to ensure that the results and knowledge acquired through the monitoring programs are shared with all appropriate parties, especially the parks and their natural resource managers. Park managers will be provided in a timely manner with clear, meaningful products. Because the monitoring data will be of interest to a broader scientific community, reports will be provided to the states in which the national park units reside, the NPS I&M Program, and when appropriate, articles will be submitted to peer-reviewed journals for publication. Findings will also be presented orally and in poster format at regional and national meetings.

Regular reports and publications will be prepared by the diatom cooperators in collaboration with GLKN's aquatic ecologist. As parks are monitored repeatedly, these products will become progressively more in-depth and will include syntheses and analyses of data over time. The reports will place the observed results in both a regional and historical context by relating them to other published literature, the significance of the results will be discussed in terms of environmental change, and management recommendations will be provided based on the findings. See SOP #10, Reporting, for more details.

4.6. Recommended Report Format

Reports should follow the format of a typical peer-reviewed journal article. The following outline is a good example of the type of report to be produced.

> TITLE PAGE (Title, Author(s), Participating Institutions, For Whom Prepared, and Date)
> TABLE OF CONTENTS PAGE
> EXECUTIVE SUMMARY PAGE (abstract)
> 1.0 INTRODUCTION

1.1 Background
1.2 Justification for Study
1.3 Objectives

2.0 METHODS
2.1 Study area(s)
2.2 Field methods(s)
2.3 Analytical method(s)

3.0 RESULTS
4.0 DISCUSSION
5.0 MANAGEMENT IMPLICATIONS
6.0 ACKNOWLEDGEMENTS
7.0 LITERATURE CITED (if any)
8.0 TABLES
9.0 FIGURES
1.0 APPENDICES (if any)

Reports should include tabular and graphic displays of data. Tables are appropriate for displaying simple data summaries, but can also be used to show results of more comprehensive analyses. Graphical display of data is especially useful for depicting trends across years (e.g., Figures 1 and 2) or the correlations among multiple variables or lakes (e.g., Figure 3). See SOP # 9, Data Analysis and Management, for more details on presentation of data.

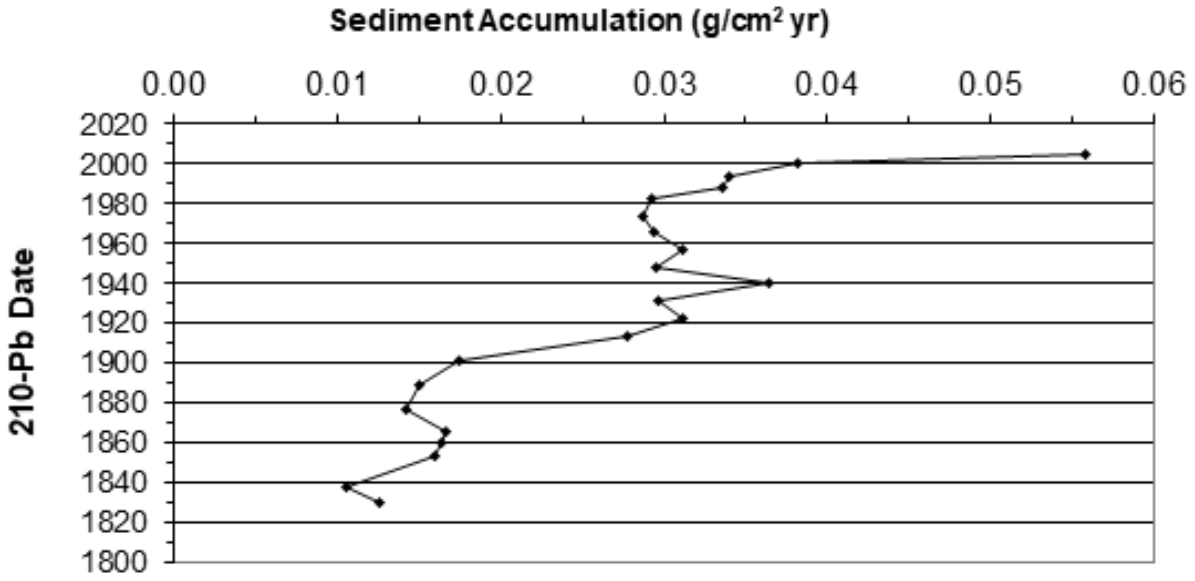


Figure 1. Sediment accumulation rate over time at Lake Manitou, Sleeping Bear Dunes National Lakeshore.

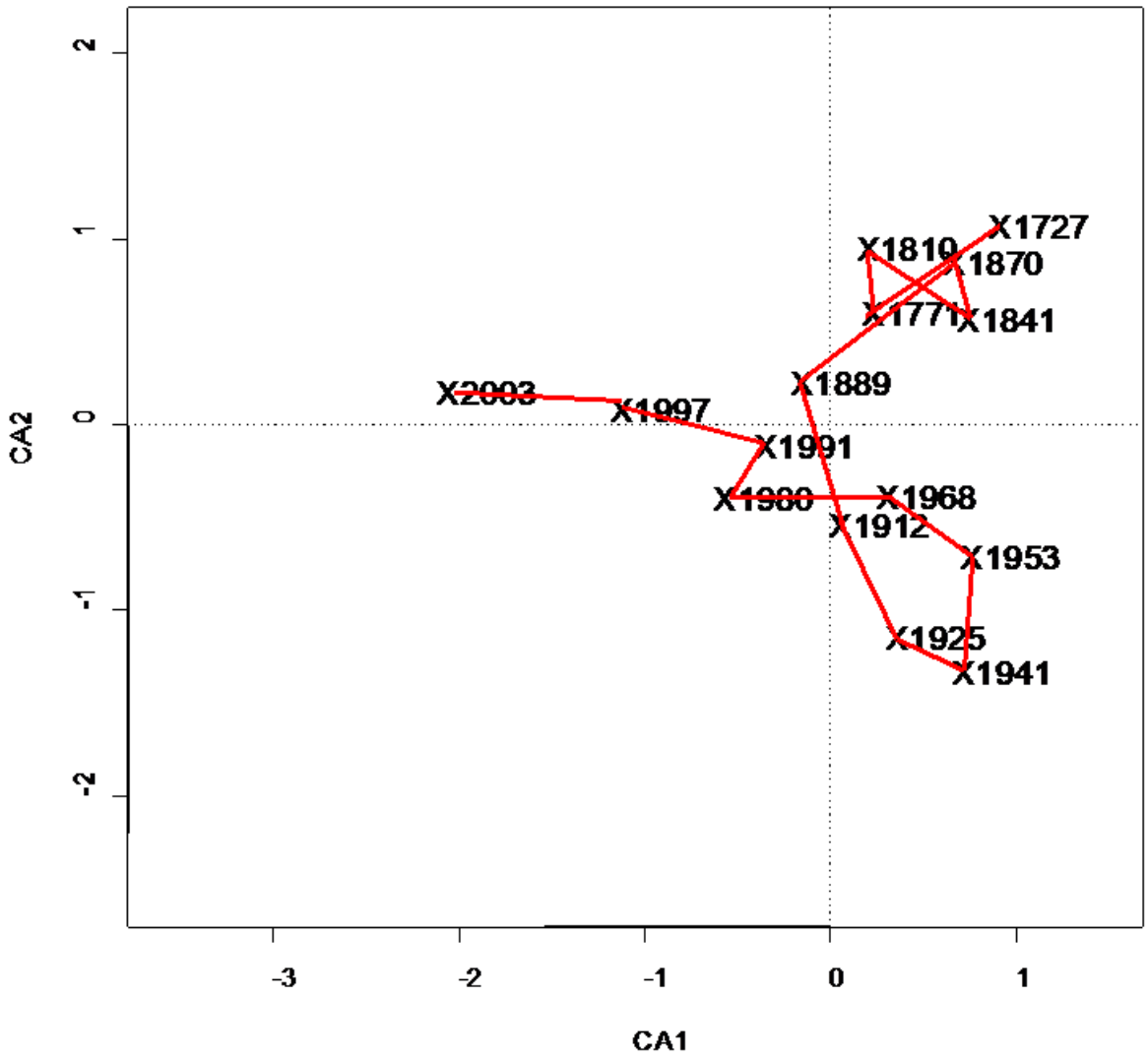


Figure 2. Correspondence analysis of downcore samples from Shell Lake (Sleeping Bear Dunes National Lakeshore) based on diatom species assemblages, from sediments dating from 1727 to 2003.

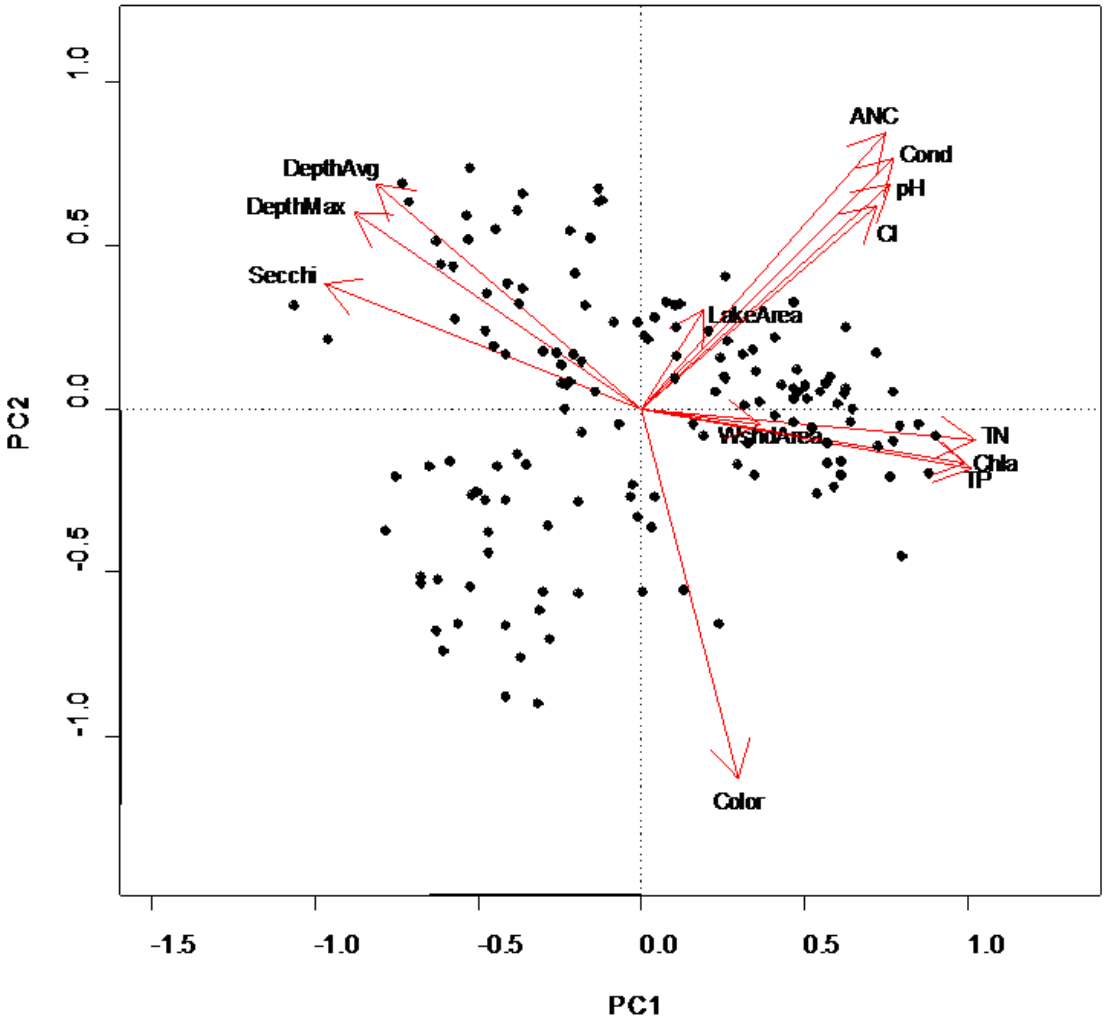


Figure 3. Principal components analysis of environmental data from 145 Minnesota lakes.

4.7. Sample Archival Procedures

Both freeze-dried sediment samples and diatom slides will be archived (refer to SOP #8, Archiving for details). Researchers will coordinate with each park unit to decide where the collections for each park will be housed. Representatives from each park will also work with researchers to ensure that the archived materials are entered into the appropriate NPS database, if necessary.

5.0. Personnel Requirements and Training

The requirements of GLKN personnel and cooperators differ; both will be addressed in the following section.

5.1. Roles, Responsibilities, and Qualifications

Field personnel for the GLKN water quality monitoring project will collect the surficial sediment samples. Qualifications of GLKN field staff are detailed in the protocol for monitoring water quality of inland lakes (Elias et al. 2015).

The project manager (GLKN aquatic ecologist) will oversee all aspects of the NPS involvement with the diatom monitoring project. Specific responsibilities of the project manager will be to:

- Hire and train field personnel
- Coordinate field logistics with park staff
- Administer the contract with cooperators for diatom analysis
- Collaborate closely with cooperators on data summaries, reports, and publications
- Ensure collaborators receive water quality monitoring data in a timely manner
- Work with cooperators to ensure data are entered into Neotoma, verified, and validated
- Ensure parks and other interested parties are informed of monitoring results

The GLKN will contract with an organization or institution experienced with all aspects of diatom identification, enumeration, and analyses of species assemblages. The cooperators should have the following specific qualifications:

- Experience in multivariate data analysis and paleoecology
- Experience using lake sediment records to explain long-term environmental change, including the effects of human activities on water quality, atmospheric chemistry, and biogeochemical processes
- Extensive experience in diatom taxonomy
- Facilities that include:
    - Research-grade light microscopes with bright field and DIC optics, 875-1200X magnification, numerical aperture (N.A.) >1.3, and image capture
    - Computing facilities with software for multivariate statistical analysis
    - Analytical laboratory
    - Extensive literature on diatom taxonomy
    - Diatom reference collection or stated intent to use specific diatom herbarium (or herbaria) for checking collected specimens against voucher specimens

Specific requirements of the cooperators may vary with the contract language, but in general the cooperators will be responsible for:

- Hiring and training of laboratory and analytical personnel
- Processing sediment samples
- Enumerating and analyzing diatom communities
- Collaborating with GLKN on data summaries, reports, and publications
- Providing data to GLKN in a timely manner
- Collaborating with GLKN to ensure parks and other interested parties are informed of results

6.0. Operational Requirements

6.1. Annual Workload and Field Schedule

Surficial sediment samples will be collected annually by GLKN field crews, on a rotational basis across parks such that sampling is repeated on a given lake approximately every 5 years. Approximately ten sites will be sampled each year. Because the sampling will be conducted during the final round of water quality sampling for the season, little additional field time or travel by GLKN staff is required.

The GLKN project manager will provide cooperators with raw and summarized water quality data in a timely manner and will collaborate on reports. The project manager will ensure parks and other interested parties are informed of progress and results. The cooperators will process the sediment samples collected by NPS personnel each year, identify the diatoms, and analyze the species assemblages relative to the GLKN calibration set. Changes in species since the last sampling will be related to changes in water quality. Annual reports will be prepared in collaboration with GLKN's aquatic ecologist.

6.2. Facility and Equipment Needs

Equipment required by GLKN for collection and storage of sediment samples consists of the following:

- Gravity corers (Wiegner corer), two or more to ensure availability at all parks
- Sample containers
- Container labels
- Pipettes
- Refrigerator space for storing samples

The collaborators will need all laboratory supplies and equipment required for processing of sediment samples, preparation of microscope slides, identification and enumeration of diatoms, and computing facilities with software for multivariate statistical analysis.

6.3. Startup Costs and Budget Considerations

The costs of collecting surficial sediment samples for diatom analysis are minimal if combined with the routine water quality monitoring. Because GLKN will make use of water quality monitoring personnel, no additional staff costs are anticipated. Similarly, no additional travel costs are anticipated. The equipment required for collecting the samples is minimal, consisting of a gravity corer, specimen cups, pipettes, and labels. GLKN currently has two gravity corers, which cost approximately $600 each. We expect these corers to remain functional for many years, with annual costs consisting of consumables amounting to approximately $200.

The majority of the costs will be associated with a contract (or cooperative agreement) with the cooperators for processing samples, microscopy, analysis, report-writing, supplies, and travel.

Because GLKN will request bids from interested contractors, the exact cost is not known. However, we expect the cost of the contract to be approximately $15,000–$20,000 annually.

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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